A First Directory of Ethiopian Wetlands:

Descriptions, Ecosystem Services, Causes of Degradation & Recommendations for Restoration and Sustainability

EWNHS

Wetlands International

INTERNATIONAL CLIMATE INITIATIVE (IKI)

Supported by:

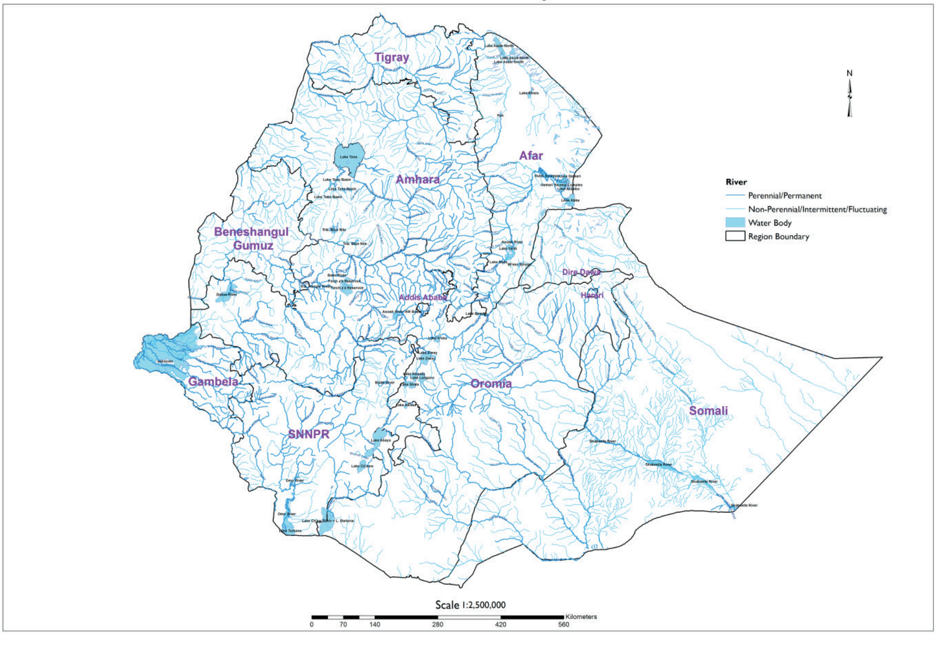
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

based on a decision of the German Bundestag

A First Directory of Ethiopian Wetlands:

Descriptions, Ecosystem Services, Causes of Degradation & Recommendations for Restoration and Sustainability

Wetlands of Ethiopia



Front Cover Page: Gillo River in Nuer Zone, Gambella (photo credit: Abebe Getahun)

Published and distributed by:	Ethiopian Wildlife and Natural History Society (EWNHS) in collaboration with Wetlands International ©2018
Editor:	Mengistu Wondafrash CEO, EWNHS Wondafrash.mj61@gmail.com; Cell phone: + 251 (0)911242369
Cartography	Hermela Lemma
Design and Layout	Eclipse Printing and Graphics, Addis Ababa, Ethiopia
ISBN	978-99944-73-47-2
Recommended citation	Ethiopian Wildlife and Natural History Society and Wetlands International (2018). **A First Directory of Ethiopian Wetlands:** Descriptions, Ecosystem Services, Causes of Degradation & Recommendations for Restoration and Sustainability
Copyright	All rights reserved: No part of this Book may be reproduced or transmitted in any form or by any means, electronic or mechanical, including tracing, photocopying, recording or by any information storage and retrieval system, without prior written permission or consent from the publishers. This book may not be disposed of by way of trade in any form of binding or cover other than that in which it is published
Disclaimer	The information contained within this Book is for general information purposes. The opinions expressed are in good faith and while every care has been taken to keep the information up-to-date and correct, the publishers give no warranties of whatever nature in respect of the publication, including but not limited to the completeness, accuracy, reliability, suitability or availability of any information, facts and/or opinions contained therein. The maps in this directory are used for assessment and report purposes only. They are not intended to be used for conveyance, authoritative definition of legal boundary, or property title. The designations and the presentation of the material on these maps do not imply the expression of any opinion whatsoever concerning the legal status of any country, territory, or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. All images are copyrighted to their respectful owners and every effort is made to ensure maps are free of errors, but there is no warranty that the maps or its features are either spatially or temporally accurate.
Financial Support	This project is part of the International Climate Initiative (IKI). The German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) supports this initiative on the basis of a decision adopted by the German Bundestag
Can be obtained from	Ethiopian Wildlife and Natural History Society (EWNHS) ewnhs.ble@gmail.com; + 251 (0)116 636792; www.ewnhs.org
Printing and binding	Eclipse Printing and Graphics, Addis Ababa, Ethiopia

Wetlands INTERNATIONAL

Brief Profile of Wetlands International

Wetlands International is an independent, non-profit organization, active in around 100 countries and works through a network of partners and experts to achieve its goals. We are driven by the knowledge that safeguarding and restoring wetlands is urgent and vital for water security, biodiversity, climate regulation, sustainable development and human health.

A world without wetlands is a world without water. Wetlands act as water sources and purifiers. They are rich in nature and vital to human life. They protect our shores. They are crucial to agriculture and fisheries, and are the planet's greatest natural carbon stores. But we have lost so much of our wetland treasure. And those that remain are under growing pressure. This makes people and nature vulnerable. It's time to reverse the trend.

Our vision is to have a world where wetlands are treasured and nurtured for their beauty, the life they support and the resources they provide. As such, we seek to understand how wetlands function in a wider landscape in order to sustain them. Using scientific knowledge makes us a well-trusted source of information, while powerful demonstration projects on the ground inspire people to act. By working with local partners and building the capacity of local communities whose lives closely connect to wetlands, we empower civil society to more effectively engage with governments and the private sector on decisions which affect them. To leverage change, we engage in partnerships with public and private sector to safeguard and restore wetlands. By connecting our work through networks, we combine local experiences and successes and increase our impact on national, regional and global policies, practices and investments.

In Ethiopia, we are working to conserve wetlands that are the most important for migratory waterbirds, including lakes Abijatta-Shalla and Ziway in the Rift Valley. Together with many partners around the world, Wetlands International works to safeguard and restore wetlands to benefit people and nature.

Read more https://africa.wetlands.org/east-africa or https://www.wetlands.org/

Contact

P.O. Box 471;

6700 AL Wageningen

The Netherlands

Tel. +31 (0) 318 660 910; E-mail: post@wetlands.org

Contents

List of Tables

List of Figures

List of Plates

Acronyms and Abbreviations

AAU	Addis Ababa University
ABWRMA	Awash Basin Water Resources Management Authority
AEWA	African-Eurasian Waterbird Agreement
ANRS	Amhara National Regional State
ARBA	Abay River Basin Authority
AwBA	Awash Basin Authority
BCM	Billion cubic meter
CBINREMP	Community-based Integrated Natural Resources Management Plan
CETA	Communication, Education, Training, Awareness
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CRGE	Climate Resilient Green Economy
CMS	Convention on the Conservation of Migratory Species of Wild Animals
CSA	Central Statistical Agency
DO	Dissolved oxygen
EARS	Ethiopian Agriculture Research System
EBI	Ethiopian Biodiversity Institute
EFASA	Ethiopian Fisheries and Aquatic Sciences Association
EIA	Environmental Impact Assessment
ENTRO	Eastern Nile Technical Regional Office

EPA	Environmental Protection Authority
EPCC	Ethiopian Panel for Climate Change
EPA	Environmental Protection Authority
ESIA	Environmental and Social Impact Analysis
ES	Ecosystem Services
ESEA	Equatorial and Subtropical Eastern Africa
ETC	Ethiopian Tourism Commission
EVDSA	Ethiopian Valleys Development Studies Authority
EWCA	Ethiopian Wildlife Conservation Authority
EWNHS	Ethiopian Wildlife & Natural History Society
EWNRA	Ethiopian Wetlands and Natural Resources Association
EWRP	Ethiopian Wetland Research Project
FAO	Food & Agriculture Organization
FDRE	Federal Democratic Republic of Ethiopia
GEF	Global Environmental Facility
GERD	Grand Ethiopian Renaissance Dam
HGM	Hydrogeomorphology
IBA	Important Bird Areas
IPCC	Intergovernmental Panel on Climate Change
IRBM	Integrated River Basin Management
ISEE	International Society for Ecological Economics
IUCN	International Union for the Conservation of Nature
IWRM	Integrated Water Resources Management

IWMI	Integrated Water Management Institute
JERBE	Joint Ethio-Russian Biological Expedition
masl	meters above sea level
MEA	Millennium Ecosystem Assessment
MER	Main Ethiopian Rift
MBWSR	Minnesota Board of Water and Soil Resources
MoEFCC	Ministry of Environment, Forest and Climate Change
MoWIE	Ministry of Water, Irrigation & Electricity
MoWR	Ministry of Water Resources
NABU	Nature and Biodiversity Conservation Union
NFP	National Focal Point
NGO	Non-Governmental Organization
NMSA	National Meteorological Services Agency
NWC	National Water Committee
ONRS	Oromia National Regional State
PET	Potential Evapo-transpiration
PIC	Prior Informed Consent
POP	Persistent Organic Pollutants
RCS	Ramsar Convention Secretariat
REDD	Reducing Emission from Deforestation and Forest Degradation
RVLBA	Rift Valley Lakes Basin Authority
RWSC	Regional Water Sub-committee
SEA	Strategic Environmental Assessment

SNNPRS	Southern Peoples, Nations & Nationalities Regional State
SWS	Society of Wetland Scientists
TDS	Total Dissolved Solids
UK	United Kingdom (Britain)
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
UNEP	United Nations Environmental Program
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VB	Valley Bottom (wetlands)
WBISPP	Woody Biomass Inventory & Strategic Planning Project
WMO	World Meteorological Organization
WMP	Wetland Management Plan
WRIP	Wetland Restoration Implementation Program
WSSE	Wonji Shoa Sugar Estate
WWDSE	Water Works Design & Supervision Authority
WWF	World Wildlife Fund
WWT	Wildlife and Wetland Trust
Z max	Maximum depth

Acknowledgments

First and foremost, we would like to express our deep and sincere gratitude to the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) - through the International Climate Initiative (IKI) - without whose financial support, the publishing of this book would have been impossible. Our heart-felt and grateful thanks are due to the staffs of Wetlands International (at various levels) – the project executants - for their genuine support, guidance and technical backstopping. The production of this comprehensive directory would have been impossible, were it not for the valuable time, inputs and guidance from quite a number of resource persons, organizations and validation workshop participants. We are hugely grateful and indebted to them. We are entirely grateful to the many individuals who have directly or indirectly helped us in so many ways to the betterment and production of the book. We regret that we may not have listed everyone's names that should be listed here. Finally, yet importantly, the editor would like to extend sincere thanks and a huge debt of appreciation to Wzo. Zewditu Tessema for her invaluable inputs in the final layout of the book. The time allocated to finalize this directory was relatively short. We have done our best to make the information clear, consistent and comprehensive. But we know there could be gaps and errors, for which we take the full responsibility.

Executive Summary

The objective of this report is to present an overview of the current ecological condition and restoration options for degraded wetlands in Ethiopia using practical approaches and recommendations. It has become evident in recent years that several wetlands in Ethiopia face imminent threat of degradation and total loss unless appropriate rehabilitation and regulatory actions are taken in time. For this report, the operational definition used for 'wetlands' is the one adopted by the Ramsar Convention (1971, 1997), and includes (in the Ethiopian context) water bodies such as lakes and rivers, and other wetlands such as floodplains, swamps, marshes, fringes, seasonal pans and flooded areas, valley bottom wetlands, irrigation fields, plantations and reservoirs. After a brief introduction of the profile of Ethiopia in general, the international, national and regional policies and regulations that touch on wetlands are discussed in detail in chapter 1, which also mentions the major ecosystem services of wetlands – provisioning, supportive, regulatory and cultural. Only the wetlands for which secondary sources were available from the scientific literature, reports of basin organizations, ministries and research institutions are included in this report.

In chapter 2, the wetlands are listed in relation to their distribution in the 12 drainage basins of the country. Each basin is further discussed in relation to the Regional States that bound the wetlands. Each wetland is described in terms of its location and biophysical characteristics such as geology, soil, climate variables such as rainfall, evapo-transpiration, hydrology, biodiversity, and social activities around the wetlands. The 12 drainage basins are all mentioned in this report, but the water basins of Abay, Tekeze, Awash, Rift Valley, Omo-Ghibe, Baro-Akobo, Ghenale-Dawa and Wabe Shebelle are given more coverage. The narrative descriptions are supported and illustrated with tables, figures and pictures (plates) which the authors had amassed earlier during their numerous field studies in Limnology and Fisheries Sciences. Particular notes are made on wetlands in which ecological stresses are evident. The ecosystem services and ecological condition are stated for each wetland based on literature sources and our own analysis, with particular note on wetlands that need restorative measures.

In chapter 3, the major causes for the degradation of wetlands in Ethiopia are mentioned. These include among others, water abstraction from lakes and feeder rivers, draining wetlands for agricultural purposes, catchment degradation by deforestation and water table lowering, human activities such as mining, overgrazing, pollution, overexploitation and unregulated settlement. Exotic plants introduced in wetlands, such as water hyacinth, have caused ecological havoc in some lakes and rivers (Tana, Finchaa, Wonji, Koka). Besides anthropogenic impacts, climate change and natural hazards such as tectonism (seismic instability) cause wetland degradation. In general, the lack of a stand-alone policy on wetlands has exacerbated and accelerated degradation of wetlands in Ethiopia.

In chapter 4, the degradation status of 16 wetlands is discussed and they are ranked from high to low degradation, with priorities set accordingly for their restoration. We used the approach and methodologies developed for prioritization of temperate wetlands (Wheeler *et al.*, 1995). But also took local conditions into consideration when constructing the prioritization matrix. The wetlands with high scores were those possible to restore immediately, to others with less score which were difficult to restore, and lastly to the least scored ones, which were almost impossible to restore. Factors such as the present ecological condition of the wetlands in terms of ecosystem functions and social values, how cost effective and feasible restoration will be and the sustainability of the restoration actions were considered. The average of three independent experts scores were taken to rank the priority of the wetlands from highest prioritized to least prioritized. Accordingly, Lake Haramaya with the highest score ranked as the wetland that should be restored immediately, while Lake Chelekleka, a seasonal pan which has already disappeared as a wetland, was the least prioritized for restoration action.

Chapter 5 discusses at length the type of restoration approaches to be used for degraded wetlands and the history of alteration of the 16 degraded wetlands considered in this report. The major causes for wetland degradation (HIPO – Habitat alteration, Invasive species, Pollution, Over-exploitation) are all evident in Ethiopian wetlands. Hence, we categorized the degraded wetlands into 4 groups – degradation caused by hydrological changes and drainage, pollution, overexploitation and those incurred by natural causes. Under each category, the causal factors and their manifestations in the wetlands are discussed normatively and using figures. For instance, for wetlands degraded due to habitat alteration, restorations approaches such as water use regulation, buffer zone demarcation, catchment forestation and soil-water conservation measures are recommended. For wetlands degraded due to relentless pollution, restorations will be pragmatically possible only by enforcement and implementation of State policy and regulatory legislations; both of these measures being in rather poor state in Ethiopia at present. The ecological and operational approaches to rehabilitate valley bottom wetlands and wetlands desiccated by eucalyptus plantations are also mentioned. The alteration history of the 16 wetlands is depicted by showing their changes in area (and volume) during the last 25 years from 1991 to 2016. In general, we have used a pragmatic approach to systematically and practically deal with the restoration of the 16 degraded wetlands, but the suggestions discussed could also be extended to other Ethiopian wetlands.

In chapter 6, detailed guidelines for wetland restoration are given. Although the approaches and methodologies used by Ramsar Convention Secretariat are adopted, several hints are given where these approaches can be customized to the Ethiopian condition. The guidelines can be used in the context of the 12 drainage basins adopted by the country. Equally, each basin can be considered from its administrative structure at the Nations, Regional States, Zones or even Woredas level. Administrative layers can be created by local to national institutions to draw protocols and procedures for restoration and rehabilitation of the degraded wetlands of Ethiopia. The Ministry of Environment, Forests and Climate Change is suggested as the lead body to coordinate, regulate and implement the restorations actions recommended for the wetlands. It is believed that adoption and implementation of the restoration measures will reverse the degradation processes and rehabilitate wetlands with the appropriate follow-up of the responsible bodies.

Chapter 1
INTRODUCTION

1.1 Ethiopia: Country profile

(This chapter is mostly derived from baseline study submitted to IGAD, Djibouti, by Brook Lemma on: "***Natural Resources and Environmental Protection in Ethiopia***" October 2014; 114 pages)

The Federal Democratic Republic of Ethiopia (FDRE) is located at the Horn of Africa between 3°24` and 14°53` N; and 32°42` and 48°12` E (Fig. 1.1). It is a landlocked country in the Horn of Africa, bounded to the north by Eritrea, to the west by Sudan, to the South west by South Sudan, to the south by Kenya and to the east by Somalia and Djibouti. The country has a surface area of 1,127,127 km² including a water surface area of 7,444 km². The topography is characterized by an extreme range in altitude, with the Danakil Depression located at 125 m below sea level (b.s.l.), while the highest point is Ras Dejen (Dashen), with an altitude of 4,620 m above sea level (a.s.l.) (EPA, 2003a; FAO 2006). The northern and western parts of Ethiopia, with the exception of the Afar Triangle, are dominated by very rugged terrain with high plateaus (more than 2200 m a.s.l.) and deeply incised valleys, such as the Nile drainage system.

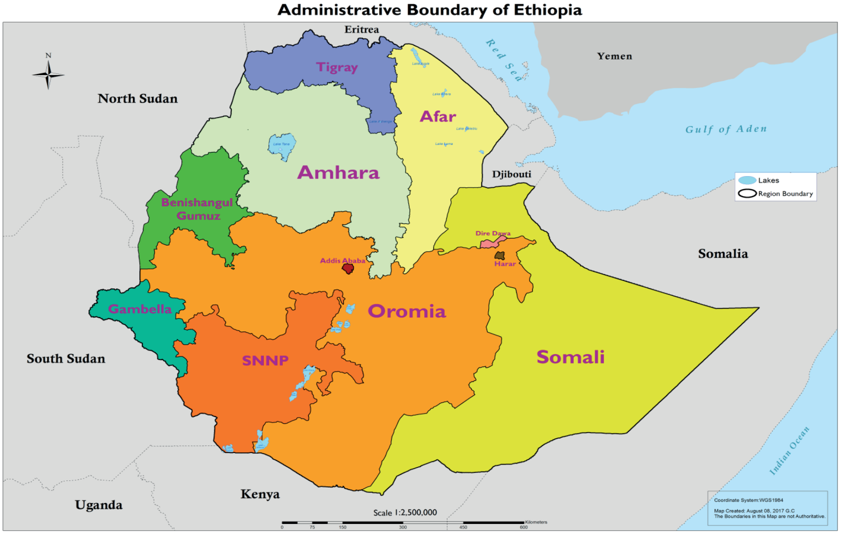


Figure 1.1: Map of the Federal Democratic Republic of Ethiopia.

Ethiopia has extremely varied topography. The complex geological history that began long ago and accentuates the unevenness of the surface; a highland complex of mountains and bisected plateaux characterizes the landscape. According to some estimates about 50% of African mountains, about 371 432 km^2above 2 000 m, are in Ethiopia (USAID, 2009). Within the above mentioned altitude ranges (125 m b.s.l and 4620 a.s.l.), the plateau in the northern half of the country is rugged and bisected by the East African Rift Valley, which runs from the Afar Depression all the way down to the Kenyan border.

With its dramatic geological history and broad latitudinal and altitudinal ranges, Ethiopia encompasses an extraordinary number of the world's broad ecological zones (USAID, 2009).

Climatic elements such as precipitation, temperature, humidity, sunshine and wind are affected by geographic location and altitude. Ethiopia, being near the equator and with an extensive altitude range, has a wide range of climatic features suitable for different agricultural production systems. Climatic heterogeneity is a general characteristic of the country (FAO, 2006). Ethiopia's mean annual rainfall distribution decreases from the south-western areas of the country, which have high rainfall to the Northern and Eastern parts. The maximum mean annual rainfall reaches up to 2,000 mm in some of the South-western parts of the country, while the lowest mean annual rainfall is below 250 mm in the North-eastern and South-eastern lowland areas of the country (EPA, 2003a).

Temperature in Ethiopia is estimated to range between 10^0C in the North-western South-eastern highland areas of the country and 35^0C in the North-eastern parts of the country. The highest mean maximum temperature of 45 ^{0}C occurs from October and March in the lowland parts of the country. On the other hand, the highland parts of the country record nightly minimum mean temperatures of 0^0C or below between November and February (EPA, 2003a).

According to Zerihun Woldu (1999), Ethiopia was once heavily forested with trees, with about 34% of its area and 57% of the land above 1 500 m covered by dense forests and a further 20% by wooded savannah. Further, the State of the Environment report of EPA (2003), states that Ethiopia has diverse topography and climatic conditions, and it is the home for various plant and animal species. There are no less than 7,000 different higher plant species out of which about 12 percent are endemic to Ethiopia. Ethiopia is the centre of origin for various crop species such as Coffee, Teff, Noug (*Guizotia abyssinica*), Enset (*Enseteven tricosum*), etc. Ethiopia is also home to crop species with useful genetic diversity such as sorghum, barley, wheat, horse beans, field peas, lentils, etc. Out of the total wildlife resources, 30 mammals (12 %), 28 bird (3.2 %) 3 reptile (3.9 %), 17 amphibian (31.5 %) and a number fish particularly *Labeobarbus* species are endemic to Ethiopia (See also Redeat Habteselassie, 2012; Shimellis A. Zelelew, 2013). For instance, among the 862 bird species recorded in Ethiopia 30.2 percent have been accorded international importance. In addition, about 31 of the species existing in Ethiopia are among the globally threatened. Moreover, there are 5 critically endangered, 12 endangered and 14 vulnerable species.

Ethiopia is known as the water tower of North East Africa. Running water resources in Ethiopia, flow in 12 major river basins. It is estimated that an average of 122.19 billion m^3 of water is annually discharged from these basins. The country's total ground water resources are estimated to be around 2.6 billion m^3. The waters of eleven Ethiopian rivers flow into neighbouring countries. The amount of discharge that remains in the country is not more than 9 percent (EPA, 2003, Seleshi Awulachew *et al.*, 2007). Ethiopia has more than 11 freshwater lakes and 9 saline lakes, 8 crater lakes and over 12 major swamps or wetlands. Majority of the lakes are found in the Rift Valley Basin (Seleshi Awulachew *et al.*, 2007). In addition a number of reservoirs have been added to the list including Koka, Gilgel Gibe, and the Hidasse Dams of which the latter will be the first in Africa and the eighth largest in the world when complete. The wetlands in the various parts of the country cover 18,587 km^2. This is estimated to be 1.5 percent of the country's surface area. Because of Ethiopia's topography the rivers have enormous hydropower generating capacity estimated at 650 Terra Watts. However, very little of this capacity is being actually used (EPA, 2003b).

The size of Ethiopia is 111.5 million ha. Out of this 74 million ha or 66 percent of total area is suitable for agriculture. However, the actual size of land cultivated is estimated to be only 16.5 million ha or 14.8 percent of the total (EPA, 2003). There are 10 major soil types that are estimated to cover 75.2 percent of the total area, in Ethiopia (Mesfin Abebe, 2007). Some studies have indicated that these soil types are, in many cases, deficient in Nitrogen and Phosphorus (EPA, 2003a).

A number of studies indicate that up to 400 tons of fertile soil per hectare is lost annually due to various factors from land devoid of vegetative cover as well as land where no soil conservation works have been constructed. The soil thus lost annually is from the farmlands, which make up 13 % of the total area. This kind of erosion is common at altitudes between 1,700 to 2, 600 m a.s.l. and where land cultivation is extensively practiced. It is estimated that the country loses 1.5-1.9 billion tons of soil annually due to wind and water erosion.

To combat land degradation, particularly soil erosion and loss of soil fertility, activities such as the construction of terraces, soil bunds, micro-basins and cut-off drains, as well as tree planting in slope lands and in watersheds, are being carried out. However, in view of the great magnitude of the erosion and soil fertility loss that is occurring, far more and greater effort is required with respect to soil conservation and protection (EPA, 2003a).

The recent data on forest resources of Ethiopia reported in FAO (2005) puts Ethiopia among countries with forest cover of 10-30%. According to this report, Ethiopia's forest cover (FAO definition) is 12.2 million ha (11%), clearly underestimated compared to the IPCC definition. It further indicated that the forest cover shows a decline from 15.11million ha in 1990 to 12.2 million ha in 2010, during which 2.65% of the forest cover was deforested. The cover belonging to other wooded land remained constant in the same period (Yitebitu Moges *et al.*, 2010).

It is estimated that there is 500,000 km^2 of rangelands in the lowland parts of the country and 57,000 km^2 in the "*Dega*" and "*Woyna Dega*" parts of the country. In addition, in the "*Dega*" and "*Woyna Dega*" parts of the country, fallow land is also used for grazing. In total, the extent of rangelands in Ethiopia is estimated to be 51 percent of total area (EPA, 2003).

According to the Central Statistics Office, Addis Ababa, by 2013/14 livestock population is estimated to be about 55.03 million cattle, sheep about 27.35 million, goats about 28.16 million, horses about 1.96 million, donkeys about 6.95 million, mules 0.36 million and about 1.1 million camels in the sedentary areas of the country (PCC, 2008).

1.2 Distribution of wetlands in Ethiopia

Wetland: definition and classification

There are more than 50 definitions of wetlands (Yilma Abebe and Geheb, 2003) and it appears that there is no universal definition that everyone will agree upon. This is because of the legal and economic consequences that each definitions may entail, especially when considering wetlands close to urban centers and areas of economic zones. What criteria are most important in defining wetlands have also been changing with time. The earliest definition of wetlands considered water depth, hydro-period and the dominant vegetation as determinant factors in defining wetlands for the US Fish and Wildlife Service (Cowardine *et al.*, 1979). The US Army Corps of Engineers defined wetlands as systems that fulfilled one of the three important features – hydrological source, hydric soil and hydrophyte vegetation. On the other hand, the Hydro-geomorphological approach (HGM) considers wetlands mainly in terms of hydrology, geological formation and landscape features, and does not consider vegetation and soil type as being important.

It should also be underscored that wetlands are defined in different terms in different countries. For example, Zambian wetlands are defined by a combination of 3 factors - mode of formation, moisture regime and physiographic position (Mukanda, 1985). Most of Zambian wetlands fall in the category of swamps, floodplains and 'dambos' (wetlands formed in mountain depressions, grassy valleys and seepage zone slope). It has been widely reported that valley bottom wetlands are an important component of wetlands in East Africa (Roggeri, 1995).

There is no national definition of wetlands for Ethiopia until now.

The Ramsar definition of wetlands has been largely adopted for this study. The most common definition of wetlands by Ramsar Convention Bureau (1997) is:

"Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters".

The Ramsar Convention recognizes five major wetland systems (Ramsar Convention Bureau, 1997). The major Ramsar groupings are Marine (coastal wetlands), Estuarine (deltas, tidal marshes, and mangroves), Lacustrine (lakes and associated wetlands), Riverine (rivers, streams and associated wetlands), Palustrine (marshes, swamps and bogs). The inland wetlands of Ethiopia mostly fall in the latter three categories – lacustrine, riverine and palustrine. It should be emphasized that lakes and rivers are understood to be covered by the Ramsar definition of wetlands in their entirety, regardless of their depth (RCS, 2016)

In order to include more representative wetlands in Ethiopia such as lakes, fringes, valley bottom and mountain seepage wetlands, hot springs and irrigation fields (surface or ground-water sourced), we opted to adopt also another operational definition from the South African experience in this study.

According to South African Water Act (1998), wetlands are defined as: "Land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is periodically covered with shallow water and which in normal circumstances supports or would support vegetation typically adapted to life in saturated soils". Land where water is the dominant factor determines the nature of soil development and the types of plants and animals living at the soil surface (Cowardin *et al.*, 1979).

In the Ethiopian context, wetlands refer to a variety of inland water ecosystems that embrace marshy areas, freshwater swamp lands, flood plains, ponds, lakes, peat lands and upland bogs, and reservoirs. Thus, Ethiopia has diverse wetlands of a range of origins in different parts of the country. Of the wetland types, flood plains are currently the dominant forms in Ethiopia (Yilma Delelelgn and Geheb, 2003). However, the distinction between floodplains and valley bottom wetlands is fuzzy as most floodplains are formed in the lower part of river valleys, but unlike upland valley bottom (VB), wetlands tend to be water-saturated all year-round. Upland VB wetlands may dry up for some months of the year as a result of lowered water table and no recharge from upland sources (because of deforested catchments). Upland VB wetlands have been traditionally de-vegetated and farmed for centuries, with the result that their agricultural features stand out more prominently than their wetland features.

The categorizing of wetlands in Ethiopia has followed different schemes and criteria such as biomes, habitat type, physical and biological characteristics of wetlands. For instance, Tesfaye Seifu (1990), Hughes and Hughes (1992) and Hillman (1993) classified Ethiopian and Eritrean wetlands into four, ten and ten, respectively. Similarly, Tilahun Hailu *et al*. (1996) classified wetlands of Ethiopia into four based on their biomes, namely, the Somali-Masai, the Sudan-Guinea, the Sahelian Transition Zone groups and the Afro-tropical Highlands. On the other hand, Afework Hailu (2003) classified the wetlands into three: freshwater, salt water and human-made wetlands using general criteria of the Ramsar Convention. Although the Ramsar definition of wetlands is adopted for this study, we have also included other definitions, whenever necessary. The classification of wetlands based on their hydrologic sources and flooding characteristics, macrophytes and hydric soils (Cowardine *et al*., 1979) and hydrogeomorphological (HGM) characteristics is sometimes more relevant to define wetlands, especially when considered from the point of view of conservation and restoration.

Using the Directory of African Wetlands as a basis, Ethiopian wetlands are classified into ten major groups, lakes being included (Hughes and Hughes, 1992). This classification is based mainly on river and lake drainage systems. The classification is not complete and will need revision

Distribution

The Ethiopian wetlands are distributed in different parts of the country, in almost all ecological and altitudinal ranges covering approximately 2% of its total surface area (EPA, 2003). The Dallol depression which is located at about 110m below sea level flourishes with wetlands such as Lake Afdera (salty lake). Swamps, marshes, lakes and riverine ecosystems are also distributed in central highlands, rift valley areas and mainly in the southwest borders of the country. The country lacks wetland database as comprehensive wetland study has not been carried out yet.

The wetlands have been categorized based on their drainage basins. Ethiopia has 12 river basins and 77 administrative zones (Fig.1.2). The wetlands covered in this study are listed under the drainage basins and the different administrative areas in the basin are indicated in different colors in the maps. The list of wetlands included in this study are described individually in each drainage basin and further classified under each of the administrative regions covered in the basin.

Figure 1.2: Map showing the administrative zones used in this report.

Drainage basins of Ethiopia

Ethiopia is divided into 12 drainage basins, characterized mostly by river drainages (except the Rift Valley lakes basin and the dry Ayisha and Ogaden basins). Most wetlands are concentrated in 8 river basins – Abay (Blue Nile), Tekeze, Awash, Danakil, Rift valley, Baro-Akobo, Omo-Ghibe and Genale-Dawa (Fig. 1.3).

In the descriptions of the major river basins, the geographic distribution and coordinates of the river basin and its major biophysical features are described in relation to all types of wetlands present in the basin and sub-basins. The major river basins considered are the Abay, Awash, Tekeze, Omo-Ghibe, Ghenale-Dawa, Baro-Akobo, Wabe Shebele and Danakil basins. Then individual wetlands found in each basin and sub-basin are described separately under the administrative areas where they are located. The inclusion of individual wetlands was based on the availability of literature on the wetland, and not on its relative importance in terms of human use or HGM features.

Figure 1.3: Major drainage basins of Ethiopia.

Lakes of Ethiopia

Ethiopia has about 30 lakes distributed all over the country, but more concentrated in the rift valley (Fig. 1.4). Except for some lakes which are deep and > 150 m, such as Lakes Shala (266 m), Babogaya (65 m), and some crater lakes (Zengena Kibeb in Awi zone) and Lake Wonchi, most of the other lakes are shallow (about 20 – 50 m). But the largest lakes, such as Tana and Zwai are shallow and < 10 m deep, although in previous citations, they were reported to be > 10 m. In this report, all lakes are treated as wetlands, irrespective of their mean depths and the area of the littoral region. Most human activities are, however, believed to impact mainly the shallow littoral zones of the lakes.

Rivers of Ethiopia

The rivers of Ethiopia are too numerous to be listed in detail, because some of the smaller rivers and streams are known only by the local people and a few have not been recorded by anyone. The large rivers drain large catchments and the basins are named after them; hence the 12 river basins are named after the big rivers that drain the catchments – these are the Abay, Tekeze, Awash, Wabe Shebelle, Baro-Akobo and others (Fig.1.5). Some drainage basins lack rivers (Aysha, Danakil, Ogaden) and are described as dry basins, while the rift valley basin is described as a lake basin.

Lakes and Rivers of Ethiopia (2016)

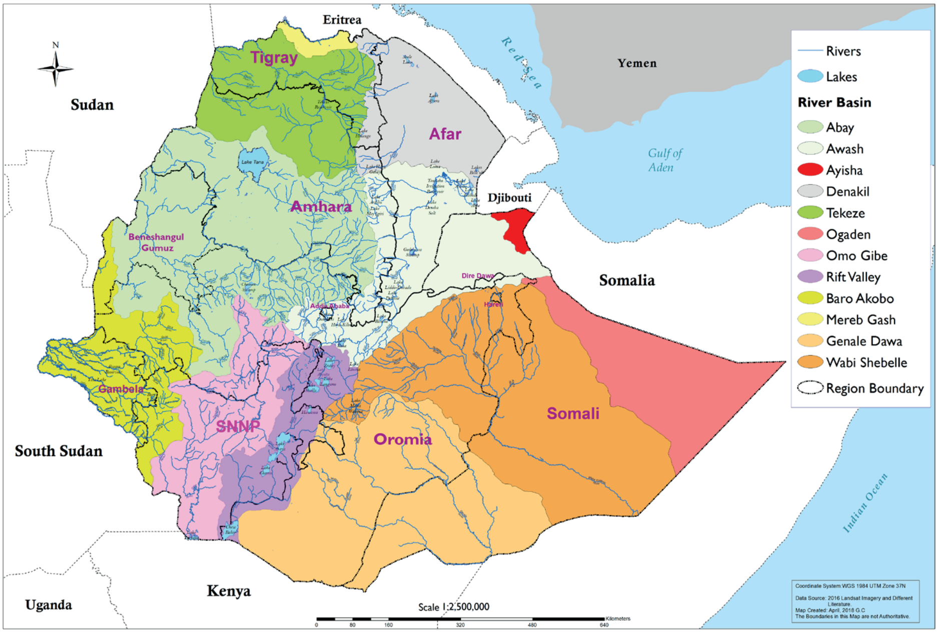


Figure 1.4: Lakes and Rivers of Ethiopia (blue-colored).

Other wetlands of Ethiopia

The marshes, swamps, floodplains, lake fringes, plantations, irrigation fields and other shallow vegetated wet areas are categorized under 'wetlands' although the term wetland is also used to denote rivers (riverine wetlands), lakes (lacustrine wetlands), reservoirs (artificial wetlands), pans (seasonal wetlands) and irrigated fields (artificial wetlands). Due to the seasonal nature of such wetlands, the maps may indicate their wetland features only during the wet (*kiremt*) season and these wetlands may completely dry up during the long, dry season. Such seasonal behavior is also exhibited by the numerous small pans, streams, ponds, wet meadows, marshes and swamps; thus the distribution of such wetlands may vary from season to season.

Given these anomalies, Unusual wetlands such as plantations, hot springs, lake fringes, deltas and pans are also included in Fig.1. 5.

For most rivers, floods are formed during the *kiremt* rainy season but some large rivers such as Abay, Awash and Wabe Shebele may swell at other times and spill over the river banks creating huge flooded areas. Floodplains are usually formed near river deltas whereas flooded wetlands can form on any reach depending on the topography and flow dynamics. These wetlands bring a lot of nutrient-rich soil and hence induce high productivity of plants and invertebrates, which serve as food for wildlife and livestock. During low water, the floodplains and flooded areas also serve for recession agriculture and livestock grazing. Figure 1.5 also shows the distribution of floodplains and flooded areas in Ethiopia.

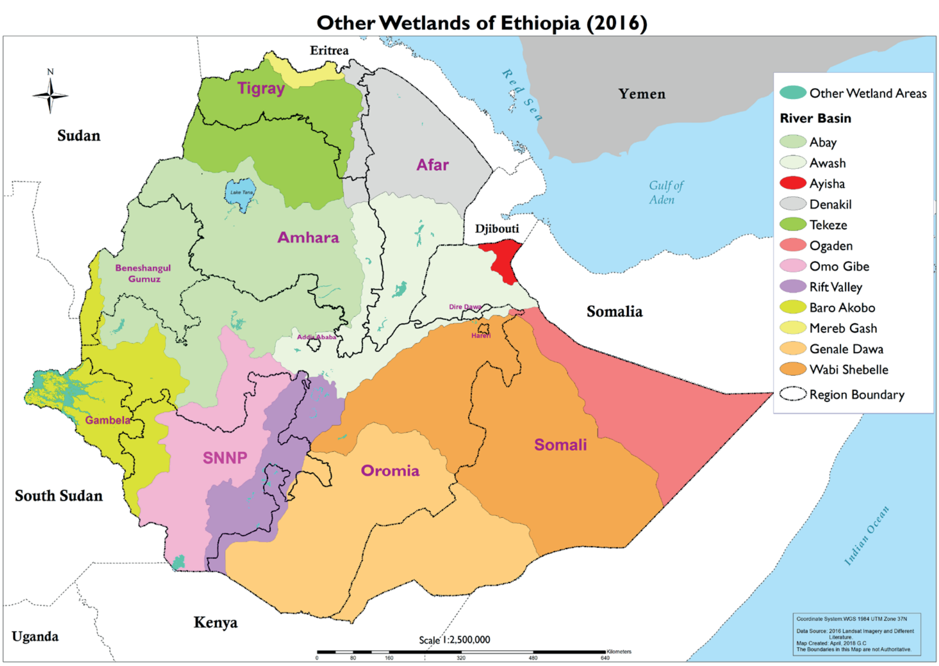


Figure 1.5: Other wetlands of Ethiopia (small lakes are shown as square).

1.3 Wetland related policies/conventions/ treaties/ regulations and institutions

The following are important definitions of terms that are used under this topic:

A policy is a collection of principles that could guide governments and all relevant institutions to take informed and rational decisions.

Convention is a meeting or formal assembly, as of representatives or delegates, for discussion of action on particular matters of common concern

Treaties are formally concluded and ratified agreement between countries

Institution refer to an organization, establishment, foundation, society or the like, devoted to the promotion of a particular cause or program, especially one of a public, educational, or charitable character.

The following are some of the conventions, treaties, policies and organizations that are relevant to wetland use and conservation designed and available at international and national levels, although Ethiopia is not a signatory of some of the international conventions. Policies and strategies regarding wetlands could be evaluated at different levels; at International, National and NGO levels.

International Level

Convention on wetlands

The convention on wetlands is formally known as "Convention on Wetlands of International Importance especially as Waterfowl Habitat". It is, however, often referred to as the 'Ramsar Convention' as it was signed in the Iranian city of Ramsar in 1971. It is an intergovernmental treaty for the conservation and wise use of wetlands by national action and international cooperation as a means of achieving sustainable development throughout the world. Ethiopia has not ratified the Ramsar Convention, and hence has not designated any Ramsar Site, as it stands during publishing of this book.

Obligations of parties include the following (Ramsar Convention, 1971):

- Designate wetlands for inclusion on the List of Wetlands of International Importance;
- Promote the significance of these wetlands and monitor and advise of any changes to their ecological character;
- Promote the wise use of all wetlands, especially through formulating and implementing national policy on wetland conservation management;
- Promote conservation of wetlands and waterfowl by establishing nature reserves on wetlands generally, to compensate for any loss of wetland resources of listed sites, encourage research, increase waterfowl populations and promote training in wetlands research, management and wardening;
- Promote international co-operation in wetlands conservation, including the sharing of resources and expertise;
- Be represented at Conferences of the Contracting Parties, to govern implementation of the Convention.

Convention on Biological Diversity

The Convention was adopted in 1992 as a way to help develop national strategies for the conservation and sustainable use of biodiversity. Opened for signature at the Earth Summit in Rio de Janeiro in 1992, and entering into force in December 1993, the Convention on Biological Diversity is an international treaty for the conservation of biodiversity, the sustainable use of the components of biodiversity and the equitable sharing of the benefits derived from the use of genetic resources. By 2016 with 196 members so far, the Convention has near universal participation among countries. Ethiopia has become member of the parties and ratified the convention in 1994. The Convention seeks to address all threats to biodiversity and ecosystem services, including threats from climate change, through scientific assessments, and active involvement of relevant stakeholders including indigenous and local communities, youth, NGOs, women and the business community. The Cartagena Protocol on Biosafety and the Nagoya Protocol on Access and Benefit Sharing are supplementary agreements to the Convention. The Cartagena Protocol, which entered into force on 11 September 2003, seeks to protect biological diversity from the potential risks posed by living modified organisms resulting from modern biotechnology. The Nagoya Protocol aims at sharing the benefits arising from the utilization of genetic resources in a fair and equitable way, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies. It entered into force on 12 October 2014 and to date has been ratified by 93 Parties. Ethiopia is a member of the parties and also ratified the protocol but has not yet signed the protocol. To date, 170 Parties have ratified the Cartagena Protocol. Ethiopia has ratified and has become a member in 2004.

The convention on biological diversity and the Ramsar Convention are mutually supportive and had joint work plans. They agreed to create synergies and work together to deliver on the objectives of both conventions effectively.

The Convention on International Trade in Endangered Species (CITES)

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), also known as the 'Washington Convention" is a multilateral treaty to protect endangered plants and animals. It was drafted as a result of a resolution adopted in 1963 at a meeting of members of the International Union for Conservation of Nature (IUCN). The convention was opened for signature in 1973 and CITES entered into force on 1 July 1975. Its aim is to ensure that international trade in specimens of wild animals and plants does not threaten the survival of the species in the wild, and it accords varying degrees of protection to more than 35,000 species of animals and plants. Obviously, several of the CITES species inhabit wetlands and associated habitats and Ethiopia joined the parties in 1989.

International Union for Conservation of Nature

The IUCN is an international organization dedicated to natural resource conservation. IUCN is working with the Ramsar Convention and Contracting Parties, but also with grassroots communities and river basin agencies, to implement wetland conservation as part of its water management work. The benefits are clear: not only does it help to conserve biodiversity and livelihoods, but wetland conservation brings benefits to water quality, fisheries and protection against floods.

In 1985, IUCN together with WWF started a major wetlands campaign called 'Life at the Water's Edge'. This campaign promoted the need for wetland conservation, produced a vast array of communication materials, and set out a clear wetland conservation programme. The knowledge that millions of people around the world rely on wetlands for livelihoods is familiar now to many.

The Convention of the Conservation of Migratory Species (CMS)

The Convention on the Conservation of Migratory Species is an international convention in which Ethiopia has become a member since 2010. As an environmental treaty under the auspices of the United Nations Environment Programme, CMS provides a global platform for the conservation and sustainable use of migratory animals and their habitats. A large extent of these habitats in which these migratory species dwell or pass through around the world is wetland. CMS brings together the States through which migratory animals pass, the Range States, and lays the legal foundation for internationally coordinated conservation measures throughout a migratory range.

CMS Parties strive towards strictly protecting these migratory animals, conserving or restoring the places where they live, mitigating obstacles to migration and controlling other factors that might endanger them. Besides establishing obligations for each State joining the Convention, CMS promotes concerted action among the Range States of many of these species.

In this respect, CMS acts as a framework Convention. The agreements may range from legally binding treaties (called Agreements) to less formal instruments, such as Memoranda of Understanding, and can be adapted to the requirements of particular regions. The development of models tailored according to the conservation needs throughout the migratory range is a unique capacity to CMS.

The African-Eurasian Migratory Waterbirds Agreement

The Agreement on the Conservation of African-Eurasian Migratory Waterbirds Agreement (AEWA) is an intergovernmental treaty dedicated to the conservation of migratory waterbirds and their habitats across Africa, Europe, the Middle East, Central Asia, Greenland and the Canadian Archipelago. Developed under the framework of the Convention on Migratory Species (CMS) and administered by the United Nations Environment Programme (UNEP), AEWA brings together countries and the wider international conservation community in an effort to establish coordinated conservation and management of migratory waterbirds throughout their entire migratory range. It covers 254 species of birds ecologically dependent on wetlands for at least part of their annual cycle. Ethiopia is a party to the African-Eurasian Migratory Waterbirds Agreement since 2010.

World Heritage Convention

The most significant feature of the 1972 World Heritage Convention is that it links together in a single document the concepts of nature conservation and the preservation of cultural properties. The Convention recognizes the way in which people interact with nature, and the fundamental need to preserve the balance between the two

The World Heritage Convention encourages the identification, protection and preservation of the world's outstanding cultural and natural heritage sites for the international community and future generations.

The Convention sets out the duties of States Parties in identifying potential sites and their role in protecting and preserving them. By signing the Convention, each country pledges to conserve not only the World Heritage sites situated on its territory, but also to protect its national heritage. The States Parties are encouraged to integrate the protection of the cultural and natural heritage into regional planning programmes, set up staff and services at their sites, undertake scientific and technical conservation research and adopt measures, which give this heritage a function in the day-to-day life of the community.

It also encourages States Parties to strengthen the appreciation of the public for World Heritage properties and to enhance their protection through educational and information programmes. Ethiopia has been a member of the parties since 1977.

United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC entered into force on 21 March 1994. Today, it has near-universal membership. The 197 countries that have ratified the Convention are called Parties to the Convention and Ethiopia is one.

The UNFCCC is a "Rio Convention", one of three adopted at the "Rio Earth Summit" in 1992. Its sister Rio Conventions are the UN Convention on Biological Diversity and the Convention to Combat Desertification. The three are intrinsically linked and it now also incorporates the Ramsar Convention on Wetlands. The ultimate objective of the Convention is to stabilize greenhouse gas concentrations at a level that would prevent dangerous anthropogenic (human induced) interferences with the climate system. It states that such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

Intergovernmental Panel on Climate Change (IPCC)

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. In the same year, the UN General Assembly endorsed the action by WMO and UNEP in jointly establishing the IPCC. The IPCC reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters.

As an intergovernmental body, membership of the IPCC is open to all member countries of the United Nations (UN) and WMO. Currently 195 countries are members of the IPCC. Governments participate in the review process and the plenary Sessions, where main decisions about the IPCC work programme are taken and reports are accepted, adopted and approved.

The IPCC in 2006 has adopted a new Methodology Report, prepared by its task force on National Greenhouse Gas Inventories. The 2013 supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (**Wetlands Supplement**) provides new guidance for countries to cover wetlands. It provides guidance on emissions from wetlands and it also creates a mandate for governments to improve their reporting of greenhouse gas emissions from wetlands Ethiopia signed the agreement on April 22, 2016, accepted and ratified on 9 March, 2017 and entered into force on 8 April, 2017.

The Basel, Rotterdam, Stockholm and Bamako Conventions

The Basel Convention is on the control of trans-boundary movements of hazardous wastes and their disposal, which was adopted in 1989 in response to concerns about toxic wastes from industrialized countries being dumped in developing countries and countries with economies in transition. The convention entered into force on 5 May, 1992.The primary recipient environment, usually, is the wetland habitat.

The Rotterdam Convention on the Prior Informed Consent (PIC) procedure for certain hazardous chemicals and pesticides in international trade was adopted in 1998. In the 1980s the voluntary codes of conduct were developed by UNEP and FAO and the convention replaces this arrangement with a mandatory PIC procedure. The convention entered into force on 24 February 2004.

The Stockholm Convention on Persistent Organic Pollutants (POPs) was adopted in 2001 in response to the urgent need for global action to protect human health and the environment from "POPs". These are one of the pollutants of the aquatic environment that are highly toxic, persistent, bioaccumulate and move long distances in the environment. The convention entered into force on 17 May, 2004.

The Bamako Convention is a convention on the ban of import into Africa and the control of trans-boundary movement and management of hazardous wastes within Africa. It is a treaty of African nations prohibiting the import of any hazardous (including radioactive) wastes. The convention was negotiated by twelve nations of the Organization of African Unity at Bamako, Mali in January and came to force in 1998.

National Government level Policies:

A National Wetland Policy is a significant opportunity to jointly establish the priorities and mechanisms to enhance awareness of wetland resources in a nation.

In many Governments of the world there is controversy on the use of wetlands. Some may consider wetlands as critical areas for conservation due to their support of biodiversity, while several others recognize wetlands as important agro-development resources. Several governments are not yet decided on how they should respond to these differing viewpoints. The Government of Ethiopia appears to have taken the last stand on taking time to see what policies would be appropriate in conserving the biodiversity within wetlands while at the same time not hindering development activities, which are at the core of all its other policies.

Therefore, there is no specific policy on wetlands in Ethiopia. As a matter of fact, little attention has been given to conservation and sustainable use of wetlands. Because of the critical role that wetlands play in the water cycle and Ethiopia's hydrology, the survival of several organisms and livelihoods of millions of people, there may be a need to develop a stand-alone National Wetlands Policy as an important integral part of Ethiopia's Land Use Policy.

However, the several policies (some mentioned below) relate to wetlands and also mention wetlands in their declarations. Some experts argue that although wetland issues are slightly touched upon in quite a number of sectoral policies and proclamations (e.g. environmental, water resources management, fisheries, land use policies), there is a strong need to synchronize these and ensure their implementations, especially at regional and local levels (Mengistu Wondafrash, 2003).

Ethiopian Water Resources Management Policy (Ethiopian Water Resources Management Proclamation-197/2000

- The general objective of the Ethiopian Water Resources Management Policy with regard to wetlands is to ensure that measures such as protection of aquatic life, and the planning and implementation of water resource conservation activities are implemented to protect wetland ecosystems.

The Federal Environmental Policy and the proclamation on Environmental Impact Assessment (No 299 of 2002)

- It provides a basis upon which environmental impact assessments (EIAs) can occur prior to any development undertakings in an environmentally sensitive area, which potentially include wetlands.

The Federal Rural Land Administration Proclamation (No. 456/2005).

- It appears that the greatest threat to wetlands is land use policy and planning (Mengistu Wondafrash, 2003). It targets land to be set aside for social services, in particular grazing and other communal land use to be carried out in accordance with a location's peculiarities and through communal participation, in which wetlands could be part of that..

The Policy on Disasters, Emergencies and Public Safety

- It states that the protection of water bodies and water systems from pollution and depletion should be ensured.

Rural development policy and strategies

- This policy and strategy on rural development was issued in 2003and mentions about the use and conservation of the available water resources in the country for crop and animal production.

Ethiopia Pesticide and floriculture codes 674/2010; 207/2011

- Proclamation No. 674/2010 is a proclamation that provides guidelines on the registration, monitoring and control of pesticides, which potentially could pollute wetlands.
- Proclamation No. 207/2011 is on Code of Practice of the Floriculture Sector in Ethiopia, which is closely associated with pollution of several water bodies in the country.
- Institutions

The Ministry of Water, Irrigation and Electricity (MoWIE)

- Involved in planning, development, management, utilization and protection of the country's water resources,
- Supervises all medium and large dams and irrigation schemes and drilling of wells
- Involved in development of drinking water supplies.

Ministry of Agriculture and Livestock

- Water management (irrigation extension), including water harvesting for smallholder irrigated and rain-fed agriculture
- Development of small dams and pans for domestic stock.
- Involved in formulating land-use plans.
- Actively involved in the conversion of wetlands into farmlands (drainage, micro-dam construction, development of pans and ponds).

Ministry of Industry

- Establishment of industries, such as tanneries and textiles, on wetland edges.
- Pollution.

Ministry of Health

- Draining and spraying wetlands to combat water-borne diseases

Ministry of Environment, Forest and Climate Change (MEFCC)

- Preparation of environmental protection policy, laws and directives.
- Environmental Impact Assessment (EIA) procedures
- In charge of evaluating the impact of social and economic development projects, particularly irrigation and hydropower projects, on the environment and is further responsible for follow-up work.

Ethiopian Tourism Commission (ETC)

- Considers wetlands as one important area for tourism.

The Ethiopian Wildlife Conservation Authority (EWCA):

- Wetland distribution, preliminary mapping and gathering information, protected area management;

Ethiopian Biodiversity Institute (EBI)

- Biodiversity conservation in Aquatic Ecosystems of the country;

Universities in the different parts of the country

- Limnological studies, wetland biodiversity and social studies.
- Researches on biodiversity, awareness creation, conservation and sustainable management of wetlands

Ethiopian Electric Power

- Macro-dams (hydroelectric plants).
- Irrigated farms (adjacent to dams).

River Basin Authorities

- Comprising a Basin High Council and River Basin Authorities to ensure integrated water resources management at basin level:
- Awash Basin Authority (AwBA), replacing the former only basin-level institution, the Awash Basin Water Resources Management Agency (ABWRMA).
    - Most of the medium- and large-scale irrigation projects and salinity and flooding problems are concentrated in this basin;
- Abay River Basin Authority (ARBA) and
- Rift Valley Lakes Basin Authority (RVLBA).

Community and NGO levels

- Wetland International
    - Wetland International is a global not-for-profit organization dedicated to the conservation and restoration of wetlands. Their vision is a world where wetlands are treasured and nurtured for their beauty, the life they support and the resources they provide.
    - Wetland International is Partner to the Ramsar Convention on Wetlands, and has worked to guide resolutions on better wetland management. Over the last decade it has, amongst others, been instrumental in assisting the development of resolutions on wetland inventory, flyway conservation, avian influenza, sustainable fisheries, poverty reduction, climate change adaptation and mitigation, human health and disaster risk reduction.
- Ethiopian Wildlife and Natural History Society (EWNHS):
    - Wetland birds, identification of wetland Important Bird Areas (IBAs), Waterbirds Census and monitoring of wetlands, and research and management of threatened species;
- Ethiopian Wetlands and Natural Resource Association (EWNRA)
    - Works on sustainable wetland management
    - Carries out various researches on wetlands
    - Undertakes awareness enhancing activities, engaging local communities, governmental organizations and NGO staffs,
- Ethiopian Panel on Climate Change (EPCC)
- Nature and Biodiversity conservation Union (NABU)
- Forum for Environment (FfE)

- EFASA (Ethiopian Aquatic Fisheries and Aquatic Science Association),
- Ecohydrology Project under the Ministry of water and Irrigation,
- Community-based Integrated Natural Resources Management Project (CBINREMP) under the Bureau of Agriculture in Amhara Region

In general, the policy environment regarding wetlands in Ethiopia is fragmented in different government institutions, with mandates overlapping across several sectors. There is as yet no stand-alone policy on wetlands in Ethiopia. The country is not a signatory member of the Ramsar Convention or other wetland treaties; thus it appears that a lot has to be done to improve the policy support and administrative structures to protect and restore wetlands in Ethiopia.

1.4 Socio-economic importance and ecosystem services of Ethiopian wetlands

Socio-economic importance of wetlands

Wetlands are internationally recognized as important natural and depending on the characteristics of each wetland type, may perform some of the following functions (Table 1.1.)

Table 1.1: Typical wetland ecosystem services (Source: Davies and Day, 1998)

	No. Main service-types	Examples
	Provisioning services	
1	Food	Fish, game, fruit
2	Water	For drinking, irrigation, cleaning
3	Raw materials	Fiber, timber, fuel wood, fodder, fertilizer
4	Genetic resources	For crop-improvement and medicinal purposes
5	Medicinal resources	Biochemical products, models and test-organisms
6	Ornamental resources	Artisan work, decorative plants, pet animals, fashion

	Regulating services	
7	Air quality regulation	Capturing (fine) dust, chemicals, etc
8	Climate regulation	C-sequestration, influence of vegetation. On rainfall, etc.
9	Moderation of extreme events	Storm protection and flood prevention
10	Regulation of water flows	Natural drainage, irrigation and drought prevention
11	Waste treatment	Water purification
12	Erosion prevention	Retention of soil and / or sediment
13	Maintenance of soil fertility	Soil formation
14	Pollination	
15	Biological control	Seed dispersal, pest and disease control
	Supporting services	
16	Maintenance of life cycles of migratory species	Nursery services (regulation of species reproduction)
17	Maintenance of genetic diversity (esp. gene pool protection)	Provision of habitat for wild plant and animal species
	Cultural services	
18	Aesthetic information	Provision of attractive landscape features
19	Opportunities for recreation and tourism	Provision of access for tourism and recreation
20	Inspiration for culture, art and design	Provision of cultural and artistic inspiration
21	Spiritual experience	Religious heritage (sacred forests)
22	Information for cognitive development	Provision of scientific and educational information

The economic values of these services have been computed for some countries.

According to the Millennium Ecosystem Assessment (2005) and De Groot *et al*. (2012), wetland ecosystem services deliver benefits to human society worth over €12 trillion every year.

Ecosystem services valuation

The valuation protocol proposes three levels for the valuation of wetland services, namely, comprehensive, intermediate and rapid, which can be carried out at local, catchment/ regional or national scales.

Once the scope and extent of services and beneficiaries have been decided, a guide to design the methodological approach for each service is adopted. These include Standard valuation methods such as Travel Cost Method and Contingent Valuation method (MEA, 2005). Guidelines are available for the valuation of the following services:

- provision of natural resources;
- flow regulation (flood attenuation, base flow maintenance);
- water treatment (water quality amelioration);
- recreational and tourism resources;
- scientific and educational value; and
- intangible (cultural, spiritual and existence) values.

Ecosystem Services and functions

Ecosystem services (ESs) are the benefits people obtain from ecosystems or from nature (MEA, 2005). ESs can also be defined as the goods and services derived from biodiversity. Based on these definitions, ESs of wetlands are defined as the products (food, water and other raw materials) and services (regulation, cultural and supporting services) provided by wetlands that can be used to human and other animals, and to maintain the normal ecological processes of wetlands and their surroundings. These ESs are the products of ecosystem processes or functions of an ecosystem. Ecosystem functions are also defined as "the capacity of ecosystem process and components to provide goods and services that satisfy human needs, directly or indirectly" (de Groot *et al.*, 2002).

Despite some others, several authors (e.g., de Groot *et al.*, 2002; MEA, 2005) group the ESs and functions into four major categories. Accordingly, the categories of ESs are presented in Table 1.1 and described as follows.

1) **Regulating services** include runoff regulation, sediment/soil retention, pest and disease control, pollination, disturbance regulation, climate regulation, waste treatment and water purification.

2) **Provisioning services** refer to the provision of water, food, medicinal and genetic resources, and raw materials such as grasses and clay.

3) **Cultural services** are other ESs encompassing recreation and ecotourism, education and research, cultural heritage, religious and aesthetic services.

4) **Supporting services** are the biophysical services that underlie the other three ecosystem services categories. Supporting services refer to providing refugium, nursery and soil formation functions. Accordingly, provisioning, cultural, regulating and supporting services identified from the study wetlands were also analyzed and presented following this classification system

Like the ESs, the **functions of an ecosystem** are also classified into four: provisioning, regulating, supporting and cultural functions, following the protocols of the classification system and nomenclature of ESs recommended by the same authors mentioned before as follows:

1) ***Regulation functions***: These are processes that contribute economic production such as flood and ground water discharge regulation, carbon sequestration, water purification and sediment regulation, disease and pollination regulation. Thus, regulation functions maintain a healthy ecosystem at different scale levels, and provide and maintain the conditions for life on Earth. The ecosystem / landscape unit regulation functions provide services, which have direct and indirect benefits to humans [e.g., maintaining air, water and soil quality; prevention of soil erosion, enhancement of soil formation and biological control services (diseases, pollination)].

2) ***Supporting functions***: wetlands also provide living space for wild plants and animals and nursery areas for many taxa so that they contribute to the conservation of biological and genetic diversity and evolutionary processes. Supporting functions in some reviews are termed as habitat functions. The habitat functions can be described in terms of the carrying capacity and spatial needs of the natural ecosystems which provide them. As their name indicates, the supporting functions also provide the necessary pre-conditions for all other functions.

3) ***Production functions***: natural and semi-natural ecosystems provide many resources, ranging from oxygen, water, food, medicinal and genetic resources to sources of energy and raw materials (wood, timber, fiber, etc.) for clothing and building.

4) ***Cultural functions***: The natural ecosystems provide spiritual, educational, cultural, recreational, bequest and existence values derived from use and appreciation of their biodiversity and landscapes.

Despite the expectation that wetlands in Ethiopia would also provide all the four functional services, it is understood that only the provisioning service is widely recognized and documented in Ethiopia. Wetlands in Ethiopia have been used through the centuries for provisioning services such as potable water, fish production, grazing and fodder production for livestock, aquatic plants used for constructions, medicine and ceremonial purposes, boat building, etc.

Other ecosystem services provided by wetlands in Ethiopia, although well understood, have not received the attention they deserve and have not even been considered in the various studies done on wetlands so far. The regulatory services in terms of improving water quality and providing habitat for fish, aquatic birds, macorphytes and microphyes have not been appreciated or quantified. Less is also known about the regulatory services of the wetlands such as sediment control and nutrient cycling. Such services are difficult to quantify and more so to valuate. However, detailed studies were undertaken by BirdLife International Secretariat to identify wetland areas important for the breeding and survival of birds, and it was noted that many Ethiopian wetlands have useful supportive services in providing habitats for threatened and vulnerable bird species (Table 1.2); they therefore provide critical habitats for the conservation and survival of birds in Ethiopia. Admassu Moges (2016) made detailed studies on ecosystem services of six wetlands in the Jimma highlands, Oromia Region – Boye, Agaro, Merewa, Hare, Bonchie and Duda wetlands, and he recorded that they predominantly performed provisioning services such as crops, vegetables, fruits, fish, honey, potable water, firewood, grazing and medicinal plants. It was mentioned that these wetlands also had regulatory services – microclimate regulation, runoff and erosion and flow regulation, water and sediment purification, carbon sequestration, pollination and disease control. The wetlands also had supportive services by acting as nursery and refugia for aquatic biota and contributed to the cultural and spiritual heritage of the surrounding communities.

The cultural services of wetlands are better understood in the Ethiopian context. Various wetlands serve as meeting sites for cultural events and ceremonies. However, the economic values of such services have not been estimated so far.

Table 1.2: Wetland Important Bird Areas of Ethiopia, with their qualifying criteria (EWNHS, 1996).

SITE CODE	SITE NAMES	REGION	CRITERIA USED TO SELECT SITES								
			1	2	3 (biomes)			4 (Congregations)			
					H	SM	SG	4i	4ii	4iii	4iv
001	Lake Abbe Wetland System	Af	x							x	
002	Abijatta-Shalla Lakes National Park	Or	x					x		x	
003	Aba–Samuel Wetlands	Or	x					x			
004	Lakes Haramaya and Adele	Or						x			
009	Lake Hashenge	Ti	x					x			
015	Bahir Dar–Lake Tana	Am	x		x					x	
017	Baro River	Ga	x					x		x	
019	Bishoftu Lake	Or	x								
023	Boyo Wetland	Sp	x							x	
024	Chelekleka Wetland	Or	x					x		x	
025	Lake Chew Bahir	Sp	x			x		x		x	
029	Dilu Meda (Tefki)	Or	x								
033	Finchaa and Chomen Swamps	Or	x		x						
034	Fogera Plains	Am	x								
036	Gefersa Reservoir	AA, Or	x		x						
037	Genale River	Or	x	x		x					
038	Green Lake	Or	x					x		x	
043	Koffe Swamp	Or	x								
044	Koka Dam	Or	x					x		x	
046	Lake Langano	Or	x								
061	Sululta Plains	Or	x		x						
063	Lake Turkana & Omo Delta	Sp						x		x	
068	Zwai Lake	Or						x		x	

Key

Regions	Criteria
AA - Addis Ababa Region Af - Afar Region Am - Amhara Region Ga - Gambella Region Or - Oromia Region Sp - Southern Nation, Nationalities and Peoples' Region Ti - Tigray Region	1 - globally threatened species 2 - restricted range species H - Afrotropical Highland Biome SM - Somali–Masai Biome SG - Sudan–Guinea Savannah Biome 4i – 4iv: 4i - The site is known or thought to hold, on a regular basis, ^{3} 1% of a biogeographic population of a congregatory waterbird species 4ii - The site is known or thought to hold, on a regular basis, ^{3} 1% of the global population of a congregatory seabird or terrestrial species 4iii - The site is known or thought to hold, on a regular basis, ^{3} 20,000 waterbirds or ^{3} 10,000 pairs of seabirds of one or more species. 4iv - The site is known or thought to exceed thresholds set for migratory species at bottleneck sites

Some of the ecosystem services of some Ethiopian wetlands are shown in Plates 1.1. – 1.9. (Most images are original from Brook Lemma.)

In general, the Ethiopian wetlands serve as a source of water for large rivers, flood retention and groundwater recharge. They are critical resources because they are areas of high biodiversity and are often vital to the livelihood strategies of local communities through the provision of environmental services and socio-economic benefits. Ethiopia has so far put no emphasis on developing and protecting the large wetlands, although external initiatives are emerging.

Plate1.1: Highland wetlands of Seneati plains (4300 masl, peak of Bale Mountains National Park) and Dinsho wetlands with endemic Mountain Nyala

Plate1.2: Provisioning service of wetlands (fishers from Lake Tana) Photo credit: Dr. Ayalew Wondie, and fish-landing site at Lake Hawassa.

Plate 1.3: Lakes Shalla (left) and Abijata (right corner) seen from the View Point of the Shalla-Abijata National Park (lakes with high touristic values).

Plate 1.4: Wetlands in arid areas of Lake Shalla, Rift Valley lakes basin and Dallol wetlands in Afar at an altitude of 110 m, below sea-level, which are refugia for killifishes (Aphanius dispar)

Plate 1.5: Wetlands are used for their macrophytes (Lake Tana) and for potable use (River Kulfo as it enters Lake Chamo)

Plate 1.6: Wetlands are used for income generation (provisioning) and as breeding ground for fish (supportive). Images show fishers harvesting papyrus for sale and papyrus stands as breeding ground for tilapia in Lake Tana (Photo credit: Dr. Ayalew Wondie).

Plate 1.7: River Kulfo crossing the Nech SAR Wetland forest to join Lake Chamo, which provides the last refuge to hundreds of crocodiles commonly known as "Crocodile Market".

Plate1.8: Part of River Baro close to the town of Etang, Gambella and Tata wetlands with rich fishery resources, which is being challenged with water hyacinth.

Plate1.9: Excursion on the Baro River (recreational and eco-tourism value of wetlands)

1.5 Climate Change and Wetlands

Drivers of climate change

The situation of people and the resources at their disposal around the world are changing very fast, given the rise in population and their desire for quality of life in all its forms. There is unprecedented desire to access information given the current advancements in communication technologies. The interaction of all these factors are demanding today that man stops for a while and re-visits the impacts of his own actions on the environment in general, and that of the climate in particular. It is therefore important to point out what the drivers are to get man to re-consider his position in the context of changing climate, population increase, increasing demand for quality by the same and dwindling natural resources, in this case, those of wetland ecosystems.

- Natural resources, in this context, wetland biodiversity and freshwater are under severe pressure as human livelihoods have become so demanding.
- Climate change has increasingly become real cause of droughts, floods and in general extreme variability's that left billions of people, particularly those in the South, uncertain and vulnerable to all sorts of related disadvantages.
- The continuous degradation of the environment (deforestation, emissions, alterations of wetlands and their landscape through unsustainable development endeavors) has left the world with ever increasing temperature and warm conditions.
- The impact of the above changes has resulted to increasing UV radiations that exposed biodiversity to undesirable and unpredictable genetic alterations.
- Again the above factors (human, emissions, precipitation changes, warming, UV radiations, etc.) have led to development of invasive organisms and diseases in wetlands that are favored by the new environmental changes (Karvina *et al.*, 2010).

- It is global that development efforts cannot anymore continue in the conventional economic development patterns of exploitation of natural resources as experienced in the North.
- The competition for wetland resources has increased dramatically in light of global warming and rainfall variabilities extending into frequent drought periods.
- Overhauling the economic development paths and finding sustainable ways with the intention of green economic development should be sought imperatively.
- Information exchange and engagement of stakeholders for the common sustainable development should be approached with urgent purpose.
- Platforms for knowledge and technology exchange and adapting them to local conditions should be developed to mitigate such problems of humanity in general and those of developing countries like in Africa in particular.

Impact, vulnerability and risks

Global warming has significantly influenced physical and biological processes at global and regional scales (Allison *et al.,* 2009). As the planet's climate changes, so too will populations, species and ecosystems (Hall-Spencer *et al.,* 2008). As a result of this change, many countries have become vulnerable to the effects of these changes, of which the world's least developed countries whose inhabitants are among the world's poorest are the most affected (Allison *et al.* 2009). According to Funk *et al.* (2005) the majority of this crisis is expressed in tendencies of drought over the past couple of decades occurring in the equatorial and subtropical eastern Africa (ESEA) located at 23^0N/S, 21-52^0E. Although as a globe the world is experiencing increase in rainfall, the subtropical regions that include ESEA will experience spells of drought and sporadic showers that do not match the regular patterns of farming and fisheries practices (Gitay, *et al.,* 2002). As a result populations of the region are challenged and seem to be at a loss, for they do not know what causes this incompatibility between the traditions of farming and fishing they inherited from their fathers and grandfathers and the climate pattern they grew up in.

One does not have to go to great lengths to find living examples. Up until the 1980s Lake Alemaya (Haramaya) (eastern Ethiopia) was such a thriving lake with fishery practices, irrigation, municipal water supply source and instrument of waste assimilation of the people in the watershed. By the turn of the millennium (in 2005), it completely dried out and turned into a terrestrial environment where livestock graze in the field (described in chapters 2 - 5).

Ethiopia, being one of the ESEA countries, faces the largest food insecurity, for the past ten years it has seen declines in rainfall and an average annual increase of about 0.5 million people needing food aid or an additional 1.5-2 million individuals per year who are born without food, in a country where less than 8% of the population uses any form of family planning (Funk *et al.,* 2003; 2005). This is coupled with declining health conditions with outbreaks of malaria, tuberculosis, Rift Valley Fever, various forms of flu and dysenteries that have taken away lives of particularly children, and limited the productivity of people and livestock, leading to severe food shortage, and limited livestock exports, both in terms of numbers and quality (Funk *et al.,* 2005).

The parts of Ethiopia, such as the Great Rift Valley to which the Lake Zwai watershed belongs, is exposed to increasing warming and declining rainfall leading to increasing demands for wetland, water and irrigated agriculture (Handisyde *et al.* 2006, Funk *et al.* 2005), pushing people to the lake in search of fresh water for irrigation, in-doors flower farming and direct fishing exercises with free-access-to-all policy. The Zwai area is specifically identified as one that is exposed to declining rainfall, increasing warming and hence designated as one of the highly populated areas of the country with high risk as impacted upon by climate change (Funk *et al.*, 2007; Allison *et al.,* 2009).

Lake Zwai that provides about 70% of the fish supply of the country (Dawit Taye, 2004) has been reported that the fishery at Lake Zwai was closed for some time in the 1980s, when individual length and total catch of Nile-tilapia failed drastically (Zinabu GebreMariam, 1998). After about 14 years, over-fishing reappeared in Lakes Zwai and Langano, where fishing was banned as of August 26, 2004 (Dawit Taye, 2004). Today the problem persisted that fillet sizes of *Oreochromis niloticus* (Nile-tilapia) collected from Lake Zwai are much smaller and cheaper than those collected from Lakes Chamo and Tana, as it is marketed in Addis Ababa today (personal observation). It has however increasingly become clear that declining fish catches and sizes of individual fishes is not a matter of overfishing alone, but also another face of the impacts of climate change on freshwater ecosystems (Allison *et al.,* 2009). In the deeper Rift Valley lakes, such as Lake Tanganyika, climate change has been associated with increases in surface water temperature, reduced primary productivity and fish catch rate over the last century (Ficke*et al.,* 2005). Such lakes as Lake Chad in central Africa have faced increasing shrinkage due to excessive evaporation and evapotranspiration which pushed people to converge on the narrowing and continuously shallow lakes (Sarch and Birkett, 2000; Béné*et al.,* 2009). At the same time the quality of the water chemistry and fish has deteriorated so much with the additional pain of losing so many species forever (Sarch and Birkett, 2000; Béné*et al.,* 2009). The fate of another lake called Haramaya in the eastern part of Ethiopia is an outstanding example of the effects of climate change and the increasing demands for fresh water by increasing populations. In Lake Haramaya which has gone to the extremes of changing from once thriving fresh water supplying municipal water to over 100 000 people of the region, fishes, animal watering source, bathing and recreation, turned from freshwater to completely terrestrial environment (See Brook Lemma 1991; 1995; 2002) and the web after the names of the lake and the author). Likewise climate change impacts have been noted in Lakes Chelekleka, Abijata, Beseka, Kilole and others.

The effects of climate change on freshwater systems such as Lakes Tanganyika or Zwai or any other lakes and wetlands in the tropics and subtropics have been expressed in terms of:

- Increased epilimnetic water temperature that resulted in prolonged stratification (De Silva and Sota, 2009; Jeppesen and Kronvang, 2009),
- The same impact in turn hinders the uplifting of nutrients to upper illuminated and widening epilimnetic layers (Gitayet al., 2002; Sharp, 2003),
- Increased incidences of red tides, frequent algal blooms with Cyanobacteria and associated fish, animals and human poisoning (Michael, 2001; Patzet al., 2006),
- Decrease in the amount of dissolved oxygen in contrast to high biological activity due to increased temperature (Dawet al., 2009),
- Narrowing of migration spaces as lakes shrink (Gitayet al., 2002),

- Increase in human numbers and their demand for fresh water (Michael, 2001; Funk et al., 2005; Allison et al., 2009)
- Overfishing as human needs for fish and fishery products increase by the day
- Collateral damage by fishing gears (e.g. nets) to non-fish vertebrates such as amphibians, reptiles, aquatic birds and mammals.
- Habitat destruction has led to disappearance of aquatic biodiversity that have limited adaptive capacities, such as changes in temperatures, level of turbidity, dissolved oxygen, selectivity in food type, etc.
- Hunting of non-fish vertebrates for commercial purposes or just to remove them from fishing grounds as they may be considered nuisance to fishing practices.
- Lack of ownership of wetlands and their biodiversity as all these are government properties (at least in Ethiopia) with open access to all who have fishing gears or pumps who would take fresh water for any purpose, etc.
- Lack of awareness of wetland resources (e.g. grasses, wetland trees, fresh water, fishes) by local populations who consider them inexhaustible.

Adaptation, mitigation and managing risks

Adaptation strategies: Although there is a growing consensus on several general adaptation principles, capacity for taking action continues to lag, adaptation strategies and solutions are generally very specific to a region, limiting widespread application (Staudinger *et al.,* 2012). Twentieth-century water planning was based in part on the idea that climatic conditions of the past would be representative of those in the future; but this model is much less useful in the twenty-first century (Udall, 2013). Further, adaptation is also constrained by numerous non-climate factors, such as, un-integrated development plans, free access to water and aquatic biodiversity (e.g. any person with a fishing gear can scoop out any fish of any size and number and make some income).

Despite the above backdrop, the following adaptation strategies are suggested:

- Develop water and aquatic biodiversity sustaining policy in collaboration with all stakeholders, including local populations
- Build implementation procedures for the same, sufficiently empowering and making accountable local populations, whose livelihoods are directly intertwined with their lives.
- Invest heavily in climate-change studies relating to water resources and their sustainable development and application of such data and knowledge for impact assessment and adaptation.
- Identify and minimize greenhouse gas emissions and seek for alternative adaptation mechanisms to cut back on emitting actions.
- Developing successful human response strategies to climate change, which would include adopting approaches that benefit biodiversity and enhance the ability of its elements to adapt to change (Klein et al., 2007).
- Climate change adaptation seeks to reduce key vulnerabilities of natural and human systems against actual or expected climate change effects, and when possible, take advantage of beneficial opportunities (Klein et al., 2007)
- Conserving populations with higher genetic diversity or more plastic behaviors or morphologies
- Changing seed sources for re-planting to introduce species or ecotypes that are better suited for future climates
- Assisted migration to help move species and populations from current locations to those areas expected to become more suitable in the future
- ex-situ conservation such as seed banking and captive breeding.
- Support and improvement of governance for climate change adaptation
- Build livelihood resilience to climate change
- Develop targeted approaches for conservation and sustainable management of biodiversity

- Identify, support and application of innovative technologies
- Improved disaster risk management.

Mitigation strategies: The following mitigation strategies for wetland resources are adapted from FAO (2005):

- Strengthen agriculture, forestry and other land-based sectors in climate change negotiations and international agreements
- Develop integrated and accessible knowledge database for mitigation
- Seek for various methods and technologies that are used elsewhere and develop modalities of contextualizing them for mitigation to local conditions
- Develop policies that are participatory for all stakeholders and that allow good governance for climate change mitigation actions
- Reduce emissions from fishing operations which tend to increase long distance travels due to overfishing, as this is now the case in most countries. Mitigations in this regard could be use of fuel efficient engines, safer fuels (e.g. alcohol, chargeable batteries driven engines, manual operations when possible).
- Reduce emissions during the processing and transport of fish and fishery products along the value chain.
- Reduce emissions from waste products from fish processing (offal), which either lays around to decompose and release GHGs into the atmosphere or during handling to change it into animal feed or fertilizer. In all cases, organic wastes should be handled in a way they can be changed into biofuels.
- The above procedure can be used as mitigation procedure to cut back on the use of conventional fuels.
- Attempt to convert wetlands into systems of carbon sequestration and set up policy actions for such mitigation actions. These solutions require innovative approaches such as funding for Reducing Emissions from Deforestation and Forest Degradation (REDD), which demonstrates the potential for catchment forest protection under REDD following Ethiopia's Climate Resilient Green Economy Strategy (CRGE).

- Developing low-carbon aquaculture production systems.

Information, data gaps and research needs

- Information

This report attempts to give some highlights on the wetland resources Ethiopia has and the life forms they support. These information may not be exhaustive, but they are important indicators as to what to expect in the Ethiopian waters.

Data gaps and research needs

There are major data gaps particularly in the form of lack of database where one accesses for information on wetlands and the biodiversity in them. These gaps and research needs can be summarized as follows.

- There is lack of regular platforms where scientists, users and policy makers could meet to discuss and exchange views on current issues and future trends of use and conservation of wetland resources. In the past few years the Ethiopian Fisheries and Aquatic Sciences Association (EFASA) has been regularly holding annual conferences and publishing outcomes of the same. The circulation of the same material to national and international stakeholders is limited. Other institutions such as EPA and, EWNRA have put substantial efforts in the study and conservation of Ethiopian wetlands.

- Rapid development work, mostly without compatible conservation procedures, is being done in this country by international donor organizations in collaboration with national public and private organizations. A recent publication of the Ethiopian Academy of Sciences authored by Brook Lemma (2014) shows that there is limited communication between all these actors as shown in the redundancy of the work they do and the lack of integrated information supply to decision makers and users.

- The absence of such organization as Ethiopian Panel for Climate Change (EPCC) and other related institutions causes further separation rather than integration of knowledge.

- There may be sizable amount of scientific data locked up in academic and research institutes of the country. There is no mechanism to get this information into local languages to be usable by ordinary people and there are not any institutional system that would transform knowledge into contextual practices.
- Lack of collaborators, fund or lack of knowledge of both
- Climate change database to access information on when rain fails or flood comes or to obtain any weather data that may affect livelihoods and safety of the environment, such as landslide.
- Inadequate use or lack of recognition to indigenous knowledge and ineffective or non-existent awareness creation mechanisms and lack of transferring whatever knowledge is created to the education system.
- Given the opportunities of working with CRGE strategy in Ethiopia, the desire to build many dams that would create more wetland resources and hence improving the green cover of the national landscape.
- It is therefore imperative that rresearchers seize the opportunity to engage users and decision makers in designing and implementing targeted research activities that would generate desirable and usable outcomes.
- Researchers need to conduct collaborative research that would address overarching national problems like food security, sustainable use of natural resources particularly wetland biodiversity and fresh water.

Policy implications and recommendations

- The understanding that could be learned from the above information inevitably leads to the suggestion that responsible decision makers should reach out to create open and transparent platforms where scenarios are discussed and knowledge databases have to be referred to and experts have to be consulted.

- There does not seem to be any other alternative way other than engaging stakeholders and draw lines where each follows guidelines to sustainably use aquatic resources and ensure that they are passed to future generations.

- Such effort will not be let alone without enforcing regulations and reaching consensuses with all stakeholders for the sake of sustainable outcomes in the use of natural resources. Decision makers and stakeholders at large need to put in place implementation procedures that make all users accountable for their actions while using aquatic resources.

- The fact that Ethiopia is not signatory to the Ramsar Convention may give it the right to act unilaterally with regards to the management of wetlands in its own boarders. As these aquatic systems are influenced by numerous international conditions such as climate, migration of animals, etc., it would be worthwhile to revisit the signing of the Convention and reap the benefits of global opportunities.

- The Ethiopian Constitution at Article 92 states that as Ethiopians have the right to live in a clean and healthy environment, they have also the obligation to safeguard it for sustainable use. As a result, numerous policies have been developed and put into action. These include the policies for environment protection, land use, forest use and development and so on. So far however, there is not any policy developed on the management of wetlands. This may be because sustainable management of wetlands is mentioned in all of the above policies and others such as the use and protection of Ethiopian fishery resources and other. It may be time to revisit and consider a stand-alone wetland policy that is aligned with all other national policies and the Ramsar Convention for the management of wetlands.

- The Growth and Transformation Plans (I and II) of Ethiopia have consistently used the Climate Resilient Green Economy (CRGE) strategy that clearly defines that countries like Ethiopia cannot proceed to develop their economy and reach to achieve what the developed countries accomplished in conventional ways. Lessons have shown that developments in the past have not been environmentally friendly and have put nations into the kind of environmental crisis they are in. It was therefore necessary for Ethiopia, a country completely dependent on its natural resources to grow, to find alternative paths that consider sustainability of natural resources and at the same time continue to develop economically. Such endeavors require the use of hydro-power instead of conventional fuels, reduce emissions and expand green cover to join the carbon trade, harness alternative energy sources such as thermal, solar and wind energy sources which are at its disposal and work strongly and consistently on climate mitigation and adaptation technologies to safeguard livelihoods and ensure the transfer of natural resources to future generations.

References

Admassu Moges (2016). Studies on ecosystem services and ecological status, and development of plant-based monitoring tool, in Jimma wetlands, Ethiopia. Ph.D. Thesis. Jimma University.

Afework Hailu (2003). Wetlands research in south-western Ethiopia: the experience of the Ethiopian Wetlands Research Programme. In: Wetlands of Ethiopia: Proceedings of a seminar on the resources and status of Ethiopia's wetlands. Yilma D. Abebe and Kim Geheb (eds.) IUCN

Allison, E. D., Perry, A. L., Badjeck, M. C., Adger, W. N., Brown, k., Conway, D., Halls, A. S., Pilling, G. M., Reynolds, J. D., Andrew, N. L. and Duvy, N. K. (2009). Vulnerability of national economies to the impact of climate change on fisheries. *Fish and fisheries* 10: 173-196.

Béné, C., Neiland, A., Jolley, T., Ovie, S., (2009). Inland fisheries, poverty and rural livelihood in the Lake Chad basin. *Journal of Asian and African Studies* 38(1): 17-51.

Brook Lemma (1991). Preliminary limnological studies on L. Haramaya, Ethiopia, and some questions arising. In: K. Koop (ed.), Aquaculture in Africa, held in Harare, Zimbabwe, 23-27 January 1991. IFS publication, Stockholm, pp. 134-148.

Brook Lemma (1995). Seasonal limnological studies on Lake Haramaya: a tropical African lake, Ethiopia. *Arch. Hydrobiol./Suppl*. 107(2): 263-285.

Brook Lemma (2002). Contrasting effects of human activities on aquatic habitats and biodiversity of two Ethiopian lakes. *Ethiopian Journal of Natural Resources* 4(1): 127 – 148.

Brook Lemma (2011). The impact of climate change and population increase on Lakes Haramaya and Hora-Kilole (1986 – 2006). In: Impacts of climate change and population on tropical aquatic resources. Proceedings of the Ethiopian Fisheries and Aquatic Sciences (EFASA); Haramaya University, 03-06 February 2011. pp. 11-36.

Brook Lemma (2014). Baseline Studies on Climate Change Research in Ethiopia. Published by the Ethiopian Academy of Sciences, Addis Ababa, Ethiopia, 125pp.

Cowardin, L.M., Carter, F., C. Goler and E.T. LaRoe (1979). Classification of wetlands and deepwater habitats of the United States. U.S. Wildlife and Fisheries Service, Washington, DC, 103 pp.

Davies, B. and Day, H. (1998). Vanishing Waters. University of Capetown, Capetown.

Daw, T., Adger, W. N., Brown, K., and Badject, M-C. (2009). Climate change and capture fisheries. FAO Technical Paper No. 530, FAO Rome. Pp. 96-136.

Dawit Taye (2004). Fishing banned in Lakes Zwai and Langano (2004) *Fortune: An Ethiopian weekly newspaper*, Vol. 5, No. 227, September 05, 2004.

Dessalagne Mesfin (2003). Wetlands policy development in Ethiopia. In: Wetlands of Ethiopia: Proceedings of a seminar on the resources and status of Ethiopia's wetlands. Yilma D. Abebe and Kim Geheb (eds.) IUCN

De Silva, S. S. and Sota, D. (2009). Climate change and aquaculture: potential impacts, adaptation and mitigation. Fisheries Technical paper 537: 137-215.

De Groot, R.S., Wilson, M.A., Boumans, R.M.J., (2002). A typology for the classification, description and valuation of ecosystem function, goods and services. *Ecological Economics* 41:393–408.

De Groot and 16 others (2012). Global estimates of the value of ecosystems and their services in monetary units. *Ecosystems Services* **1**: 50-61.

EPA (Environmental Protection Authority of Ethiopia) (2003a). State of the Environment Report of Ethiopia. Federal Democratic Republic of Ethiopia, Addis Ababa, 192 pp.

EPA (2003b). Environmental Impact Assessment Guideline for Mineral and Petroleum Operation Projects. Federal Democratic Republic of Ethiopia. Environmental Protection Authority. 40pp.

EWNHS (1996). Important Bird Areas of Ethiopia: A First Inventory. Semayata Press, Addis Ababa, Ethiopia.

FAO (1984) Land evaluation for forestry. FAO Forestry Paper 48, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, ISBN: 92-5 102123-6, 130 pp. FAO, 1984d.

FAO (2005). Global Forest Resources Assessment 2005: progress Towards Sustainable Forest Management. FAO, Rome, IT.

FAO (2006). Country Pasture/Forage Resource Profile. Compiled by Alemayehu Mengistu, Publishing Policy and Support Branch, Office of Knowledge Exchange, Research and Extension, FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy.36 pp.

Ficke, A. A., Myrick, C. A. and Hansen, L. J. (2005). Potential impacts of global climate change on freshwater fisheries. Department of Fisheries and Wildlife Fisheries, Colorado State University, 91 pp.

Funk, C., Asfaw, A., Steffen, P., Senay, G., Rowland, J. and Verdin (2003). Estimating *Meher* crop production using rainfall in the long cycle region of Ethiopia. FEWS NET Special Report.

Funk, C., Gabriel Senay, Alemu Asfaw, Verdin, J., Rowland, J. *et al.* (2005). Recent drought tendencies in Ethiopia and equatorial subtropical eastern Africa. FEWS NET Famine early Warning Systems Network, USAID. Vulnerability to Food Insecurity: factor identification and Characterization Report, No. 01/2005. 12 pp.

Gitay, H., Suárez, A., Anisimov, O., & Cruz, R. V. (2002). Climate change and biodiversity. International Panel on Climate Change (IPCC of UNDP and WMO)) and administered by IPCC Working Group II technical support Unit.

Hall-Spencer, J. M., Rodolfo-Metalpa, R., & Martin, S. (2008). Volcanic carbon dioxide vents show ecosystem effects of ocean acidification. *Nature* 454: 96-99.

Handisyde, N. T., Ross, L. G. and Badjeck, M-C.and Allison, E. H. (2006). The effect of climate change on world aquaculture: A global perspective. Final Technical Report by the Institute of Aquaculture, Sterling, U. K. and sponsored by the Department for International Development (DFID). 151 pp.

Hillman, J. C. (ed.) (1993). Ethiopia: Compendium of Wildlife Conservation Information. NYZS - The Wildlife Conservation Society, International, New York Zoological Park, Bronx, NY and Ethiopian Wildlife Conservation Organization, Addis Ababa, Vol. 2, 786 pp

Hughes, R. H. and Hughes J. S. (1992). *A Directory of African Wetlands.* IUCN, Gland, Switzerland and Cambridge, UK/UNEP, Nairobi, Kenya/WCMC, Cambridge, UK. 820pp.

Jeppesen, E. and Kronvang, B. (2009). Climate change effects on runoff, catchment phosphorus loading and lake ecological state and potential adaptations. *J. Environ. Qual.* 38: 1930-1941.

Karvonen, A., Rintamaski, P., Jokela, J., and Valtonen, E. T. (2010). Increasing water temperature and disease risks in aquatic systems: Climate change increases the risk of some, but not all, diseases. Int. J. Parasitol. 40(3): 1483-8 (doi: 10.1016/j.ijpara.2010.04.015 Epub 2010 May 23

Klein, R.J.T., Huq, S., Denton, F., Downing, T.E., Richels, R.G., Robinson, J.B., Toth, F.L. (2007). Inter-relationships between adaptation and mitigation. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C. E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 745-777.

Mengistu Wendafrash (2003). Wetlands, birds and important Bird Areas in Ethiopia. In: *Wetlands of Ethiopia*, pp 25-36 (Yilma Abebe and Geheb, K., eds.). IUCN, Nairobi.

Mesele Fisseha (2003). Water resources policy and river basin development as related to wetlands. In: Wetlands of Ethiopia: Proceedings of a seminar on the resources and status of Ethiopia's wetlands. Yilma D. Abebe and Kim Geheb (eds.) IUCN

Mesfin Abebe (2007). Nature and Management of Acid Soils in Ethiopia

Michael, A. J. (2001). Impact of climatic and other environmental changes on food production and population health in the coming decades. *Proceedings of the nutrition Society* 60: 195-201.

Millennium Ecosystem Assessment MEA (2005). Ecosystems and human well-being: A synthesis. A Report of the Millennium Ecosystem Assessment. World Resources Institute and Island Press, Washington, DC. Available at: www.maweb.org/documents/document.356.aspx.pdf

MoWR (Ministry of Water Resources) (1999). Water Resource Management Policy (WRMP), Addis Ababa: Ethiopia.

Mukanda, N. (1985). Land evaluation for multi-purpose land development in Masansa Area, Mkushi District, Zambia. Msc. Thesis. (unpublished). University of East Anglia, Norwich, U.K.

Patz, J. A., Olson, S. and Gray, A. L. (2006). Climate change, oceans and human health. *Oceanography I*, 19 (2): 52-59.

PCC (Population Census Commission) (2008). Summary and Statistical Report of the 2007 Population and Housing Census Results: Population Size by Age and Sex. Sponsored by UNFPA and printed by United Nations Population Fund (UNFPA). 113pp

Ramsar Convention Secretariat (2016). An Introduction to the Ramsar Convention on Wetlands,

7th ed. 2016 (previously The Ramsar Convention Manual)., Gland, Switzerland.

Ramsar Convention Bureau (1997). The Ramsar Convention Manual: A Guide to the Required Action. IUCN, Gland, Switzerland 94pp

Redeat Habteselassie (2012). Fishes of Ethiopia: Annotated Checklist with Pictorial Identification Guide. Sponsored by the Austrian Development Cooperation and published by the Ethiopian Fisheries and Aquatic Sciences Association, EFASA. Printed by Eclipse Printer, Addis Ababa. ISBN 978-99944-989-8-7.250 pp.

Roggeri, H. (1995). Tropical Freshwater Wetlands: A Guide to Current Knowledge Sustainable Management. Developments in Hydrobiology 112. Kluwer Academic Publishers, Dordrecht, 363pp.

Sarch, M-T., and Birkett, C. (2000). Fishing and farming at Lake Chad: Responses to lake-level fluctuations. *The Geographical Journal* 166(2):156-172.

Schmitt, M. (2010). Climate Change and Water Resource Management: Adaptation Strategies for Protecting People and the Environment. Natural Resources Defence Council (NRDC), www.nrdc.org/policy

Sharp, G. D. (2003). Future climate change and regional fisheries: A collective analysis. FAO Fisheries Technical paper, No. 452, Rome, 75 pp.

Silesh B. Awulachew, Yilma, A. D.; Loulseged, M.; Loiskandl, W., Ayana, M.; Alamirew, T. (2007). Water Resources and Irrigation Development in Ethiopia. Colombo, Sri Lanka: International Water Management Institute. 78p. (Working Paper 123)

Shimellis A. Zelelew (2013). Birds of Lake Tana area: A photographic field guide. Editors: B. Pfister, Afework Bekele and G. Archibald. ISBN 978-99944-989-4-0. 235pp.

South Africa Water Act (Act 36 of 1998). UNESCO Office, Windhoek.

Staudinger, M, D., Grimm, N. B., Staudt, A., Carter, S. L. F., Chapin III, S., Kareiva, P., Ruckelshaus, M. and Stein. B. A. (2012). *Impacts of Climate Change* *on Biodiversity, Ecosystems, and Ecosystem Services: Technical Input to the 2013 National Climate Assessment.* Cooperative Report to the 2013 National Climate Assessment. 296 p. Available at: http://assessment.globalchange.gov

Tesfaye Seifu (1990). *The Conservation Status of Wetlands and Waterfowl in Ethiopia*. Paper Presented to IWRP Workshop. 3 - 12 March, 1990, Uganda. 18pp.

Tilahun Hailu, S., S. Edwards, and Tewolde B. G. Egziabher (eds.). (1996). *Important Bird Areas of Ethiopia: A First Inventory.* Ethiopian Wildlife and Natural History Society, Addis Ababa. 300pp.

Udall, B. (2013). "Water: Impacts, Risks, and Adaptation." In: *Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment*, edited by G. Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy, 197–217. A report by the Southwest Climate Alliance. Washington, DC: Island Press.

USAID (2009). Ethiopia food security outlook – April to September 2009.

Wheeler, B.D., Shaw, S.C., Fotj, W.J. and Robertson, R.A. (1995). *Restoration of temperate wetlands.* Wiley, Chichester, UK. 562 pp.

Yilma Delelegn and Geheb, K. (eds.) (2003). *Wetlands of Ethiopia*. IUCN, Nairobi.

Yitebitu Moges, Zewdu Eshetu and Sisay Nune (2010). Ethiopian forest resources: Current status and future management options in view of access to Carbon finances. Prepared for the Ethiopian Climate Research and Networking Group and UNDP.

Zerihun Woldu (1999). *Vegetation map of Ethiopia*. Addis Ababa University, Addis Ababa, Ethiopia

Zinabu GebreMariam (1998). Seasonality and spatial variation in abundance, biomass and activity of heterotrophic bacterioplankton in relation to some biotic variables in an Ethiopian rift-valley lake (Awasa). *Freshwat. Biol* .22: 355-381.

Chapter 2

DESCRIPTION OF WETLANDS (DRAINAGE BASIN APPROACH)

2.1. Abay basin (general)

Description of the Abay (Blue Nile) basin

The Abay basin covers three Ethiopian regional states, namely the Amhara, Oromia and Benishangul-Gumuz regional states.

According to Getnet Hunegnaw *et al.*, (2013), the Abay River basin may be divided into 16 sub-basins. The present report has some information on 14 of them, namely Tana, Beshilo, Welaka, North Gojam, Jemma, Muger, Guder, South Gojam, Finchaa, Anger, Didessa, Wenbera, Dabus and Beles, that are located in Ethiopia. About 35% of the total population of Ethiopia live in the Blue Nile (Abay) River basin.

The total area of wetlands in Abay basin is estimated to be above 188,528 hectares of marshy or swampy areas. This indicates the disappearance of more than 80 thousand of marshy and swampy wetlands which were estimated to 238,400 ha during the Abay Basin Master Plan study document (Getnet Hunegnaw *et al.*, 2013).

The geology of the Abay River basin signifies different formations, such as basalt, alluvium, lacustrine deposits, sand stone, granite and marble, with basalt dominating. The eastern part of the basin is characterized by dominantly cultivated land, while grassland, wood lands and forest prevail in the west. The major soil types in the Abay River basin are alisols and leptisols, followed by nitosols, vertisols, cambrisols, fluvisols and luvisols. The agro-ecology of the basin is divided into three major climatic zones, namely cold to very cold, tepid to cold and hot to warm that may be further divided into moist, sub-moist, humid and sub-humid.

Rainfall in the Abay River basin ranges from 787 to 2,200 mm per year. Higher rainfall values (1,500 to 2,200 mm) are observed in highlands whereas rainfall reaches values lower than 1,500 mm per year in lowlands. The lowest rainfall values (< 1,000 mm/year) are observed in Beshilo, Welaka, Jemma, Muger and Guder. Higher temperature values are observed in the northern-west part of the basin, namely in parts of Beles and Dabus (max: 28°C to 38°C, min: 15°C to 20°C). Lower temperature values are observed in the central and eastern part of the basin, where highlands are located (max: 12°C to 20°C, min: -1°C to 8°C).

Potential evapotranspiration (PET) in the Abay River basin ranges from 1,056 to 2,232 mm per year. High PET values (1,800 mm to 2,232 mm per year) are observed in the northern-west parts of the basin, namely in parts of Beles and Didessa. Lower PET values are observed in the eastern and southern parts of the basin (1,200 mm to 1,800 mm per year). The lowest PET values (<1,200 mm per year) are observed in some parts of highlands.

According to the Water Atlas of Eastern Nile Technical Regional Office (ENTRO, 2006), the Abay River is the largest contributor of the Eastern Nile Basin system, since it accounts for 67 % of the inflow at Aswan in Egypt (56 BCM/year). The flow of the Abay River has two main characteristics: extreme seasonal and extreme inter-annual variability. More importantly, during the flood season from July to October, more than 80 % of the flow occurs. In contrast, only 4 % of the flow occurs during the dry season from February to May.

Wetlands in Abay Basin (2016)

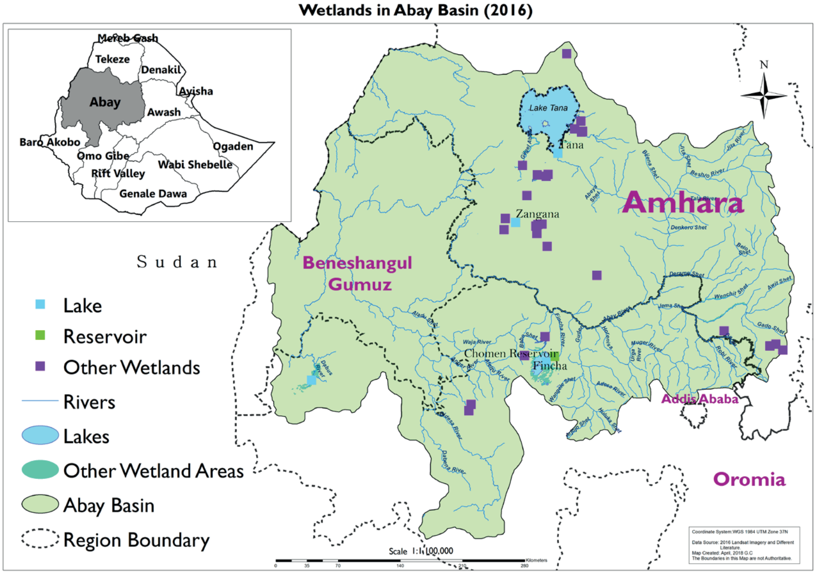


Figure 2. 1 Wetlands in the Abay basin (small lakes are shown as blue squares).

In Figure 2.1, all the wetlands found in the Abay basin are shown. Further, Abay Basin is subdivided into 16 sub-basins as listed in Table 2.1.

Table 2. 1 List of sub-basins in the Abay basin (Abay Basin Authority, 2013)

No.	Wetland name	Type	Area (ha)
	Lake Tana sub-basin	Lacustrine, fringe, swamp	24000
	Beles sub-basin	riverine	23908
	Dinder sub-basin	Riverine	Na
	Rahad sub-basin	Irrigation field	Na
	Dabus sub-basin	Riverine, floodplain	35564
	Anger sub-basin	Riverine	15309
	Muger sub-basin	Riverine	32
	Guder sub-basin	Riverine	Na
	Jemma sub-basin	Riverine	1516
	Walaka sub-basin	Riverine	11
	Beshilo sub-basin	Riverine	53
	East Gojam sub-basin	Valley bottom, riverine, dambo	16123
	West Gojam sub-basin	Dambo seepage, riverine	38.8
	Dedessa sub-basin	Riverine	54124
	Wenbera sub-basin	Riverine	Na
	Fincha sub-basin	Lacustrine swamp	17884

Na – Not available

2.1.1. Wetlands in the Amhara National Regional State (ANRS)

2.1.1.1. Lakes and rivers in the ANRS

The lakes and rivers found in the Abay basin are shown in Figure 2.2. The rivers found in the ANRS are listed in Appendix 2. It is evident that the region is rich in water resources and wetlands, which have great significance for the livelihood of the people, where agriculture is the predominant form of subsistence.

Although lakes are not a notable feature of the Abay basin, one of the largest lakes in Ethiopia, Lake Tana, is located near the city of Bahr Dar.

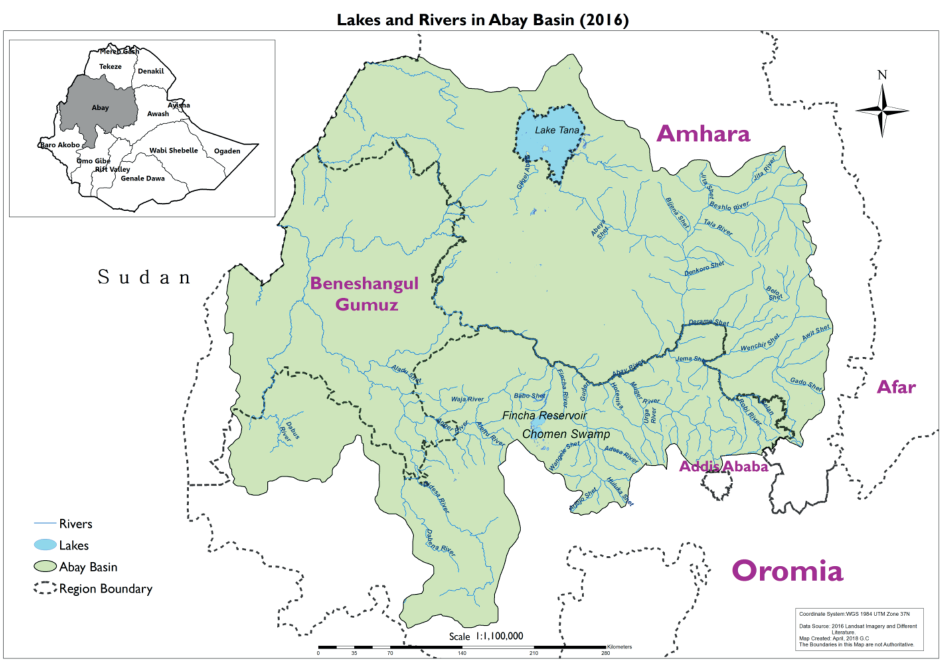


Figure 2. 2: Lakes and rivers in the Abay basin

2.1.1.1.1. Lake Tana

Lake Tana is located at latitude 12oN and longitude 37o15'E on the basaltic plateau of the north western highlands of Ethiopia. Its surface area ranges from about 3050km2 in the dry season to 3,600 km2 at close of the rainy season. With an average depth of 8.8m, the volume of the lake is about 28 km3 and it depends heavily on the local climate but is also highly influenced by the surface area, which exposes it to the high evaporation rate (1800 mm/yr).The lake is the largest freshwater lake in Ethiopia located approximately 563km northwest of Addis Ababa at an altitude of around 1,830 masl.

The lake is replenished by five large permanent rivers as well as many small seasonal rivers in addition to surface diffuse runoff. The main tributaries to the lake are the Little Nile River (Gilgel Abay) which is the major source originating from the mountains in the south west at 2850m a s l (Stave *et al.,* 2017). The major water sources of Lake Tana are from surface water, rainfall and ground water recharge due to the presence of extensive fringe wetlands. The extent of the discharge and recharge functions of the Tana wetlands has not been studied. During the wet season, Lake Tana is fed by over sixty rivers and streams, but year round it is fed by five permanent rivers, such as Gilgel Abay, Gumera, Rib, Megech, Gelda and Enfranz (Infranz). The total area of the largest rivers draining into Lake Tana (Gilgel Abay, Gumara, Rib and Megech) is 5112 km^2 , an area quite feasible to concentrate management than the larger sub-basin area of 16 500 km^2, where the drainage is a diffuse runoff. A lot of information on Lake Tana has been documented in different publications, too numerous to cite in this report. The most recent compilation of all the information available on the Lake Tana basin in a single book is a major contribution to bring together the fragmented data on this important lake in Ethiopia together (Stave *et al.*, 2017)

Ecosystem services of Lake Tana

The Lake Tana watershed wetlands have critical functions of nutrient and sediment retention, biodiversity and hydrological functions of water storage and flood abatement. The wetlands support the livelihoods of hundreds of thousands of people in various ways (Stave et al., 2017). The wetlands support large biodiversity of plankton, fish, macrophytes, mammals and birds, and the Lake Tana fringe is migratory route for some overwintering birds such as the

Pallid Harrier (EWNHS, 1996). The regulatory functions of the Abay basin in terms of regulation of local and regional climate have been discussed in Stave *et al.,* (2017). The Lake Tana sub-basin is culturally an important site for some indigenous communities such as the Weyto. The transboundary nature of the Abay River makes it an important area of regional and international importance, especially to downstream riparians such as Sudan and Egypt.

2.1.1.1.2. Awi zone lakes

The Awi zone lakes and rivers are located in the ANRS at coordinates 10°51'N 36°47'E, at an altitude between 2,300–2,500m and cover a total area of 131,844 ha,

Biophysical characteristics

Agaw Medir is relatively flat and fertile with an altitude of c. 2,300 m. The lowest parts are at 1,800 m and the highest at 3,100 m on the nearby hills and mountains. The area is crossed by about **nine permanent rivers** that drain into the Abay and has two crater lakes, **Zengena** and **Tirba**. The good agricultural practices of the Agaw have enabled them to sustain the fertility of the soil and minimize erosion so that this area is recognized as one of the most productive in the Amhara Region. Zengena Lake is a crater lake with average altitude at the rim at 2,480 m and there is a drop of nearly 1,000 m down to the bottom of the crater. Vegetation around the crater rim is dominated by a plantation of *Cupressus lusitanica* which is managed by the Agricultural Department in Kosso Ber. Although the forests on the hills face a threat from expanding small-holder agriculture and grazing by domestic stock, it is interesting to note that the vegetation has existed to this date and is still in good condition. The conservation of the forests appears to be a result of traditional land management.

The zone has also extensive wetlands as marshes. **Zimbiri marsh** is located on the Kosso Ber–Bahir Dar road, at an altitude of 2,300–2,350 m. The largest wetlands in the Awi zone are found in Dangila Woreda (247 ha), Banja Woreda (255 ha) and Ankasa Woreda (361 ha). The vegetation in these wetlands includes short annual grasses, sedges, bulrushes and some trees such as *Croton macrostachyus*. The marshy area is very extensive, encircling a number of peasant associations that are on the slightly higher and drier ground (EWNHS, 1996).

Ecosystem services and ecological status

The Awi zone lakes have been relatively well managed and continue to give ecosystem services even today. The forests and marshes serve as agricultural and grazing land and provide water and vegetation. Cattle and other domestic stock use the mountain for grazing; several footpaths and cut trees are evidence that the forest is an important source of wood for the town below. The forest is managed by Ankesha Woreda Agriculture Office in Kesa town. The ecological condition of the Awi zone wetlands is excellent but the conservation and wise use management practice of the Agaw people have to be sustained.

2.1.1.1.3. Gilgel Abay (Wetet Abay) River

The Gilgel Abay catchment is located at coordinates 26.833 – 37.333° E and 11 – 11.33 ° N. This catchment is the largest (5000 km^2) of the four sub-catchments of Lake Tana, and provides about 60% of the lake inflow. The catchment includes the two gauged sub-catchments, namely the Upper Gilgel Abay (1654 km^2) and Koga (307 km^2).

Biophysical characteristics

The geology of the Gilgel Abay is composed of quaternary basalts and alluviums. The soils are dominated by clays and clayey loams. The dominant land use units are agricultural (65%) and agro-pastoral land (33%) (BCEOM, 1999). Among these, the rain-fed agriculture is prevailing, covering 74% and 64% of Upper Gilgel Abay and Koga sub-catchments, respectively. Seasonal wetlands (dambos or marshlands) are observed mostly in the gentle slopes of the catchment. The influence of dambos in enhancing catchment evapotranspiration and base flow while reducing or retarding floods is still not well understood.

The runoff generation in the Upper Gilgel Abay sub-catchment is mainly dominated by quick flow of about 70% (direct runoff and interflow components), while in Koga sub-catchment this component is less important (40 to 50%). The direct runoff in the Koga is noticeably smaller (4%) compared to the Upper Gilgel Abay (14 to 30%). The water storage and base flow production in the Koga sub-catchment is larger, very likely due to the existence of marshland and dambos (Uhlenbrook *et al.*, 2010).

Ecosystem services and ecological status

The Gilgel Abay catchment is an important area for agriculture and livestock husbandry, and provides several services, including the controversial eucalyptus plantations. Studies done in the Koga catchment indicated that farmers in this area prefer eucalyptus stands to horticulture. The Gilgel Abay arises from the Choke Mountain and intensive slope agriculture has resulted in severe erosion so that the rivers carry high sediment load. Both the Gilgel Abay and Koga rivers are extremely muddy with high silt loads and poor ecological condition.

2.1.1.1.4. Choke mountain rivers

The Choke Mountains are located in the ANRS, South Gojam, at coordinates 10°42'N 37°52'E and altitude between 2,800–4,070 masl.

Biophysical characteristics

The Choke Mountain lies between the altitudes of 810 m and 4070 masl and the Choke Mountain Range Wetland Ecosystem is considered as the water tower of the Abay River. More than **59 rivers** and **273 small springs,** which are the main tributaries of Blue Nile or Abay originate from this mountain. The mountain contains approximately 3386 km^2 wetlands, ranging from sedge swamps to seasonally flooded grasslands.

Among the major rivers that originate from the Choke Mountain, the following are the most important ones: **Chemoga, Temecha, Gedeb, Tijan, Tefe, Teme, Azewari, Sede, Inat Muga, Gilgel Muga**, **Zimbl, Komed, Oromo Meshageriya, Tiliku Abeya, Tinishu Abeya, Ayabab, Kurt Bahir** and **Gudela.** Kurt Bahir is one of the seasonal wetlands which shrink drastically during the dry season. Due to extreme degradation by human mismanagement and natural causes, about 607 km^2 of seasonal wetland with low moisture and 22.4 km ^{2} of open water of the mountain have been lost within the last 20 years (Abay Basin Authority, 2013).

The major natural habitats are moist moorland with giant *Lobelia* spp., *Alchemilla* spp., sedges and tussocks of *Festuca* spp. and other grasses, montane grasslands and meadows, cliffs and rocky areas. Woody plants, *Erica* spp., *Hypericum revolutum* and *Arundinaria alpina* are only found in patches. Agricultural activity is extensive, with cultivation up to 3,000 m.

The **Chemoga** and **Jedeb** rivers are tributaries of the Abay/Upper Abay, located south of Lake Tana, and extend between approximately 10?100 and 10?40 ^{0} N latitude and 37°300′ and 37°540′ E longitude. Both rivers originate from the Choke Mountains at an elevation of 4000 masl. Chemoga has a catchment area of 358 km ^{2} and Jedeb 296 km ^{2}. Precipitation ranges from 500 – 1300 mm and the long-term average annual temperature over the period of 1973–2008 at Debre Markos weather station was about 16.3?C. Almost half of the land use pattern in the Jedeb catchment has experienced changes over the last half century and 70% is currently used for agriculture

Ecosystem services and ecological status

The Choke mountain catchment is a major contributor to the Abay River and contains numerous wetlands, both seasonal and perennial. The Choke Mountain also has huge Carbon reserves in the vegetation and soil and undoubtedly serves as an important element in regulating climate and hydrology in the Abay basin. The mountain is an important food production area, although the unwise traditional way of farming and animal husbandry has resulted in extreme degradation and impoverishment of the habitat and peoples' livelihoods. The numerous rivers and streams flowing down from the Choke Mountain carry heavy sediment, which ultimately ends in Lake Tana, and has resulted in the silting and volume reduction of the lake.

Although serious attempts are undergoing to reduce water and soil loss from the Choke mountain, and to re-vegetate the forest to sequester more Carbon, it is clear that given the scale and severity of the ecological degradation compounded in the Choke catchment, more work has to continue to restore the vital regulatory and supportive ecological functions of this important wetland in the Lake Tana sub-basin.

2.1.1.1.5. Jemma River

Jemma River is located on coordinates 10°07′N 38°56′E in the ANRS, and starts from the Shoa uplands between altitude 1300–2000. The valley shows extreme degradation and denudation (Plate 2.1).

Biophysical characteristics

The steep-sided gorges have been cut through basalt to expose the underlying large blocks of limestone and sandstone. The bottoms the valleys comprise gently sloping land, and the rivers have created gravel flood-plains of varying width. The vegetation consist of *Typha* spp. beds beside the permanent rivers; blocks of limestone that support *Sterculia africana* trees, *Tamarindus indica* and *Ficus thonningii*; the endemic *Aloe schelpii*; and acacia woodland away from the rivers and on the sides of the gorge. The sides of the gorge support extensive areas of grassland. *Acacia* woodland, the dominant vegetation in this area, is both denser and more extensive in the Jarra than in the Jemma valley. There are some large figs and larger trees of *Cordia africana* and *Syzygium guineense* by the river as well as on the sloping areas at the base of the cliffs. There is no well-developed riverine forest. Much of the valley bottom and sloping sides are cultivated with sorghum and sesame. Tef (*Eragrostis tef*) becomes increasingly common with altitude.

Jemma Valley and the surrounding area are well known for the bird watching tours. The main target for bird watchers is the endemic and range restricted Harwood's Francolin and others possible to spot are; Banded Barbet, the Black-headed Forest Oriole, the White-billed Starling, the Red-billed Starling, the White-winged Cliff Chat, the White-backed Black Tit, the White-cheeked Turaco and Hemprich's Hornbill. One can also see one of Ethiopia's endemic mammals, the Gelada or bleeding heart baboon. In the gorge, a variety of vultures - Lamergeyer, Ruppell's and Lappet faced vultures are observed.

Ecosystem services and ecological status

The Jemma River gorge and surrounding landscape (Plate 2.1) have important provisioning and cultural services. The catchment is an important sanctuary for endemic and threatened bird and mammal species, and as such can benefit from eco-tourism, if managed properly. The ecological condition can be said to be moderately degraded, with need for both protection and restoration approaches.

Plate 2. 1 Jemma and Zaga Rivers (a tributary) and the upland landscape

2.1.1.1.6. Beles River

Beles River has an elevation of 2,720 masl, highest at Balaya Mountain and 500 masl, lowest at the confluence of Beles and Abay River. It has a total catchment area of about 14,200 Km^2.

Beles River is a tributary of Abay River, which rises in Dangur woreda to flow in a south-west direction to its confluence. The two rivers of Gilgel and Abat Beles emerge from the highlands of North Achefer and Dangila woredas and join to form Beles River in Pawe woreda. The Beles River shows extreme fluctuations in water volume and quality during its high and low flow season (Plate 2.2). Other rivers in the Beles catchment include **Durra**, **Ardi**, **Dinder**, **Alaltu**, **Dondor**, **Qarsa** and **Shar** Rivers.

Plate 2. 2 Beles River during the dry and kiremt seasons

Biophysical characteristics

The rainfall pattern of the basin is unimodal with an aerial depth of precipitation of 1352.9 mm/yr. The precipitation condition has high orographic effect. The geology of the basin is Precambrian basement complex, undifferentiated formations, tertiary and quaternary volcanic and quaternary sediments and Cenozoic volcanic rocks. The hydrogeological characterization of the basin includes porous aquifers (alluvium, colluviums), fissured and karst aquifers (marble), fissured aquifers (sandstone and volcanic rock and aquitards (some non-carbonate metamorphic and intrusive rocks). Accordingly, the aquifer of the basin varies from very low to very high productive formations.

The discharge areas are intimately linked with groundwater flow lines and the regional groundwater flow direction is to the southwest following the topographic gradient. The general natural water type of the basin is Ca dominated cation and HCO_3 dominated anion, low pH and TDS values. Diga Dam is the only hydraulic structure that has been constructed on Gilgel Beles River for water supply purposes for some parts of Pawe Woreda.

Flora and fauna

Vegetation of Beles basin is dominated by *Acacia abyssinica, Cordia africana, Syzgium guineense, Borasive aethiopium, Phoenix reclinata* and *Ceibia pentandra* (Metekel zone Agriculture Department, 2006). Vegetations on either side of the river bank are mainly trees and dominated by *Acacia abyssinica* and *Cordia africana*. The fauna include **-** Nile crocodile, tortoise, phyton, snakes and Nile monitor (lizard). The fish species around Chagnie at 11° 10' N 36° 22' E include *Barbus* large sp., *Garra* sp., *Varicorhinus beso* and *Oreochromis niloticus.* In another study (JERBE, 2008) done on the Beles River at 25 km SE of Mankush at 11^0 7' N 35^0 24' 30' E, a total of 25 fish species belonging to four orders and eight families were recorded.

These were categorized in four orders, that is, Cypriniformes, Siluriformes, Perciformes and Tetraodontiformes and eight families, that is, *Cyprinidae, Characidae, Distichodontidae, Mochokidae, Bagridae, Schilbeidae, Cichlidae*and *Tetraodontidae.*

Some of the common species documented include: *Brycinus macrolepidotus*, *Labeo coubie*, L. *cylindricus, L. Forskali, L. horie*, *Lates niloticus*, *Bagrus bajad*, *B. Docmak*, *Synodontis schall*, *S. serratus*, *Oreochromis niloticus*, *Tetraodon lineatus*, *Distichodus engycephalus, Chelaethiops bibie*, *Garra spp.* and *Schilbe mystus.*

Ecosystem services and ecological status

The Beles sub-basin supports several ecological services in the wide catchment it occupies (14 200 km^2). Numerous streams and rivers flow in this sub-basin and contribute much to the flow of the Abay River. The sub-basin has huge potential for irrigated agriculture which is poorly developed at present, except at the Diga dam. The sub-basin serves as important habitat for many fish species that will eventually enter into the GERD reservoir. Further, its ground water and irrigation potential will influence its regulatory and supportive functions as several habitats may be modified and flows regulated in the future. As this sub-basin is mostly untouched at present, cautious approaches and plans will have to be undertaken in order to use this important wetland without compromising its ecosystem and ecological values in future. Preventive rather than restorative approaches appear to be of priority in the case of the Beles sub-basin wetlands.

2.1.1.1.7. Beshilo River

Beshilo River is located at 11.0580996 N and 38.4611465 E in the Abay River basin. Beshilo River is one of the sixth categories of the Nile basins and it is situated in the upper Abay basin. The river drains from the upper land areas of Wello and its large catchments (13,242 km^2**)** lie in Wadela Delanta province (now Tenta and Delanta Dawnt districts). The headwaters of the Beshilo River Catchments are highly dominated by steep mountainous parts with rugged topography and dissected features (MOWR, 1995, 1999). Beshilo River is very large river with a width of about 300 – 600 m. This varies from place to place along the length of the river. The Beshilo River joins the Abay River from a southwest direction. Beshilo River is a high-order river as it has a number of its own tributaries, all of which flow in a deep gorge below the plateau area, even if most are sporadic. The major contributors are "**Gerado**" and **"Terie"** Rivers.

Biophysical characteristics

The climate in the area is classified as sub-humid with very wet and dry seasons. Distribution of rainfall is bimodal, highest rainfall (mm) from July to August ("Kremet" or "Meker") and the short rainy season ("Belg") is March to May. The dry season lasts from October to January (Figure 2.3). Rainfall varies from highest peak of 230 mm in July to absence during the dry months of December to January. Monthly air temperature data collected from the Wegeltena meteorological station indicated high values of close to 30 ^{0}C in June to low of 22 ^{0}C for most other months (Figure 2.4).

The Beshilo River area is characterized with poor vegetation cover, often in patches along the river bank. The mountainous areas to both sides of the river are eroded highly and remain almost bare. The sediment deposition and flood strength is immense in the rainy season. The vegetation cover consists of Tid (*Juniperus procera*), Tembelel (*Jasminum sp)*, Acacia (*Acacia tortilis; A. polyacantha*) Weira (*Oleana africana* sub.sp), Agam (*Carisa edulis*), Kega (*Rosa abyssinica*), *Cordia africana* (Wanza), Kitkita (*Dodonea viscosa) and Warka (ficus vasta).* The fauna in the Beshilio area is poorly known. Some of the most common birds documented by Moges Beletew (2007) include: Erkum (Abyssinian Ground-hornbill, *Bucorvus abysinicus*), Jigra (Helmeted Guineafowl, *Numida meleagris*), Erckl's Francolin *Pternistis erckelii*, Chestnut-naped Fancolin *Pternistis castaneicollisi*), Spot-breasted Plover *Vanellus melanocephalus*, Black-winged Plover *Vanellus melanopterus*, Common Pochard, Great White Egret, Cattle Egret, Ruppel's Starling, Hamerkop, Pied King Fisher, Egyptian Goose, Black-headed Weaver, Red-billed Firefinch, Red-eyed Dove, African Fish Eagle and King Fisher. Larger mammals observed include: Grivet Monkey *Cercopitthecus aethiops*, Klipspringer *Oreotragus oreotragus*, Rock hyrax *Procavia habessinica*, Spotted hyaena *Crucuta crucuta*, Crocodile *Crocodylus niloticus*, Monitor lizards *Varanus niloticus*, and different lizards and rodents (after Moges Beletew, 2007).

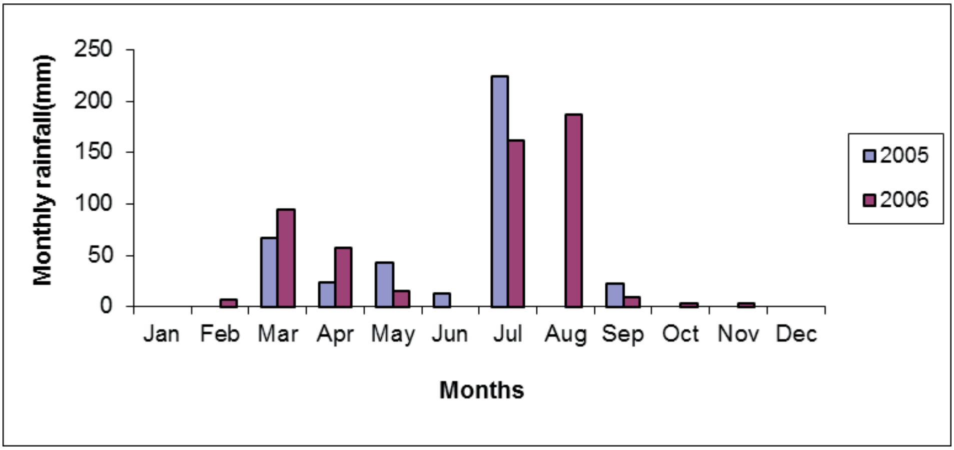


Figure 2. 3: Monthly rainfalls (mm) of Goshmeda of Beshilo area

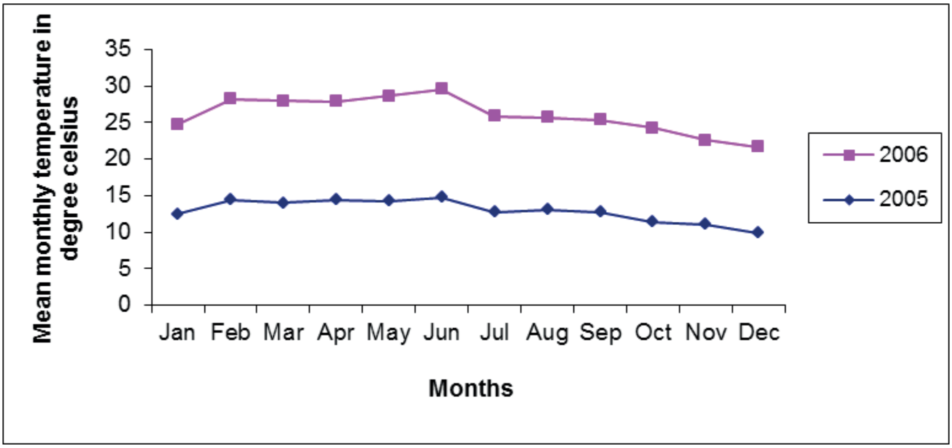


Figure 2. 4: Mean monthly temperature of Wegeltena station

Ecosystem services

Due to scarcity of land holdings in the area, farmers cultivate the river banks extensively during the dry season for recession agriculture (Plate 2.3). Farmers plant *teff* at the end of the rainy season, and in the dry season in November, the same areas being used for planting green pepper and cotton. Farmers use fertilizers and pesticides and the river appears to be polluted with imminent danger to the fish stocks, on which the livelihoods of the riparian communities depend.

Plate 2. 3: Beshilo River showing farming of the river bank (Photo credit: Moges Beletew)

2.1.1.1.8. Koga River and dam

The Koga dam is located in West Gojam zone near Merawi town at coordinates 11 ^{0} 22'N and 37 ^{0} 03'E. The catchment is situated between altitude of 1803 m (at dam site) and 3200 m (at source of the river) above sea level. The Koga wetlands, formed as floodplains of the Koga River, cover an estimated area of 1200 ha (Stave *et al.*, 2017)

Biophysical characteristics

The river has a catchment area of 27850 ha and length of 64 km and flows into the Gilgel Abay River after it cross the Debre-Markos-Bahir Dar road, downstream of the town of Wetet Abay, at an altitude of 1985 masl. The Koga Irrigation and Watershed Management Project consists of three segments namely catchment area, submergence area and command area. Submergence area is 1750 ha at full supply level comprising of Bojed plain, a seasonal wetland which had been used for dry season grazing by the local inhabitants as well as outsiders. It was assumed that the water would be available at an area of about 800 - 1000 ha for most part of the year as dead storage and that this area could be utilized for fisheries development both within the reservoir and in the form of finger ponds depending on the operational activities

Water chemistry and plankton

Abile Teshita and Ayalew Wondie (2014) conducted limnological studies on the Koga reservoir in 2013 with emphasis on impact of the impoundment on the macro-invertebrate community structure. They reported that temperature, dissolved oxygen, conductivity, TDS, Secchi-depth, NO_3, PO_4 and SiO_2 on average ranged from 21.8 - 26.4 ⍰, 5.5 l - 7.5 mg/l, 100 - 158 µS/cm, 50 - 102.8 ppm, 8.8 - 175 cm, 0.2l - 1.6 mg/l, 0.1 - 1.0 mg and 0.0 - 17.3 mg/l, respectively. Chlorophyll a concentration ranged from 3.6 mg/l at littoral zone in rainy season to 27.5 mg/l at the same site in post-rainy season. Three phytoplankton main groups were identified as Chlorophyceae, Bacillariophyceae and Cyanophyceae, comprising of 22, 12 and 5 genera in each group, respectively. Most of the physico-chemical data were optimal and biologically the reservoir was rich in plankton diversity and conducive for fishery development, either as cage culture or through stocking seasonally (Abay Basin Authority, 2013).

Ecosystem services and ecological status

The Koga catchment has important provisioning services such as agriculture, dry season grazing in the dambos (seasonal swamps), potable water and eucalyptus plantation. The Koga reservoir is being considered for aquaculture use by expatriate investors but the local people have not shown enthusiasm for fisheries or horticulture, as they fetch good money from the eucalyptus stands. The effect of eucalyptus on the hydrological contribution of the Wetet Abay catchment to Lake Tana water volume has been controversial.

Most of the Wetet Abay catchment shows the same degradation symptoms as other wetlands in Ethiopia – overgrazing and soil compaction, bank erosion, siltation and eucalyptus encroachment. Restoration and amelioration measures are mandatory in this important wetland.

2.1.1.1.9. Ayma River

The Ayma River (also called Dinder River in Sudan) drains the western part of the ANRS to eventually flow into Sudan. The Dinder catchment has an area of 8269 km^2 and annual flow of 1102 Mm^3. Rainfall is erratic but the Dinder River has been used for gravity irrigation and it irrigates an area of 49550 ha (Table 2.2).

Ayima River arises from Jawi woreda, which is found in Awi zone of region three and the river crosses the country by bisecting two regions (Amhara Region and Benishangul Gumuz Region). Major tributaries of Ayima River are **Adebluk, Sid, Awjemis, Demo** and **Tsira Rivers**. Fishery Cooperatives organized in the above mentioned rivers are at their early stage. **Selferege, Dubaba** and **Gelegu Rivers** are rivers, which are potentially rich in fish that are found across the main road from Shinfa to Gelegu town (Quara woreda)

Table 2. 2: Irrigation projects in the Dinder and Rahad basins (Abay Basin Authority)

Name of project	Type	Net Irrig. Area (ha)	Status[1] See Note 1	Comments/Alternatives to be Considered
Rahad (1)	Gravity	45,135	Pos. for AMP	Multi-purpose operation of dam
Galegu (1)	Gravity	9,894	Pos. for AMP	Multi-purpose operation of dam
Dindir (1)	Gravity	49,550	Pos. for AMP	Multi-purpose operation of 2 dams. Excl.

Ecosystem services and ecological status

The Ayma/Dinder River is an important contributor to the Abay although most of its flow is being regulated for irrigation, both in Ethiopia and Sudan. Such trans-boundary rivers require the cooperation and wise guidance for their use by all riparian countries. Any action requiring the restoration or maintenance of the ecosystem services of the Dinder River will have to be managed by Ethiopia and Sudan. At present, further information on the ecosystem services of this important riverine wetland is sadly deficient

2.1.1.2. Other wetlands in the ANRS

Numerous wetlands other than lakes and rivers abound in the ANRS, among which the following can be mentioned - floodplains, fringes, marshes, wet meadows, swamps, irrigation fields, seasonal dambos such as valley bottom wetlands, headwater dambos and reservoirs.

Other Wetlands in Abay Basin (2016)

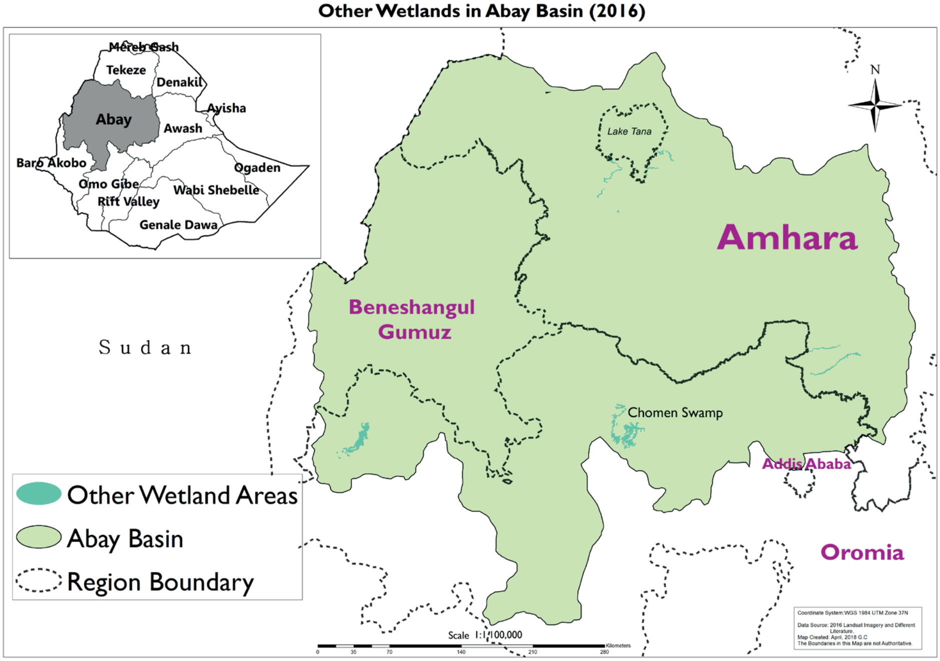


Figure 2. 5: Other wetlands in the ANRS

2.1.1.2.1. Lake Tana sub-basin wetlands

The Lake Tana sub-basin is located within the coordinates of 11^{0} - 11^{0}37` N and 37 $^{0}$ - $37^{0}$ 58` E, and encompasses Lake Tana and its surrounding wetlands in the catchment. Tana sub-basin contributes 23999.8 hectares of swampy areas and 315960 hectares of water bodies (NTEAP, 2008). The wetlands around the lake are formed from overflowing of the lake during the rainy season (fringe wetlands) or as remnant swamps bordering the lake in large tracts (papyrus stands) throughout the year. The riverine wetlands include the inflowing rivers of Megech, Rib, Gumara and Gilgel Abay. The floodplains of Fogera, Dembia, Achefer, Chemoga and Chimba form part of the wetland complex surrounding the Lake Tana sub-basin. The major fringe wetlands include:

1. Zeghe wetland at Gerima
2. Bahir Dar Zuria wetlands
3. Delgi-Takua wetlands
4. Fogera floodplain wetlands
5. Riverside wetlands (Gelda, Infranz)
6. Gilgel Abay floodplain wetlands (Chimba)

The wetlands in the Tana sub-basin can be broadly categorized as permanent and seasonal, riverine, lacustrine and ponds and have a total area of 340 929 ha (Table 2.3). In Appendix 1, the list of wetlands in the LTSB and in the ANRS is given in detail (Abay Basin Authority, 2013). Some of these wetlands are very small (0.25 ha) and may dry up completely during long dry spells. Seasonal valley bottom wetlands of the type described as 'dambos' in other parts of Africa (Malawi, Uganda) are very common in the LTSB due to slow seepage and pervious soil type in the basin. Both surface runoff and base flow are important water sources for the bamboo wetlands. Wet meadows are common landscape feature of the LTSB wetlands.

Table 2. 3: Type and area of wetlands in the Lake Tana sub-basin

No	Wetland type	Total area (ha)
1	Permanent Wetlands	17133.95
2	Seasonal Wetlands	7642.07
3	LakeTana	311277.3
4	Ponds and Dams	2057.128
5	Rivers	2818.333
	Total wetland area (ha)	**340 928.8**

Biophysical characteristics

The major soils in the Tana basin are nitisols on the upland plateau, luvisols on the slopes and vertisols in the lowlands and floodplains. Gilgel Abay River contributes 749791 tons of the 1141 197 tons sediment yield into Lake Tana (65%). Rainfall consists of one long rainy season, from March/ April to October/ November followed by long and heavy rainfall from July to September. Rainfall records in Bahir Dar for the last thirty years (1961-1996) show an average of 1447 mm. with a maximum annual rainfall of 2036 mm and a minimum of 895 mm. The average temperature during the year is recorded as 18.5 ^{0}C with a maximum of 26.3 C^0 and a minimum 10.7 C^0. The monthly maximum evaporation ranges from 270 mm in January and February to a minimum of 75 mm in August.

The Lake Tana basin consists of permanent swamps, seasonal swamps, and areas subjected to inundation. These wetlands are connected with the lake during the rainy period and are considered to act as nurseries for most of the fish populations in the lake, and serve as breeding ground for waterfowl and mammals. About 8 of the 15 *Labeobarbus* species and three other commercially important fish species, Nile tilapia (*Oreochromis niloticus*), African catfish (*Clarias gariepinus*) and Beso (*Varicorhinus beso*) spawn in the wetlands and their juveniles use the first years of their life to feed and grow in the wetlands. The littoral region of the lake is dominated by papyrus reed (*Cyperus papyrus*), bulrush (*Typha latifolia*) and common reed (*Phragmites karka*), whereas *Persicaria senegalensis*, hippo grass (*Vossia* spp.), bull rush (*Scrirpus* spp.) and Nymphea lotus are common.

Fogera plains

The Fogera plains lie to the east of Lake Tana, near the town of Woreta on the road from Bahir Dar to Gondar, c.582 km from Addis Ababa

Biophysical characteristics

This area mainly consists of a flat, open plain across which the Rib River flows into Lake Tana. The Gumera River forms the southern boundary. During and after the rainy season, as the Rib River approaches the level of Lake Tana, water overflows its banks and floods the surrounding area. The perennial Gumera River also overflows its banks as it approaches the lake, but causes less flooding than the Rib. A perennial swamp has been formed around the mouths of these rivers. Lake Tana, which forms the western boundary of this area, also floods up to 1.5 km inland during the rainy season. During the dry season, the water retreats and the flooded area is used for seasonal grazing and recession cultivation. The extent of the marsh depends on the amount of rain, as no other surface water feeds it (Gebrekidan Worku, 2014). The shoreline of the lake supports well-established papyrus beds 4 m tall. Further inland the vegetation is dominated by sedges, reed grasses and bulrushes, along with swamp grasses such as *Echinochloa* spp. and *Cynodon aethiopicus* that make very good grazing in the dry season. Patches of mixed small and broadleaved trees and bushes are found around churches on small, rocky hills near the lake shore. The more shrubby areas comprise species typical of degraded forest, with *Carissa edulis*, small *Acacia* spp., *Rosa abyssinica* and *Dodonea angustifolia*. A variety of plants are found in and around homesteads, including *Arundo donax*, *Guizotia scabra*, *Solanum* spp. and other broadleaved plants (EWNHS, 1996).

The Fogera floodplain has important ecosystem services of providing horticulture, rice, grazing fields, recession agriculture, papyrus stands for making boats and roofing, and potable water. Farmers also cultivate vegetables and shallots, besides rice. Recently, extensive rice cultivation has replaced traditional cereal agriculture. This impacts the hydrological balance of the sub-basin and water budget of Lake Tana and inflowing rivers. The Fogera floodplains are degraded to some extent which calls for some hydrological intervention.

Ecosystem services of the LTSB

Lake Tana sub-basin has some of the largest area of floodplains, including Fogera and Dembia flood plains which are some of the largest wetlands cultivated by man in Ethiopia. Besides serving for rice and cereal production, these wetlands shelter indigenous and migratory bird species that come from Europe during the winter season. The wetlands also serve as grazing grounds for indigenous unique cattle breeds (Fogera breed) and as home for many wetland animals.

In general, the study indicated that like most other wetlands in Ethiopia, the provisioning services of the wetlands were more pronounced than the regulatory and supportive services. Some wetlands such as Delgi-Takua and riverine corridors serve as important stopover sites for migratory birds from Europe and Asia. The cultural services of the LTSB wetlands were quite high, given the historical religious importance of the region as a pivotal center for the Gondar dynasty in Medieval Abyssinia. Even today, it is not uncommon to see papyrus plants and lakeshore vegetation being used in coffee ceremonies at household level and in churches and public gatherings at the village level.

In terms of their vital ecological functions, the LTSB wetlands score poorly, indicting the need for intervention to slow down degradation processes and enhance restorative ones.

The mountainous nature of the landscape in the ANRS has made proliferation of many wetlands with low water tables possible. Besides, the rivers form floodplains at lower elevations and many flooded areas remain wet for most parts of the year. Other wetlands include lake fringes, floodplains, flooded areas, deltas, irrigation fields, plantations and seasonal pans which are indicated in Fig 2.5.

Shesher and Welella fringe wetlands

Welella wetland is located at 12.37 N, 35 E and Shesher wetland at 11.56 N and 37 38 E. Both wetlands are formed from overflow of the Rib River and partly supplemented as fringe from overflow of Lake Tana during the *kiremt* months but become reduced without complete dry out during the dry season (Table 2.4) The area covered by the two wetlands is estimated as 1354 ha (Stave *et al.*, 2017)

Biophysical characteristics

Earlier studies indicate that the conductivity of Shesher and Welala wetlands was in the range of 197 to- 250 µS/cm. Turbidity was very high during rainy season (Secchi disc depth: 3 cm). In both wetlands, pH values varied within narrow limits (range 6.7 - 7.8) and dissolved oxygen levels ranged between 4.8 and 7.8 mg/l, which are generally considered favorable for most aquatic organisms. Nutrients were generally low. There were no significant differences in physico-chemical parameters between Shesher and Welala except for higher nutrient levels during the rainy season due to inputs from the catchment. A total of 13 taxa of macro-invertebrates were identified from Welala and Shesher Wetlands. Macrophytes were dominated by *Ludwigia* spp. (23%) followed by *Lemna* spp. (17%) and *Chara* spp. (16%). *Nymphaea* spp. were the least represented (1%) followed by *Nuphar lutea* (2%). Two species, *Phragmites australis*a and *Nuphar lutea*were were absent in Shesher. A total of 62 bird species consisting of 32,699 individuals were recorded in both wetlands, the common ones being Egyptian Goose (*Alopochen aegyptiacus*) followed by Curlew Sandpiper (*Calidris ferruginea*), Common Crane (*Grus grus*), Black-crowned Crane (*Balearica pavonina*), Spur-winged Goose (*Plectropterus gambensis*) and Ruff (*Philomachus pugnax*). Eurasian Marsh Harrier (*Circus aeruginosus)*, White Headed Vulture (*Aegypius occipitalis*), Yellow-billed Stork (*Mycteria ibis*) and Little Grebe (*Tachybaptus ruficollis*) were least abundant. Greater Flamingo (*Phoenicopterus ruber*) and Lesser Flamingo (*Phoeniconaias minor*) were observed in pre-rainy season in Welala only (Negash Atnafu *et al.*, 2011).

Ecosystem services and ecological status

These wetlands provide fish, water, and grazing for livestock and harbor large diversity of bird species including internationally endangered and threatened ones (Negash Atnafu *et al.*, 2011). The wetlands are also ideal spawning and nursery habitats for *C.gariepinus* (Wassie Anteneh *et al.*, 2012). The wetlands serve as buffering zones of Lake Tana (Nagelkerke, 1997). But due to unwise farming practices by local farmers, the existence of these floodplain wetlands and associated ecological services as well as their socio-economic importance is under threat (Sileshi Nemomissa, 2008). The two wetlands are shrinking at an alarming rate (Table 2.4), mainly because of unsustainable farming practices and a huge irrigation project on Ribb River, which is already in operation. Farming practices include draining and pumping of water for irrigation and expansion of farmland at the cost of the wetlands. The construction of a dam at Ribb River prevents overflow from Ribb River into the wetlands and disrupts the connection with Lake Tana, which is vital for the survival of these two wetlands (Negash Atnafu *et al.*, 2011). It is concluded that the major ecosystem services of these fringe wetlands (provisioning, supporting and regulating) are severely hampered and in need of urgent restoration measures.

Table 2. 4: Fast shrinking Shesher and Welella wetlands (Source: Negash Atnafu et al., 2011)

Wetlands	Area(ha)		
	1987	2008	loss in 21 years
Shesher	1557	136	1405
Wlela	298	159	139
Dega- Takua	248	45	181
Total	2103	370	1733

2.1.1.2.2. Angereb catchment

The Angereb watershed is located on the eastern side of Gondar town between 37⁰25'2" and 37⁰ 30'28" E longitudes and 12⁰36'22"m and 12⁰43'34.8" N latitude and has an area of 7653.73 ha. It partly belongs to the Abay basin and has an average altitude of 2125 masl. The altitude ranges from 2111 to 2854 masl.

Biophysical characteristics

The watershed has an area of 69.42 km^2. At the outlet of the watershed, the Angereb reservoir is the main source of potable water for Gonder town. The rainfall can be characterized as heavy and erratic. The annual rainfall of Angereb varies from 712 to 1823 mm with a mean annual value of 1159 mm. The main rainy season is from June to September. The mean monthly maximum and minimum temperatures of the Angereb area is about 29°C in April and 10°C in December and January, respectively. The watershed experienced a significant change in land use between 1985 and 2011. It is concluded that the decrease in forest land and grassland are accompanied by the increase in agricultural and built up areas.

The continuation of the land use/land cover change is becoming a serious threat to the Angereb watershed. The land use/land cover change should be controlled in the watershed and some measures should be taken for the stabilization of the land cover change. Understanding the sediment dynamics in response to land use change and hence its impact on the reservoir management and operation is useful to consider for future studies.

Ecosystem services and ecological status

The Angereb catchment has important provisioning services as it is a source of drinking water for the city of Gondar and also supports artisanal fisheries along the river bank. The ecological condition of the Angereb River appears to be good as the river flows through rugged and deep gorges mostly, but where there is human and livestock encroachment, sediment and organic pollution is common and it is suspected that water hyacinth infestation in Lake Tana could partly have been initiated due to nutrient loading from the Angereb catchment into the Megech River influent. Also, the water level fluctuation of the river needs to be regulated through hydrological management of water resources in the catchment and the Abay basin in general. The Angereb watershed needs urgent action to protect its existing habitat structure and restore some of its degraded ecological services such as fish production, provision of clean water, etc.

2.1.1.2.3. Guassa grassland wetland

The **Guassa area of Menz** (North Shewa zone) in the ANRS at coordinates 10°22'N 39°48'E, area 106,000 ha, and altitude 3,200 - 3,600m is an interface between the Abay and Awash basins. The area forms part of the high-altitude plateau of the central Ethiopian highlands at the edge of the Rift Valley escarpment. The Guassa range is a water catchment area for many streams and rivers draining into the low-lying areas of North Shewa. It provides water to two major river systems, namely the Abay to the west and the Awash to the east. The area comprises hills and valleys interspersed with swamps and open areas of montane and alpine grassland. The vegetation is Afro-montane with a diverse herb complement including tussock-grasses such as *Festuca* spp. (the Amharic name for which is Guassa). Other plants found in the area include *Erica* spp., *Helichrysum* spp., *Lobelia rhynchopetalum*, *Thymus* spp. and A*lchemilla* spp. (EWNHS, 1996). This conserved area has important provisioning, regulatory and cultural services which should be continued through involvement of the government, as the present conservation effort is supported mainly by NGOs.

2.1.1.2.4. Anjeni watershed

Anjeni gauged watershed is situated in 37°31'E / 10°40'N, in the northern part of Ethiopia in West Gogam. Its altitude ranges from 2407 to 2507 masl.

Biophysical characteristics

According to the study conducted by the Soil Conservation Research Project (1981), the hydrological catchment area of the gauged watershed is 113.4 ha. Mean annual rainfall and temperature is 1690 mm and 16°C, respectively. The land use map of Anjeni area indicated that 36 % of the land is cultivated for field crops, legumes and vegetables, 36 % of the watershed is pasture land and 29 % of the watershed is forest land.

The majority of the soil type of the watershed is similar to Lake Tana basin with Verticols, Luvisols, Humic Nitisols, Haplic Acrisols, Humic Alisols and Dydtric Cambisol.

Ecosystem services and ecological status

Anjeni watershed is an agricultural area, farmed in unsustainable traditional ways, and showed extreme ecological degradation like soil erosion, deforestation, overgrazing, siltation, impoverished livelihoods and barren landscape. Through the intervention of some institutions like the Soil Conservation Research Project of the Ministry of Agriculture (1981) and Swiss Government funding, some of these degradations have improved but a lot still needs to be done in terms of restoring the supportive and regulatory services of the riverine wetland.

2.1.1.2.5. Achefer and Chimba floodplains

South Achefer woreda (district) of West Gojam Zone is geographically located at 11°50′N latitude and 37°10′E longitude, and covers an area of 11835 km^2. Other wetlands around the Acehefer district include **Etsumit wetland** (area 2048 ha) and **Shola wetland** (area 1624 ha). **Chimba wetlands** extend as floodplain from the Gilgel Abay River and cross through 7 'kebeles, covering a total area of 3250 ha. The Lata Amba Kebele area alone covers about 1234 ha. The Chimba wetlands are formed by the annual flooding of the Gilgel Abay River during the kiremt months (Stave *et al.*, 2017). The area of the wetlands found in west Gojam, Mecha woreda is about 1003 ha, while in east Gojam in Gozamin woreda, wetlands cover an area of 14644 ha and about 254 ha in Debre Elias Woreda (Abay Basin Authority, 2013). Although most of these wetlands are floodplains formed from swelling of the rivers during *kiremt,* a number of the wetlands are also of the type described as 'seasonal dambos,' which are formed from slow infiltration and seepage of water close to the water table for a considerable part of the year. Unsustainable traditional ways of farming has lowered water tables so much that many of these wetlands have been converted into agricultural crop lands (see also chapter 5).

Biophysical characteristics

The elevation of the Achefer district varies from 1500 - 2500 masl. The annual mean temperature for most part of the district is 23°C and the mean annual rainfall is 1522 mm.

The Achefer wetlands are characterized by high plateaus, mountains and broad valleys and can be categorized in the valley bottom or mountain seepage types where the major hydrological sources are surface runoff and stream flows from the upland catchment.

Ecosystem services and ecological status

The Achefer wetlands are an important center for cereal production and animal husbandry. Top soil erosion, sediment loading into rivers and streams, overgrazing and land slumping are common. The ecological status of the aquatic habitat can only be described as "poor" despite the high agricultural productivity of the area. In order to sustain high agricultural productivity without compromising the ecological integrity of the aquatic ecosystem, an integrated approach involving restoration of the hydrology and flow regime of the rivers through intervention in the water table appears to be mandatory.

There are several small fringe wetlands around the Lake Tana watershed, but detailed studies about their ecology are lacking. These data in Table 2.5 are retrieved from the recent book by Stave *et al.*, (2017)

Table 2. 5: Fringe and floodplain wetlands around Lake Tana watershed (Abay Basin Authority)

No.	Name of Wetland	Water source	Estimated area (ha)
1	Gelda	Gelda River	315.8
2	Yiganda	Lake Tana and Mina stream	468
3	Dirma	Lake Tana	71.5
4	Debre Mariam-Bahir Dar	Lake Tana	100 - 120
5	Amluk	Lake Tana	10
6	Ambo Bahir	Lake Tana	56
7	Kurt Bahir	Koga River	45
8	Dibanko	Dangla	25

2.1.2. Wetlands in the Benshagul Gumuz NRS

2.1.2.1. Lakes and rivers in the BSGNRS

2.1.2.1.1. Dabus River

This river is partly in the ANRS but most of it is in Benshangul Region. The Dabus River is located in southwestern Ethiopia at 10°36′38″N 35°8′58″E and has a drainage area of about 21,032 Km^2.

Biophysical characteristics

The Dabus River at its headwaters has an area of wetlands of approximately 900 km^2 which has a considerable smoothing effect on the runoff distribution, as peak flows occur in September and flows remain quite high for most of the year. The Dabus River has an annual discharge of 4.67 Km^3 and is one of the most important contributors to the total flow of the Abay River (7.3%). The drainage area of the Dabus River covers 5.7% of the total drainage basin of the Abay. The river is very muddy at the height of the flood season (Plate 2.4).

Plate 2. 4: Dabus River at high flood

Ecosystem services and ecological status

The Dabus basin contributes 7.3% of the flow to the Abay River, and unfortunately also a lot of sediment loading into the Abay. The catchment is rich in wildlife, forest and fish resources and supports large livestock and human population. The Dabus basin influences micro-climate and hydrology all the way beyond

GERD and South Sudan and is a connection corridor for migratory birds and wildlife. Despite the low human population in the basin, one observes ecological degradation in terms of high soil erosion, deforestation and sedimentation. Clearly, the basin requires intervention to reduce soil, water and nutrient losses and maintain the carbon stock through forestation practices.

2.1.2.1.2. Gilgel Beles River

Gilgel Beles River has smaller watershed area, which is elongated along the main course of the river, broadening towards south west as more tributary streams join the main river. Gelegel Beles River is one of the largest tributaries of Beles River in its middle course.

Gilgel Beles River is found in hot lowland with undulating plains and a thick tropical forest that receives heavy rainfall. The lowest and the highest mean annual average temperatures are between 18.53 and 39.43°C at Mankush station; and 12.6 and 38.6°C at Pawi station (Fig. 2.6). The main rainy season occurs between May and mid November. Mean annual average rainfall ranges between 0 and 281.56 mm at Mankush station; 0 and 393.86 mm at Pawi station (Fig. 2.7).

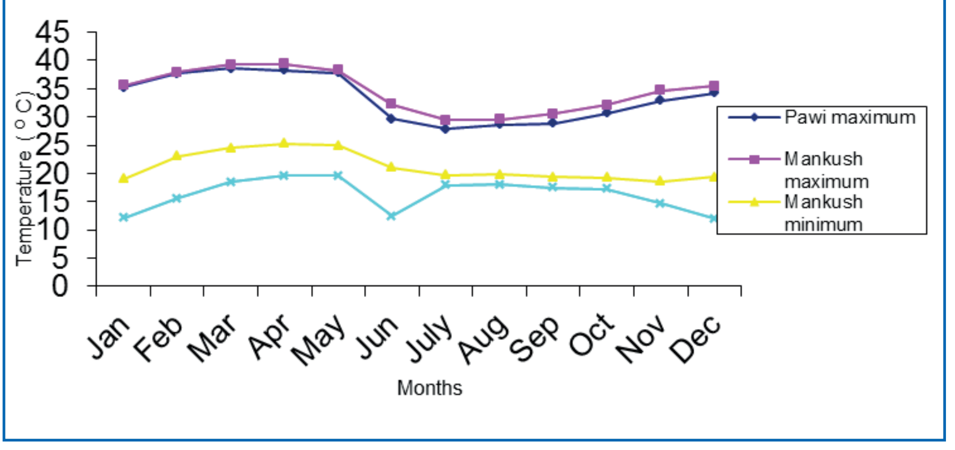


Figure 2. 6: Monthly mean maximum and minimum temperature at Mankush and Pawi stations from 2003-2005 (Ethiopian Meteorological Agency, 2006)

Ecosystem services and ecological status

The Gilgel Beles contributes much to the flow of the Beles River and the fish resource is exploited by the local people.

The ecological status of this river appears to be similar to that of other riverine wetlands in the Abay basin, with river bank erosion, siltation, livestock trampling and pollution and unsustainable farming around river edges being the most observable one. Buffer zone demarcation around the streams and rivers, point livestock watering and related actions would go a long way to improve the ecological condition of the Gilgel Beles River.

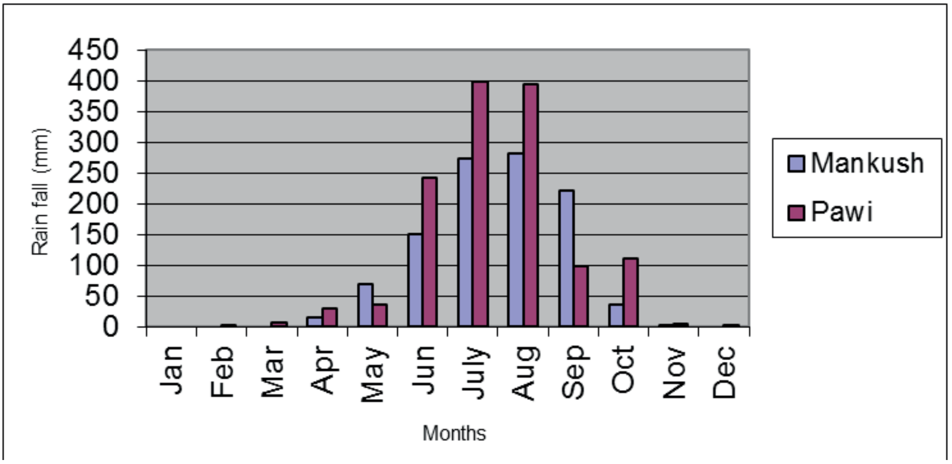


Figure 2. 7: Mean monthly rainfall at Mankush and Pawi stations 2003-2005 (Ethiopian Meteorological Agency, 2006).

2.1.3. Wetlands in the ONRS of the Abay basin

2.1.3.1. Lakes and rivers in the ONRS

2.1.3.1.1. Lake Dendi

Lake Dendi is located at $8^0$50'N, $38^0$01'E. It is a deep crater lake formed as a result of volcanic activity in the past.

Biophysical characteristics

Lake Dendi, a double crater at an elevation of 2,840 m a.s.l., is located 130 km south-west of Addis Ababa and 20 km north-west of Lake Wonchi. It covers an area of 7.2 km^2 and has a maximum and mean depth of 60 m and 35 m, respectively. The lake is 8 km long and 4 km wide. It has no permanent surface inlet or outlets. It is mainly fed by seasonal rivers and springs during the rainy season. The lake is surrounded by very steep shores and vertical drop-offs that rise 50 to 120 m above the lake surface; it is only accessible at three distinct sites. The littoral zone of the lake is characterized by a belt of emergent macrophytes, mainly *Typha angustifolia*.

The fish in Lake Dendi consist of *Garra* sp. and *Cyprinus carpio* (common carp). The latter species was introduced in the lake in the late 1990s, together with *Oreochromi niloticus* (Nile tilapia), by the National Fisheries and Other Aquatic Life Research Center (NFLARC) in an attempt to establish a pelagic fishery and increase availability of protein for local communities. Lake Dendi is categorized in the unproductive (oligotrophic) status (Fasil Deguefu *et al.*, 2014).

Ecosystem services and ecological status

Lake Dendi is less encroached by man because it is difficult to access. The lake fishery is not exploited because the people do not have the culture of catching fish. The ecological integrity of Lake Dendi can be said to be almost pristine and this should be maintained and protected.

2.1.3.1.2. Muger River

The Muger sub-basin is located in the Oromiya NRS at coordinates 09°12'N 38°43'E, and altitude 2,500 masl. The sub-basin has as an area of 8,188 km^2 at the confluence with Abay River, and 490 km^2 at the gauging station near Chancho. The altitude ranges between 953 masl and 3550 masl. The lowlands along the Muger River have altitude less than 1700 masl.

Biophysical characteristics

The Muger River drains the Sululta plain, which is about 20 km north of Addis Ababa. The plain is a wide, shallow valley almost completely surrounded by mountains from which many small rivers drain, feeding the Muger River that flows north-west into the Abay River. Sululta plain is swampy with some quite large areas of open water in the rainy season, but it reverts to grazing land during the dry months. This is a typical example of a valley bottom wetland. The surrounding mountain sides were covered with forest dominated by *Juniperus procera*, and the lower slopes supported groves of *Acacia* spp. However, most of the hillsides around Sululta are now covered with plantations of *Eucalyptus*, with only odd native trees remaining, except for the groves protected by the Ethiopian Orthodox Church.

The riverbanks are better drained than the surrounding areas and thus support small bushes, scramblers and the occasional tree. The highland areas surrounding the valleys are intensively cropped. Crop production is heavily dependent on a large population of cattle, which provide oxen for ploughing, and manure that is put on selected fields. The wide valleys provide these cattle with important grazing. Sedges and rushes are used extensively to cover the floors of houses. In Sululta, the farmers cut and bale the mixture of grasses, sedges and herbs, and sell it to numerous dairy farmers in Addis Ababa.

The geology of the sub-basin is mainly dominated by basalt and sandstone. There are alluvium deposits in southern and eastern parts of the basin. Major and dominant soil types identified in the sub-basin are Leptosols, Luvisols, Vertisols, Fluvisols, and Alisols. The most dominant soil type is Leptosols and the second dominant soil is Luvisols.

The sub-basin has an annual rainfall ranging between 833 mm and 1326 mm. The annual maximum and minimum temperature varies between 16^0C - 31.5^0C and 13^0C - 16.5^0C, respectively. Potential Evapotranspiration (PET) in the sub-basin is between 1215 mm and 1970 mm per year. The annual PET (1310.5 mm) is higher than the annual rainfall (1131.9 mm) with a total annual flow of 500 mm. Monthly flows of the Muger River are low for nine months of the year (Nov–June) and the highest flows (109–257 mm/month) are recorded for three months from July to September each year.

Muger sub-basin covers 15 woredas; Ejersa (Addis Alem), Walmara, Jeldu, Mulo, Sululta, Adda Berga, Meta Robi, Yaya Gulelena Debre Libanos, Wichalena Jido, Ginde Beret, Kuyu, Kutaya, Gerar Jarso, Degem, and Wara Jarso. The total population of the woredas is 2,442,247.

Ecosystem services and ecological status

The Muger River serves as source of potable and irrigation water, and supports livelihood of a large segment of the farming population along the riparian. Muger River has significant contribution to the flow of the Abay in its middle course.

2.1.3.1.3. Guder River

The **Guder** is a tributary of the Abay on the left side and its tributaries include the **Dabissa** and the **Taranta** rivers. The Guder River has a drainage area about 7,011 square kilometers in size.

Ecosystem services and ecological status

The Guder River is an important contributor to the water flow of the Abay River. The river is also used for wine farms and irrigation agriculture. It appears that the Guder River is relatively on good ecological status, but pollution from the wine farms should be monitored on continual basis.

2.1.3.1.4. Didessa River

The Didessa river basin is geographically located between $07^0 40'$N and $10^0 00'$N - Latitude and $35^0 30'$E – $37^0 15'$E Longitude. Contributing roughly a quarter of the total flow of the Abay as measured at the Sudan border, the Didessa River is the largest tributary of the Abay in terms of volume of water.

Biophysical characteristics

The Didessa sub-basin drainage area is nearly 27,000 km^2 originating from the mountain ranges of Gomma. The drainage area touches the three administrative zones of Oromia Regional State: Jimma Zone in the most upper and middle part, Illu Aba Bora Zone in the middle part and East/West Wellega in the lower part down to its confluence to the Abay River.

The mean annual rainfall in the Didessa basin ranges between 1509 mm in the southern to 2322 mm in the northern catchments. The maximum and minimum temperature varies between 21.1 – 36.5 ^{0}c and 7.9 -16.8 ^{0}c, respectively. The altitude ranges between 1720 m and 2088 m above sea level (excluding some top hills and mountains which can go more than 3500 masl).

Sub-basins of Didessa

The 4 sub-basins of the Didessa basin include:

1. Dabena-Didessa
2. Anger
3. Wama
4. Yebu-Tamsa

In each sub-basin, there are several stream orders from 1 to 6. Tributaries of the Didessa River system include **Urgessa, Indris, Anger** and **Tato** rivers.

Ecosystem services and ecological status

The Didessa River has vital supportive ecosystem services. It contributes 25% of the flow of the Abay River. As most of its catchment is relatively pristine, it regulates climate change, arrests soil erosion and improves soil fertility. The river provides fish and vegetation and is habitat for much biodiversity. Its cultural and supportive services may be less. Although human encroachment is increasing in the sub-basin, still the ecological condition of the Didessa River basin can be said to be good to moderate.

2.1.3.1.5. Huluka River

Huluka River is located at 8^{0}54'N, 37^{0}53'E and an elevation of 2223 masl with an average slope of 10% and a catchment area of 152 km^2 (Plate 2.5). The river originates from Dendi Lake at about 39 km south of Ambo town. **Debis River** which flows in the northern part of the town at a distance of 3 km from its center joins Huluka River before they both join Guder River to ultimately end up in Abay River. Huluka River is perennial with a mean flow of about 15,000 and 75,000m^3/day during dry and rainy seasons, respectively (Awulachew *et al.*, 2007).

Biophysical characteristics

The mean precipitation around Huluka River is about 912 mm and the main rainy months range from June to September (Tadesse Mumicha, 2010). Annual precipitation varies between 1800 mm and 2200 mm (National Meteorological Agency, 2012). The highest rainfall occurs in July and August whereas the dry months extend from October to May with some intermittent rains in February to April. The mean annual temperature is about 16.7^{0}C and March to May constitutes the hottest months while October to December makes up the coldest months (Tadesse Mumicha, 2010).

The vegetation around Lake Dendi includes indigenous trees such as *Juniperus procera, Acacia abyssinica, Apodytes dimidiate, Olea Africana, Podocarpus falcatus, Prunus Africana* as well as the exotic eucalyptus tree.A total of 115 diatom species belonging to 21 genera with *Achnanthes, Gopmhonema, Navicula* and *Nitzschia* being the most common ones were identified . A total of 20 families of benthic macroinvertebrates were identified (Alemayehu Negassa, 2005).

The soils in the catchments of Huluka River differ in color and type depending on topography. The commonly observed soils in the upper catchments vary in color from black to red. Koticha (vertisols) soils predominate in the catchments of the downstream sites. Crops commonly grown in the catchments of the upstream sites include vegetables, barley, wheat, bean, pea and inset which shift to teff, wheat and chick pea at the downstream sites. The dominant livestock species in the Huluka catchments of the upstream sites include cattle, sheep, horse, donkey, goat in the order of importance and mainly supported by the wetland around Lake Dendi in large numbers.

Intensive agricultural catchment land use, the discharge of untreated or poorly treated sewage and poor solid waste management were the major environmental stressors that affected the water quality of Huluka River. Some of the physico-chemical features of the Huluka River are given in Table 2.6, while in Plate 2.5, the level of encroachment on the river ecosystem are shown with some examples.

Table 2. 6: Some Physico-chemical features of Huluka River (sources included)

Feature	Value	Reference
Temperature	16.2-23^{0}C	Prabu et al., 2011
pH	6.64-7.9	Tadesse Mumicha, 2010
DO	3.24-7.86 mg l^{-1}	″
EC	191.17-313.3 μS/cm^{-1}	″
TDS	122.91-398.6 mg l^{-1}	″
TSS	316.5-579.58 mg l^{-1}	″
TS	458.7-843.74 mg l^{-1}	″
Z_{SD}	12.1-26.42 cm	″
NH_3	0.009-0.098 μgl^{-1}	″
NO_3^-	0.88-3.50 mgl^{-1}	Prabu et al., 2011
PO_4^{3-}	0.28-1.88 mgl^{-1}	″
BOD	5.5-46 mg l^{-1}	Prabu et al., 2008
COD	23-285 mg l^{-1}	″
Na	75.44-103.68 mg l^{-1}	Tadesse Mumicha, 2010
K	22.38-85.56 mg l^{-1}	″
Ca^{++}	14-72 mg l^{-1}	Prabu et al., 2008
Mg^{++}	3.2-25.2 mg l^{-1}	″
Cl^-	7.5-46.3 mg l^{-1}	″

Plate 2. 5: Huluka River showing encroachment by farmers and livestock (Photo credit: Alemayehu Negassa)

Ecosystem services

The Huluka River has high provisioning services for potable water, food, livestock grazing and farming. The habitat quality and ecosystem services are deteriorating because of increasing human and livestock pressure in the catchment. The PhD studies of Alemayehu Negassa (2016) concluded that the river was severely degraded at downstream sites and during the wet season, and in need of restoration efforts.

2.1.3.1.6. Dabena River

The Dabena River is an important tributary of the Didessa River which form an extensive river valley wetland. The area has not been highly encroached by man due to its inhospitable environment with tsetse fly and malaria. The wetland harbours rich biodiversity of plants and animals, and in recent years, a lot of investment ventures in horticulture and fruits are taking place. Habte Jebessa (2016) has proposed a protected area for the rich wildlife of the area, which includes the last of buffalo populations in the country.

Ecosystem services and ecological condition

Not many studies have been done on the Dabena River and its valley bottom wetlands. From the high forest cover and pristine condition of the Dabena catchment, it is possible to suggest that the wetland provides important provisioning and supportive services to the rich biodiversity of flora and fauna, which includes wildlife resources. The Dabena catchment also regulates hydrological flows and moderates micro-climate in the region.

2.1.3.2. Other wetlands in the ONRS

2.1.3.2.1. Chomen swamps

Fincha-Chomen marsh is located at 09°34′N and 37°21′E at an average elevation of 2,222 masl with a surface area of about 60,000 ha. (Dikaso Unbushe Gojamme 2013). Chomen swamps (also known as Abay Chomen) is one of the woredas in Horo Gudru Welega Zone, and is bordered on the south by Lake Fincha’a (created when Finicha’a Dam flooded the Chomen swamp).

The altitude of this swamp ranges from 880 to 2,400 masl. Rivers within the woreda include the **Nedi, Finchawa, Agemsa, Korke, Gogoldas, Boyi** and **Bedessa** Rivers. The land in this woreda shows that 11.4% is arable or cultivable, 2.2% pasture, 1.4% forest, and the remaining 83.8% is considered mountainous, unusable, or part of the Fincha'a Sugar Project.

Abay Chomen has 69.5 kilometers of all-weather road, for an average road density of 87.8 kilometers per 1000 square kilometers. About 70% of the urban and 12% of the rural population have access to drinking water.

Biophysical characteristics

The soils in Fincha Valley are made of alluvial and colluvial materials from the surrounding escarpments. Based on climate data of 10 years (2001-2010) from Finchaa meteorological station, the mean annual rainfall in the area is about 1650 mm, rainfall peak period between May to September, and decreasing in October with little or no rainfall in November. The mean annual temperature is about 18.2°C whereas the mean minimum temperature of the coldest month and the mean daily maximum temperature of the warmest month are 9.5°C and 28.4°C, respectively(Dikaso Unbushe Gojamme, 2013). Fincha'a-Chomen marshes are extensively covered by floating vegetation. The most common species is the perennial grass *Panicum hygrocharis*, which forms floating islands over Finchaa Reservoir.

2.1.3.2.2 Finchaa reservoir

Fincha Hydroelectric Power Plant, Ethiopia, is located at coordinates latitude 9.558, longitude 37.3663. This infrastructure is of TYPE Hydro Power Plant with a design capacity of 134 MW. It has 4 unit (s). The first unit was commissioned in 1974 and the last in 2003. It is operated by Ethiopian Electric and Power Company.

Ecosystem services and ecological status

The Finchaa sub-basin is an important area for hydropower production, irrigation and livestock husbandry. The Finchaa valley is rich in fish resources and wildlife. Extensive wetlands (Chomen) recharge the river and regulate the hydrology of the basin, besides providing drinking water. The numerous rivers and wetlands in the basin serve as important buffers to regulate flows and moderate climate change.

2.1.3.2.3. Dabus marsh

The Dabus River drains an area of approximately 14,400 square kilometers. Dabus Marsh is found in Oromia Regional State in central western parts of West Wollega Zone (Figure 2.8). It is located at 09°16.2N and 34°48E at an average elevation of 1,300 m with a surface area of about 70,000 ha (700 km2) (EMA, 1988). Ethiopian Wildlife and Natural History Society (EWNHS, 1996) designated Dabus Marsh as one of the Important Bird Areas. Dabus River is an important tributary draining the relatively wet southeast region of the Abay Basin. According to Sutcliffe (2009) and MoARD (2005), Dabus and Didessa rivers together contribute a third of the total flow in the Abay Abay Basin.

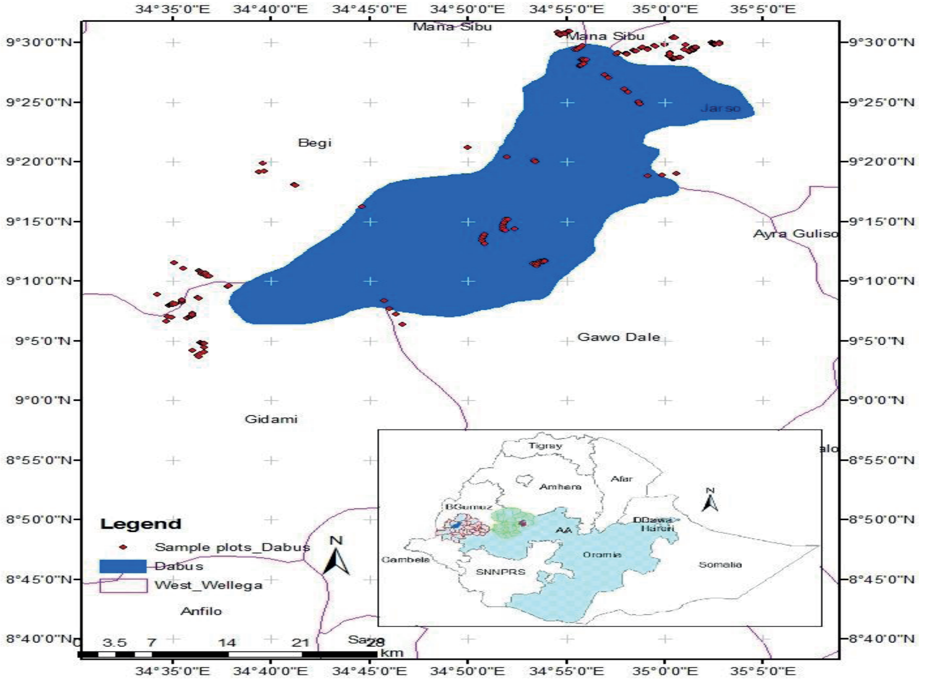


Figure 2. 8: Location of the Dabus marsh

Biophysical characteristics

The occurrences of geologic elements in the West Wollega (or Wollega Province) are the results of Precambrian and Cenozoic era (Mohr, 1971). The tertiary basaltic rocks account for the majority of high land rock cover of West Wollega (Mohr, 1971). Dystric Nitosols form the major group of soil units occurring in most parts of the Zone.

According to Daniel Gamachu (1977), there are 14 rainfall regimes in Ethiopia which fall into two main types, and the southwestern highlands come under type one that is characterized by contiguously distributed rainy months and evenly distributed rainfall. The distribution of rainfall is unimodal type (Figure 2.9) which begins usually in April and continues up to mid October and is uniformly distributed in most years. There is a long dry period from mid October to the end of March. Based on 10 years climate data from Begi meteorological station, the mean annual rainfall in the study area is about 1415 mm and the mean annual temperature is about 19.8°C whereas the mean minimum temperature of the coldest month and the mean daily maximum temperature of the warmest month is 11.8°C and 30.9°C, respectively.

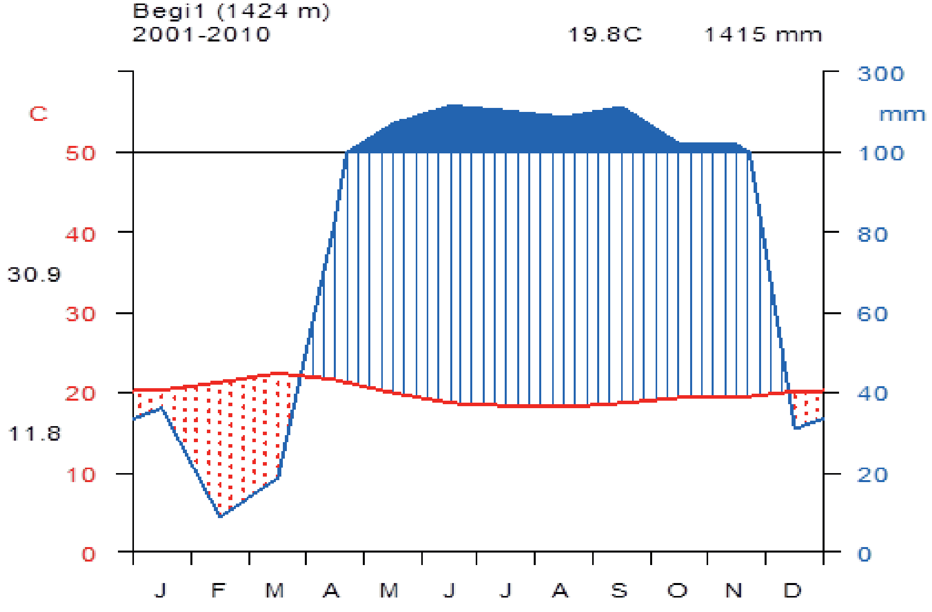


Figure 2.9: Climate diagram for Dabus wetlands (Sources: EMSA, Ethiopian Meteorological Service Agency, 2012)

According to the 2007 Population and Housing Census report, the total population of West Wollega Zone was 1,351,979. Agriculture is characterized by mixed cropping practices mainly coffee, maize, tef, sorghum, barely, wheat and noug (GWSPMFRDA, 2004). The forest patches are found mostly in limited areas in the eastern and northeastern parts, grassland occupy western, northwestern, southwestern, central and southern and swamps and marshes occur in the central western part of the Zone. Broad leafed forest, grasslands and wetland (marshes and swamps) are the common types of climatic climax vegetation of West Wollega (GWSPMFRDA, 2004).

Ecosystem services and ecological status of the Dabus floodplain

The Dabus basin contributes 7.3% of the flow to the Abay River, and unfortunately also a lot of sediment loading into the Abay. The catchment is rich in wildlife, forest and fish resources and supports large livestock and human population. The Dabus basin influences micro-climate and hydrology all the way beyond GERD and South Sudan and is a connection corridor for migratory birds and wildlife. Despite the low human population in the basin, one observes ecological degradation in terms of unregulated settlements, high soil erosion, deforestation and sedimentation. Clearly, the basin requires intervention to reduce soil, water and nutrient losses and maintain the carbon stock through forestation practices.

2.1.3.2.4. Dhati swamp (Lake)

The Dhati swamp is a wetland complex located in Wellega area of the Oromiya Regional State at latitude 9 49 22 N and longitude 35 41 34.4 E (Plate 2.6). The swamp is also known as '*gumare*' or hippopotamus lake and is believed to harbor a large number of the animals.

There is not much information about Dhati swamp as it is relatively inaccessible being surrounded by a thick forest cover. Its major ecosystem service is as habitat for the hippo population and it also regulates water flow in the forest floor. The good forest cover and hydrological condition moderate local climate. It is not known how the local human population uses the natural resources in the area, including the resident hippopotamus fauna.

Plate 2. 6: Lake (swamp) Dhati (Google map, 2017)

2.2. Awash basin – general

Figure 2.10 shows the general wetlands found in the Awash Basin. The major drainage feature of the basin is the Awash River, which originates from a small mountain stream in the Shoa highlands and ends on the shore sands of Lake Abe near the Djibouti border.

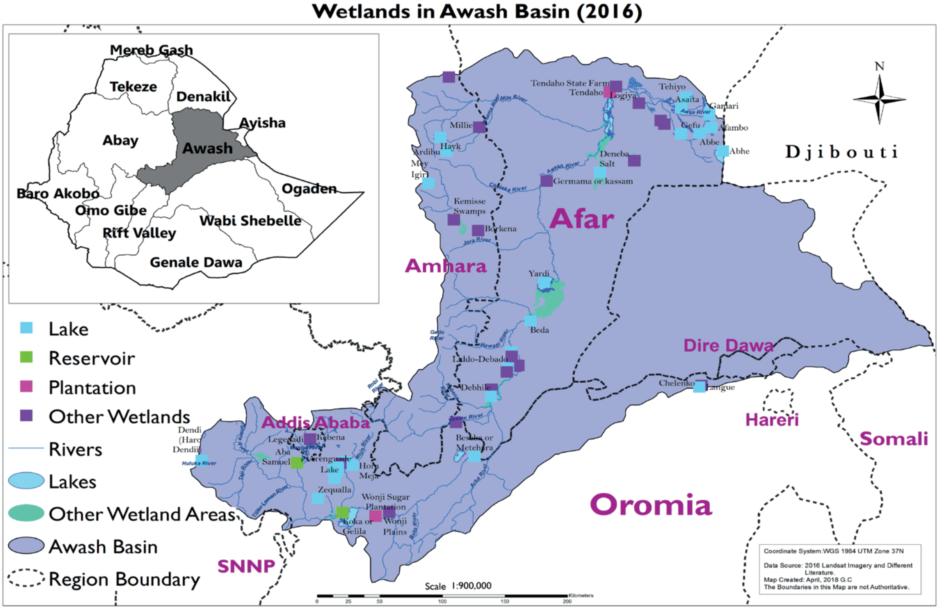


Figure 2. 10: Wetlands in the Awash Basin

Based on the reports of FAO (1965), Desalegn Chemeda Edossa (2010), Water Governance Center (2013) and others, the Awash River rises on the high plateau to the west of Addis Ababa, at an altitude of about 3000 masl. It is fed by several major tributaries. The river flows in an easterly direction through Amhara, Addis Ababa, Oromia, Afar, Dire Dawa and Somali regions and has a length of about 1,250 km. The part of the catchment situated in the east, accounting for some 40% of the total basin area, does not contribute any surface runoff to the river. The Awash Basin covers an area of 110,000km² and contains two lakes, namely Besaka and Gedebassa Lakes (Fig. 2.10). Lake Basaka is highly saline and rapidly expanding, threatening residence areas, arable land, and the water quality of the Awash.

The Awash Basin is the most utilized river basin in Ethiopia with a number of small, medium and large scale irrigation schemes; industries located along the river; urban and rural water supply schemes (both from surface and groundwater), etc. Some 200,000 ha of suitable land could be available for irrigation. The net area currently commended by irrigation is estimated to be 89,000 ha. Approximately 70% of the irrigable land is owned by the Federal Government, 5% by Afar Regional State and 7% by Oromia Regional State. The remaining 18% is owned by private farms. Some 3% of the land is known to have been abandoned as a result of salinity problems and due to surface area increase of Lake Besaka.

Many of the big industrial hotspots in the country are found inside the Awash Basin. These include the industrial corridor extending from Addis Ababa to Adama town, Metehara area, and Dire Dawa City. For several industries, the River Awash is used as source for water consumption and for disposing of their waste. River Awash is the most polluted river in the country. The release of untreated waste waters from industries, waste from households and soil erosion from the upper watershed critically hampers the water quality of the river. River Awash is also used for generating energy in Koka 1 and 2 hydropower plants.

The River Awash and its tributaries are sources of drinking water for large and small cities such as Addis Ababa, Adama, Awash and Metehara towns. As a matter of fact, it is also the main source of domestic water for the majority of the pastoralist people in the eastern Afar Region.

The Awash Basin has been divided into three distinct zones: Upper Basin, Middle Basin, and Lower Basin on the basis of various inter-related factors such as location, altitude, climate, topography, agricultural development, inhabitants, administrative boundaries, etc. The mean annual rainfall of the basin varies from about 1,600 mm, in the highlands north east of Addis Ababa, to 160 mm, in the northern point of the basin. Rainfall distribution is generally bi-modal in the Middle and Lower Awash and uni-modal in the Upper Awash. The mean annual rainfall over the entire Western catchment is 850 mm and over at the headwaters of the Awash, it is 1,216 mm. Over the Eastern catchment the mean annual rainfall is estimated to be 465 mm. Minor rains normally occur in March and April and major rains from July to August. As such, the occurrence of rainfall is highly erratic. The total amount of rainfall also varies greatly from year to year, resulting in severe droughts in some years and flooding in others.

The total annual surface runoff in the Awash Basin amounts to some $4{,}900 \times 10^6\ m^3$ of which $3{,}650 \times 10^6\ m^3$ is utilizable, the remaining being largely lost to Gedebassa swamp. According to EVDSA (1979) the potential for exploitation of groundwater resources is very meager in this part of the continent. Frequent and persistent droughts and the associated food insecurity have drastically affected the human and livestock population, especially in the Middle and Lower Basins of River Awash. As a result, the survival of thousands of people in the basin depends on international food assistance. The development of irrigation projects in the upper reaches of the basin, coupled with drought (climatic) occurrences have caused serious threat to the region's water resources, affecting the socioeconomic activity of the people and the diversity of ecosystem especially in the lower reach of the basin.

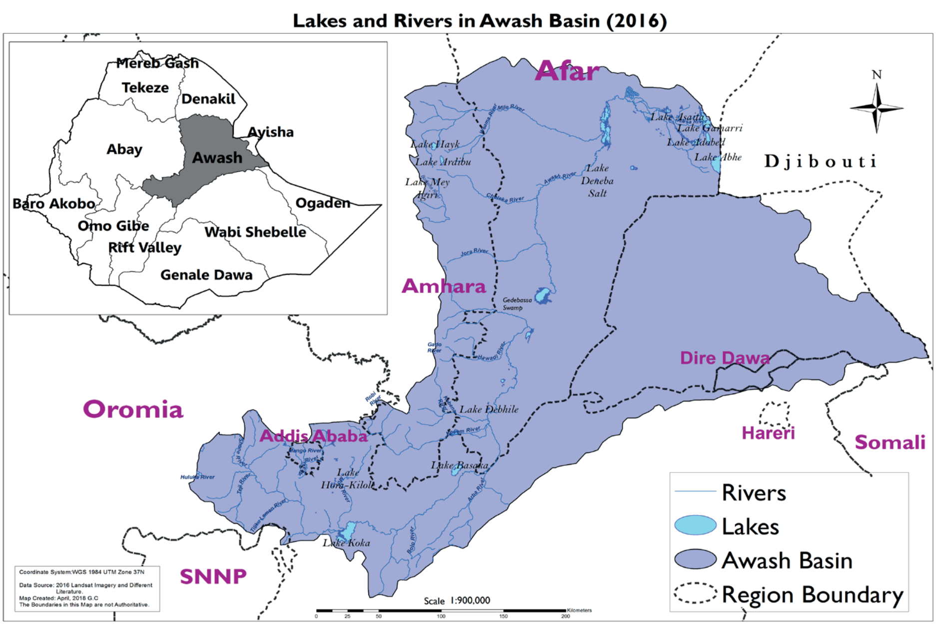


Figure 2. 11: Lakes and rivers in the Awash basin

2.2.1. Wetlands in the Afar NRS

2.2.1.1. Lakes and Rivers in the Afar Region

2.2.1.1.1. Lakes Abe, Afambo and Gamari

There are a number of wetlands that are fresh and saline and include Lakes **Afambo**, **Gamari** and **Abe.** The water volumes of these lakes are dependent on the rainfall during wet season in the highlands, whereas during the dry season most of the wetlands in the area form large tracts of salt pans**.**

The water chemistry is dominated by concentrations of chloride anions and, with sodium as the only cation, often forming concentrated brine solutions which dry out as large slacks of salt because of the high temperature. Salinities are high, except for Lake Gamari and Lake Metehara; the latter was diluted recently due to freshwater influx from the River Awash. The pH may even shift to the acidic range in Lake Afdera.

The sizes and ages of the lakes in the Danakil basin are variable; some are extremely small while others are extremely old. The major reason for such variations is that the Afar Depression area is tectonically actively moving with continuous drifting of the three major plates described above with frequent volcanic eruptions and hence earth movements.

The Danakil basin includes salt lakes, such as Lakes **ArtaAlé, Afdera, Yadi Gaddabasa, Laido, Kesem Reservoir, Abhe, Bancili, Afambo, Generi, Assalé, Karum, bakili** and **Catherine Ash Ring** and some eleven or twelve of them with no specific names, as these may be too small to be recognized as such by the local people or some may be of recent formations to obtain name in the cultures of the local population. Some of these lakes are fast disappearing and other new ones forming as a result of tectonic anomalies (Fig 2.12).

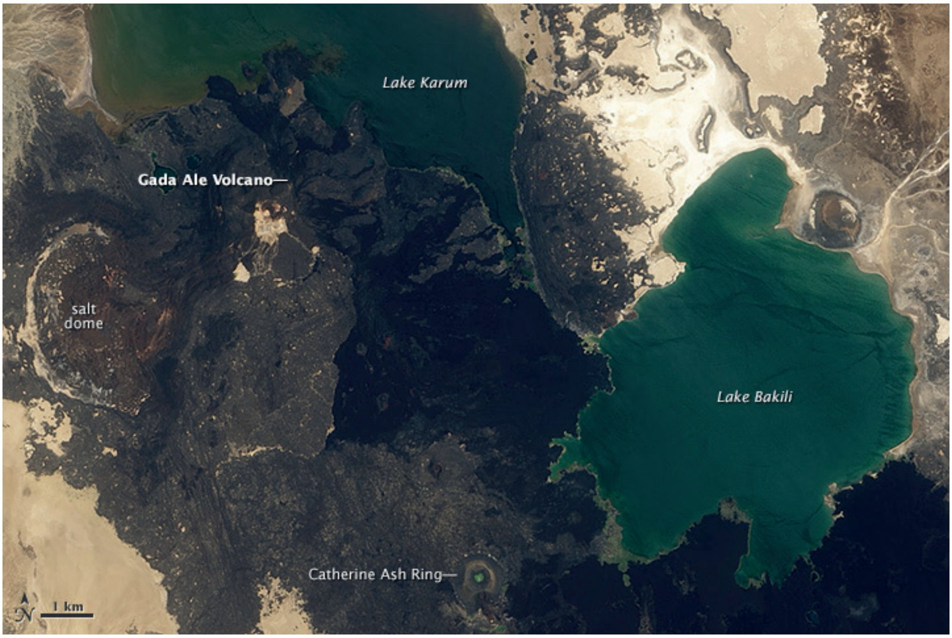


Figure 2. 12: Fast disappearing lakes in the Danakil basin (from Google map 2017).

Despite the aridity, inhospitable environment and the high salinity in the Afar basin, some of the lakes have endemic fish species (Lake Afdera) (Abebe Getahun and Stiassny, 1998) and many have chironomids and brine flies, while some look appealing for recreational activities (Plate 2.7)

Plate 2. 7: Afar lakes with fish, recreational and scientific values (Right photo credit: Brook Lemma).

Ecosystem services and ecological status

The major ecosystem services of the Afar wetlands are potable water from freshwater springs, salt production from the lakes, potash mining, generating hydrothermal power, and in recent years leasing land to investors who develop sugar plantations using water from River Awash. As the area is relatively sparse and arid, wetlands could contribute to alternative livelihoods such as tourism of the active volcano and endemic fish.

2.2.1.2. Other wetlands in the Afar NRS

2.2.1.2.1. Gedebassa swamp

The largest river crossing the Afar Region is the Awash River. Parts of the Borkena River from the Amhara Region and the Mille River form tributaries to the Awash. At certain reaches, the Awash River widens to form extensive floodplains and swamps. The **Gedebassa swamp** is one such wetland which supports a rich biodiversity of invertebrates, fish, birds and large mammals during the flooding season. According to Kinfe Hailemariam (1999), the hydrology of the Awash River Basin has recently been affected by climate change, and the livelihood of the Afar communities has become precarious. More information is available on the characteristics of the Awash River as it finally disappears into the sand plains of Lake Abe.

Reservoirs:

Tendaho Dam is an earth-filled dam in the eastern Afar Region of Ethiopia which is situated on the Awash River, between Dubti and Mille and its reservoir also receives the output of Mille River. The purpose of the reservoir is to provide irrigation primarily for the sugar cane plantation for the Tendaho Sugar Factory and also providing drinking water for humans and animals.

This large reservoir has faced a great problem being highly vulnerable for evaporation and drought as well as with a problem of seepage in which it has dried, at least, once in the last two years (it totally dried out in 2016) with a total loss of its fish fauna. The seismic changes happening around this dam and surrounding Afar region has been well documented.

2.2.1.2.2 Tendaho state farm

The Tendaho Irrigation Project, which is later known as the Tendaho State Farm is situated in the Lower Awash Valley of the Afar National Regional State (ANRS), northeastern Ethiopia. The Project is located at about 600 km from Addis Ababa. It is situated at 11° 40′ 77′′N and 40°57′49′′E between Dubti and Asaita Districts at an altitude of 402 masl. It is a man-made dam constructed, mainly, for the purpose of irrigation of sugar cane plantations. TIP is designed to irrigate about 60,000 ha of land at the Dubti, Dat-Bahri, Asaita and Afambo areas for sugarcane plantations. The project is expected to benefit nearly 35,000 families living in the basin from irrigated pasture development and animal feed from sugar by-products. During the implementation process, a number of job opportunities have been created. It is fed by the River Awash, one of the longest perennial rivers originating from the highlands of Ethiopia. The vast irrigable land resources, grazing land, bush lands and the Awash River flood plain are the most important dryland resources in Ethiopia (Solomon Kebede 2005, Desale Kidane *et al*. 2014, Tadesse Gobena Shonka 2017 and Mulat Asmamaw 2018).

TIP is characterized by lowland plain and a very hot area located in the arid zone of Ethiopia. The mean maximum temperature ranges from about 32 to 42 °C and mean minimum temperature as about 16 to 25 °C. The hottest months occur from March to October and the coldest months from November to February. Mean monthly rainfall ranges from about 4 to 58 mm. March, April, July and August receive more rainfall (Solomon Kebede 2005, Desale Kidane *et al*. 2014, Tadesse Gobena Shonka 2017 and Mulat Asmamaw 2018).

2.2.1.2.3. Lake Abe wetlands

Lake Abe wetland system is located in the Afar NRS at coordinates 11°16′N 41°45′E and altitude 240 masl.

Biophysical characteristics

The Lake Abe wetland complex comprises of a number of saline lakes such as Gamari, Afambo, Bario and Abe. All these lakes lie to the east of Asaita, the regional capital. Lake Afambo is about 30 km east of Asaita, and Lake Abe is on the eastern border with Djibouti, 600 km north-east of Addis Ababa. Lake Abe comprises 34,000 ha of open water and 11,000 ha of the surrounding salt-flats that can extend for 10 km from the edge of the water. Records give a maximum depth of 37 m (mean 8.6 m). However, the water level is gradually dropping due to droughts and abstraction of water upstream. The Awash enters Lakes Abe and Afambo on their north-western shores and is the only source of fresh water for these lakes. Very little is known of the vegetation except that the surrounding shrubs and bushes are all highly salt tolerant.

Ecosystem services and ecological status

The salt plains have useful ecosystem services in regulating the extreme hot climate and supporting biodiversity, which otherwise would be impossible in such an arid environment. The lakes provide fish and fresh water for the sparse human population and domestic animals.

2.2.2. Wetlands in the ANRS

2.2.2.1. Lakes and rivers in the ANRS

2.2.2.1.1. Lake Hardibo

Lake Hardibo is located between 39.75° to 39.78° E longitude and 11.20° to 11.27° N latitude within the Awash River Basin. The lake basin is a closed drainage with no surface outflow.

Biophysical characteristics

The basin encompasses comprehensively high mountain ranges with ground levels varying from 2,134 to 2,880 m. The area is characterized by sub-humid tropical climate of bimodal rainfall pattern with a mean annual rainfall of 1,141 mm and mean annual temperature of 18.2 °C. Currently, there is no permanent stream contributing to Lake Hardibo from the basin. All streams contributing runoff to Lake Hardibo are ephemerals and the lake is closed with no surface water outflow. The area is characterized by sub-humid tropical climate of bimodal rainfall pattern with a mean annual rainfall of 1,141 mm and mean annual temperature of 18.2 °C. The major soil types are vertic Cambisols, eutric Leptosols, eutric Regosols, and eutric Cambisols, which cover an area of 12.75%, 22.27%, 25.33%, and 8.70%, respectively (FAO, 2006). The lake with a proportional area of 30.35% covers the rest of the watershed.

Water chemistry

The total dissolved solids (TDS) are less than 780 mg/liter. From the hydro-chemical analysis result, the lake water is fresh, where both human and livestock population use the lake for drinking purpose. Water with total ionic concentration < 3 g/liter and TDS < 1,500 mg/liter is considered to be fresh. The lake has no algal outbreaks or growth of aquatic weeds and the water clarity seems to be in a good condition due to reduced non-point nutrient sources in the basin owing to limited use of fertilizers by the farmers and limited effluents from animals in the drainage basin.

Ecosystem services and ecological status

Lake Hardibo water is pumped for irrigation (Plate 2.8)., Despite increasing food production, water removal from the lake is compromising many of its ecosystem services, including its habitat suitability for fish and birds, fish stock depletion, hydrological instability and regulatory functions. Restoration efforts should focus on maintaining hydrological stability in the lake catchment

Plate 2. 8: Lake Hardibo showing plastic-lined canal draining for irrigation (Photo credit: Assefa Tesemma)

2.2.2.1.2. Lake Hayq (Lego Hayq)

Lake Hayq is geographically bounded by 39.69° to 39.74° E longitudes and 11.32° to 11.38° N latitudes within the Awash River Basin. The lake basin is a closed drainage with no surface outflow.

Biophysical characteristics

The area is characterized by sub-humid tropical climate of bimodal rainfall pattern with a mean annual rainfall of 1,141 mm and mean annual temperature of 18.2 ^{0}C. Baxter and Golobitsh (1970) reported that the lake watershed was a closed basin with no surface water outlet(s). The only stream of any size entering the lake is the **Ankerkah River**, which flows into the lake permanently in its southeast corner. Currently, all streams contributing runoff to Lake Hayq are ephemerals.

Water chemistry

The ionic concentration of Lake Hayq is 10 meq/l (Baxter and Golobitsh, 1970), and the Total Dissolved Solids (TDS) is < 790 mg/l. The water chemistry makes the lake fresh and used for drinking purposes by human and livestock population. Water with total ionic concentration < 3000 mg/liter) is considered fresh. The lake is remarkably transparent, low density of plankton, deep oxygenated layer of 40 m (Baxter and Golobitsh, 1970).

The lake can be categorized as an oligotrophic lake, which has low nutrient concentrations and low plant growth. Watershed area to lake surface area ratio is small, so the lake tends to have good water quality. No littoral zone was observed in Lake Hayq, except few patches of macrophytes in the southwest corner, which are transitional between terrestrial and aquatic systems during dropping and rising of lake level within a year.

Ecosystem services and ecological status

Lego Hayq has in recent years been transformed into a recreational center and resort area. Despite its provision of fish and potable water, the lake has become polluted with sewage and plastic wastes commonly littering the lake shore. The lake also serves as a meeting place for some cultural and religious activities. Although the trophic status of the lake was described as "oligotrophic" (unproductive), there are clear indications that the lake is undergoing ecological deterioration and depletion of its fish stock. Wollo University has undertaken custodianship to restore the lake ecological services and upgrade its ecological integrity and this initiative should be given recognition.

2.2.2.1.3. Lake Maybar

Maybar is also called Kori Sheleko watershed and is located between 10°58'and 11°02'north latitude and 39°38'and 39°40'east longitude covering nearly 450 ha.

Biophysical characteristics

The watershed is located 23 km southwest of Dessie and covers an area of 113.75 hectares. It has elevation ranging from 2,530 to 2,858 m, with mean elevation of 2,710 masl. The area drains to the Borkena stream, which is a tributary of the Awash River Basin. Sediment yield has been monitored at the watershed outlet since 1981. The moisture regime of the area can be divided into four seasons: (1) small rainy season from March to May, caused by moist easterly and south easterly winds, (2) very small dry period in June, (3) big rainy season from July to September and (4) dry season from October to February.

The mean annual precipitation is 1,211 mm. The mean annual air temperature is 16°C with coolest and hottest temperatures in November (8°C mean daily minimum) and June (26°C mean daily maximum) months, respectively.

According to the FAO classification system, the major soils of the watershed are Phaeozems, Regosols, Leptosols, Gleysols and Fluvisols. Cambisols, Phaeozems and Leptosols are found on the lower, middle to upper and steeper slopes, respectively. The area receives about 1120 mm mean annual rainfall that on average falls within five months in the two rainy seasons.

Ecosystem services and ecological status

The Maybar watershed recharges the Borkena River and is habitat to some fish stocks which are increasingly being familiarized by the local people for food. The watershed has benefitted from some intervention by the Government but more needs to maintain the ecosystem services and ecological integrity of the catchment.

2.2.2.2.4. Borkena River

The Borkena catchment is located between 10°12' to 12°22'N latitude and 38°30' to 40°14'E longitude and cover about 30,000 km ^{2}. The fault bounded graben form large plain areas such as the **Boru plain**, **Alasha plain**, **Mariam Weha plain**, and large flat lands in Kombolcha and its surroundings. These plains are seasonally flooded by the Borkena River.

Biophysical characteristics

The Borkena catchment in Wollo has three distinct seasons namely. Bega, Belg and Kiremt. Bega is a dry season from October to January. Belg is the small rainy season that occurs between mid- February and mid- May, while Kiremt is the main rainy season that extends from mid- June to mid- September (NMSA 1996). The mean annual temperature and mean annual rainfall ranges from 14°C to 20°C and from 680 mm to 1200 mm, respectively. Based on the moisture index, the climate of Wollo is classified as dry with arid to dry sub-humid condition.

Wollo is covered by Cenozoic volcanic rocks with some sedimentary intrusions. The Cenozoic volcanic rocks and the associated sedimentary rocks are further subdivided in various formations. The major soils in Wello are Leptosols, Cambisols, Vertisols, Andosols and Luvisols (FAO, 2006). The major soil types in the Borkena catchment are clay, loam soil, residual clay soil rich in organic material, gravelly sand soil and fractured rock with big boulders and cobbles.

The Borkena catchment drains three major river basins of the country, namely Abay (Abay), Tekeze, Awash and Golina. The Abay, Tekeze, Awash and Golina rivers drain 17550 km^2, 5265 km^2, 4385 km^2 and 2770 km^2, respectively.

Ecosystem services and ecological status

The Borkena River and its expansive mountain seepage and valley bottom wetlands form an important ecosystem for maintenance of flow and water table in the Awash basin. The Borkena River has been channelized and has lost many of its regulatory services, but still has important provisioning and supportive services.

The wetlands support the livelihoods of people and livestock but unfortunately, some have been drained for agriculture and totally lost their wetland features. Seasonal migration of large herds of livestock for grazing has resulted in soil compaction and eucalyptus plantations have lowered the water table and totally dried rivers in several places. Clearly, the Borkena catchment is in poor ecological condition and in need of intervention. Catchment management and restoration of key ecosystem services of the wetlands should be on the priority list.

2.2.2.2. Other wetlands in the ANRS

2.2..2.2.1. Kemisse swamps

Also called Dawa Cheffe swamps (Kemisse), this seasonal wetland is located within 1003210058 N latitude and 390 4639056 E longitude in the Borkena and Jara Rivers Basins.

Biophysical characteristics

Its total area is estimated to be 82,000 ha. The altitude of the wetlands ranges from 1445 m to 1520 masl but altitudes exceed 2000 m and even 3000 m in the surrounding Ethiopian Highlands.

The population of the nearby Woredas (districts) of Dewa-Cheffa, Artuma-Fursi, Kemise Town, Antsokiya Gemza, Efratagidim and Kalu was 614,476 during the 2007 census. The major town near the periphery of the wetland is Kemise, with a population of about 20,000 (CSA, 2007).

Field observations on ecological condition

Valley bottom wetland has the following characteristics

- is showing degradation due to encroachments (corral and settlements in middle of wetlands),
- eucalyptus has replaced natural forest in the catchment which has resulted in drying up of many of the small streams and reduction of larger river volumes of Borkena and **Jarra** rivers,

- dry season grazing and large-scale farming is practiced but could be more productive and sustainable if 'wise use' planning is in place,

- low water table indicates that wetland features can be maintained for almost year round if catchment restoration efforts are done, such as replacing or interspersing the eucalyptus cover with plants that can retain soil moisture and improve infiltration in the valley,

- the present use of the Cheffa wetland for grazing appears more appropriate than its use for farming because the former does not deplete water and lower the water table as the latter; however, studies should be conducted on the carrying capacity of the wetland for livestock. It appears that the livestock population in the Cheffa wetland is very high (Plate 2.9).

Plate 2. 9: Overgrazing in Cheffa wetland, Amhara Region

- Best agricultural practices and catchment re-forestation appear to be appropriate restoration options for the Cheffa wetland.

2.2.2.2.2 Raya and Kobo wetlands

The Raya and Kobo valleys cover 2369 km^2 and 1439 km^2, respectively, and form an extensive valley bottom wetland that sustains high population pressure. The major sources of groundwater recharge for the plain are unconsolidated sediment aquifers that drain water from the fracture openings of the volcanic rocks of the western Lasta mountainous area and also rainfall.

The annual groundwater recharge capacity of the Kobo-Robit sub-basin is 59.3 million cubic meters. The amount of groundwater that is currently discharged for irrigation purpose in Raya and Kobo valley is 10755.9 m^3 /day and 30600 m^3 / day, respectively. The depth of ground water table in the valley varies according to local hydrogeological and morphological conditions. In the western and central part it varies from 20 to 5 m and it gets shallower towards southeast. It is greater than 50 meters along volcanic ridge of Mendefera, western flank and near the inselberg hills. Shallower groundwater depth condition is expected along the proximity of dry rivers (Nata Tadesse *et al.*, 2015).

The average groundwater recharge in the Raya area is estimated to be 84 MCM per year and that of the Kobo valley is 122.9 MCM and the static groundwater reserve is estimated at 7150 MCM (Nata Tadesse *et al.*, 2015). With regard to the irrigation development in the valleys, the problem is not lack of water but rather absence of or poor management.

Ecosystem services and ecological status

This valley bottom wetland, which is mainly recharged from groundwater source, is excessively being pumped for irrigation. Lowering of the water table and exhaustion of the aquifers will eventually result in abandoning of the wetland. The wetlands require urgent intervention in planning and allocation of water management in the sub-basin. Efficient irrigation methods should be used to reduce wastage of ground water.

2.2.3. Wetlands in the ONRS

2.2.3.1. Lakes and rivers in the ONRS

2.2.3.1.1. Lake Koka/Gelila

Koka reservoir is located at 8°26′N 39°02′E with an elevation of 1,595 masl and surface area of 180 km^2

Biophysical characteristics

Lake Koka is a reservoir in south-central Ethiopia created by the construction of the Koka Dam across the Awash River. The Koka dam consists of concrete wall with a length of 458 meters and a maximum height of 47 meters. The construction was commissioned by Emperor Haile Selassie to Italian companies, which was started in December 1957 and was formally dedicated on 4 May 1960. The power plant began full operations on 28 August 1960. Addis Ababa is the primary benefactor. The total electric output is 110 GWh/year.

There is very little capacity for wastewater treatment for Addis Ababa City; therefore, wastewater is discharged directly into the natural watercourses of the Akaki Rivers, which eventually joins the Awash River. The Akaki River is an important water source for small farm operations in and around Addis producing vegetables and livestock fodder. The Akaki-Aba Samuel Catchment, within which the city of Addis Ababa is located, contains major industrial zones such as Bole Lemi I and II, Kilinto, Alemgena that produce huge amounts of industrial wastes that are washed into Akaki Rivers to eventually join Lake Koka through Lake Aba Samuel and the Awash River (Fassil Degefu *et al*. 2014, Karlsson 2015). Along these rivers and lakes there are numerous foods, leather, textile and other industries. The uncontrolled industrial wastes from all these industries eventually end up in Lake Koka and the Awash River system.

Potential pollution sources in the Koka catchment include wastewaters from industries, farms and households. In the catchment that extends to the northern extremes of Addis Ababa (Akaki Rivers catchment) there are at least 14 tanneries, with the largest tannery of Ethiopia located in Mojo City in the catchment area of Mojo River. Zinabu GebreMariam and Pearce (2003) measured Chromium (Cr) (141.1 μgL^{-1}), Arsenic (As) (14.8 $\mu g\ L^{-1}$) and Selenium (Se) (19.2 $\mu g\ L^{-1}$) in the tannery effluents. Mercury (Hg) and Cadmium (Cd) were not detected, and Pb occurred at a relatively low concentration (3.4 $\mu g\ L^{-1}$). On the west side of the lake, there is floriculture industry. The rapid expansion of this industry has raised concerns about possible environmental impacts because of the use of large amounts of chemical fertilizers and pesticides (Jansen *et al*. 2007). *O. niloticus*, *Clarius gariepinus* and *Labeobarbus intermedius* from Lake Koka contain low levels of DDT residues probably originating from the usage of DDT for malaria control (Ermias Deribe *et al*., 2011). All possible combinations of wastes coming from industries, households and farms that use different kinds of agricultural inputs such as fertilizers, pesticides, herbicides and organic wastes enter Koka and the Awash River system uncontrolled, despite the environmental protection agreements put in place by the industries and government administrative bodies.

Another aspect of the Lake Koka is the uncontrolled soil erosion and land degradation of the Awash River catchment resulting in heavy sediment transport in streams and rivers has caused significant reduction of the capacity of the Koka reservoir, which serves as the only impoundment for Awash River flows. Water supply for irrigation and hydropower generation downstream depends on releases from this reservoir.

Ecosystem services and ecological status

Koka reservoir serves as means of flood retention to protect downstream settlements. Sedimentation and pollution undermine the capacity of the reservoir to hold water for the above mentioned functions and for flood control to protect humans and their livelihoods downstream (regulatory service). Provisioning services of Lake Koka include supply of household water for the population in the watershed, mostly Adama town, irrigation water supply, fisheries, flood control and even the salient services of waste assimilation, climate moderation, cultural services and tourism where a variety of wildlife and birds are observed in islands and around the lake. According to the Ethiopian Department of Fisheries and Aquaculture, 625 tons of fish are landed each year, which the department estimates is either 52% or 89% of its sustainable amount. The reservoir is threatened by increasing sedimentation caused by environmental degradation, water hyacinth infestation and pollution. Its ecological status can be said to be poor and in dire need of restoration actions.

2.2.3.1.2. Lake Basaka

Lake Basaka is located in the Middle Awash Basin, Fantalle Woreda of Oromia Region (8.5 ^{0}N, 39.5 ^{0}E, 950 masl.), about 200 km south-east of the Ethiopia's capital city, Addis Ababa, along the Addis–Dire Dawa– Djibouti or Addis–Harar–Jigjjiga highway road. The lake was essentially a small (surface) pond before the establishment of Matahara Sugar Estate (MSE) in the 1960s (Megersa Dinka, 2012).

Biophysical characteristics

The area can be viewed physiographically as a topographic depression, where run-off and alluvial sediments overflow from the surrounding catchment areas (Mohr 1971). The area is bordered by older volcanoes and a rift margin in the east, by young Quaternary complexes of Fantalle Crater in the north and by Kone on the west side. The formation of common rock types in the area is the product of the recent volcano complexes, along with fissural basalt, rhyolite, alluvial and lacustrine sediments (Mohr 1971). The area is characterized by a bimodal and erratic rainfall distribution pattern, with the major rainy season being between July and September. Occasional minor rains can occur between March and May. Megersa Dinka (2012) reported that based on long-term weather data (1966–2010), the mean annual rainfall and temperature were about 543.7 mm and 26.5^{0}C, respectively, and the pan evaporation for the area was 6.92 mm day^{-1}. The general climate of the area is semi-arid.

Lake Basaka (Metehara) is different from other wetlands in Ethiopia in that its surface area and water volume have increased enormously in recent years and has resulted in the rise in the water table of the Wonji Sugar Estate plantation that came as close as 20 cm to the surface and caused overflow of the lake into the Addis Ababa-Djibouti highway and railway. This increase is recorded irrespective of climate factors such as rainfall and evapo-transpiration, which otherwise could have resulted in the drying of the lake.

Despite the potential evapotranspiration that exceeded the annual rainfall budget of the watershed, Lake Basaka has increased in volumes and surface coverage by infiltration of groundwater that mainly comes from the Awash River, be it from the irrigation for sugarcane plantation and the natural subsurface infiltration of water through the porous nature of the geological formation of the area (Seifu Kebede *et al.*, 2007). Figure 2.13 further elucidates the scenario that is in play presently.

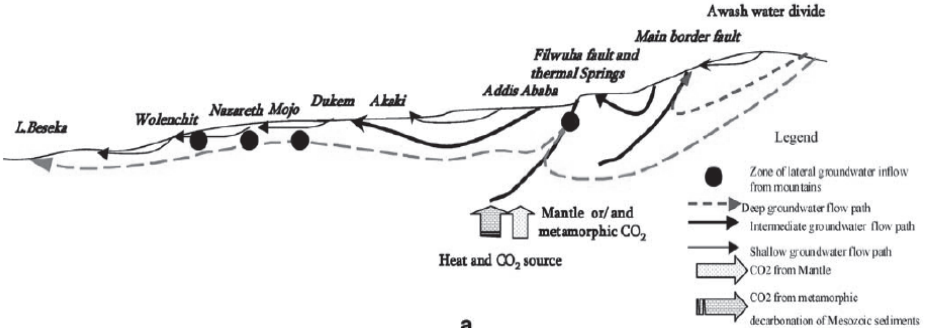


Figure 2.13: Possible causes for Lake Basaka's increase in volume (After Seifu Ketema et al., 2007)

Ecosystem services and ecological status

The provisioning services of this lacustrine wetland have been compromised as a result of lake dilution and expansion– fish production has declined followed by reduced crocodile populations. The ecological integrity of Lake Basaka is affected by the hydrological and resulting biological changes experienced over the last five decades. There is urgent need to restore its lacustrine features but it appears that the natural changes in this wetland have far outstripped what can be managed by human intervention. Still, this wetland was ranked as one in the lower group of wetlands that could be restored through rigorous ecological, political and hydrological interventions.

2.2.3.1.3. Ziquala Lake

Lake Ziqualla (Zuqualla, Zequalla, Zequala) located at $8^{0}33'$N $38^{0}52'$E in Ada'a Chukala Woreda of the Misraq (Misrak) (East) Shewa Zone at an elevation of 2,989 m and has an area of 42 580 ha.

Biophysical characteristics

The lake is a small, shallow endorrheic (closed) lake with a surface area of approximately 0.25 km^2 and maximum depth of 3 m. A monastery is situated in the north-eastern portion of the caldera. There is a lake at the bottom, and the surrounding slopes support dry montane forest dominated by *Juniperus procera*, with some patches of *Olea africana cuspidata* and grassland. The extent of forest is c.197 ha, the grassland c.31 ha and the lake surface c.39 ha. The lake is surrounded by *Typha* spp., sedges and rushes, and is only disturbed where the monks and nuns collect water.

The forest is diverse, with 217 species of flowering plants and ferns recorded. The forest adjacent to the grassland is the richest, with several tree species beside the dominant *Juniperus procera* and *Olea africana cuspidata*, namely *Ilex mitis*, *Pittosporum viridiflorum*, *Buddleja polystachya* and *Maytenus obscura*. The canopy is open, providing light for a rich herb flora as well as the climbers. Only *Juniperus procera* is found on the steeper slopes and this gives way to *Erica arborea* on the western half of the crater rim. The rim of the crater is covered with a natural conifer forest and other alpine type vegetation, which offers a natural habitat to various birds and mammals (e.g., the eastern black-and-white colobus monkey *Colobus guereza*). This "holy" lake is completely surrounded by a reed belt and is strictly protected by the community of monks living in a nearby monastery.

This lake is not fully investigated and literature is very scanty. This is due to the belief the administration of the Orthodox Christian Monastery on the top of the lake hold that this Lake Zuqualla is a holy water that should not be sampled for investigation (Plate 2.10). However, a recent limnological study has recorded that the lake belongs to the mesotrophic (moderate productive) status (Fasil Deguefu *et al.*, 2014)

Plate 2. 10: Lake Ziquala from distance and at closer range (source Google 2017)

Ecosystem services and ecological status

Lake Ziquala has been protected from encroachment by the local monastery for centuries and because of its pristine riparian vegetation, catchment erosion and soil fertility have been maintained (regulatory services). It has religious and cultural value and although limited to the local church community, it also has provisioning services for potable water, fish and herb production. Although a recent limnological study concluded that the lake's trophic status is mesotrophic (Fasil Deguefu *et al.*, 2014), its overall ecological condition can be described as good to excellent, and no immediate restorative measures appear to be necessary.

2.2.3.1.4. Bishoftu crater lakes

The Bishoftu Crater lakes and the surrounding wetlands

The Bishoftu area delineated by coordinates 8°45'N 38°59'E and 8°45'N 38°59'E is a region of crater lakes located in close proximity with each other, namely, Lakes **Bishoftu, Hora-Harsedi** (Hora or Bete-Mengist), **Bishoftu-Guda (Babogaya), Hora-Kilole**, Hora-Hoda (**Arenguade** or Green Lake) and Lake **Zequalla (Zuquala or Ziquala**). Some of these lakes are shown in Figures 2.14 and 2.15. In addition to these, there are a few wetlands such as Lake Cheleklaka and dams that appeared as part of irrigation development projects such as Belbela or Cuba Dam.

Physico-chemical features

In Tables 2.7 and 2.8, some data on the morphometric and physico-chemical features of the Bishoftu crater lakes are given. Most of the lakes are small with surface area less than 1 km^2. Two of the lakes, Lakes Bishoftu and Bishftu-Guda (Babogaya), are very deep and remain stratified for most of the year, partly because of protection from intense wind action by the deep crater wall. They may occasionally destratify and mix, bringing bottom waters rich in Hydrogen Sulfide to the surface (local people believe this is due to the devil's work). Lakes Arenguade and Hora-Harsedi are moderately deep (> 30 m) but rarely mix because of the deep crater wall (> 200 m). The other Lakes, Kurifu and Kilole, are shallow and also highly impacted by human encroachment but not Lake Ziquala, which is considered as sacred water by the local priests and sampling is rarely allowed.

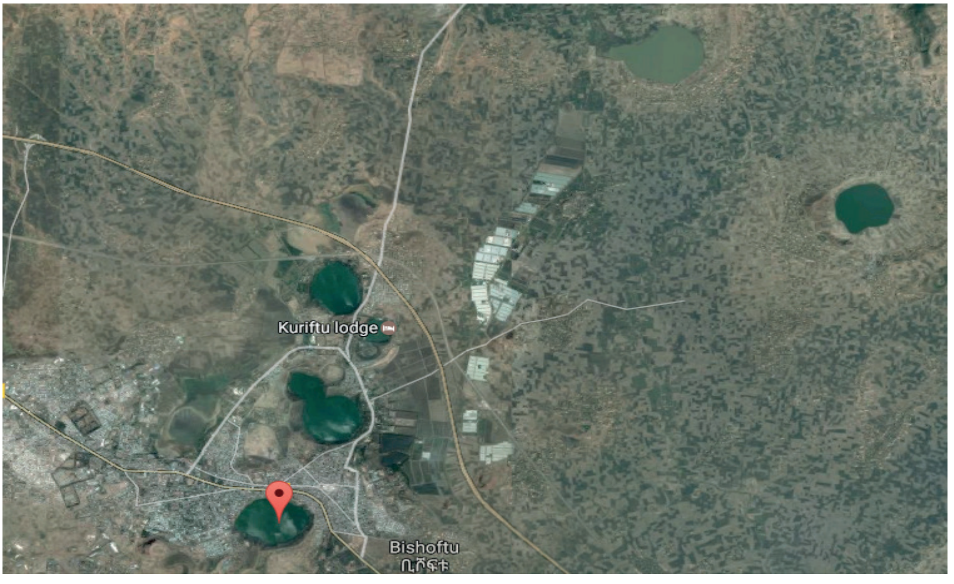


Figure 2.14: Google map showing Lake Bishoftu (marked), Lake Hora Arsedi and Lake Kuriftu (Kuriftu Lodge indicated)

The white blocks are flower farms that use the waters of River Wedecha.

Figure 2. 15: Google imagery of Lake Hora-Hoda (Arenguade or Green Lake)

Table 2. 7: Morphometric features of Bishoftu Crater Lakes (after Wood and Talling, 1988 and Fasil Degefu et al., 2014)

Lakes	Altitude, masl	Surface area, km^2	Max. Depth, m	Mean depth, m	Volume, km^3	Salinity
Hora Kilole[1]	2000	0.77	6.4	2.6	0.0087	0.771
Bishoftu	1870	0.93	87	55	0.052	1.92
Arenguade	1900	0.54	32	18.5	0.010	5.541
Bishoftu Guda (Babogaya)	1870	0.58	65	38	0.022	0.928
Hora Arsedi	1850	1.03	38	17.5	0.022	0.928
Kuriftu	2000	0.4	6.0	2.0	0.3	240 μScm^{-1}
Zequala	2989	0.25	3.0	----	----	77 μScm^{-1})

The water chemistry of these crate lakes was summarized in Seyoum Mengistou (2006) and is given in Table 2.8.

Table 2. 8: Water chemistry of the Bishoftu crater lakes (After Seyoum Mengistou, 2006)

Lake	Salinity (g/l)	Cond. (µS/cm)	pH	∑cations (meq/l)	∑anions (meq/l)	SiO_2	PO_4 (µg/l)	Chl a (µg/l)
Hora Harsedi (Biete Mengist)	2.56	2340	9.2	29.5	32.9	53	< 5	29
Kuriftu	0.26	3190	8.4	3.12	3.46	-	-	61
Babogaya (Pawlo)	0.94	1000	9.2	10.8	11.7	38	14	54
Bishoftu	1.92	1830	9.2	23.61	24.7	38	< 5	34
Arenguade (HoraHoda)	5.54	6000	9.4	79.8	65.3	50	4100	5000
Kilole	5.7 (0.57)	5930	9.6	75.7	77.4	45	5000	400
Chelekleka (ephemeral)	-	-	-	7.3	7.0	1.5	-	-
Ziquala	0.22	238	7.5	2.69	2.93	-	-	-

Despite the closed (endorrheic) nature of the lakes, most of the crater lakes are not saline. The most saline of them, such as Lakes Arenguade and Kilotes, have become dilute in recent years, the latter due to diversion of the River Mojo (Brook Lemma, 2011). The reasons for the dilute nature of the waters may be the surface influx from freshwater springs and inflows and groundwater intrusion. Only the saline lakes show some discrepancy in the ionic proportions of the waters, possibly as a result of excess leaching of cations from the lake basement.

Nutrients such as silicate and phosphate do not appear to be limiting in most of the Bishoftu crater lakes, with the exception of Lakes Hora and Bishoftu. And yet, these lakes are teeming with blooms of *Microcysi*s most times of the year. Perhaps Nitrogen is a limiting factor, as is true for most tropical African lakes (Talling and Lemoalle, 1998). The huge reserve of phosphate in Lake Arenguade was partly responsible for the blooms of *Spirulina (Arthrospira*) that the lake used to enjoy some years earlier. Silicate is high in all the crater lakes, but they are dominated by blue-greens, not diatoms. There are no long-term studies on nutrient and primary production studies in the crater lakes, as compared with the rift valley ones.

The last two lakes are the least known. Lake Chelekleka has been continuously decreasing in area and volume, and because it is a shallow pan, it has dried up completely in recent years. Not much is known about the last crater Lake Ziquala, which occupies a crater depression on mount Ziquala and has only been sampled recently (Fasil Deguefu *et al.*, 2014). Measurements of its conductivity indicate decrease from 238 uS/cm pre-2006 to 77 uS/cm in 2014. Whether this is sampling artifact or actual decrease in salinity should be investigated further.

More detailed studies were carried out on some of these crater lakes, including Lake Kilole (Brook Lemma, 2011; 2014).

Lake Hora Kilole

Situated at coordinates 08^{0}48.486'N and 039^{0}05.072'E and at an elevation of 1879 m, this crater lake witnessed drastic changes in its ecology due to diversion of the Mojo River into it.

Biophysical characteristics

In 1989, the Ministry of Agriculture diverted River Mojo into the saline-alkaline Lake Kilole

with the intention of converting it into a reservoir to use the captured water for gravitational irrigation to the south and west of the lake. With the water column rising from 6.4 m in pre-1989 years to 29-30 m in the rainy seasons that completely diluted the lake with complete changes in the constellation of the lake chemistry and the biota from almost monoculture of *Arthrospira*

fusiformis (*Spirulina*) and spoonbills and flamingos that fed on them to freshwater algae such as *Cosmarium* and *Peridinium,* typical freshwater fishes such as *Oreochromis niloticus* and *Labeobarbus spp. (barbus)* that came in with the river water and to cormorants and Egyptian geese. In the course of time around 2005 within less than a month the water of the lake sunk into the ground only to reappear in Lake Hora-Arsedi, a lake located at the lowest point among a chain of Bishoftu Crater lakes only 13 km to the west of Lake Hora-Kilole. This even is documented in Brook Lemma (2003 and 2011). Since 2005, the project has been abandoned and the lake has changed from its natural saline-alkaline nature to ordinary tropical freshwater system, maybe never to revert to its original nature. Today, horticultural crops are harvested along the shores using the freshwater and some fishermen operate to supplement their daily incomes (Fig. 2.16).

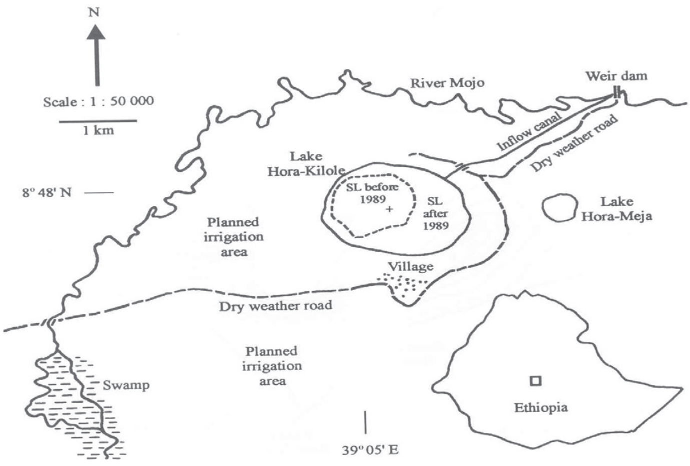


Figure 2. 16: Lake Hora-Kilole shoreline (SL) before and after 1989, after the diversion of River Mojo into it (Brook Lemma. 2014)

Ecosystem services and ecological status

The ecosystem services and ecological status of the Bishoftu crater lakes have been summarized in Table 2.9.

Table 2. 9: Major ecosystem services and ecological status of the Bishoftu crater lakes

Lake	Provisioning	Regulatory	Supportive	Cultural	Degradation status
Hora Harsedi	Fish, recreation			Iretcha	++
Hora Bishoftu	Recreation				
Kuriftu	Irrigation, fruits, fish, recreation				++
Babogaya (Bishoftu Guda)	Fish, water navigation				+
Hora Kilole	Irrigation				+++
Arenguade (Hora Hado)					+
Chelekleka					Lost or beyond restoration

+: slightly degraded; ++: moderately degraded, requires intervention and +++ : extremely degraded and in need of restoration. Empty cells indicate that the extent of ecosystem services is unknown in these lakes.

2.2.3.2. Other wetlands in the ONRS

2.2.3.2.1. Berga wetlands

The Berga floodplain wetland is located in the Oromia NRS, West Shoa zone, at coordinates 09°16′N 38°23′E and altitude between 2,450–2,500 masl.

Biophysical characteristics

The Berga River, the main tributary of the Awash River, drains the plain. The vegetation of the Berga floodplains comprises of grasses, sedges and other plants peculiar to these areas, e.g. *Trifolium* spp. (including the endemic *T. schimperi* and *T. calancephalum*), *Haplocarpha schimperi*, *H. hastata*, *Cerastium* sp., *Cyperus* spp. (including *C. dichroostachyus*, *C. atronervatus* and *C. atroviridis*), *Ranunculus multifidus*, *R. simensis*, *Rumex natalensis*, *R. marginulata*, *Uebelinia kigesiensis*, *Schoenopletus corymbosus*, *Vossiacus pidata* and *Habenaria filicornis*. The most important and palatable grasses in this area are species of *Pennisetum* and *Andropogon*. In some places, water lies up to 50 cm deep, and such areas are often covered with floating grasses, particularly *Odontelytrum abyssinicum*, and pondweeds *Potamogeton* spp., and often have the purple flower spikes of *Aponogeton abyssinicus* emerging from the surface.

The Berga wetland has been designated as an Important Bird Area (IBA) and is home to the endangered White-winged Fluftail (Berga wetland project). The birds build their nests in the tall grasses and community members patrol the area to prevent people from cutting the grass. The White-winged Flufftail is a little-known species thought to be undergoing a rapid decline. It was recognized as Critically Endangered species in 2013, and its number is currently estimated at fewer than 250 birds. The species occurs in Ethiopia and South Africa (with isolated records also from Zambia and Zimbabwe). Berga wetland is known to be the only known breeding site for the species in Ethiopia.

Plate 2. 11: Berga wetland (Source: Berga wetland project)

Ecosystem services and ecological status

The Berga wetland provides habitat for large populations of livestock and horses (Plate 2.11). The wetland provides food, water and shelter to endangered bird species such as white-winged flufftail. As this is critically-endangered species with only less that 250 birds left in 2013, protection of the Berga wetlands is of high priority. The wetland also conserves water and regulates flow in the Awash Basin.

2.2.3.2.2. Becho plain

The Becho plain is found near Dilu Meda (Tefki), ONRS at coordinates 08°53′N 38°27′E, and altitude 2080 masl. It has an area of c.9,000 ha. The Upper Awash River sub catchment has an area of around 11500 km^2 and is located between 8 and 9 N latitude and 38 and 39 E longitude. According to Messele Fisseha (2003), the Becho Plain is located in the upland area of the Awash Basin at an altitude of about 2,100 m. The main area of annual flooding comprises some 4,500 ha, where several tributaries of the Awash come together. Much of the land adjacent to the flooded area – some 16,000 ha - suffers from poor surface and internal drainage.

Biophysical characteristics

Dilu Meda is east of the Addis–Woliso road, 35 km south-west of Addis Ababa in the Becho plains, West Shewa Zone. The Becho plains comprise flat seasonally inundated land crossed by the Awash River and surrounded by volcanic hills.

Two peaks, Wata Dalecha (2,505 m) and Debel (2,421 m) are situated to north and south, respectively of Dilu Meda. Two small rivers, the **Sendafa** and **Dulolo Dilu**, feed directly into Dilu Meda. Flood water from the Awash and Holeta rivers covers a large area of the basin from July to September. There are no sizeable beds of bulrush or tall sedges, but a variety of smaller sedges have been found in flooded areas along with *Potamogeton* spp. and *Persicaria* spp. Uncultivated grassland around the flooded areas is rich in species, including a number of endemic *Trifolium* spp. The farming community has developed a sophisticated system for using this difficult area. The soils, with the annual enrichment of silt and alluvium, are rich and can be cropped year after year with cereals, particularly *teff* (*Eragrostis tef*) and durum wheat. Other crops well adapted to grow on residual moisture are chickpea and grass-pea.

The Becho plain has an average elevation of 2060 m and is surrounded by Wechecha Mountain in the east, the Guraghe highlands in the south and the Weliso highlands in the west (WWDSE, 2008). The catchment of this upstream part of the upper Awash reach, until the gauging station at Melka Kunture, is 4541 km^2. Mean annual rainfall varies from over 1200 mm per year in the high-elevated uplands to below 700 mm per year in the lower areas surrounding Lake Koka. 70 to 75% of the total rainfall occurs in the main wet season. The clay content between 20 and 40% results in a permeability of around 6 m^{-3} m/day and retains water after floods in the wet season. The dominant soil type in the Becho plain is vertisols. Around 80% of the land is used for agriculture, and 10% for grazing land.

Ecosystem services and ecological status

This seasonal wetland is used as fertile agricultural land, being one of the important *teff*- producing areas in the country. The seasonal wetland suffers from poor water logging and serves for recession agriculture during the dry season. The hydrological imbalance between the dry and wet seasons needs to be addressed through soil conservation, water storage and hydrological management. The Becho plains represent an interface between a seasonal wetland and crop land.

2.2.3.2.3 Wonji floodplains

Wonji Shoa Sugar Estate (WSSE) is one of the key and early large scale irrigation schemes in the Awash River Basin (Megersa Dinka et al., 2014). Its establishment in the basin marked the first era of large-scale irrigation development and era of domestic sugar production in the Ethiopian history. The plain was a sparsely populated swampy area, and frequently affected by flooding (due to Awash River flow characteristics) and infestation of Malaria.

The Wonji plains experience bimodal and erratic rainfall distribution pattern. The long-term average annual rainfall is about 830 mm, mostly (≈76%) falling during the main rainy season (Jun-Sept). Temperature of the area (15.2–27.6 °C) is specifically suitable for sugarcane. The climate of the area is between the transition of the two zones: semi-arid to dry sub-humid. The soils of WSSE are of alluvial-coluvial origin developed under hot, tropical conditions. Texturally, the soil can be categorized into light (course textured) and heavy (clayey black) soils. The heavy clay soils (≈70%) are the dominant soil group in the plantation and characterized by inherent problems such as compaction, poor structure, shallow GWTD, etc. Consequently, these soils are regarded as problematic by plantation's agricultural managers. The geology of Woni plain is characterized by volcanic activities and rift tectonics, which is characteristics of the Main Ethiopian Rift (MER).

A network of irrigation (≈280 km) and drainage (≈203 km) canals are used in the area. Irrigation water is diverted to the estate from Awash River using centrifugal pumps and then to masonry lined main canal. There are seven main and twelve tertiary night storage reservoirs distributed across the estate to store water during the continuous pump operation in the night time. Field water application is through block-ended furrow irrigation system and the excess water from the plantation fields are drained through the network of surface drains. The network of irrigation system consists of primary canals (480 m), secondary canals (≈76 km) and tertiary canals (≈203 km).

Ecosystem services and ecological status

This man-made wetland has important provisioning services for production of sugar cane plants and many aquatic birds also frequent the area for food and shelter. However, this has deprived its use as habitat for fish and compromised its regulatory, supportive and cultural services. Efficient storage and use of water is required to optimize the ecosystem services which will supplement the economic services derived from the irrigation fields.

2.2.3.2.4. Belbela dam and Wedecha River

Belbela or Cuba Dam lies at an altitude of 1923 masl (08^{0}49.937’N and 039^{0}02.541’) (Abebe Damtew, 2006).

Biophysical characteristics

The Godino and Goha Woriko irrigation schemes are on both sides of the Wedecha River, located in East Shewa zone, in Oromia region near the town of Bishoftu (Debre Zeit) about 70km from Addis Ababa. The schemes are part of a cascade system which includes two earthen dams and reservoirs. The upper dam, which is located north of the two schemes Godino and Goha Worko, is called Wedecha Dam and River Wedecha is the main water source of both schemes. The dam was constructed in 1980 by Kuba (Cuba) Construction Brigade having the Agricultural Development Minister of Ethiopia as a client. Amibara Irrigation Project II is located in the south-eastern flood plain of the Awash River in a typical semi-arid agro ecological zone with an extensive pastoral production system based on camels, cattle, goats and sheep. In 1980 the Amibara Irrigation Project II (AIP II) was established and production was mainly focused on cotton for foreign markets. The major threat to the Amibara wetland is intrusion of salt water (Table 2.10).

Table 2. 10: Major environmental problems in some of the wetlands in the Awash basin. (After Loiskandl et al., 2008).

Nr	Scheme	Basin	Hydrology/ natural resources	Water quality	Soil quality	Poverty alleviation	Others
1	Wonji	AWASH	Rising water table, Seepage of reservoirs	Slight EC increase	water logging Infiltration		Heavy machines
2, 3, 4	Oromyia		Inefficient water use (except Marcos)	Stagnant water	Salinity	Marketing, poor access to health facilities	Need for education, management
5	Amibara II		Flood hazard, degradation	Linkage with Lake Beseka (very high sodium cont)	Salinity	questioned	livestock, Negative Social effects
6	Ziway Holota			Toxicity	Salinity Permeability increase	Malaria, Market access	New plant diseases, training

Ecosystem services and ecological status

The Belbela wetlands provide fish, water and plants. Due to its small size, it may not have significant contribution in regulatory and supportive services. In recent years irrigation activities are being conducted to produce horticultural crops, including cut flowers.

2.2. 3.2.5. Chelekleka Lake (Swamp or pan)

Chelekleka Lake and Swamp is located at coordinates 08°51′N 38°58′E at an altitude between 1,800–1,900 masl. Chelekleka is a seasonally inundated pan, the western and south-western sides of which form the periphery of Bishoftu (Debre Zeit) town. Chelekleka is in a shallow pan into which fresh water seeps and flows from the surrounding cultivated slopes. Water fills the muddy depression during the rainy season and persists well into the dry season. The two highland ranges of Teltele and Sofa, on the north-eastern side of the swamp, are the main catchments for Chelekleka. Because of its shallow nature, the lake's shoreline is wide. The size of the inundated area varies dramatically from year to year, although recently the size of the swamp has been reduced through the construction of flood-control dykes in the feeder streams, and channeling run-off from the town into Bishoftu Lake. The swamp is relatively rich in aquatic vegetation, with *Typha* spp., sedges, rushes, *Potamogeton* spp., *Persicaria* spp. and the floating grass *Odontelytrum abyssinicum*. The area around the lake is intensively used. As the waters retreat, farmers cultivate vegetables on the rich alluvial soils left behind on its northern and eastern sides, and it is not uncommon to see some cultivation throughout the year. A thriving private citrus farm exists on the lake's southern side. This wetland is also an important watering point for cattle in the area. In recent years, this shallow pan has completely dried up and the lake bed converted into agricultural and residential area. This is an example where a shallow wetland can completely disappear into a terrestrial ecosystem due to mismanagement and perhaps, some climate change effects also (continual absence of rains). It appears that this wetland is completely degraded and beyond any possibility for restoration or recovery.

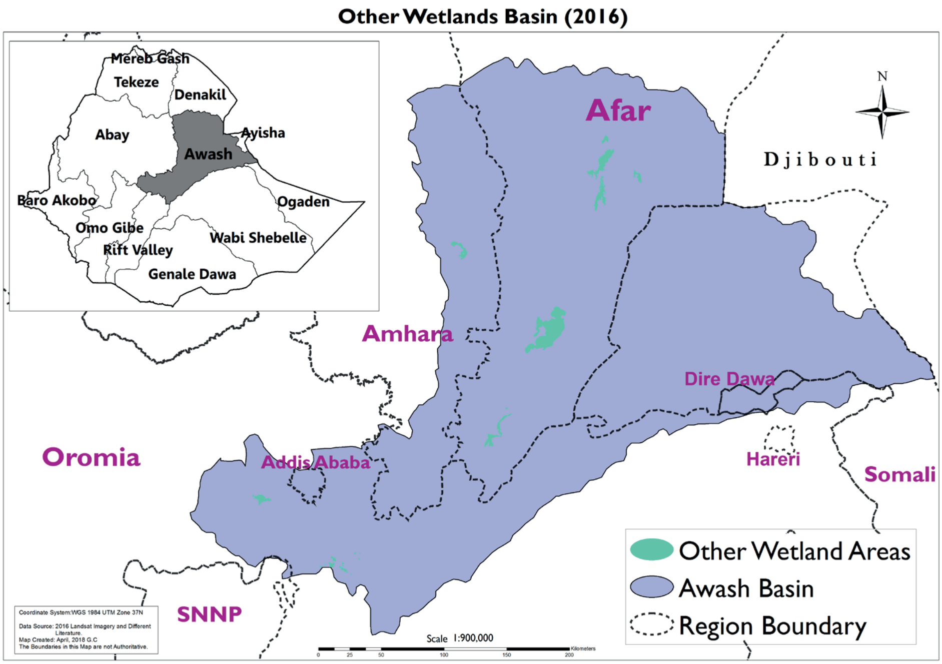


Figure 2. 17: Other Wetlands in the Awash basin in general

The Awash River forms extensive floodplains, swamps, wet grasslands and meadows as it meanders its way from its source in the mountains north-east of Addis Ababa to its disappearance in the sands around Lake Abe near the Djibouti border (Fig. 2.17). These wetlands provide critical ecosystem services for the people and livestock in the area, and are habitat to fish, migratory birds and mammals, some of which are protected in conservation sites. The wetlands near Addis Ababa are also part of the Awash basin.

2.2.4. Wetlands in the Addis Ababa Region (general)

Description of the Akaki watershed and reservoirs for Addis Ababa: Dire, Legedadi and Gefersa I and III

At the elevation of 9.0°**N**, 38.8°E**,** the climate of Addis Ababa should have been typically tropical but its altitude of 3271, surrounded by the Entoto ridge vastly moderates its climate to semi-temperate type.

Biophysical characteristics

The mean annual temperature ranges from 15-20°C depending on the season. There are seasonal rainfalls, the main one is during June to September called "Kiremt" and a smaller one is in February to April called "Belg". These rains are mainly driven by the oscillating Inter-Tropical Convergence Zone (McSweeney *et al.*, 2007). The average rainfall is around 1200 mm/year.

Reservoirs

Rivers crossing Addis Ababa and the reservoirs built in the upstream of the same: Gefersa I and II on River Tinishu Akaki, Reservoirs Dire and Legedadi on two feeder rivers of River Tiliku Akaki. The receiving reservoir at the south, namely, Aba Samuel is discussed below as its purpose of establishment is different from the three (Tenalem Ayenew *et al.,* 2008).

The 3 reservoirs with a total capacity of 61 BMC of water (Table 2.11) have not been able to satisfy the water demand of the city, and more boreholes and ground water are dug to supply some parts of the city, including over 4,255 deep wells, 9,329 shallow wells, 27,338 hand-dug wells, 18, 908 springs and 222 sub-surface dams.

Table 2. 11: Some features of the drinking water reservoirs of Addis Ababa (Source: Daniel Elala, 2011)

	Legedadi	Dire	Gefersa I	Gefersa III
Construction year	1970	1999	1944	1966
Capacity (10^6 m^3)	40	13	7	1
Runoff (10^6 m^3/year)	70	40	27	Within Gefersa I's
Surface area (km^2)	4.0	1.3	1.4	0.4
Dam size (mxm)	22x600	46x665	15x150	18x220
Catchment area (km^2)	225	72	56	Within Gefersa I's
Supply rate (m^3/day)	127 000	38 000	30 000	Only to Gefersa I
Notes		Used first half of the year		Used for sedimentation purpuse

Akaki catchment

The geological makeup of the Akaki Catchment covers an area of 11 454 km^2 (Haile Selassie Girmay and G. Assefa 1989).

Water chemistry data showed that though most of the groundwater in Akaki –Sub-basin has fairly normal values of dissolved solutes, still surface waters revealed higher values due to the influence of anthropogenic pollution. Dissolved oxygen as low as 0.2 mgL^{-1} is by itself an indication of high load of polluting materials, particularly organic matter as measured by high BOD and COD. The type of water in the Akaki Basin is alkaline with high contents of the alkalis, with hydrogen carbonates prevailing. Among anionic measurement NO_3^- showed very high concentrations, exceeding US EPA standards. This has been reflected in the groundwater as well. Within this basin the concentration of heavy metals is lower in the surface waters than in the groundwater, where in the latter accumulation and concentrations take place over time, while the residence time in the former is very short as the water moves down the gradient all the way into River Awash.

Lake Aba-Samuel

Located at 080816984N and 380.706711E, this dammed reservoir used to connect the City of Addis Ababa and the Akaki watershed and the associated dams and rivers that cross the city loaded with household and industrial wastes to feed it (after Habtamu Haile Tolera 2007). The connection of waste outflows from Addis Ababa Rivers to Lake Koka and Awash River then after through Lake Aba-Samuel which eventually transported heavy metals and invasive plant and animal species into the reservoir. Aba-Samuel dam stopped to generate power due to siltation and fill-up by debris from decomposing water hyacinth plants. It is currently the major waste recipient for Addis Ababa.

Gefersa and Legedadi dams

In addition to Lake Aba-Samuel, Gefersa I Reservoir (9°3′59″N 38°37′56″E, covers an area of about 5700 ha and is at an altitude of 2600 masl) and Legedadi Dam (9°4′11″N 38°58′58″E) are used as reservoirs to capture some of the rivers in Addis Ababa to supply the city with drinking water. The reservoirs receive a mean rainfall of 1100 mm and have an average temperature of 16^{0}C.

Gefersa Reservoir is 18 km west of Addis Ababa (by road) in West Shewa Zone. The reservoir is in a shallow basin about 10 km wide, stretching between the Wechecha and Entoto mountains. The Gefersa River and its feeder streams are part of the Akaki river catchment. The reservoir was formed behind a main dam built in 1938 (and modified in 1954) and a second, smaller dam, built in 1966, upstream from the main dam, The water storage capacities are c.6,500,000 m^3 and c.1,500,000 m^3, respectively, and the two dams control a catchment area of c.5,700 ha. The reservoirs supply treated water to Addis Ababa. The reservoirs themselves are virtually free of large aquatic plants, probably due to the constantly fluctuating water-level. Patches of sedge occur where permanent streams flow into the reservoirs, and on the western and southern sides of the main reservoir, long, shallow valleys with small streams support swampy vegetation.

The area immediately around the dam and on the northern side of the reservoir is enclosed and supports well-established exotic trees of *Eucalyptus globulus*, *Cupressus lusitanica*, *Pinus patula* and *P. sylvestris*. Meadows in this enclosure have been protected from grazing for many years and have developed a flora quite different from the heavily used areas outside. Much of the area surrounding the reservoirs has been closely planted with *Eucalyptus*, although there are some patches of small trees, e.g. *Maesa lanceolata*, *Buddleja polystachya* and *Maytenus obscura*, the climbers *Clematis simensis* and *Jasminum abyssinicum* and also bushes of *Rosa abyssinica*. All other areas are densely inhabited and farmed. The valley bottoms are used as pastureland that flood in the rainy season, while the higher slopes are cultivated, with barley and wheat as the main crops, and smaller areas of pulses (field pea and faba bean) and oil crops (Niger seed and linseed). The bird fauna includes White winged flufftail (old record), a vulnerable bird species and two near threatened species (Ruuget's rail and Abyssinian longclaw); the wetland supporting a total of about 20 highland biome species.

Legedadi dam (in Oromia region but described with other AA dams here mainly to retain flow)

Some of the important features of the Legedadi Reservoir, which is one of the major suppliers of drinking water to the metropolitan city of Addis Ababa, are listed in Table 2.12.

Table 2. 12: Data for Legedadi reservoir from several sources

Features		References
Geographic position		
Latitude	9^0 20′ N	AAWSA, 1994
Longitude	38^0 55′E	"
Altitude (m)	2450	"
Morphometric character		
Catchment area (km^2) Area (Km^2) Volume (Km^3)	234 4.52 38.71	Andualem Gessese, 2008 AAWSA, 1994 "
Maximum depth (m)	34	"
Mean depth (m)	9	"
Physicochemical feature	**Mean (range)**	
pH	8.7	AAWSA, 1994
Color (Pt. cobalt Unit)	450	"
Alkalinity (meq L^{-1})	10.96	"
Turbidity (NTU)	322	"
Conductivity (mS cm^{-1})	63-131	Adane Sirage (2006)
Secchi depth Z_{SD} (m)	(0.082-0.11)	"
Total suspended solid (mg L^{-1})	(37-67)	"
Surface temperature (^{0}C)	20	AAWSA, 1994
Iron (mg L^{-1})	0.05	"
Manganese (mg L^{-1})	0.10	"
Total phosphate (mg L^{-1})	88	"
Fluoride (mg L^{-1})	1.0	"
SiO_2 (mg L^{-1})	7.0	"
Nitrate (NO_3^-) (mg L^{-1})	(240-1850)	Adane Sirage (2006)
Chlorophyll–*a* (mg m^{-3})	(22.19 - 39.45)	"
Biological feature	**Taxa**	
Phytoplankton	Cyanophyceae	Adane Sirage (2006)
	Microcystis aeruginosa	"
	Chroococcus turgidis	"
Pisci-fauna		
	Oreochromis niloticus	"
	Cyprinus carpio	"

Kebena River in Addis Ababa

The Kebena River rises from its source at Abo, 2600 masl ($9^0$4'N, 38^0 47'E) on Entoto mountain and drops to 2100 m crossing the city to eventually merge with the Akaki River. The river receives untreated discharges from sewage, industries, and residential areas and is heavily polluted. The Addis Ababa City Government has started rehabilitation project on the Kebena River.

Ecosystem services and ecological status

The Addis Ababa artificial wetlands (reservoirs) provide pivotal provisioning services of drinking water to major urban centers such as Addis Ababa, and some fish for riparian communities. Due to extensive eucalyptus plantations around the reservoirs, water loss through evaporation and uptake appears to be high. Most of the reservoirs are well protected from human and livestock encroachment and the ecological condition of most of the reservoirs is "good", However, there is need to address the water loss problems and to protect these wetlands to sustain their ecosystem services for the long-term in the future Many of the reservoirs have good water quality, but some like Aba Samuel dam have become so polluted that they have completely filled with organic waste and water hyacinth debris. Gefersa reservoir needs to be protected from livestock intrusion into its compound. These wetlands are on the lower list of priority for restoration action – instead, they require continued protection and good management practice. The rehabilitation efforts by the City Government on these wetlands should be maintained.

2.3. Aysha basin in general

Aysha Basin

The Aysha basin is a dry basin within the Somali NRS in Ethiopia and borders with Djibouti in the north and Somalia Republic in the south and east (Figure 2.18).

The Ethiopian Ministry of Water, Irrigation and Energy lists the drainage area of the Ayesha amongst the twelve major basins in the country, with an area of 2,223 square kilometers, although it lacks any measurable flow (Wikipedia). Typical to desert areas, wetland features may appear at single rain shower at which time plant and animal life flourish making the ground covered with green carpet and desert flowers that produce seed and die quickly.

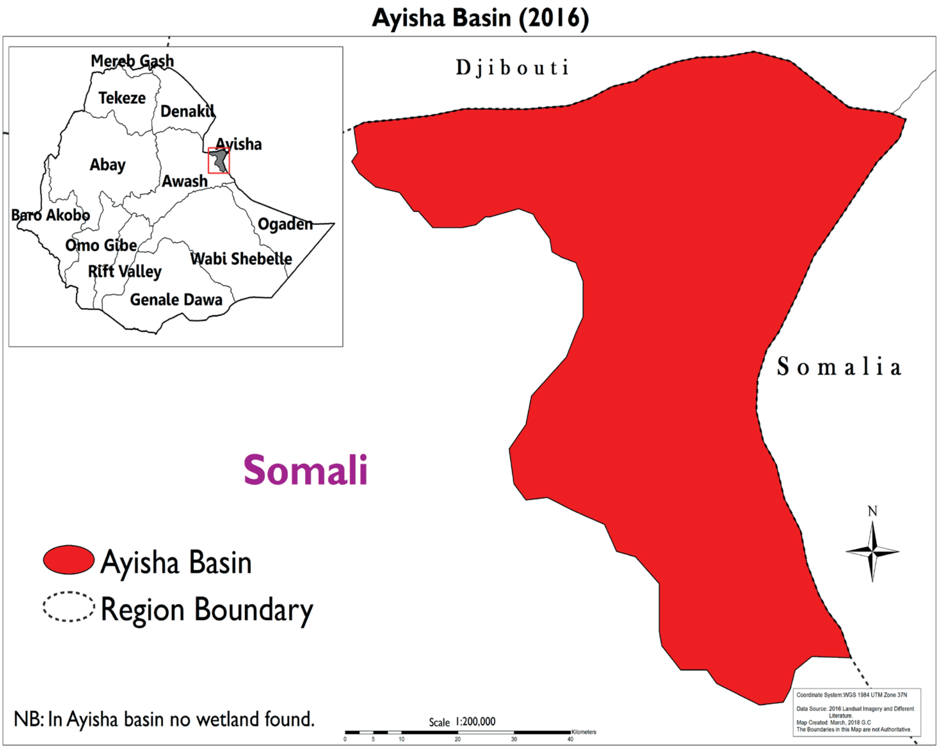


Figure 2. 18: Location of the Aysha basin

2.4. Baro-Akobo Basin – general

The **Baro-Akobo River Basin** covers all of the Gambella Region, while it extends into the Benishangul-Gumuz Region to the south and the *Oromia* Region to the north. The latter region is also part of this basin in the eastern direction (Fig. 2.19).

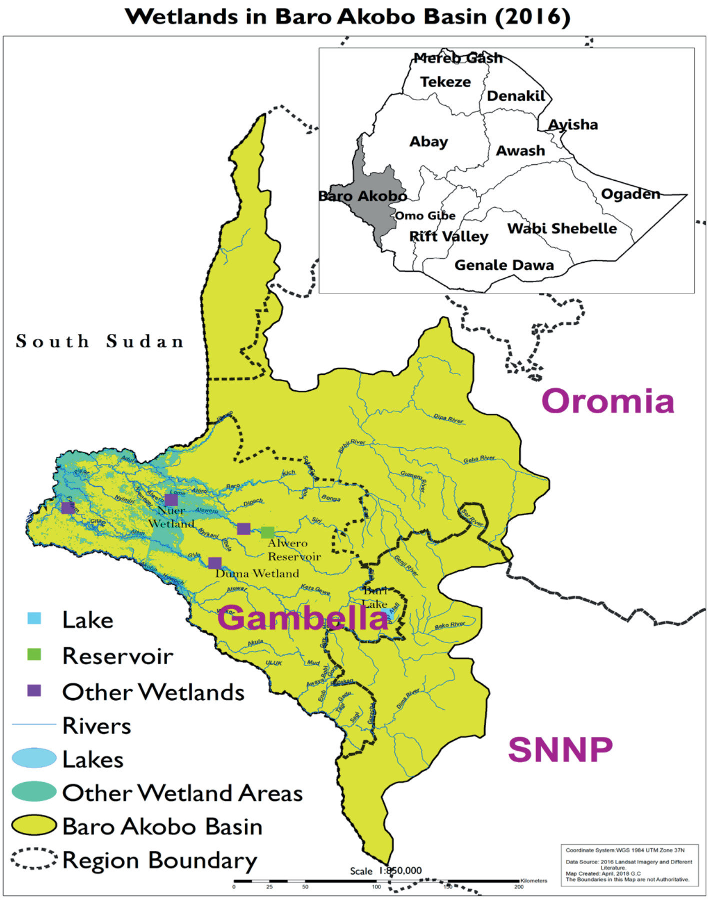


Figure 2. 19: Wetlands in the Baro-Akobo Basin

The Baro-Akobo-Sobat sub-basin covers about 468,216 km^2 [Ethiopia =76,742km^2 and Sudan = 391,474km^2] to the mouth of Jonglei canal, south of Malakal town (Figs. 2.18 and 19). River Sobat tributaries of Baro, Gilo and Akobo rise from the Ethiopian plateau and drains westwards into the Sudan. The basin has an altitude of 2000 masl, just around Jimma to 500 masl at Gambella [Ethiopian site]. It is most probable that the Sudanese site of the basin may read slightly lesser altitude to those at Gambella. Below the Pibor-Baro confluence the Sobat forms a defined channel flowing through grassy floodplain with numerous back swamps, joining the White Nile south of Malakal town. While the upper part of this sub-basin consist of hilly upland areas of Ethiopia and higher hills in Eastern

Equatoria to a flat plain in Jonglei, Upper Nile, White Nile and Khartoum states in the Sudan. The lowlands of the basin exhibit a low and uniform landform made up of poorly drained savannah grass and woodlands which renders it prone to inundation and water logging during the wet season, forming two floodplains of Gambella (9,000km^2) in Ethiopia and the *Machar marshes* (20,000km^2) in the Sudan.

This basin is relatively well watered, characterized by one rainy season that starts around May or June and ends around October. The dry season is long (November/December - April). Effective average rainfall is about 750mm to 1,250 mm per annum in the low lands and the higher lands, respectively. With mean annual temperature ranging from 17.5^{0}C – 27.5^{0}C on the higher lands and the low lands, respectively. Average annual precipitation is as low as 600 mm in the lowlands (less than 500 meters above the sea level), while it reaches as high as 3,000 mm over the highlands (over 2,000 meters above the sea level). Most of the upper 12 basins in Ethiopia have an annual total of more than 1,800 mm while Gore has an average annual total of over 2,200 mm. The rainy period in the basin is from April or May through to October or November when 85% of the annual precipitation occurs with a single peak in July. Usually average rainfall greater than 100 mm occurs from May to October (a six months heavy rainy season). Months with average rainfall greater than 200 mm are June, July, August and September. On average, November, December, January, February and March are dry months. Within Sudan, the highest rainfall is found in the south, southwest and southeast of the basin where the mean annual rainfall exceeds 1,000 mm/yr. Over much of the Pibor-Sobat sub-basin areas rainfall varies between 750 and 1,000 mm/yr. In the White Nile sub-basin, rainfall decreases northwards from 750 to 250 mm/yr to the near confluence of the White Nile and Abay. However, everywhere rainfall exhibits both seasonal and year-to-year variability. Variability increases form south to north within the basin.

The Baro and Akobo Rivers arise from the Ethiopian highlands. The highlands are covered with dense forests although these are rapidly being cleared for small and large-scale agriculture and settlement. The rivers pass through deep zone valleys before they come to the Gambella lowlands, passing through grassy and swamp plains before they reach the Pibor River forming the Sobat River.

The Pibor River joins the Akobo and Baro along the Sudan-Ethiopian border as another sub-basin with characteristically flat plain rising from the highlands in

Eastern Equatoria State 2,750 meters above the sea level. From the Pibor-Baro junction the river becomes the Sobat River, this subbasin rises in the far southeast at the Pibor and Baro rivers confluent. Just before joining the Sobat another sub-basin is formed from Baro flood spillway to Khor Machar, which flows through the *Machar Marshes.* The water from the *Machar Marshes* forms the Khor Adar River, which joins the White Nile north of Melut town in Upper Nile State.

The temperature range in the Baro–Akobo basin is from about 27.5°C below 500 meters elevation on the flood plain to about 17.5°C at 2,500 meters in the highland. Mean monthly maximum temperatures range from below 22°C, in the highlands around Kombolcha (Wollega) to about 40°C, in the lowlands of Gambella around Akobo. Maximum temperatures in the highlands rarely exceed 25°C, whereas in the lowlands they generally exceed 36°C during the hotter months of January to April. Mean maximum temperatures greater than 30°C occur from February to April in the lowlands, with mean minimum ranges of 14 – 15.4°C. While July and August have the mean maximum temperature values less than 25°C in the higher lands, with mean minimum range of 14 – 16^0C during November-February. In the Pibor-Sobat Sub-basin mean annual temperatures range from about 17°C in the southern mountains to 26°C at the Sobat-White Nile junction. In the White Nile valley temperatures are generally 16 - 30°C along the river and decrease with altitude.

The major rivers within the Baro-Akobo basin are Baro and its tributaries of **Birbir, Geba** and **Sor**. The Alwero and Gilo, with their tributaries of **Gecheb, Bitun** and **Beg;** then the Akobo with its tributary as **Kashu**. The general direction of the rivers is from the east, highland of about 2,000 – 3,500 masl, where rainfall is high with steep gradients, to the western lowland plains less than 500 masl, that have relatively low rainfall and moderate to low river gradients, which ultimately join Sobat river.

The peak flows of the major rivers closely match the rainy season, with peak discharge occurring during September. The mean annual runoff of the Baro at Gambella is estimated to be 23.237 km^3.

The Akobo appears to spill across to the Pibor through an extensive area of wetland at its junction with the **Akula River**. Just above Jakawu, there is a bifurcation into the Baro to the north and the Adura to the south, they rejoin below the junction with the Khor Machar into the *Machar Marshes*.

The major rivers in the Baro-Akobo Sub-basin confluence (join) within the Gambela plains. During peak flow period, July to October, the simultaneous peaking of these rivers subjects the Gambela plains to flooding due to overflows of river banks.

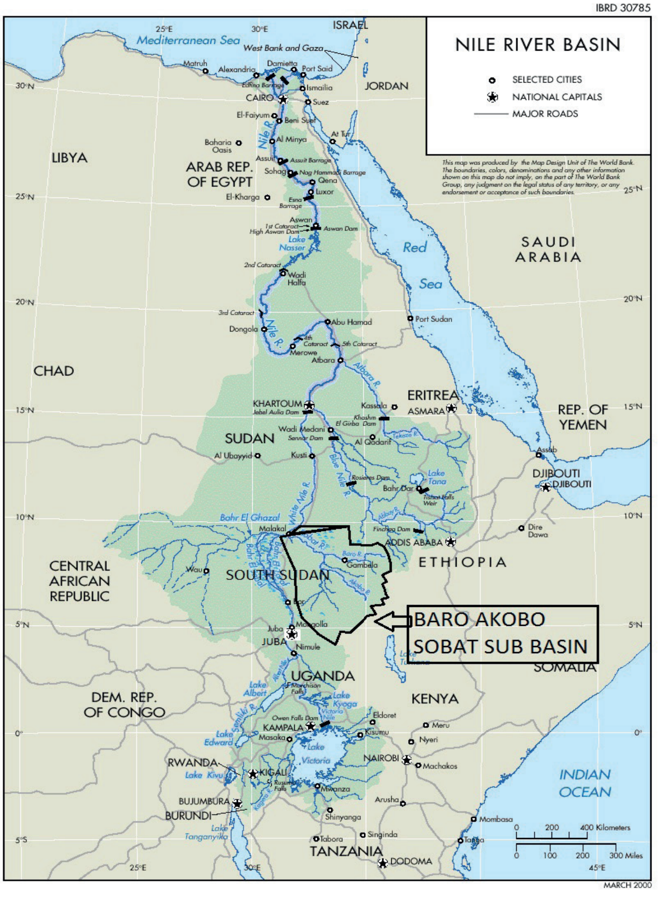


Figure 2. 20: The Baro-Akobo-Sobat sub-basin in Ethiopia (Source: Baro-Akobo-Sobat Multipurpose Studies)

Ecosystem services and ecological status

The Baro-Akobo Basin is an important hydrologic source of water for the Nile. Its contribution flows to the White Nile in southern Sudan and eventually joins with the Abay at Khartoum. The river stabilizes floods and recharges many wetlands (including the Sudd swamps); so its regulatory services are noteworthy (Fig.

2.20). The river is an important source of livelihood for the Gambella peoples in Ethiopia, providing water, fish, vegetation, grazing rangelands, medicine, etc. The cultural ties between the people and the wetlands is tight and lasting, and although the area is now open to large-scale agro-industrial investments, caution has to be exercised to compromise between the natural ecosystem services that the wetlands give and the degree of harm that the investments cause to the environment. Here is where the science of wetland management can play a pivotal role. The Baro-Akobo River and the lush woodlands are important in climate moderation and flow regulation in the south western part of the Nile basin. The ecological status of the Baro-Akobo-Sobat basin can be said to be largely good with no serious degradation currently; however, the situation is changing fast with relentless investment pressure in the GPNRS and this calls for scientific management approaches of the basin's water and fish resources.

2.4.1. Wetlands in the Gambella PNRS

2.4.1.1. Lakes and rivers in the GPNRS

2.4.1.1.1. Lake Tata

Lake Tata is actually a big natural pond formed from overflows of Gillo River as an oxbow lake. It covers about 185 hectares.

Plate 2. 12: Lake Tata Anyawa Zone, Gambella (Photo credit: Abebe Getahun)

Ecosystem services and ecological status

Tata Lake is known for its high fish diversity. Most of the estimated 113 fish species found in Gambella region are believed to inhabit this lake. Its fish potential yield is about 15 tons/ year.

There are only wooden boats and there are about 100 nets operating in Lake Tata for fishing purposes. The main commercial fish species from the lake include "Ulok" (*Heterotis niloticus*), "Urueth" (*Oreochromis niloticus*- Nile tilapia), "Aguyueele" (*Clarias gariepinus*), "Withe" (*Gymnarchus niloticus*), "Gur" (*Lates niloticus*-Nile perch) and Dolo (*Mormyrus* spp.). The market for fish in the woreda is at Pugnido, which is three hours travel from Lake Tatta. Fish produced is used for household consumption as well as for hotels in Pugnido and Gambella.

The growth of water hyacinth, especially in the ponds, is creating problem for boating and also net setting (Plate 2.12).

The lake has provisionary services of potable water, fish, and plants and as watering spots for some endemic migratory wildlife (e.g. Nile Lechwe and White-eared kob).

2.4.1.1.2. Lake Buri (Bishan Waka)

Lake Buri ("Bishan Waka") is located within Mengeshi Woreda of Majang Zone some 30 km from Tepi Town and some 13 km from Meti town (the capital of Godere Woreda) (Plate 2.13). The lake is located at Alt. 1353 m; N 07°17.960 and E035°16.344'. It is located at "Gubete Got". "Buri" in Majang, which, means "Lake". Ashini River crosses the lake on the western side of it.

It is a crater lake with some fishery activities. Fishing from the lake is using hooks and lines and boats are also employed for fishing and the boats were reportedly donated by the Mekane Yesus Church. Some fishermen are reportedly using "birbira" - intoxicating product of an endemic tree *Milletia ferruginea* to catch fishes from the lake.

There is an Orthodox Church (monastery) nearby known as "Korontos Abune Teklehaimanot" Church. The church (monastery) was established in 2013. The lake's watershed is well protected.

Plate 2. 13: Lake Bishan Waka, Mengeshi Woreda, Gambella Region (Photo credit: Abebe Getahun)

Figure 2. 21: Lakes and rivers in Baro-Akobo basin

The list of the major rivers in the GPNRS is indicated in Table 2.13.

Table 2. 13: The large rivers and their catchments in the GPNRS

River	Length (km)	Catchment area (km2)
Baro	285	38400
Akobo	203	21890
Gillo	252	13050
Alwero	321	8098
Pibor	96	4300
Total	**1157**	**85738**

2.4.1.1.3. Baro River

The Baro river is created by the confluence of the Birbir and Geba Rivers, east of Metu in the Illu-Aba-Bora Zone of the Oromia Region. Other notable tributaries of the Baro include the Alwero and Jikawo Rivers. From its source in the Ethiopian highlands it flows west for some 306 kilometers to join the Pibor River. The Baro-Pibor confluence marks the beginning of the Sobat River, a tributary of the White Nile. Baro River has the highest number of natural ponds as compared to other rivers in Gambella Region (at least 25 along the Gambella Zuria woreda alone).

The Baro and its tributaries have a surface area of 38400 km^2 and drain a watershed of 41,400 km^2. The river's mean annual discharge at its mouth is 241 m^3/s. Its mean annual runoff is 9500 km^3/year.

Plate 2. 14: Bati 1 pond in Opgana Kebele, Gambella Zuria Woreda, Gambella Region (Photo credit: Abebe Getahun)

Ecosystem services and ecological status

The Baro River is by far the largest, contributing 83% of the total water flowing into the Sobat River. During the rainy season, between June and October, the Baro River alone contributes about 10% of the Nile's water at Aswan, Egypt. In contrast, these rivers have very low flow during the dry season.

The Baro River and its natural ponds are used for fishery, irrigation and drinking purposes (humans and animals). It is a potential river for boating and recreation, as it moves gently over the plains of Gambella. It is relatively protected water body (Plate 2.15), although the current investment activity is a threat to its watershed. Planned dams and irrigation projects have to take into consideration the impacts of these projects on the quality and quantity of the water body. The Baro River around Gambella Town need special consideration as there is unregulated use and abuse (pollution) observed in and around the river.

Plate 2. 15: Riparian vegetation at the shore of Baro River, Gambella (on the way to Itang) (Photo credit: Abebe Getahun)

2.4.1.1.4. Gillo River

From its source in the Ethiopian Highlands near Mizan Teferi, River Gillo flows to the west, through Lake Tata to join the Pibor River on Ethiopia's border with Sudan. The combined waters then join the Sobat River. The river crosses Anywa and Nuer Zones of Gambella Region and enters into Pibor River around the border (Plate 2.16). There are also several natural ponds associated with the overflow of Gillo River located in Gog and Jor Woredas of the Gambella Region (mainly in the latter). These natural ponds are home to several species of fishes and other aquatic organisms.

Ecosystem services and ecological status

Gillo River together with Alwero River recharges the Duma wetland, which is an extensive wetland around the Gambella National Park, appropriate habitat for large number of wildlife. The river abounds with fish, and as a natural consequence the crocodiles are very numerous and large. It is home to wide array of fish species and the well known and very good food fish (Nile perch - *Lates niloticus*) is also found in this river (Plate 2.17).The main fishes caught are from the natural ponds (mainly) and Gillo River and the major species include "Aguyueele" (*Clarias gariepinus*), "Oluak" (*Heterotis niloticus*), "Gur" ("*Lates niloticus*"--Nile perch), "Withe" (*Gymnarchus niloticus*) and "Udela" (*Polypterus bichir*). The fishes are used for household consumption and also for marketing. The market places are at Puchala and Pugnido Towns. The fishes are transported from Gillo to Puchala by boat and then to Pugnido by road transport. Over flooding of Gillo River is a major problem occurring every year during the rainy season.

Plate 2. 16: Gillo River in Nuer Zone, Gambella (Photo credit: Abebe Getahun)

Plate 2. 17: Nile perch from Gillo River, Gambella (Photo credit: Abebe Getahun)

2.4.1.1.5. Alwero River

Alwero River flows through the Gambela National Park and through wetlands into the Baro River. The Alwero River is about 252 km in length and its catchment area is about 13050 km^2. The Alwero Reservoir is formed as a result of damming the Alwero River near Abobo Town (Abobo Woreda) and covers about 2210 hectares of land (74 km^2). Alwero River is a very gently moving river with depths of 2-3 meters as observed around Pokadi Village (which is about 36 km from Abobo Town) where the river enters into the Duma wetlands (Plate 2.18). The Duma wetlands are formed by overflowing of the Gillo and Alwero Rivers. There are about 6 natural ponds associated with Alwero River before the river forms the reservoir.

Plate 2. 18: Alwero River at the edge of Duma wetland (recharging Duma wetland)
(Photo credit: Abebe Getahun)

Plate 2. 19: Alwero Reservoir near Abobo Town, Gambella
(Photo credit: Abebe Getahun)

Plate 2. 20: Alwero Dam and the Canal for irrigation near Abobo Town, Gambella
(Photo credit: Abebe Getahun)

Ecosystem services and ecological status

The Alwero Reservoir alone has a potential fish yield of 394 tons/year but the current estimated production is only 79 tons/year. It is also known for its rich fish diversity and is home to more than 25 fish species. The Alwero Dam and Reservoir are, presumably, the most appropriate sites for fish production in the region (Plate 2.21). The commercially important fishes include "Orueth" (*Orochromis niloticus*), "Aguyueele" (*Clarias gariepinus*), "Oluak" (*Heterotis niloticus*), "Withe" (*Gymnarchus niloticus*) and "Dolo" (*Mormyrus* spp.). Water from the Alwero Dam is planned to be channeled to extensive agricultural fields (especially rice fields) for irrigation; may be a threat to the river and the reservoir if not properly regulated. The reservoir is believed to have a capacity to irrigate more than 10,000 ha and efforts are underway to make use of the water for irrigation purposes. Although their extent is currently unknown, the canals constructed for the irrigation projects (Plate 2.20) may be appropriate sites for culturing fishes. The watershed around the reservoir is relatively well maintained keeping the water blue, although there is an increasing trend of settlement around the reservoir and farm lands are pushing towards the shores of the reservoir.

Plate 2. 21: Fish market at the outskirt of Abobo Town (Piles of Nile tilapia-Oreochromis niloticus mainly from Alwero Reservoir) (Photo credit: Abebe Getahun)

2.4.1.1.6. Akobo River

The **Akobo River** (Plate 2.22) is a river on the border between South Sudan and Ethiopia. From its source in the Ethiopian Highlands near Mizan Teferi it flows west for 434 kilometers to join the Pibor River. The Pibor flows into the Sobat River, which in turn empties into the White Nile. It traverses Dimma Woreda of the Anywa Zone (passes close to the town of Dimma)

The tributaries of the Akobo River include the **Cechi**, the **Chiarini**, and the **Owag,** on the right or Ethiopian side; and the Neubari, Ajuba and Kaia on the left or South Sudanese side.

Plate 2. 22: Akobo River near Dimma Town, Anywa Zone, Gambella region (Photo credit: Abebe Getahun)

Ecosystem services and ecological status

There are tributaries of Akobo River which are used for gold mining including **Gedo, Erbo, Kari, Gashena, Gendibab, Twatwa, Joru, Chamo, Namkedo, Dembela and Gedu.** Most of the water bodies mentioned here are small streams, intermittent and not mapped earlier.

Fishermen along the Akobo River use hooks and lines as well as nets for catching fishes. The major fish species caught are "in Agnwaa", "Wit" (*Gymnarchus niloticus*), "Dollo" (*Mormyrus* spp.), "Ogere" (*Distichodus* sp., "Aguyueele" (*Clarias gariepinus*), "Urueth" (*Oreochromis niloticus*- Nile tilapia), "Weri" (*Hydrocynus forskhalii*), and "Odura" (*Bagrus docmak*). The fishes are used for household consumptions.

2.4.1.1.7. Pibor River

The Pibor River is formed by various streams that come together at Pibor Post, a colonial era outpost built in 1912 and originally called *Fort Bruce*. The Pibor flows north, receiving the Akobo River near Akobo. Continuing north the Pibor receives the Gillo River and Bela Rivers on the right, then joins the Baro River, forming the Sobat River. Much of Pibor is found outside of the territory of Ethiopia and little is known about its physico-chemical and biological features.

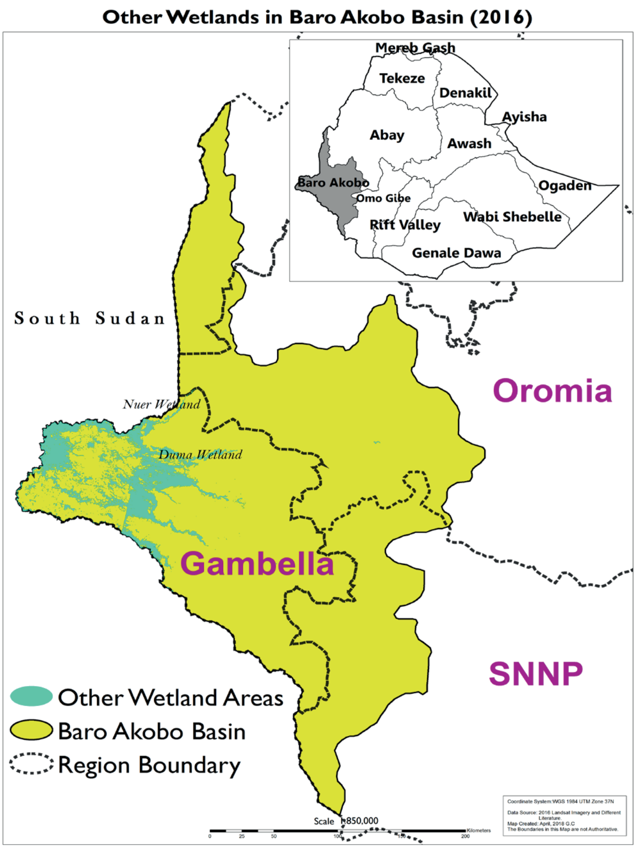


Figure 2. 22: Other wetlands in the Gambella Region

2.4.1.2. Other wetlands in Gambella region

Other large wetlands in the Baro-Akobo basin are shown in Fig. 2.22 and the major ones are located in the Gambella Region. Seasonal wetlands abound in the Gambella region, where almost half of the region is inundated by flooding from the highlands of Oromia and SNNP by the Baro, Akobo, Gillo, Alwero and several other rivers. These seasonal wetlands sustain rich biodiversity and during the dry season give way to lush growth of elephant grass.

The permanent Duma wetland is one of the largest marshes in the country and serves as watering site for wildlife, habitat for many species of birds, amphibians, reptiles and invertebrates. The wetland has not been studied well.

2.4.1.2.1. Gambella wetlands in general

The GPNRS is endowed with rich hydrographic network consisting of rivers, lakes, natural ponds and a reservoir. There are five major rivers in the region covering a total length of 1157 km and a catchment area of 85738 km^2. The swampy areas in the region are also considerable and some of the Woredas such as Jor, Itang and Jikawo are highly affected by flood. According to data on Land use land cover of the region, the total area covered with water bodies is about 101 km^2 while the seasonal wetlands cover about 1464 km^2, although the distinction between the two is not clearly delineated. There are also about **134 natural ponds**, most of which are located in Anywa Zone.

During the rainy season, the rivers in Gambella swell beyond the infiltration capacity of the soils and overlie across the extensive landscape forming swamps and marshes that are 2 m deep in water. The swamps cover considerable proportion of the woreda both during the rainy and other months and overall about 8% of the Gambella land is covered with swamps and marshes (Table 2.14)

Table 2. 14: Swampy areas in relation to the total area in Gambella Region

Woreda	Total Area (ha)	Swamp Area (ha)	Proportion of swamp in each Woreda	Proportion of swamp in the region (%)
Gambella	294000	10112	3.4	0.3
Itang	178448	55032	30.8	1.7
Akobo	366116	16696	4.6	0.5
Jikawo	235696	58516	24.8	1.8
Abobo	329720	20876	6.3	0.7
Gog	701752	16932	2.4	0.5
Jor	254880	67236	26.4	2.1
Godere	192588	-	0.0	0.0
Dima	650080	2156	0.3	0.1
Region	3203280	247556	7.7	7.7

Besides swamps and marshes, the Gambella Region is also richly endowed with natural ponds (Table 2.15). Some of these ponds are formed during retreat of the wetlands during the dry season (finger ponds) and are potentially good ponds for fish production. Other natural small ponds are found dotting the Gambella landscape and are especially abundant in the Anywa zone Jor and Gog woredas).

Table 2. 15: Natural ponds in Gambella zones and woredas

Zone	Woreda	Number of natural ponds
Anywa	Abobo	6
	Gog	27
	Jor	36
	Gambella	25
	Dimma	0
Itang Special Woreda	Cluster I	18
	Cluster 2	15
Nuer	Lare	7
		134

2.4.1.2.1.1. Anywa wetlands

Anywa Zone is relatively rich in water bodies and all the major rivers (Akobo, Gillo, Alwero and Baro) traverse the zone. The **Alwero Dam and Reservoir** are within the Abobo Woreda and they are, presumably, the most appropriate sites for fish production in the region. The Alwero Reservoir has an area of about 74 km^2 and the fish production potential has been estimated to be 394 tons per year with current estimated production of 79 tons/year. Tata Lake and the Duma wetlands are located within this zone; Tata Lake is known for its high diversity of fishes.

The Duma wetland is believed to be a crucial habitat for some aquatic and terrestrial wildlife including fishes. This crucial ecosystem which is located at the core of the Gambella National Park (GNP) was threatened because it was, reportedly, originally delivered to Karuturi Company for development and that the company was planning to drain it. Ethiopian Wildlife Conservation Authority (EWCA) was subsequently forced to deal with the Bureau of the Regional Government Land Administration with the result that concession boundaries were extended away from the park in order to save the swamp.

Out of a total of more than **134 natural ponds** reportedly found in Gambella region, 94 (70%) of them are found in Anywa Zone (36 in Jor; 27 in Gog; 25 in Gambella; and 6 in Abobo). The estimated number of households depending on fisheries in the region is estimated to be about 32400, of which, 9000 are Anywas.

Ecosystem services and ecological status

The Alwero dam provides stored water for irrigation and has ample fish resources. The proposed rice fields of Saudi Star Enterprise also depend on water from the reservoir. The hydrological balance of the Alwero dam will be critically affected by this water withdrawal, unless replenishment schemes are put in place. Sedimentation is a serious ecological challenge and the Baro, Akobo and Gillo Rivers are heavily silted. Restoration efforts focusing on catchment forestation and water use regulations should be undertaken. The rich forest resources on which the hydrological balance depends are rapidly disappearing due to agro-industrial operations by investors. There is urgent need to curb deforestation in the GPNRS in general.

2.4.1.2.1.2. Nuer wetlands

The water bodies in Nuer zone include Baro (Kir), Jikawo, Mekoi, Akobo and Pibor Rivers. Nuer Zone (Lare Woreda) is also endowed with 7 natural ponds (other woredas are not fully explored for their natural ponds, but expected to have more). The fish production mainly comes from these water bodies and include the commercially most important fishes *Clarias gariepinu*s, *Oreochromis niloticus, Citharinus lates, Heterotis niloticus, Gymnarchus niloticus*, *Lates niloticus*, and *Polypterus* species. Some of the fishing gears used by the local community for fishing include: "Bith, Deepe", Horpoon ("Roch or Arhoch"), "Ghor", Keek with "Mirmir and Dur" or Dipaw".

Ecosystem services and ecological status

The Nuer pans and ponds provide water, fish and plants to the Nuer people. During the dry season, the wetlands are used as range lands and the migrating wildlife also use the same grazing grounds and water points. Overall, the ecological status of most wetlands can be said to be good to excellent, and may require intervention in water allocation and water management.

2.4.1.2.1.3. Majang wetlands

Majang Zone has one lake (Lake Buri or Bishan Waka) and several streams, many of which ultimately join and form Gillo River that flows to Gambella Plains. As the altitude of the zone is relatively higher, it serves as the water tower of the entire region. The hydrographic network and the number of streams in the two woredas are surprisingly high. For example, in Godere Woreda alone there are about **ten main rivers** and in Mengeshi Woreda, the number is even higher than that.

Ecosystem services and ecological status

Besides the provisioning service of water and fish, the Majang wetlands also have regulatory and supportive functions. They modify climate and hydrological balance, but unfortunately, due to forest clearance for coffee plantations, some of the ecosystem services are becoming compromised and there is need for ecological intervention. The ecological condition of the Majang wetlands appear to be excellent at present, but increasing encroachment in Lake Bishan Waka and the small springs should be given attention.

2.4.1.2.1.4. Itang wetlands

The major water bodies include Baro (Openo/Kir), **Jikao, Gnigol, Loma, Berger** and **Akula** Rivers. The first four are permanent while the last two are intermittent rivers. The special woreda is also endowed with **33 natural ponds** (constituting 24.6% of the total natural ponds in Gambella Region), which are rich sources of fish production.

The Gillo, Baro and Akobo Rivers start to overflow in June due to continuous heavy rains in the central highlands. Areas along those rivers, particularly Jikawo Wereda along the Baro, were affected by floods to various degrees at various times.

Hydrology research continued to establish the impact of the damming of the Alwero River on the Duma Wetlands. Water from the river and the wetlands is currently being diverted for use in commercial agriculture operations upstream from the park. The **Duma Wetlands** is home to the only Nile Lechwe population outside the Sud Swamps in South Sudan and deserves urgent conservation status.

2.4.2. Wetlands in the ONRS

2.4.2.1. Lakes and rivers in the ONRS

2.4.2.1.1. Ilubabor (Ilu Aba Bora) valley bottom wetlands

The major wetlands in the Illu Aba Bora zone include the following:

- Wichi wetland
- Chebere wetland
- Wangenye wetland

- Kowna Chatu wetland
- Bake Chora wetland
- Dizi wetland
- Supe wetland
- Hurumu wetland
- Tulube wetland

Biophysical characteristics

Ilu Aba Bora covers 226.7 km^2 of which 1.4% is covered by swamps and marshy wetlands and if floodplains and seasonally flooded grassland are included, the total wetland area of Ilu Aba Bora is estimated to cover 4 - 5% of the zone (Afework Hailu, 1998).

The dominant wetland soils of central Ilu Aba Bora were identified as umbricgleysols, gleyicluvisols and gleyicalisols (Afework Hailu, 2003). These soils had formed on alluvial sediments that were derived from basaltic rocks on the adjacent slopes.

It has been indicated that a total of 92 species of birds were recorded from wetlands of Ilu Aba Bora and of the 48 afroalpine birds known from Ethiopia 17 (35.4%) species including three endemic and near endemic species were recorded from these wetlands (Tadesse Wolde Mariam, 1999).

Seventy-two species of vascular plants, belonging to twenty-eight families, were registered in the core wetlands in Ilu Aba Bora region; of these twenty-seven were wetland-dependent; fifty-one wetland-associated; seven non-wetland dependent species (Zerihun Woldu and Kumelachew Yeshitela, 1999). Based on the frequent occurrence and abundance of *Cyperus latifolia* and *Aeschynomene abyssinica* in most intact wetlands, the authors suggested that the pristine vegetation type of Ilu Aba Bora's wetlands may have been dominated by these species. The list of wetland-dependent, non-wetland and wetland-associated plant species is provided in Table 2.16.

Table 2. 16: Wetland-dependent, non-wetland and wetland-associated plant species in Ilu Aba Bora.(Note: G = grass; H = herb; S = shrub; F = fern (Source: Zerihun Woldu and Kumlachew Yeshitela, 2003)

Aeschynomene schimperi	S
Cyperus elegantulus	H
Cyperus flavescens	H
Cyperus latifolius	H
Cyperus mundtii	H
Cyperus platycaulis	H
Echinochloa ugandensis	G
Eragrostis botryodes	G
Fimbristylis dichotoma	H
Floscopa glomerata	H
Fuirena stricta	H
Hydrocotyle sibthorpioides	H
Impatiens ethiopica	H
Jussiaea abyssinica	H
Leersia hexandra	G
Oldenlania goreensis	H
Oldenlandia lancifolia	H
Ottelia ulvifolia	H
Panicum hymeniochilum	G
Panicum subalbidum	G
Persicaria glabra	H
Phyllanthus boehmii	H
Sacciolepis africana	G
Schenoplectus corymbosus	H
Sesbania dummeri	S
Smithia elliotii	H
Thelypteris confluens	F

Ecological status

The findings of a study done to assess the ecological condition of some of the wetlands in the Ilu Aba Bora wetlands are summarized in Table 2.17.

Table 2. 17: Status of the wetlands of Ilu Aba Bora (Source: Afework Hailu, 2003)

Wetland	Category	Description
Chebere	Pristine (little human interference)	No drainage or crop cultivation on site, natural vegetation, reed harvesting available
Wangenye and Kowna Chatu	Partially cultivated	Some areas undergoing drainage and cultivation, natural vegetation present.
Bake Chora, Dizi and Supe	Fully cultivated	Whole wetland drained and cultivated
Hurumu	Degraded	Previously cultivated and drained but now mostly abandoned. Characteristic grassland with occasional natural vegetation
Tulube	Rehabilitated	Previously cultivated and drained but exhibiting original natural vegetation

Ecosystem services and ecological status

The fertile valley bottom wetlands have been drained for recession agriculture for a long time and some of their wetland features have been degraded and lost. They still have huge provisioning and supportive services in the livelihoods of people and as habitat for birds, fish and mammals. The regulatory services of the wetlands have been compromised and it appears that some intervention is required to restore hydrological stability and conservation of biota.

2.4.2.2.2. Wichi wetland

Wichi wetland is one of the main wetlands and extensively studied in Ilu Aba Bora zone. Wichi wetland is located in Metu Woreda and occupies an approximately 8149 hectares of land and about 13,086 people live around this wetland. The climate around the wetland is tropical and dry. The landscape crosses five Kebeles (Ale Buya, Burusa, Tulube, Boto, and Adele Bise) (Ethio Wetlands and Natural Resources Association, 2009). According to Afework Hailu (2009), coffee, honey, livestock and maize are major livelihood sources around the wetlands and successful integrated watershed/landscape management in the Wichi landscape has been undertaken in order to protect the wetland ecosystem from overgrazing, depletion of water, and loss of biodiversity.

According to Afework Hailu (2009), the success story regarding Wichi wetland was mainly the introduction of Vetiver grass (a multi-purpose grass) for soil and water conservation. Between 2005 and 2007, 820 kilometers of Fanyajuu, 70.80 kms of soil bund, 4.65 kilometers of waterway, and 25.5 kilometers of cut-off drain were constructed within Wichi Micro Watershed over 1018 hectares, which is believed to have improved the wetland (Afework Hailu, 2009).

Ecosystem services and ecological status

The Wichi wetland is a good example of local intervention to manage and conserve wetlands using new approaches for water and soil conservation. The successful rehabilitation efforts of the wetlands using Vetiver grass should be continued and emulated as a lesson for other parts of Ethiopia, especially, Northern Ethiopia.

2.4.3. Wetlands in the SNNPRS

2.4.3.1. Other wetlands in the SNNPRS

2.4.3.1.1. Sheka zone wetlands

The Sheka Zone is located between 7°24′–7°52′ N latitude and 35°13′–35°35′ E longitude. The major lakes and reservoirs include **Gawach Lake** at Andracha Kebele and the major river is **Beko River.**

Biophysical characteristics

The Sheka zone wetlands and other water bodies include permanently or seasonally waterlogged areas, primarily covered with tall grasses, lakes, and riverine habitats. In Sheka Zone traditional beliefs protect forests on river banks and wetlands. Ecologically fragile areas like wetlands, lakes, rivers and steep slope areas are culturally protected from human disturbance. There is a belief that if a person cuts riparian trees, he may die since he is against the rule of the guardian spirit for which sacrament is provided by clan leaders in wetland and waterfall points. They believe that rivers need covers ("acheiedo") as people require cloth. They believe that wetlands are sources of rivers and forests keep wetlands from drying. Other works (e.g. Yilma Delelegn and Gheheb, 2003) also confirm that wetlands are important contributors to ground water and hence to the maintenance of water supply in Sheka Zone.

Ecosystem services and ecological status

The Sheka wetlands provide grasses for roof thatching of traditional houses and animal fodder for grazing cattle and pack animals during dry seasons. In some areas, where the buffer areas are degraded, bamboos are planted to serve both the protection and production function. They are also sources of water and springs. Most rivers and streams in the area originate from wetlands. Wetlands are habitats for different wild animals, including birds, like the endemic Rouget's Rail (Federal Democratic Republic of Ethiopia – Sheka Forest Biosphere Reserve Nomination Form- 2011). Rivers and lakes also provide water for humans as well as animals. They also serve as habitats for other organisms. Wetlands and water bodies play an important role in regulation of hydrological cycle.

There are over 300 higher plants, 50 mammals, 200 birds, and 20 amphibian species, occurring in all habitat types within the Kafka Biosphere Reserve. There are at least 55 endemic plant and 10 endemic bird species. There are also over 38 threatened species (included in IUCN Red list) in the area, which include 5 bird, 3 mammal and 30 plant species.

The Sheka wetlands have high cultural values for the local communities, as the peoples' livelihoods are intimately linked with the natural resources in the area. The human and livestock pressure is at present low and the ecological status of the basin is good. It has been registered as a Biosphere Reserve by UNESCO and its current status should continue to be protected

2.5. Danakil basin – general

Danakil river basin has an area of 74,002 km^2, which covers parts of Tigray, Amhara and Afar regional states (Fig. 2.23). The basin has no major river draining out of it. The basin has a lowest elevation of -197 m, below sea level at the Danakil depression, the lowest altitude of the country, and a highest elevation of 3,962 m. The total mean annual flow from the river basins is estimated to be 0.86 BMC.

Three tectonic plates contact in the Danakil basin: Nubian, Arabic and Somali. The central meeting place for these three plates is around Lake Abbe (Fig. 2.38). The Afar Triangle is characterized by strong seismic activity and a quarter of all active African volcanoes are found here. The three plates constantly move away from one another at a speed of about 12–13 mm per year (Waltham, 2010).

From the North to the South, the Danakil basin is about 570 km long, and its width varies from 80 to 400 km, which covers an area of about 200,000 km^2. Most of it lies below sea level. It also has the deepest depression of the African continent, the shoreline of Lake Asal reaching 155 masl (Waltham, 2010).

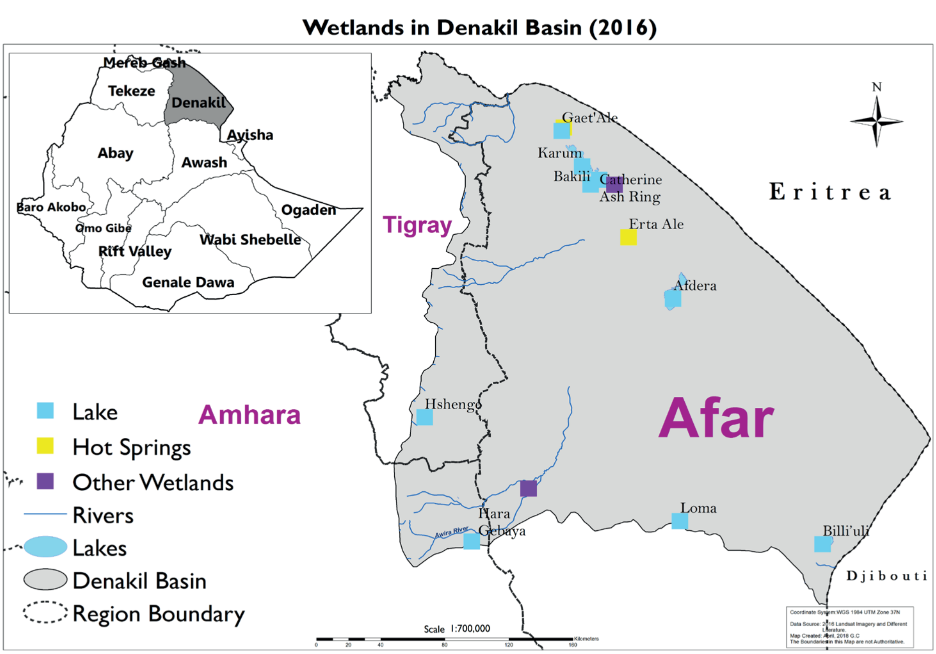


Figure 2. 23: The Danakil basin and boundaries

The Afar wetlands are located in the Sahelian - Transitional Zone Biome which is found in the extreme north-eastern part of Ethiopia (Fig. 2.24). This area where the Dallol depression is located is the hottest and driest part of the country and with the lowest point of 116m below sea level, (EWHNS, 1996). It is a semi-desert steppe where the evapo-transpiration in much of the area exceeds the mean annual precipitation by over ten times (Messele Fiseha, 2003).

Figure 2. 24: The Afar basin showing some lakes and active Ertale volcano

Biophysical characteristics

The climatic condition of the Danakil Depression is characterized with hot, desert climate. There are two main seasons here: cool (from October to April) with high humidity and hot (from May to August). The cool season is characterized with average temperatures of higher than 25 ˚C. The heat is even worse during the hot season of May to August. In May, June, August, and October wind blows from the North-East. In summer very impetuous, dry, hot carrying dust winds called *Gara* (The Fiery Wind) are common. They intensify the feeling of heat, which is heavy because of lack of shade, high humidity (40% in summer, about 90% in winter) and high temperatures. The average annual temperature is between 34 and 35 °C but it can rise to even 50 °C (Briggs, 2010). The rainfall distribution pattern is unimodal with little or unreliable rainfall and is mostly between November and February (EWNHS, 1996). Rainfall is very variable and irregular, erratically changing in different years. For example, in 1996, the sum of precipitation was only 23 mm and in 1993 it was 773 mm. Most of the rain falls in very short time creating torrential flash floods (Harris, 2008).

Water chemistry

As indicated in Table 2.18, the water chemistry of the Afar lakes is characterized by high salinity and high conductivity, with Na^+ and Cl^- making the major ions. Nutrients are relatively low in the lakes, and the high productivity of benthic invertebrates such as chironomids and brine flies is due to abundant detrital food sources (Seyoum Mengistou, 2006; 2016).

Table 2. 18: Water chemistry of the Afar lakes (After Seyoum Mengistou, 2006)

Lake	Salinity (g/l)	Cond. (µS/cm)	pH	∑ Cations (meq/l)	∑ Anions (meq/l)	SiO_2	PO_4 (µg/l)	Chl a (µg/l)
Afdera	158	250 000	6.55	2846	2676	74		
Abhe *	160	-	10.3	2562	2562	416	-	-
Assal	276.5			4793	4793	2	131	54
Gamari*	0.70	130	8.0	9.19	8.48	35	-	-

*Note that these lakes are in other basins.

Danakil Lakes and rivers

The lakes and rivers in the Danakil basin are not numerous (Fig. 2.25) and emanate from the Tigray and Amhara Regions.

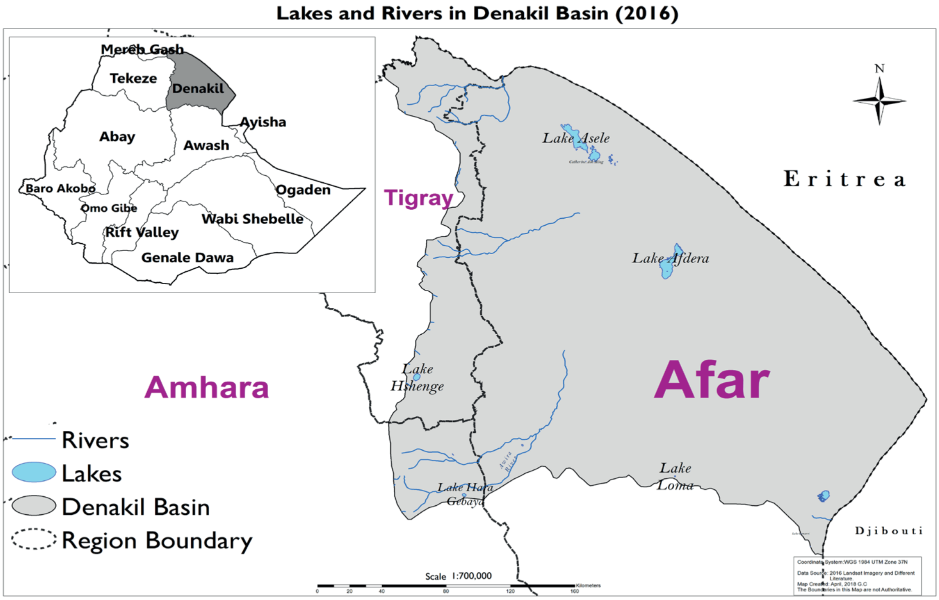


Figure 2. 25: Lakes and rivers in the Danakil basin

Lake Hashenge

Lake Hashenge is located at coordinates 12°35′N 39°30′E in the Tigray NRS at an altitude of 2,400–3,000 masl.

Biophysical characteristics

Lake Hashenge and its surrounding area occupy an old volcanic crater between the Ambalagie range to the north and the Alamata mountains to the south. The altitude at the lake is 2,400 m while the mountains to the north rise to over 3,000 m. The lake is fed by a number of small streams from the surrounding areas, and as far as is known there is no drainage out of it. The crater rim forms steep cliffs all around, except in the north-east where there is a long valley. Korem is situated in a long valley to the south. The area surrounding the lake is relatively flat, producing extensive areas of shoreline, and large areas of marshland extend into the valley to the north-east. The lake has a surface area around 14,000 ha, a mean depth of c.14 m and a maximum depth of 25.5 m. The water is slightly saline. Villages are situated on the flatter land at the foot of the cliffs, but all of the surrounding land is used for agriculture. The valley in the north-east is an important grazing area, particularly through the dry season. Land is divided between villages and access to the grazing area is carefully managed. The flora of this area has never been documented. Some trees are found in the area, often confined to domestic gardens, including *Acacia* shrubs, *Croton macrostachyus*, *Vernonia amygdalina* and *Buddleja polystachya*. Additionally, some forest trees are found around churches and in Muslim graveyards: species include *Acacia abyssinica*, *A. pilispina*, *Ekbergia capensis*, *Juniperus procera* and *Olea europaea cuspidata*. Mixed agriculture dominates the area, with cereals and pulses the main crops, and cattle and sheep the main domestic animals. Fish were introduced into the lake, but for unknown reasons, the harvest has not been sustainable. The main fish species in the lake are *Oreochromis niloticus* and *Clarias gariepinus*.

Plate 2. 23: Catchment features of Lake Hashenge

Ecosystem services and ecological status

Lake Hashenge provides water, fish, and dry season grazing to the surrounding communities. The catchment is highly degraded (Plate 2.23) because it has been farmed for centuries supporting large human and livestock populations. The more serious ecological pressures come from overfishing, shoreline farming and sediment deposition into the lake. Restoration efforts should focus on actions that will arrest catchment degradation such as SWC and management actions on overfishing and water use.

2.6. Genale -Dawa Basin - general

Description of the Genale-Dawa Basin

Biophysical characteristics

Like the Wabe Shebelle, the Genale/Juba River Basin originates from the Ethiopian Highlands, where three large tributaries, the Genale, the Dawa and the Weyb (Gestro), meet near the border with Somalia to form what is known as the Juba River inside Somalia. The Dawa River forms part of Ethio-Kenya border and, along its final reaches it also marks the Ethio-Somalia border. The Juba has a basin area of 452,000 km^2 and enters the Indian Ocean at Kismayo Town in southern Somalia. It has a total length of 1808 km, of which 840 km lies in Ethiopia and 1004 km in Somalia.

Rainfall at the source reaches 1600 mm/y, dramatically decreasing southwards, where the mean reduces to 200 mm/y in the areas near the border. The average annual rainfall of the entire basin is about 500 mm. The mean annual runoff of the river in Ethiopia is 6600 Mm^3 and 6200 Mm^3 in Somalia., Ethiopia contributing over 95%.

The fish fauna of Genale River is reportedly diverse; although it has not been systematically studied. It is, however, known that it consists of Nilo-Sudanic, East African and Endemic forms of fishes (Abebe Getahun and Stiassny, 1998). Some authors indicate that the fish diversity is so high that it is even difficult to take a bath in the river.

A number of east African fish species occur in this system such as the characid *Alestes affinis*, the cyprinid *Neobola bottegi*, the schilbeid *Irvineia orientalis*, the loach catfish *Amphilius lampei* and the cichlid *Oreochromis spilurus*. It is the only region of Ethiopia where a diadromous fish, the eel *Anguila* sp. occurs.

Formally, the list of fish endemic to this river system within the limits of Ethiopia includes only three species: *Varicorhinus jubae, Amphilius lampei* and *Chiloglanis modjensis.* According to a preliminary data compiled by the Joint Ethio-Russian Biological Expedition, about 40 species are reported from the system as a whole; 28-30 of them occur in Ethiopia. The negative correlation of the species diversity with the altitude is quite pronounced in this system.

The following families, genera and species are reportedly found on the Ethiopian limits of the above drainage basin (Golubtsov and Mina, 2003)**.**

Family	Common name	Genera	Species
Anguillidae	Eel	1	1
Mormyridae	Elephant fish	2	2
Characidae	Characin	1	1
Cyprinidae	Carps	5	14
Bagridae	Bagrid catfishes	3	3
Schilbeidae	Schilbeid catfishes	1	1
Amphiliidae	Loach catfishes	1	1
Clariidae	Air breathing catfish	1	1
Mochokidae	Squeakers	2	5
Cichlidae	Cichlids	1	1
Gobidae	Goby	1	1

The Wabe Shebele and Genale Basins are interconnected, at least at their lower ends towards the Indian Ocean, especially during high flows (Fig.2.26).

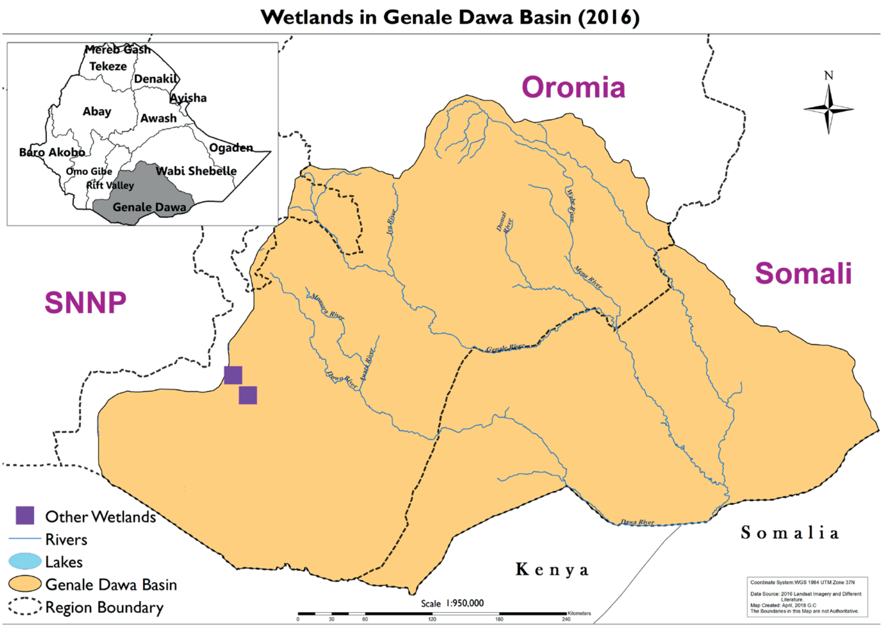


Figure 2. 26: Wetlands in Genale Dawa Basin

2.6.1. Wetlands in the ONRS

2.6.1.1. Lakes and rivers in the ONRS

2.6.1.1.1. Genale River

The Genale River is located in the Oromia NRS at coordinates 05°44′N 39°32′E within an altitudinal variation of 800–1,500 masl.

Biophysical characteristics

This site comprises the middle section of the Genale River which forms the border between Bale and Borena Zones, and lies to the east of the Borena Zonal capital, Negele. The Genale River forms a major part of the Genale–Dawa–Weyb basin, the third-largest in the country in terms of land area, draining 168,000 km² of southern Ethiopia. The river rises in the Sidamo highlands, flowing south-east to Dolo on the Somalia border. The major tributaries are the **Welmel, Dumal** and **Web**, all originating in the Bale Mountains. Little is known about the vegetation in this area. Open woodland dominated by various *Acacia* spp. prevails in the middle Genale basin, and riparian vegetation occupies a narrow strip along the river. The largest trees are *Ficus sycamorus*, *Mimusops kummel* and *Tamarindus indica*. There are probably also reedbeds and other aquatic plants in the riverbed. The gently sloping valley floor is used for rain-fed and irrigated crop production, and many domestic animals graze in the valley.

Ecosystem services and ecological status

The Genale River is an important hydrological feature of SW Ethiopia and drains an arid area which sustains high biodiversity and supports different livelihoods of people, livestock, wildlife and plants. It is relatively pristine and of low priority for restoration.

2.6.1.1.2. Dawa River

The **Dawa River** is a perennial river in southeastern Ethiopia. Rising in the mountains east of Aleta Wendo, the Dawa flows south and east to join with the Genale Dorya at the border with Somalia to become the Juba. The river forms part of the Ethiopia–Somalia border and part of the Ethiopia–Kenya border.

The river valley is relatively wide, with gently sloping sides of exposed bedrock. The lower part flows through a valley which would be classed as a relatively young erosion cycle. Prospectors have found gold along the Dawa between the Awata and Kojowa tributaries.

2.6.2.2. Other wetlands in the ONRS

2.6.2.2.1. Bule Hora wetlands

Biophysical characteristics

Bule Hora Woreda in Guji Zone of Oromia Region has a drainage system characterized by perennial and seasonal rivers. The perennial rivers include **Afalata,** which flows along the border of Dugda Dawa District and **Galana** River that drains from the Galana Metari Kebele.

Among the many wetlands found in the Bule Hora Woreda, three wetland areas are prominent and accessible; namely **Rophi Megada, Galessa Negesso**, and **Hera Liphitu**.

The Borena zone has long history of traditional institution called "the Gada System" which is well structured and organized to solve conflicts and environmental problems particularly conservation of natural resources. This tradition enforces the local communities not to degrade the different natural resources through giving counseling services. The leader of the "Gada System" gathers the local communities from time to time and proposes resource management strategies. They also punish individuals who clear trees from communal lands. It appears that the management practices that they undertake for forests are indirectly assisting management of the wetlands, although no direct concern exists for the latter.

There is also fencing of wetlands by individuals practiced in these wetlands and this is done in order to protect the wetlands from human and animal feet which may cause compaction. It is also done for the purposes of wetland products which can be harvested for sale (grass, reeds, and *Cyperus latifolius*) and construction of traditional houses for residential purposes in rural areas. Wetlands are also fenced for the purpose of seedlings of coffee and some other vegetation. However, there are different management practices of wetlands by taking into account whether these resources are either communally owned or privately owned. That means property ownership plays paramount roles in effective resource management. Most wetlands of this Woreda are communally owned and used as communal grazing lands.

Ecosystem services and ecological status

The Bule Hora swamps and marshes are habitat for different bird, fish and plant species. The wetlands also provide livelihood amenities for the local communities in the form of grazing fields and vegetation for domestic use.

2.6.2.3. Other wetlands in the SNNPR

2.6.2.3.1 Warmeda wetlands

Biophysical characteristics

In Dale Woreda, Gedeo Zone, at the upstream of the Genale Basin, there are many pockets of wetlands in different agro-ecological zones. Most of them are small except Warameda, which is the largest covering three peasant associations (Adugna Babu and Bogale Teferi, 2015). Most part of this wetland is flooded during the summer season and dries up in dry season. However, there are permanent rivers crossing the wetland and springs that supply water. From field observation, it was noticed that the wetland is highly encroached by settlement plantation of higher water demand tree species (eucalyptus plantation) and diversion of water for agriculture. The other problem of the wetland is overgrazing during dry season where large stock of animals graze without proper management.

According to Adugna Babu and Bogale Teferi (2015), there are two main watersheds**, Gidabo** and **Bilate** and four sub-watersheds in Dale Woreda. Gidabo is the largest watershed around the area covering a total area of 216.817.74 ha and comprising four sub-watersheds. Bilate watershed is the second largest watershed of the area. It covers a total area of 116.010.27 ha. Dama. Raro, Wamole and Woyima are major sub-watersheds of Gidabo each covering area of 8.170.56 ha, 5.580.72 ha, 16.938.72 ha and 4.678.11 ha, respectively.

Ecosystem services and ecological status

The Gedeo wetlands in Oromia Region have provisionary services of water, fish, plants and supportive services as habitat for several plant and animal biodiversity. Human encroachment is threatening the wetlands, which should be protected by regulatory and other means.

Lakes and Rivers in Genale Dawa Basin (2016)

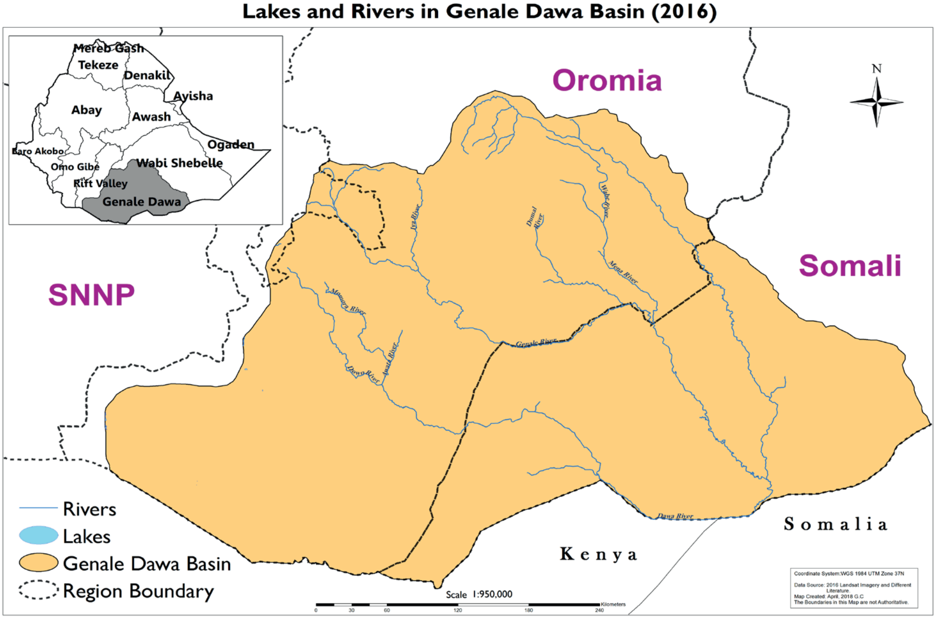


Figure 2. 27: Lakes and rivers in the Genale-Dawa basin

2.7. Mereb Gash basin

The Mereb River basin is situated between latitudes of 14 03` and 14 52` N and longitudes of 37 51` and 39 27` E. The basin covers an area of about 5,893 km^2 in Ethiopia all falling in Tigray Regional State, in Central, Northwestern and Western zones (Fig. 2.28). The basin has an annual runoff of 0.26 billion metric cube (BMC) of water.

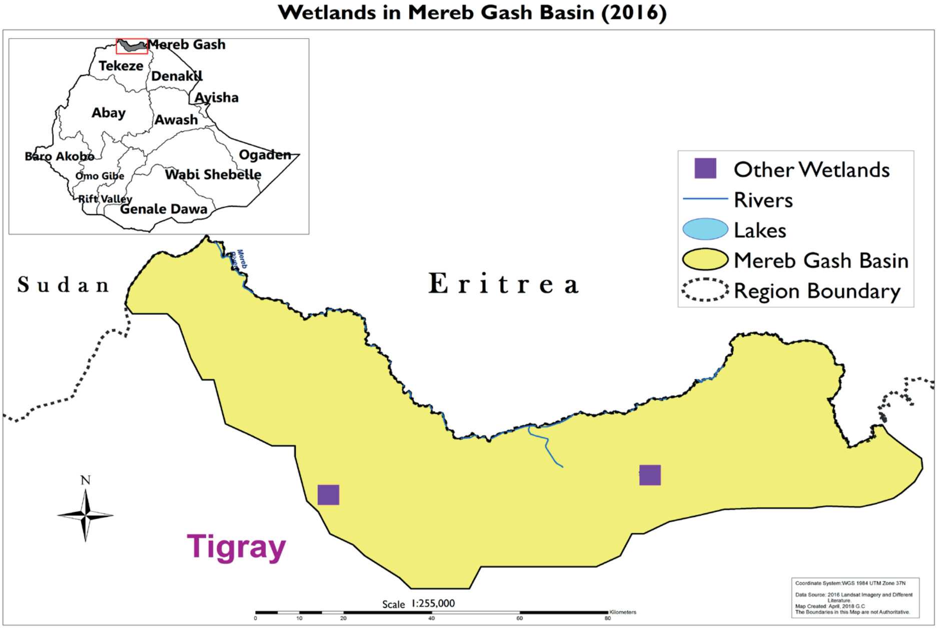


Figure 2. 28: The Mereb Gash basin

Biophysical characteristics

The relief of the basin is extremely rugged with over 65% of the basin lying in the altitude of over 1,500 masl. The upper part is surrounded by mountain ranges, elevation of which is over 2,000 masl.

The basin has 28 tributaries and 10 small catchments with mean annual flow of 650 Mm3. Ground water, which is mainly stored in hard rock is found at shallow depth in the range of 4 to 20 m and spring yields are high with average flow being

10.5 L/s. The dominant soils of the basin are Eutric and Vertic Cambisols, which are moderately, and rather dark colored soils. To minor extent, Eutric Vertisols, Vertic and Cromic Luvisols and Eutric Regosols exist in the basin. Almost 74% of the soils in the basin have an effective soil depth of less than 25 cm.

Wetlands in Mereb Gash Basin (2016)

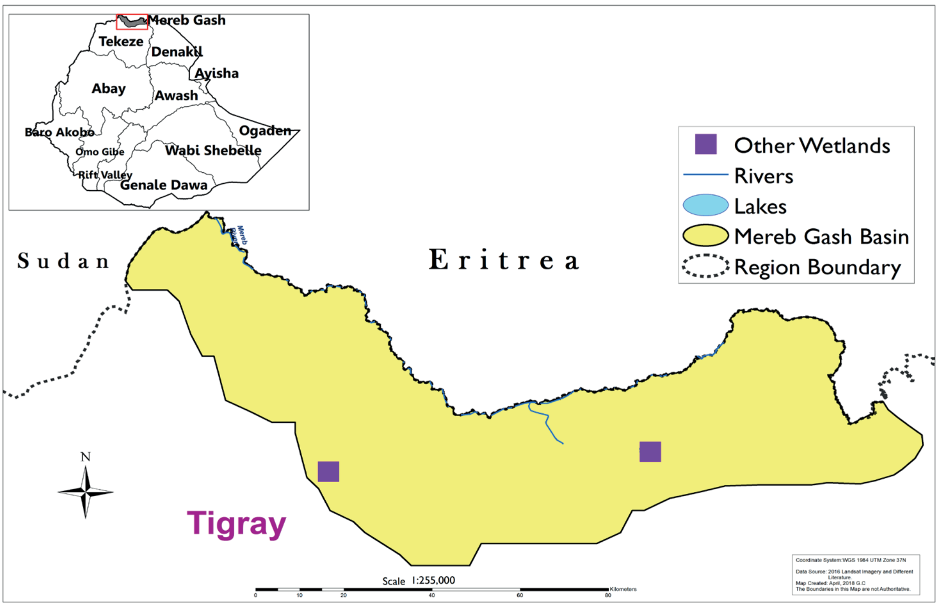


Figure 2. 29: Lakes and rivers in the Mereb basin (Mereb River as boundary between Ethiopia and Eritrea)

Status of the Mereb basin

This is a rugged and dry catchment with the Mereb River flowing through steep canyons. The vegetation cover is sparse and although population pressure is not high, restoration of the watershed appears to benefit from restrained animal and human encroachment and watershed afforestation programs. Some microdams have been constructed in the Tigray NRS in the Mereb basin, and the status of microdams in general is discussed in the Tekeze basin section 2.11.

2.8. Ogaden Basin

The **Ogaden Basin** is an area that is not known for its wetlands but the basin may hold significant reserves of crude oil and natural gas. The basin covers an area of some 350,000 km^2 and is formed from sedimentary rocks up to 10,000 meters thick (Fig. 2 30). It has geological similarities to other hydrocarbon-rich basins in the Middle East (from Wikipedia). Rains are rare in the basin, and when they come, they drench the area for a day or at most a few days in a year. This is a period of blooming of desert plants with their beautiful flowers and thriving of desert animals that follow the same pattern. Not much has been recorded about the biodiversity in the basin.

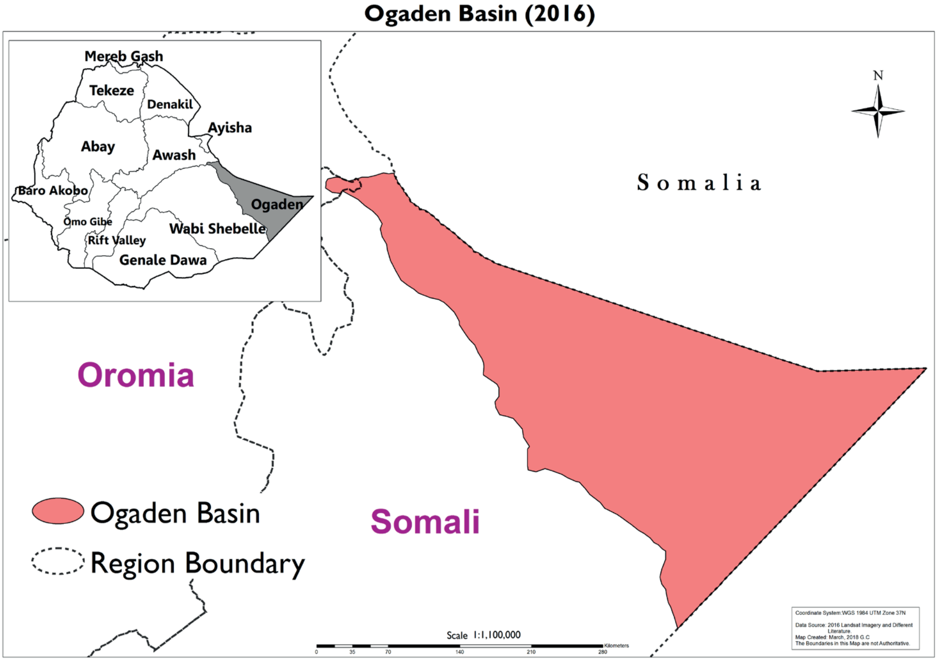


Figure 2. 30: Location of the Ogaden basin

Ecosystem services and ecological status

Of the four ecosystem services that wetlands give, all appear to be either absent or in poor state in the two dry basins of Aysha and Ogaden. However, these basins provide habitat and food for animals and plants, harbor unique biodiversity and have cultural functions of communal meetings and religious ceremonies for the local communities.

2.9. Omo-Gibe basin – general

Fig. 2.31 indicates the wetlands found in the Omo-Gibe basin in general. These wetlands are located in the Oromia and SNNP regional states, and at the southern tip, extend as far as the Kenyan border at Turkana.

Wetlands in Omo Basin (2016)

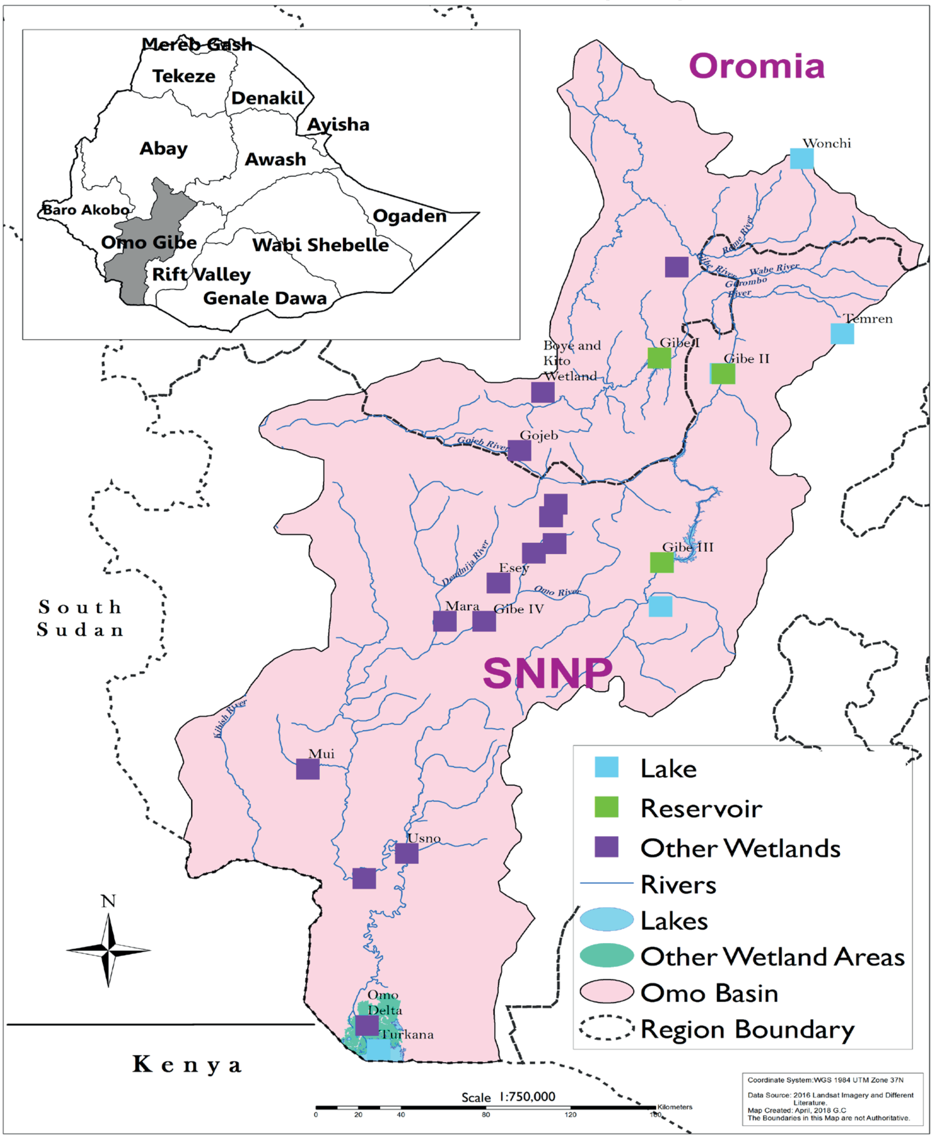


Figure 2. 31: Wetlands in the Omo-Gibe basin

2.9.1. Wetlands in the ONRS

2.9.1.1. Lakes and rivers in the ONRS

2.9.1.1.1. Lake Wonchi

Lake Wonchi is located at $8^0$47'N, 37^0 53'E and is a deep crater lake formed as a result of volcanic activity.

Biophysical characteristics

Lake Wonchi is located at an altitude of 2,887 masl. It is deep, steeply shelving with a surface area of 5.6 km^2, maximum and average depth of 107 and 28 m, respectively, and has maximum dimensions of 3.9 km long and 2.2 km wide. The height of its crater rim from the lake surface is about 460 m. The lake has a closed basin with no surface inlet. It receives water primarily from rainfall falling directly on its surface, and from subterranean cold and lukewarm springs.

The region is characterized by sub-humid climate with an annual rainfall of around 1,200 mm. The main rainy season extends from May to September (National Meteorological Service Agency of Ethiopia), and air temperature varies from 14 to 26 °C during the day and falls below 10 ° C at night.

The littoral zone of the lake is characterized by submerged aquatic macrophytes, mainly *Potomageton* sp. The fish species present in the lake are *Garra* sp. and *Cyprinus carpio* (common carp). The latter species was introduced in the lake in the late 1990s, together with *Oreochromis niloticus* (Nile tilapia), by the National Fisheries and Other Aquatic Life Research Center (NFLARC) in an attempt to establish a pelagic fishery and increase availability of protein for local communities. Lake Wonchi is categorized in the unproductive (oligotrophic) status (Fasil Deguefu *et al.*, 2014).

Ecosystem services and ecological status

Lake Wonchi is an important site for recreational and nature visit, especially by European tourists. The lake has fish but people do not have the culture of catching fish. The ecological status of the lake can be said to be *excellent* but extra effort has to be exerted to protect the ecological integrity of Lake Wonchi from recreational pollution.

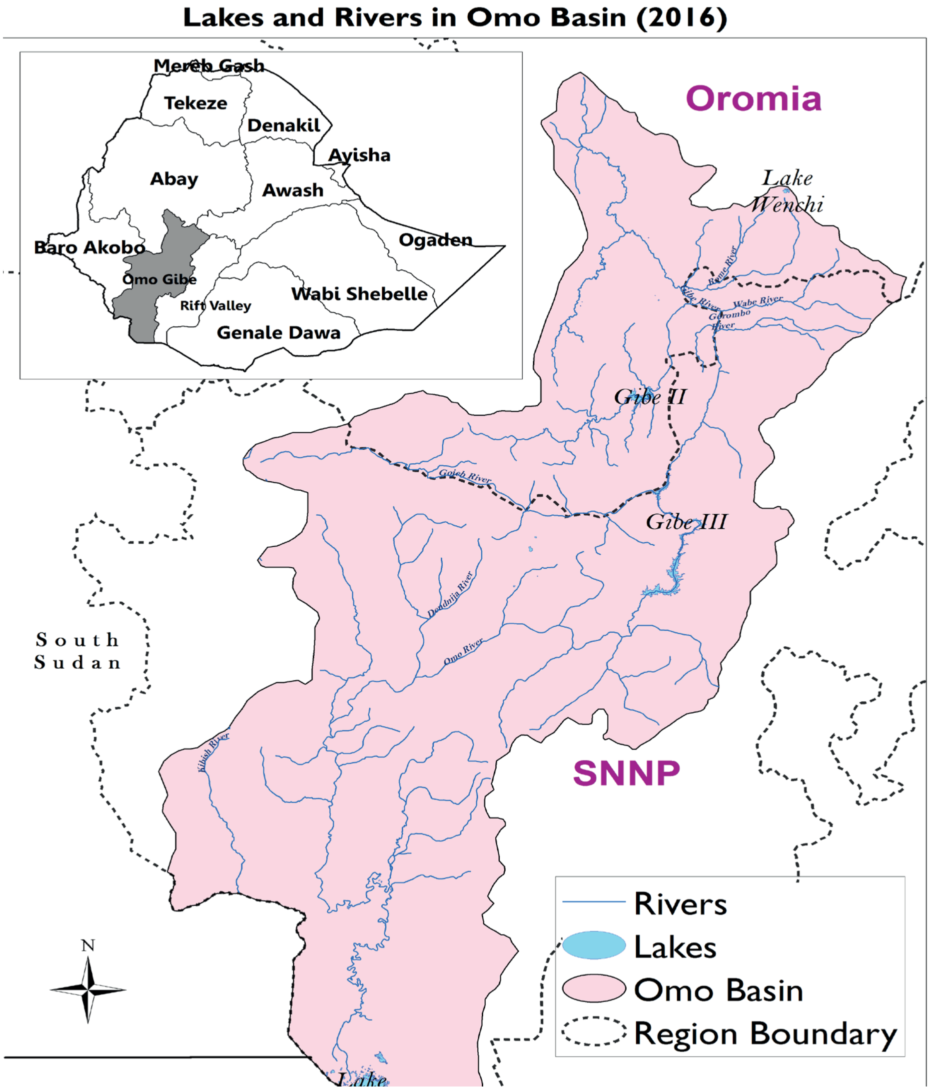


Figure 2. 32: Lakes and rivers in the Omo-Gibe basin

2.9.1.1.2. Gibe River

The Gibe River and its tributaries are indicated in Fig. 2.32. The Gibe is one of the largest tributaries of the Omo River and it rises west of the Chomen swamp (specifically, from Gudeyya Bila woreda, East Wellega Zone, Oromia Region), flowing to the southeast to its confluence with the Omo at coordinates 8°19′N37°28′E and8°19′N37°28′E. Its tributaries include the **Amara**, **Alanga** and **Gilgel Gibe** rivers.

Gibe River at Halabacho Gibe (N 06^{0} 40.278′ and E037^{0} 10.419′ at an elevation of 644 masl) is located in a locality known as Halabacho, Loma Woreda (Plate 2.24). This site is completely inaccessible by surface (land or water with low level difficult to navigate by boat and access is only possible with a helicopter). It can be described as a pristine environment, which can be used as a reference condition to other wetlands that are impacted by human activities.

Plate 2. 24: Halabacho section of Gibe River (Photo credit: Brook Lemma, 2015)

This stream joining Gibe River just above the new bridge site shows the difference in water clarity with Gibe and swarms of fish fry (larvae) were observed in small pools which are indicators for fish migration.

Water chemistry

The Halabach River is dilute, freshwater and warm water, conducive for domestic consumption, fish culture, horticulture and agricultural activities (Table 2.19)

Table 2. 19: Depth profile of some physico-chemical parameters of Halabacho, Gibe River

Depth, m	Water temperature, ^{0}C.	Salinity, mgL^{-1}	Conductivity, µScm^{-1}	Dissolved oxygen, mgL^{-1}
0	29	0	182	10.8
0.5	28	0	185	10.4
1.0	28	0	185	10.4

2.9.1.1.3. Gojeb River

The **Gojeb River** is eastward-flowing tributary of the Omo River in Ethiopia. It rises in the mountains of Guma, flowing in almost a direct line with the Omo at coordinates: 7°20′25′N, 37°21′17′E and 7.34028°N, 37.35472°E. Its canyon provided the former Kingdom of Kafka an important defensive frontier against the invading Oromo people during the 16th and 17th centuries. There are few sporadic studies and grey literature on the Gojeb River, which were largely inaccessible for this report.

Ecosystem services and ecological status

The Gojeb River sub-basin is an important source of water, fish and plants to riparian communities. Its ecological condition is believed to be excellent because of its pristine condition.

The **Gojeb-Gewata wetland** is a conspicuous part of the basin which has been declared as a UNESCO Biosphere Reserve due to its unique coffee forest.

2.9.1.1.4. Esey and Mara rivers

Esey River is found in the mountains and flows into Gibe River above Gibe IV bridge site found at a location of N 06^{0} 45.603′ and E 036^{0} 35.097′ at an elevation of 943 masl. River Esey (Plate 2.25) is one more example of the pristine streams flowing through the clean dense forests of Gibe valley.

Plate 2.25 River Esey

Mara River enters Gibe River from downstream side about 700 meters from the new bridge at a location point of N06^{0} 34.211' and E 036^{0} 32.489' at an elevation of 525masl. Mara River, which is considered as holy water by the local population is being intercepted for road construction to build Gibe IV.

Plate 2. 25: Mara River (Photo credit: Brook Lemma, 2015)

Ecosystem services and ecological status

The Gibe River and its tributaries provide fish, plants and water to riparian communities. The Gibe River and its numerous floodplain wetlands regulate flows and modify climate change. Some of the Gibe tributaries are considered as "holy" water and have cultural values (Plate 2.26). The ecological condition of the Gibe catchment is close to pristine (excellent) but anthropogenic pressure is increasing and should be curbed or managed by planning. The forest should be maintained to preserve the present hydrological balance in the basin.

2.9.1.2. Other wetlands in the SNNPRS

2.9.1.2.1. Gilgel Gibe Reservoirs

Below is a description of the Gibe dams (I, II, III) although only Gibe I and II are in ONRS and Gibe III, IV and V are in SNNPR

The **Gilgel Gibe I Dam** is a rock-filled embankment dam on the Gilgel Gibe River located about 57 km northeast of Jimma in Oromia Region. The dam is 1,700 m long and 40 m tall. Construction on the dam began in 1988 and the power station was commissioned in 2004. The Gilgel Gibe I hydroelectric power-plant has an installed capacity of 184 MW, enough to power over 123,200 households.

The **Gibe II** hydroelectric plant (commissioned in 2010) channels the water already impounded by the existing Gibe I hydroelectric plant through a 26-km long tunnel directly into the Gibe-Omo River. The resulting 500 m head is used to generate 420 MW of electric power

The **Gilgel Gibe III Dam** is a 243 m high roller-compacted concrete dam with an associated hydroelectric power plant on the Omo River in Ethiopia. It is located about 62 km west of Sodo in the Southern Nations, Nationalities, and Peoples' Region. It will be the third largest hydroelectric plant in Africa with a power output of about 1870 Megawatt (MW). The Gibe III dam is part of the Gibe cascade, a series of dams including the existing Gibe I dam (184 MW) and Gibe II power station (420 MW) as well as the planned Gibe IV (1472 MW) and Gibe V (560 MW) dams. The total storage volume of the reservoir of Gibe III dam will be between 11.75 and 14 billion cubic meter, depending on sources. The Gibe III Dam is located on the Omo River around 150 km downstream of the Gibe II outlet. Upon completion, a 150-km dammed reservoir will be created, flooding the canyon from the dam upstream on the Gibe River, retaining about 14.7 billion m^3 of water at maximum capacity, which is equivalent to the total annual flows in Omo River. Gibe III dam is the tallest dam in Africa and was completed in 2015. The mean annual inflow or discharge into the reservoir is estimated to be 438 m^3/s (13,800 million m^3/year), with seasonal inflows varying from less than 60 m^3/s in March to over 1,500 m^3/s in August. In terms of power generated, the capacity of Gibe III is around 8% of the capacity.

Gibe IV will have the capacity of producing 1472 MW and was at inception stage in 2016. Dam Site of Gibe IV where a new bridge was under construction (N 06^0 34.789' and E 036^0 33.507' at an elevation of 525masl) is shown in Plate 2.27.

Plate 2. 26: Gilgel Gibe reservoir near Asendabo and site for Gilgel Gibe IV dam and reservoir (Photo credit: Seyoum Mengistou and Brook Lemma)

Ecosystem services and ecological status

Although the main service of the Gilgel Gibe reservoirs is hydropower production, they have also been stocked with fish and provide water and protein to lakeshore communities and beyond. The medicinal and ecological values of the Gibe basin plants are widely known (Appendix 5). The reservoirs store huge amount of water and help to modify local climate and regulate the erratic flow of the Gibe River and its numerous tributaries. The ecological condition of the Gilgel Gibe reservoirs is good but sediment loading from the catchment is high. The rivers carry high nutrients into the reservoirs, which have high productivity of plankton and fish. Presently, the reservoir is stabilizing after a period of high productivity during the first 5 post-damming years (trophic surge phase). The best lesson to take home from such avoidable ecological degradation is to undertake catchment reforestation and management to reduce sedimentation and erosion into reservoirs.

2.9.1.2.2. Boye and Kito wetlands

Boye and Kito wetlands are located some 4 km from Jimma Town in the Oromia Region.

Biophysical characteristics

Kitto stream passes through Kitto wetland. At the downstream direction, Awetu stream joins with the Kitto stream. Boye wetland is located immediately after the confluence area of Kitto and Awetu streams and is continuously fed by Awetu stream, which is passing through this wetland and finally joins the Gilgel Gibe River, which originates from Bako area, western Ethiopia and ultimately enters into Omo River.

These wetlands receive rainfall between 1200 and 2400 mm per annum with an average annual rainfall of 1477 mm having the heaviest concentration from June to September, and the average maximum and minimum temperatures of 28.8 and 11.8°C, respectively, with a mean daily temperature of 19.5°C.

These two wetlands serve as a habitat for a variety of plants, birds, and mammal species and they are water sources for human and livestock populations. It has also been reported that hippopotamus inhabits the middle of the Boye wetland, but it has been highly degraded and under the risk of loss due to poor watershed management, solid and liquid waste disposal, rapid expansion of Jimma Town towards the wetlands, and conversion to agricultural land.

Seid Tiku et al., (2013) identified a total of 36 bird species in Boye wetlands. According to IUCN, (2010) among the recorded species, *Balearica pavonina* and *B. regulorum are* vulnerable while *M. flavicollis* is near threatened. These species will be endangered within a short period of time, unless the necessary conservation actions are put in place.

Ecological studies

Argaw Ambelu *et al.* (2013) identified forty-four macro invertebrates (MI) belonging to 19 families from the Boye sites, whereas, in the Kitto sites 366 MIs from 26 families were collected. The relatively higher load of pollution correlated closely with decreased pollution sensitive species diversity (like EPT) and increased abundance of number of certain pollution tolerant macroinvertebrates like Chironomidae in some sampling sites of Boye wetland.

Generally the results clearly suggest that there is a high level of anthropogenic threats to both wetlands. The more intense agricultural practices and waste discharge was closely associated with higher phosphate concentration and low level of dissolved oxygen (DO). Kitto wetland has significantly better MI diversity than Boye. Overall, Boye wetland was relatively more polluted than Kitto due to intensive pollutant input mostly from the Jimma Town as well as intensive agriculture related practices around the Boye wetland, except at downstream site.

Four other wetlands, namely **Kofe, Haro, Bulbul and Balawajo** have been identified and studied in Jimma Zone, but detailed information on these studies were not available.

Ecosystem services and ecological status

The Boye and Kito wetlands provide many livelihood amenities to communities (water, fish, medicinal plants, roofing, etc) and support unique habitats for several threatened bird species. Due to the large volume of water they retain, the wetlands may also regulate the hydrological balance and protect soil erosion and fertility. They also serve cultural functions to the several nationalities found in the basin. Despite their pristine nature, these wetlands have been encroached by human activities including drainage, farming, devegetation, pollution and brick-making. The ecological condition of these wetlands is becoming degraded and intervention is necessary in order to restore and maintain their vital ecosystem services.

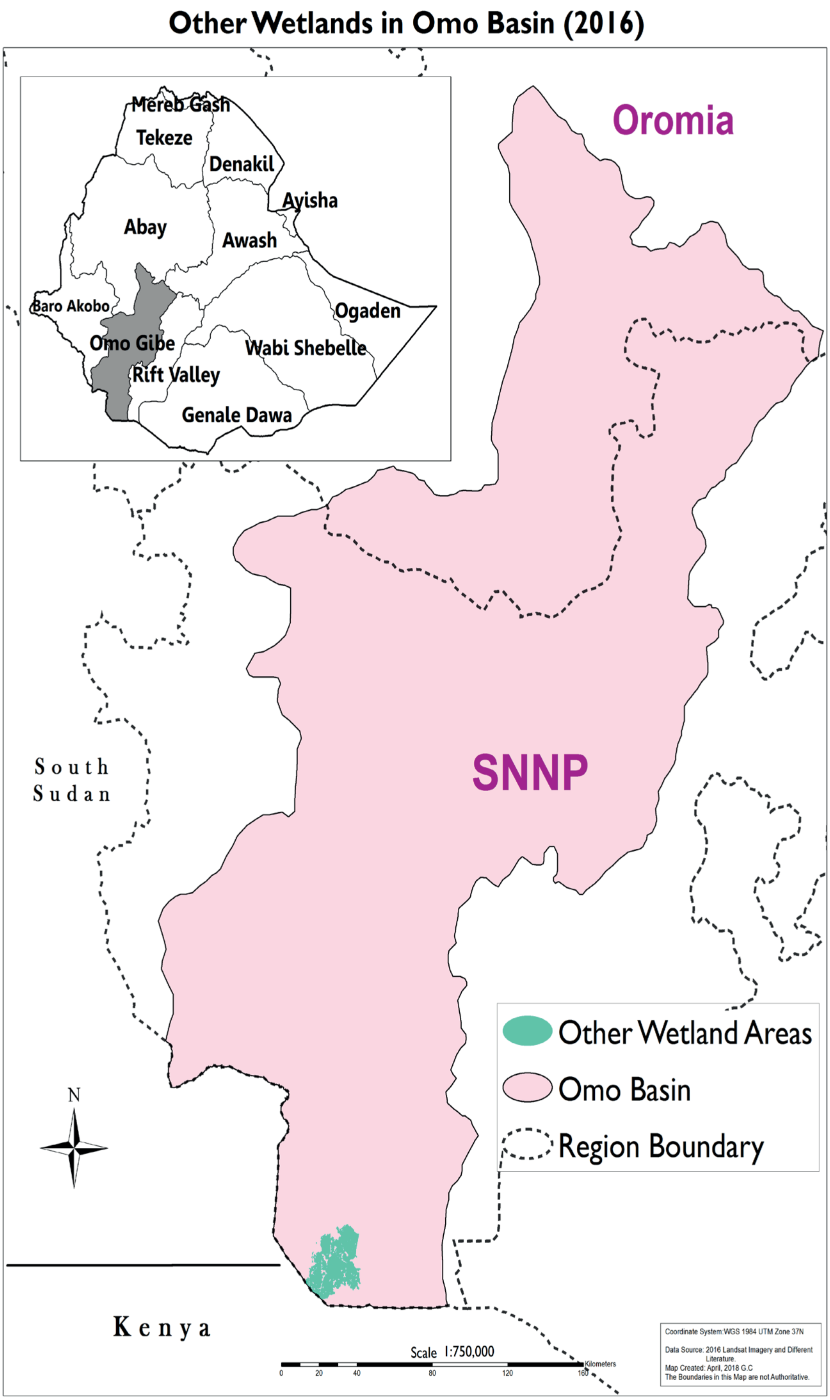


Figure 2. 33: Other Wetlands in the Omo-Gibe basin

2.9.2. Wetlands in the SNNPR

2.9.2.1. Lakes and rivers in the SNNPR

2.9.2.1.1. Omo River to Lake Turkana

Omo River

The Omo River rises in the Shewan highlands and flows to the south, with a major bend to the west at about 7° N 37° 30′ E to about 36° E where it turns south until 5° 30′ N where it makes a large S- bend then resumes its southerly course to Lake Turkana.

In its course, the Omo-Bottego has a total fall of about 2,000 m, from an elevation of 7600 ft at its source to 1600 ft at lake-level, and is consequently a very rapid stream, being broken by the Kokobi and other falls, and navigable only for a short distance above where it empties into Lake Turkana. The Omo carries 14% of Ethiopia's entire annual runoff.

Plate 2. 27: Deep gorges in the Omo River and the Omo River water turbidity

Archaeological importance

The entire Omo river basin is also important geologically and archaeologically. Several hominid fossils and archaeological localities, dating to the Pliocene and Pleistocene, have been excavated by French and American teams. Fossils belonging to the genera *Australopithecine* and *Homo* have been found at several archaeological sites, as well as tools made from quartzite, the oldest of which date back to about 2.4 million years ago. Because of this, the site was designated a UNESCO World Heritage Site in 1980.

Economic importance of the Omo River basin

Major studies such as the Golubtsov and Mina (2003) and Redeat Habteselassie (2012) describe the fish fauna with exemplary work on taxa listing. Specific limnological study of these river systems is highly scanty and particularly the segments of Gibe and Omo Rivers designated for this study have not been reported before.

The river provides about 90% of Lake Turkana's annual inflow. Its flood pulses stimulate fisheries spawning and dilute the lake's semi-saline waters while its nutrients sustain the lake's ecology.

The Omo valley is an important economic corridor for large agricultural projects (sugar, cotton), several hydroelectric power stations, large irrigation fields and the Omo National Park is also situated in this active part of the country (Fig 2.34). According to one report, the total area either allocated or considered by the Government as suitable and available for agricultural development in the Lower Omo amounts to 445,000 hectares. Of particular note is the extensive sugar development project in the Omo basin, which abstracts much water from the Omo River at several points for irrigating (Fig. 2.34)

Human settlement is relatively low in the Omo basin because of the deep river gorges, which make navigation and habitation difficult (Plate 2.28).

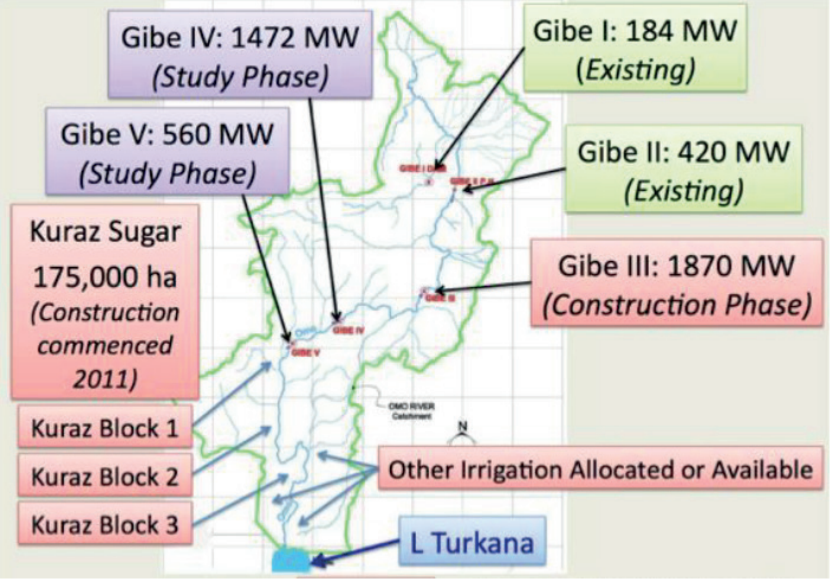


Figure 2. 34: Development projects in the Omo River valley

2.9.2.1.2. Bilate River (Greater and Lesser)

The Bilate River is composed of two major tributaries known as the bigger and smaller (greater and lesser) Bilate. It is in the **Bilate river** basin that drains from the Gurage highlands south into Lake Abaya. The two main tributaries of the Bilate river, the **Guder** (which originates in the mountains near the zonal capital Hosana) and the **Weira,** merge at Boyo wetland. The vegetation of this wetland has not been studied. The site is within one of the most intensely cultivated areas in the country. It is self-supporting in food crops and many other items, and produces much for Addis Ababa market.

Ecosystem services

Provisioning service of water, fish, vegetation, irrigation and recession agriculture.

2.9.2.2. Other wetlands in the SNNPR of Omo-Gibe basin

2.9.2.2.1. Kafa wetlands

The Kafka Zone is located in the south western part of Ethiopia within the latitude of 07^{0}8' -07^{0}26' North and longitude of 35^{0}53'-36^{0}36' East. The Zone is bounded by Oromia Regional State in the north, Sheka Zone in the north-west, Bench-Maji in the south-west, South Omo Zone in the south and Konta in the south-east.

Biophysical characteristics

The Zone has a surface area of 1,328,923 ha with a population of 725,086 inhabitants. The altitude and the topography of the area ranges between 1000-3500 masl and it experiences a mean annual rainfall of around 1,800 mm and a mean annual temperature of 19.5 ^{0}C with a mean minimum of 11.6^{0}C and mean maximum of 27.4^{0}C. There is one long rainy season and is from March to November and the wettest months are between months of May and June.

The drainage system comprises of three major river systems; the **Gojeb** River in the north and **Dincha** River in the central area drain to Omo River and the **Woshi River** drains into the Baro River to the west. The function of these rivers is, therefore, important not only to the resident and migratory faunal species diversity but also it influences the biotic communities of Sudan-Guinea Biome that lies in the west and the Somali-Massai Biome that lies in the east. These areas hold aquatic and wetland species that are important for conservation. These include, among the water dependent mammals, Hippopotamus, African buffalo, Reedbuck, Clawless otter, Swamp rat. The area is important too, as it abodes for various species of aquatic birds, such as Long-tailed Cormorant, Egrets, Herons, Egyptian Goose, African Fish Eagle, Black-crowned Crane, King Fishers and including the endemic birds such as Rouget's Rail, Abyssinian Longclaw and Wattled Ibis. Quite a number of amphibians, fishes and invertebrates also occur in the area. The riparian woodlands and wetlands lie north and north west of Kafka Zone within an altitude of 1500 and 1700 masl. It is a vast stretch of marshland and river streams with pockets of forests within and around the forest ecosystem.

Ecosystem services and ecological status

The Kafka wetlands are important sources of water, fish, birds and plants and other animals. The rich and unique forest and wetland ecosystem complex has been established as a UNESCO Biosphere reserve. As such, the basin does not require rehabilitation actions but instead its status as a Biosphere Reserve should be protected and guarded.

2.9.2.2.2. Boyo wetland

Boyo wetland is found in SNNPRS, coordinates 07°29'N 38°03'E, and altitude 1,880 masl. It was designated as controlled hunting ground for hippopotamus.

Biophysical characteristics

Boyo Wetland is 26 km north of Alaba Kulito, Hadiya Zone. It is in the **Bilate river** basin that drains from the Gurage highlands south into Lake Abaya. The two main tributaries of the Bilate river, the **Guder** (which originates in the mountains near the zonal capital Hosana) and the **Weira,** merge at Boyo wetland. Besides Boyo wetland, two other wetlands in the vicinity, the **Archuma and Wonchicho wetlands**, are important bird habitats but no ecological studies have been done on them because of their inaccessibility.

The annual rainfall for the Boyo wetland area is 1500 mm. The wetland expands to 140 ha during the rainy season and contracts to 80 ha during the dry season. Boyo wetland is an important habitat for the IUCN Red Listed "vulnerable" wattled crane (*Bugeranus caruncalatus*) and only 21 birds were counted in cultivated fields during a survey in 2013 (Yilma D. Abebe, 2013). The vegetation of this wetland has not been studied (EWNHS, 1996). The site is within one of the most intensely cultivated areas in the country. It is self-supporting in food crops and many other items, and produces much for Addis Ababa.

Ecosystem services

The Boyo wetland is habitat for the wattled crane but it has not been established whether it breeds there or not. The wetland was designated as controlled hunting ground for hippo, although this has never been enforced (EWNHS, 1996). The wetland is used for recession agriculture and animal husbandry. It also abates the high floods during the *kiremt* months, stores water and regulates hydrological flows. Human pressure is high in some parts of the wetland and extensive cultivations have lowered the water table, which clearly calls for restoration intervention.

2.9.2.2.3. Moorgate floodplains and delta

Lake Turkana and **Omo delta** are situated in SNNPRS at coordinates 04°28′N 36°15′E, and low altitude of 37 masl. The Ethiopian side of Lake Turkana flooplain is located (N 04^{0} 24.390′ and E 036^{0}12.754′ at an altitude of 364 masl (Plate 2.29).

Biophysical characteristics

Lake Turkana lies across the Ethiopia–Kenya border in South Omo Zone. Omorate is the closest settlement, 70 km north of Lake Turkana. The lake takes its name from the Turkana people who live round it (although it has previously been called Rudolph). The main part of the lake is in Kenya. Only the northern arc with about 52 km of shoreline is within Ethiopia. There is no direct access by road to the western shores of Lake Turkana from the Ethiopian side. The maximum depth of the lake is c.114 m. The water-level in the lake is largely determined by the rainfall in southwest Ethiopia. The main source of water is thus the Omo River that accounts for 98% of the riverine inflow. Before reaching the lake, the Omo

River forms a wide delta where much of the silt load is deposited. Very little is known about the vegetation and flora on the Ethiopian side of the lake—the trees and shrubs have not been documented.

The Omo Delta could be expected to support riverine forest or woodland. The lake is said to have extensive reedbeds in the past. Though it is not known whether *Typha* spp. or sedges and rushes occur but *Cyperus papyrus* is apparently absent from the lake. South Omo is one of the most culturally diverse regions of Ethiopia. The people of the area are hunter-gatherers, fishermen and pastoralists. Some crops are grown on the levees beside the river upstream of the lake

The Turkana floodplain is a biodiversity hotspot with a wide array of animals and plants during the flooding season. During the dry season, the emergent *Typha* stands dry up and as the lake recedes, fishermen can get closer to the lake to collect their catches (Plate 2.29).

Plate 2. 28: Lake Turkana shore showing dry Typha stands (Credit: Brook Lemma)

Water chemistry

As indicated in Table 2.20, the water chemistry of Lake Turkana measured during the dry season of August, 2015, indicated that it is saline, alkaline but with high dissolved oxygen. Fish catch was quite high in the lake.

Table 2. 20: Measurements of physico-chemical parameters at Lake Turkana (Brook Lemma, 2015)

	Measured parameters	Measurements
1	Surface water temperature	31.5^{0}C
2	Salinity	20.3mgL^{-1}
3	Conductivity	3800 μScm^{-1}
4	Dissolved oxygen	12.4 mgL^{-1}
5	PH	10.6
6	Water transparency	43cm

Ecosystem services and ecological status

Lake Turkana floodplain provides productive feeding ground for several local and migratory fish and bird species. It regulates the seasonal flood of the Omo River and serves as habitat for a rich biodiversity of biota adapted to the arid conditions. Lake Turkana is one of the few unique ecosystems characterized by extreme salinity, temperature and hydrological fluctuations. It is a transboundary resource between Ethiopia and Kenya, although Ethiopia's share is small. Still, the importance of transboundary cooperation for efficient lake management is exemplary in the case of Lake Turkana.

Omo River at Omorate

Omo River at Omorate town is located at coordinates N 04^0 48.138' and E 036^0 02.896' at an elevation of 372.6 masl (Plate 2.30). The town of Omorate is located at the shores of River Omo, with specific location at N 04^0 48.138' and E 036^0 02.896' at an elevation of 373 masl. People collect water for home use, bath, travel across with canoes and even fish in the river, despite existence of crocodiles.

Plate 2. 29: Omo River at Omorate town

Water chemistry

Table 2.21 shows water quality data for the Omo River at Omorate town. Generally, Omo water is highly turbid but relatively fresh, warm and with high oxygen content that sustain high fish yield on which the local community depend. However, the extreme silt load of the Omo River will have to be reduced or controlled in future if the river is to continue giving its ecological and economic services.

Table 2. 21: Water quality data of Omo River at Omorate town (Brook Lemma, 2015)

Depth, m	Water temperature, ^{0}C.	Salinity, mgL^{-1}	Conductivity, µScm^{-1}	Dissolved oxygen, mgL^{-1}
0	28.5	0	120	9.8
0.5	28.0	0	120	9.6
1.0	28.0	0	120	9.7
1.5	28.0	0	120	9.7
2.0	28.0	0	120	9.5
2.5	28.0	0	120	9.2
3.0	28.0	0	120	9.2
6.0	28.0	0	120	9.2

Flora along Gibe River: Omorate, Gibe 3 and Gibe 4 sites

The general habitat feature along the Omo River (Plate 2.31) at coordinate N 48; .716 E 036° 2; 54.551 and elevation of 365 masl indicate dominance of plant species indicative of degradation such as *Calotropis* and *Indegofera* spp.

Plate 2. 30: Riparian plants on Omo River at Omorate and plants from Gibe 3 river bank margins (N 06° 50.003 E037° 17.536 at an elevation of 680 masl)

Some of the invasive plants in the Omo basin are shown in Plate 2.32. It appears that these plants may require management action before they cause serious ecological problems. These include *Parthenium*, which is causing havoc on the livestock in the area and others like *Mimosa* and *Xanthium*, which are nuisance plants. Other plants documented from the Omo-Gibe basin are included in Appendix 4 and 5.

Plate 2. 31: Invasive plants in the Omorate area - Mimosa pigra, Parthenium hysterophorus and Xanthium strumarium (Collected by Brook Lemma, 2015)

Ecosystem services and ecological status

The Omo River, as an important transboundary resource, has important ecosystem services in all aspects, such as:

- provisioning service of potable water, fish, vegetation, navigation, irrigation with many large investment farms;
- provides raw materials for industries, including sugar, cotton, fruits, etc;
- regulatory service of climate modification of the arid Omo-Gibe basin and flow regulation through its numerous floodplains;
- supportive service as habitat for fish, migratory birds, transboundary wildlife; and
- Cultural service for the numerous indigenous ethnic groups in the region.

The Omo River floodplain near Lake Turkana is an important feeding and spawning ground for many fish and bird species. The livelihood of millions of Omotic and Turkana people is tied with the ecological integrity of the Omo River and its floodplain wetlands. The ecological status of the Omo basin can be considered as moderate with sedimentation and inappropriate use of resources being the most worrying ones. Others include poor river bank stability leading to erosion and loss of spawning grounds for fish and other aquatic animals. Restoration efforts should focus on catchment management and water allocation schemes.

2.10. Rift Valley lakes basin

Wetlands in Rift Valley Basin (2016)

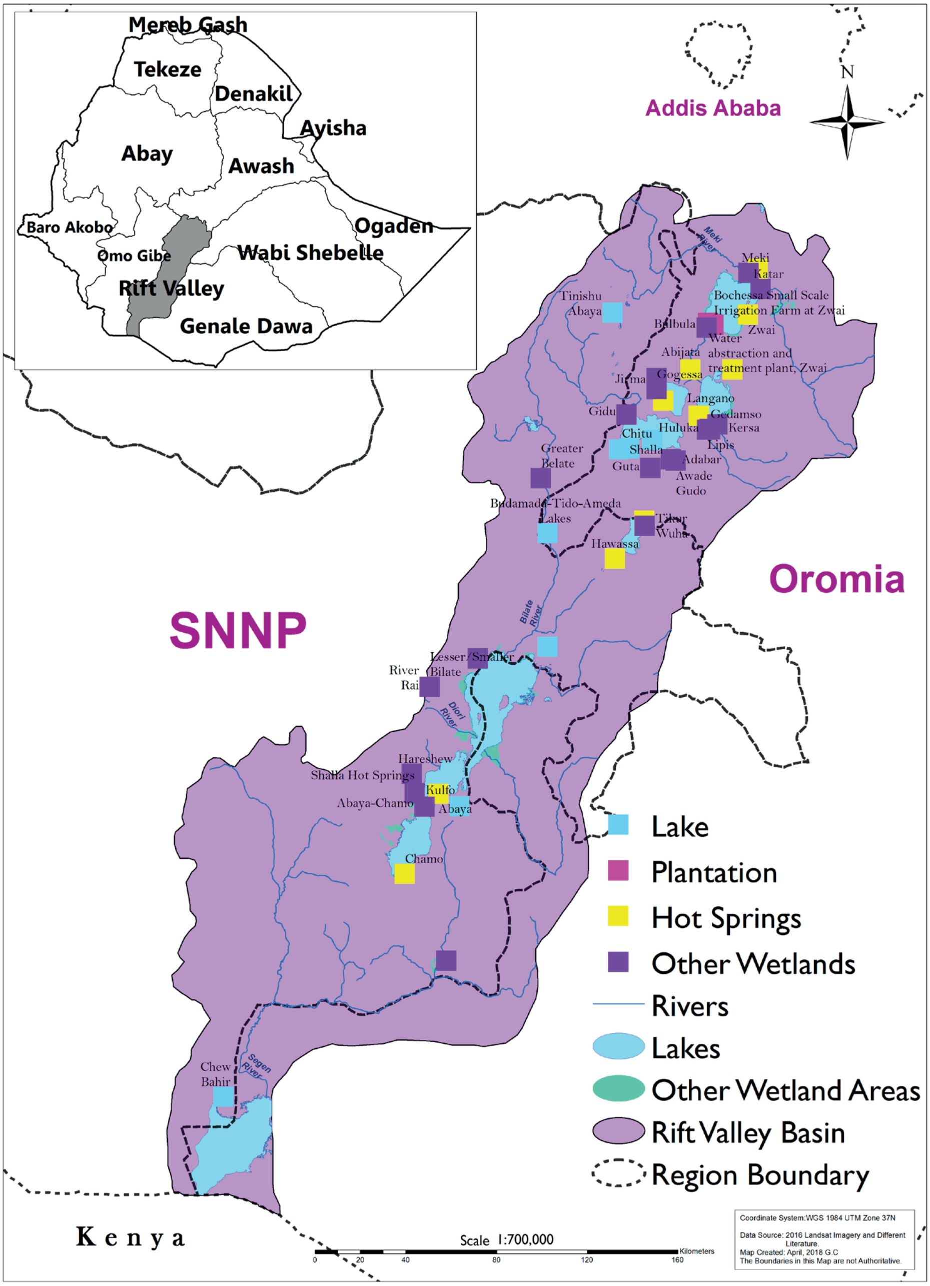


Figure 2. 35: Wetlands in the Rift Valley Lakes basin

2.10.1. Rift Valley lakes basin - general

Location and physical parameters

The lakes in the Ethiopian Rift Valley are physically arranged in north-south direction along the rift depression (Fig. 2.35). These include a total of ten lakes, of which two, namely, Shala and Chitu are crater lakes, while all the rest, **Zwai, Abijata, Langano, Hawassa (formerly (Awassa), Abaya, Chamo, Chew Bahia**[1] and partly **Turkana**[1] are depressions formed during the Late Pliocene–Early Pleistocene period (10^6 years), mainly characterized by catastrophic tectonic actions coupled with volcanic eruptions (Mohr 1962; Trudu *et al.*, 1999). At a certain stage of their evolution most of the African lakes were likely to have been one or a few mega-lakes (Groove *et al.*, 1975; Street, 1979; Tenalem Ayenew, 2009). With the water regressing continuously those meg-lakes started to assume their present shapes. This is discussed in some details in Trudu *et al.* (1999).

In general, the Rift Valley Basin has an area of 52,739 km^2, runoff potentials in its rivers and seasonal floods of 5.6 billion m^3, potential irrigable land of 139,300 ha, hydroelectric power potentials of 0.10 Gwh/year and standing waters having volume in excess of 55.2 X109 m^3 (Seleshi Bekele Awulachew *et al.*, 2007).

The Chew Bahir part of the Rift Valley, in the south-western corner of RVLB, is the lowest part of the rift system. This rift, connected to the north through the Weyto Valley, is bounded with steep fault scarps on both sides, which rise to over 3000 masl. The valley floors are sites of current sediment deposition, mainly in the form of alluvial fans but also, in the cases of the Chew Bahir basin and Ururu valley, of fluviatile and lacustrine sediments. The horst block between the Chew Bahir and the Turkano Rift Basin Systems is covered by Precambrian crystalline basement rocks. A watershed at about 1700-1750 masl, separates Lake Koka from the depression occupied by Lake Zwai (at 1637 masl). South from Lake Zwai, lakes Langano, Shala and Abiyata, all of which have water levels of about 1580 masl, occupy an isolated depression, farther south again, there is one more separate depression occupied by Lake Awasa, at an altitude of 1625 masl. As a result of all this activity, the RVLB exhibits striking contrasts in its topography. Adjacent to the lakes, valley bottoms are characterised by flat plains and gently undulating topography. In the relatively elevated North-western and Eastern sides of the basin, level lands form plateau. Elsewhere, zones of parallel, elongated ridges and depressions occur.

1 The latter two lakes (Chew bahir and Turkana), although part of the rift system, they are discussed in the Omo-Gibe basin.

The rift lakes have features that reflect their past relations in the form of mega-lakes and the events that eventually developed to give them their present shapes. There are a whole range of fish and plankton species that they share today and more so with lakes that presently share watersheds, e.g. lakes of the Zwai-Shala Basin and the Abaya-Chamo Basin. As time progressed, (i) these lakes showed differences in their salinity-alkalinity and eventually followed by (ii) the differences in fauna and flora which led to differences in their productivity (iii) the changes in climate factors contributed their shares in slow but persistent alterations of these water bodies and (iv) humans with progressive increase in their number, needs and technologies of exploiting these resources to satisfy their needs, thereby leaving their footprints in them.

Locations and some physical parameters of the Ethiopian Rift Valley lakes are given in Table 2.21. The bathymetry indicates that most of the lakes are very shallow and it may be inferred from the same that they were part of one or a few mega-lakes in the past (Tenalem Ayenew, 2009). From among them, Lakes Shala and Chitu were formed because of volcanic action, with cone-like basins.

The wetlands shared by the above two lakes serve as corridors to crossover from Arba Minch town to the Nechsar national park where numerous game animals dominated by Zebras are observed. At times when Lake Abaya fills up after good rains, it tends to spill over into Lake Chamo, which is found at a slightly lower altitude.

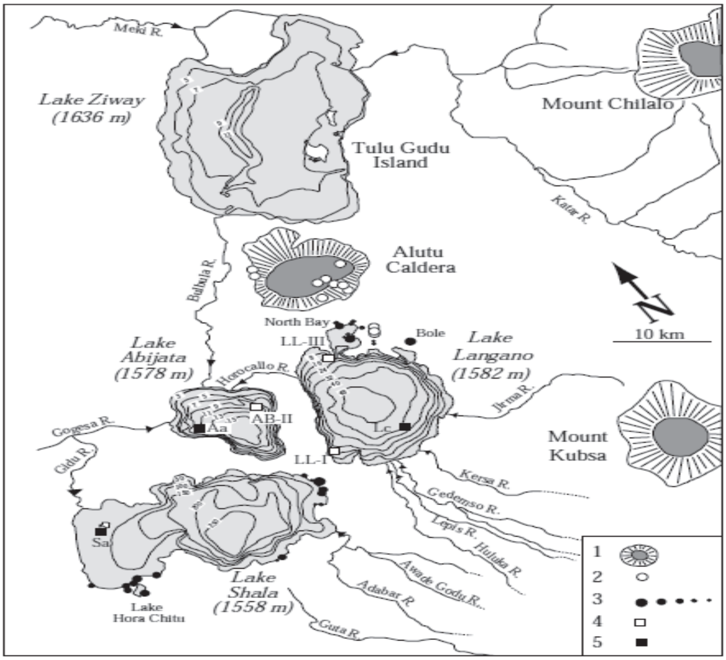


Figure 2. 36: Hydrological network, Lake Bathymetry, core location and distribution of hydrothermal activity and fumaroles within the Zwai–Shala Lake Basin system

(Lake Hora-Chitu in this figure refers to Lake Chitu.1 = volcanoes and calderas; 2 = fumaroles; 3 = hydrothermal springs; the diameter of the black dots indicates the spring discharge in Ls^{-1} (liters per second), from >10Ls^{-1} (large dot) to <0.25 Ls^{-1} (small dot), 4= Equarift and Livingstone cores; 5 = Mackereth cores (after Turdu *et al.*, 1999).

Descriptions of the flora and fauna of the rift valley lakes

Most of the rift valley lakes show similar constellation of biodiversity in them owing to the similarity of their physico-chemical characteristics. These are shown in their physical features discussed above and the water quality below. However, a few lakes of the rift system stand out unique, namely, Lakes Abijata Chitu and Shalla, whose salinity is very high and hence uniqueness of the biodiversity they host. As one scans through the biodiversity differences of the water systems in the Rift valley Basin, one can then check out the uniqueness of Lakes Abijata, Chitu and Shalla.

Table 2. 22: Locations and some physical parameters of the rift valley lakes

The lakes are arranged top-down in their increasing salinity-alkalinity series. Elevations are given in brackets: A is for surface area in square kilometers, Alt. for altitude above sea-level in meters (masl), W for width in kilometers, L for length, Zmax for maximum depth, Zmean for mean depth, WSA for watershed area, DAA for approximate distance from Addis Ababa and nd for no data (Tenalem Ayenew, 2002; Wood and Talling, 1988; Tenalem Ayenew, 2009; Brook Lemma and Hayal Desta, 2015 and miscellaneous other reports).

Lakes	Location	A, km^2	Alt.,m	W,km	L, km	Zmax, m	Zmean, m	Vol., m^3	WSA,km^2	DAA, km	Feeder rivers/ springs
Zwai	7°51′-8°07′N/38°43′-38°56′E	440	1636 (1635)	20	29	9	2.5	$1.1x10^9$	7025	163	Maki, Katar, hot springs
Hawassa	6°58 ′-7°07′N/38°22′-38°29′E	80	(1680)	11	17	22	10.0	$1.3x10^9$	1250	220	TekurWoha[2]
Abaya	6°02′-6°37′N/37°40′-38°06′E	1140	1285 (1179)	29	70	13	7.0	$8.2x10^9$	17300	505	Greater Bilate[3], Lesser Bilate[4], Hamassa[5], Rai[6], hot 40 springs, others
Chamo	5°43′-5°59′N/37°32′-37°45′E	317	1233 (1113)	23	36	13	nd	nd	2220	535	Kulfo[7] and others
Langano	7°32′-7°43′N/38°42′-38°50′E	230	1582 (1570)	16	23	46	17.0	$3.8x10^9$	1600	190	Huluka[8], Jirma, Kersa, Gedemso, Lepis, hot springs
Shala	7°24′-7°33′N/38°23′-38°39′E	370	1558 (1560)	17	27	266	87	$37x10^9$	2700	170	AwadeGodu, Guta, Gidu, Adabar, hot springs[9]
Abijata	7°33′-7°43′N/38°27′-38°40′E	176	1578 (1579)			14	7.6	$3.8x10^9$	10740	175	Bulbula[10], HoraKello, Gogessa
Chitu	7°24′13.2″N/38°25′26.6″E	0.8	(1566)	nd	nd	20.5	nd	nd	nd	180	Onshore hot springs[11]

[3]N07°05'29.2"/E38028'55.8", elevation: 1692masl
[4]N07°17'08.8"/E38004'21.5", elevation: 1718masl
[5]GPS Coordinates not taken, but found about 2 km south of Greater Belate River along the main road.
[6]N06°34'18.1"/E37049'23.0", elevation: 1260masl
[7]N06°27'35.4"/E37024'43.6", elevation: 1224masl
[8]N06°02'10.15"/E37034'02.4", elevation: 1216masl
[9]N07°29'10.7"/E38043'27.0", elevation: 1639masl as one heads eastwards from River Huluka along the Asela Road; one finds Rivers Jirma, Kersa, Gedemso, and Lepis a few km apart from each other.
[10]N07°28'40.9"/E38038'06.0", elevation 1567 (eastern shore) and N07025'3.81"/E38026'18", elevation 1560masl western shore)
[11]N07°43'/38043', elevation: 1700masl; River HoraKelo is found some 12 km southwards.
[12]N07°24'13.2"/E38025'26.6", elevation 1566masl

Phytoplankton

With increase in salinity-alkalinity, the diversity of phytoplankton changes to a few tolerant species, as it will be seen in the cases of lakes Abijata and Chitui (Wood and Talling, 1988; Zinabu GebreMariam and Taylor, 1997; Elizabeth Kebede and Willen, 1998).

Table 2.23 shows the list of most common phytoplankton recorded in a salinity-alkalinity series of Ethiopian rift Valley lakes (after Tudorancea and Taylor, 2002).

Table 2. 23: List of phytoplankton species recorded in the Rift Valley lakes basin

Phytoplankton	Lakes in Salinity Alkalinity Series							
	Zwai	Hawassa	Abaya	Chamo	Langano	Shala	Abijata	Chitu
Cyanophyceae								
Aphanocapsa elachista				P				
A. elachista v. plancronica		P						
Merismopedia punctata		P						
Microcystis aeruginosa	P	P	P	P	P			
M. wesenbergii		P						
Myxobactron sp.	P							
Radiocystis geminate	P	P						
Synechococcus elegans		P						
Anabaena aphanizomendiodes	P			P				
A. compacta				P				
Anabaenopsis abijatae							P	
A. elenkinii				P				
Arthrospira fusiformis							P	P
Cylindrospermopsis africana	P	P						
Limnothrix planctonica				P				
Planktolyngbya limnetica	P	P						
P. nyassae	P	P						
P. tallyingii	P	P						
Pseudanabaena limnetica			P					
P. moniliformis			P					
Raphidiopsis curvata				P				
Spirulina laxissima		P						
Cryptophceae								
Gymnodinium spp.	P	P			P			
Peridinium umbonatum					P			
Chrysophyceae								
Mallomonas sp.					P			
Diatomophyceae								
Aulacoseira granulate	P							
Cyclotella sp.				P				
Stephanodiscus sp.	P							
Thalassiosira rudolfi					P	P		
Navicula spp.	P	P						
Nitzschia subacicularis						P		

Phytoplankton	Lakes in Salinity Alkalinity Series							
	Zwai	Hawassa	Abaya	Chamo	Langano	Shala	Abijata	Chitu
Charophyceae								
Cosmarium contractum		P						
C. variolatum				P				
Staurastrum tetracerum	P	P						
Chlorophyceae								
Botryococcus braunii	P							
Monoraphidium sp.				P				
Oocystis spp.		P		P			P	
Pediastrum borynum	P							
P. duplex	P	P						
P. tetras				P				
Scenedesmus spp.	P	P		P				
Tetraedron minimum		P						
Coccoids	P							
Dunaliella sp.							P	
Euglenophyceae								
Phacus spp.	P	P	P	P	P			
Euglena spp.	P	P	P	P	P			
Flagellata spp.	P							

Zooplankton

The diversity and composition of zooplankton in tropical Africa is also a reflection of the salinity-alkalinity series of lakes, the impact of predation by fishes and climatic conditions that keep lakes open to predation effect the year round (Nilssen, 1984; Green and Seyoum Mengistu, 1991; Fernando, 1994; and Brook Lemma, 2001).

In the tropics, including the Ethiopian rift valley lakes, where water temperature is always high, fish predation activity on zooplankton is high throughout the year. When macrozooplankton (e.g. *D. Barbata*) are removed by fish, grazing pressure of zooplankton on phytoplankton becomes low. The elimination of macrozooplankton results in increase of phytoplankton biomass and diversity, which is assisted by nutrient inputs from extensive uncontrolled fertilizer use in the watersheds (Tudorancea and Taylor, 2002; Brook Lemma, 2001).

As a result of combinations of the above factors in waters of the Ethiopian Rift Valley lakes:

- Cladocerans are generally absent in saline lakes (Shala, Abijata and Chitu) (Green and Seyoum Mengistu, 1991).

- Rotifers are generally abundant in the Ethiopian Rift Valley lakes as a response to year-round predation by fishes on macrozooplankton (Brook Lemma, 2007).
- Rotifers exhibit a marked deduction in species in salinity over 2 mgL^{-1} (Shala, Abijata and Chitu) (Green and Seyoum Mengistu, 1991).
- Cladocerans of freshwater lakes such as Zwai, Hawassa, Abaya, Chamo and Langano, are dominated by small-bodied forms such as *Bosmina*, *Ceriodaphnia*, *Diaphanosoma* and *Moina* (Green and Seyoum Mengistu, 1991 and Brook Lemma current observations).
- Although large-bodied calanoids are generally absent in the Ethiopian Rift Valley lakes mainly due to predation pressures by fishes such as *Barbus* spp. and *O. niloticus*, *Lovenula africana* (synonymous with *Paradiaptomus africanus*) is widely distributed and maybe the only planktonic crustacean in saline lakes (Tudorancea and Taylor, 2002; Brook Lemma, 2008b).
- Small-bodied cyclopoids such as *Africocyclops*, *Thermocyclops*, *Eucyclops* and *paracyclops* are common in freshwater lakes such as Zwai, Hawassa, Abaya, Chamo and Langano (Defaye, 1988).
- As stated above the large-bodied cladoceran *D. Barbata* appears rarely in the freshwaters of the Ethiopian Rift Valley depending on the availability of some form of refuge be it in the form of siltation (high turbidity), dense macrophytes, or darker depths where these organisms have to do some trade-off to survive (Brook Lemma, 2007).

Macroinvertebrates (benthic fauna)

The existing literature indicates the presence of 87 genera of benthic invertebrates in the benthos of the rift lakes. Table 2.24 shows some of the major invertebrates and the lakes in which they are found. At this point, it is difficult to draw conclusions on the relations between the abundance of invertebrates and the salinity-alkalinity series of the lakes.

The most common benthic fauna recorded from the Ethiopian Rift valley lakes are shown in Table 2.24. (Tudorancea *et al.,* 1989; Tilahun Kibret and Harrison, 1989; Eyualem Abebe and Coomans, 1996a-d; Balemwal Atnafu and Russo, 2004).

Table 2. 24: List of zoobentos recorded from Rift Valley lakes basin (after several authors)

Invertebrates	Zwai	Hawassa	Abaya	Langano	Chamo	Shala	Abijata	Chitu
Nematoda								
Monhystera stagnalis	P	P	P		P			
Brevitobrilus graciloides	P	P			P		P	
Dorylaimus sp.	P		P	P	P			
Mesodorylaimus macrospiculum						P	P	
Ironus tenuicaudatus	P		P					
Oligochaeta								
Tubificidae	P	P	P	P	P	P	P	
Gastropoda								
Melanoides tuberculata	P				P			
Ostracoda								
Limnocythere thomasi	P							
L. borisi		P	P	P		P		
Gomphocythere angulata	P	P				P		
Darwinula stevensoni	P	P	P	P	P	P		
Chironomidae	P	P	P	P	P	P	P	
Tanypodinae	P	P	P	P	P			
Chironominae	P	P	P	P	P	P	P	
Stictochironomus caffraius	P	P	P	P	P			
Nilodorum spp.	P	P		P				
Kiefferulus disparilis				P		P	P	
Cladotanytarsus pseudomancus	P	P		P	P	P	P	
Microchironomus deribae			P	P	P	P	P	
Ephydridae								P

Fishes

The rift valley lakes of Ethiopia share many species of fish. This is one of the indications that they have been united into one or a few major water body back in their geologic history. Despite this fact, since their separation and continuous regression into smaller pockets, they have their own uniqueness in fish species diversity. In general, the northern lakes, namely, Zwai, Langano and Hawassa, share more similar species while the southern lakes, namely, Abaya and Chamo, share a different set of fishes. The latter two lakes show this diversity (Table 2.25), since they have stayed longer together and shared waters with lakes of East Africa.

The three saline-alkaline lakes, namely, Abijata, Shala and Chitu, do not apparently show diversity in fish species. Lake Abijata used to have quite substantial amount of *Oreochromis niloticus* stocks. In recent years fishermen and fish eating birds are not seen on the lake. Quite recently, Klemperer and Cash (2007) reported that small-sized fishes of *Apocheilichthyes antinorii* in addition to *Oreochromis niloticus* were observed dead on the water surface of Lake Shala after underwater borehole detonations.

In addition to this, there are some games people played in moving some species such as *Clarias gariepinus* (the African catfish), *Tilapia zillii* and *Cyprinus carpio* (the common carp) from one system to the other with the purpose of adding value to the exploitation of unoccupied niches to increase in fishery productivity.

Table 2. 25: List of fish species recorded from Rift Valley lakes basin (after several sources)

Fish species	Zwai	Hawassa	Langano	Abaya	Chamo	Shala	Abijata	Chitu
Famiy Mormyridae								
Mormyrus caschive				+	+			
Hyperopisus bebe				+				
Marcusenius cyprinoides				+				
Family Characidae								
Hydrocynus forskahlii				+	+			
Family Cyprinidae								
Barbus bynni				+	+			
B. ethiopicus	e							
B. intermidius	+	+	+	+	+			
B. kerstennii				+	+			
B. paludinosus	+	+	+					
B. stigmatopygus				+	+			
Carassius carassius	+							
C. auratus	+							
Cyprinus carpio	+	+	+	+	+			
Garra makiensis	e							
G. hirticeps	+	+		+	+			
G. quadrimaculata	+			+	+			
G. dembecha	+							
Labeo cylindericus				+	+			
L. horie				+	+			
L. niloticus				+	+			
L. varicorhinus				+	+			
Family Bagridae								
Bagrus docmak				+	+			
Family Schilbeidae				+	+			
Schilbe intermidius				+				
Family Clariidae								
Clarius gariepinus	+	+	+	+	+			

Fish species	Zwai	Hawassa	Langano	Abaya	Chamo	Shala	Abijata	Chitu
Family Machokidae								
Synodontis schall				+	+			
Family Cyprinodontidae								
Aplheilichthys aninorii	+	+	+		+			
Lebias dispar	+							
Family Centropomidae								
Lates niloticus				+	+			
Family Cichlidae								
Oreochromis niloticus	+	+	+	+	+	+	+	
Tilapia zillii	+	+	+	+	+			
Family Poeciliidae								
Aplocheilichthyes antinorii						+		
Total native species (77)	**15**	**8**	**7**	**23**	**22**	**1**	**1**	**---**

"**+**" sign indicates presence of fish species and "**e**" is for species that are endemic to that water body. (Sources: Tudorancea and Taylor, 2002; Klemperer and Cash, 2007; Redeat Habteselassie, 2012; and Vijverberg *et al.*, 2012)

Lakes from Zwai down to Hawassa show similarities in the fish diversity that thrive in them, while Abaya and Chamo that have been separated from the rest long show similarities not among each other only but also to the rest of the rift valley lakes southwards.

Reptiles

Among the reptiles, crocodiles used to be very common in the Ethiopian Rift Valley lakes. These have been hunted out for their skins during the Emperor's times by a European company called Doffan. Presently, crocodiles are seen in Abaya and Chamo only (Plate 2.33). They are particularly abundant and find their sanctuary at Lake Chamo, specifically at the mouth of River Kulfo, one of the feeder rivers that comes from the Chencha Mountains west of the lake. Presently, this particular spot is known as Crocodile Market. Another development with crocodiles is the establishment of crocodile farm on the shores of Lake Abaya where they are reared for their skins alone, and their meat is recycled to feed young crocodiles in the same farm. This farm obtains seeds from Crocodile Market at Lake Chamo, where juvenile crocodiles emerge from the sand in which the mother crocodile has buried its eggs.

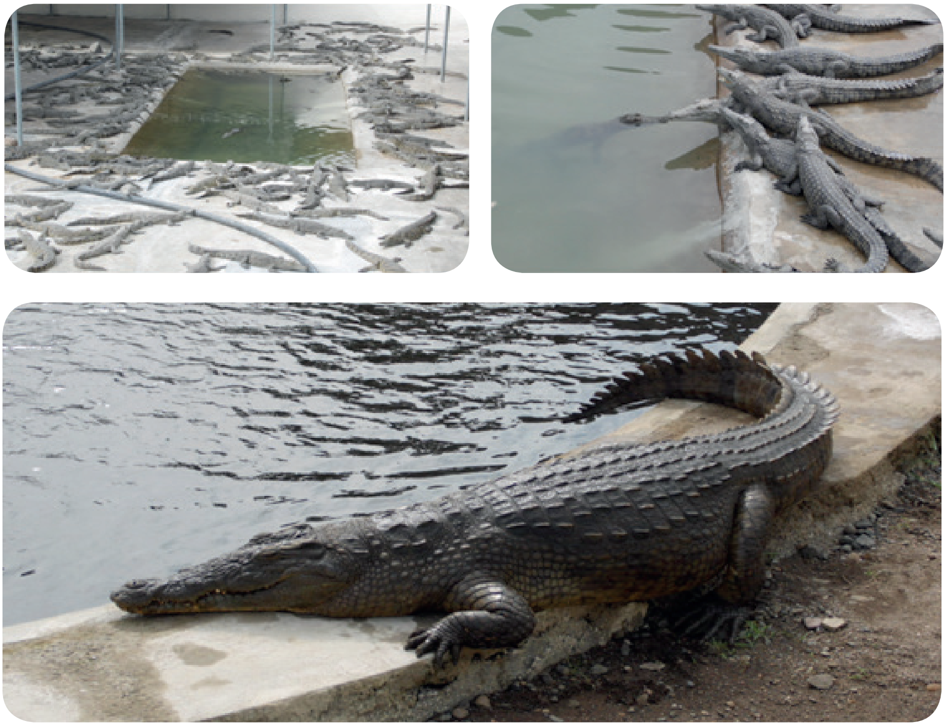


Plate 2. 32: Some features of the crocodile farm on the shores of Lake Abaya (Photo credit: Brook Lemma)

Nile monitor (*Varanus niloticus*) shown below in Plate 2.34 is also common in the rift lakes of Ethiopia and elsewhere in other lakes and rivers of Ethiopia. These as well are being taken out by constant loss of habitat and that hostile attitude of people to kill them whenever they surface mainly because of the misconception that they are "ugly" and "they are dangerous to people".

Plate 2. 33: An aquatic reptile (Nile monitor: Varanus niloticus) found on the shores of Lake Zwai (Photo credit: Brook Lemma)

Birds

Lake Zwai supports over 20,000 water birds (Birdlife International, 2013). The most common species are *Pelecanus onocrotalus*, *Phalacrocorax lucidus*, *Scopus umbretta*, *Chroicocephalus cirrocephalus*, *Threskiornis aethiopicus*, *Chlidonias leucopterus*, *Leptoptilos crumeniferus*, *Haliaeetus vocifer*, etc. The Lake's ecosystem serves as breeding and wintering ground and as a migration stopover habitat for several resident and migratory bird species. It is one of the best sites in Ethiopia to see a diversity of bird species. Lakes like, Zwai Abaya and Chamo have islands which serve as refuge for birds. An island known as Birds' Island in Lake Zwai is a safe refuge to the birds and hence it is popular in the ornithological literature. Again, Lakes such as Shalla, Chitu and Abijata are visited each day by thousands of flamingoes and spoonbills, owing to almost monoculture populations *Arthrospira fusiformes* (*Spirulina*) in these lakes on which these two bird species feed on.

About 80 wetland birds and 24 Palearctic migrants are reported by several workers in and around the rift valley lakes. Of these birds, four are endemic recorded from the woodlands nearby. They are yellow-fronted Parrot *Poicephalus flavifrons*, Black-winged Lovebird *Agapornis taranta,* Banded Barbet *Lybius undatus* and Forest Oriole, *Oriolus monacha.* Wetland birds including the following are frequently observed in the lake, namely, Egyptian Goose, *Alopochen aegyptiacus,* Pygmy Goose, *Nettapus coromandelianus,* White-faced Wistling Duck, *Dendrocygna viduata,* Spur-winged Goose, *Dendrocygna viduata,* Knob-billed Duck, Red-knobbed Coot, *Sarkidiornis melanotos* and African Fish Eagle, *Haliaeetus vocifer* are seen in lake Hawassa and they are very common in other lakes of the country (see Pattnaik, 2014).

The rift valley lakes of Ethiopia then show two major groups of bird watching sites with the freshwater systems of Zwai, Langano, Hawassa, Ababaya and Chamo providing habitats and north-south migration corridors to the birds mention above in connection to Lake Zwai. The second group of lakes that are highly saline-alkaline, namely, Abijata, Shalla and Chitu provide the same services to flamingoes and spoonbills for reasons of their rich supply of *Arthrospira fusifomes* which these birds enjoy feeding while on their north-south migration routes.

Mammals

Much like the case of crocodiles, hippopotamus used to be widespread in the Ethiopian Rift Valley lakes. Presently, they are found in Lakes Zwai Hawassa and Chamo only. In all these lakes they are restricted to certain specific sites where they find sanctuary in quieter corners of the respective lakes. In Lake Zwai they are found in the north-western corner of the lake while in Hawassa they are found in the northern corner at the entrance of River Tekur Wuha (N07^{0}05'29.2"/ E38^{0}28'55.8", elevation: 1692 masl) into Lake Hawassa. At this spot the river entrance poses some difficulties for human interference and along the same shore there is a small protected (fenced) forest area, which is now used as a park.

At Lake Chamo, the hippopotamus share some sector of the Crocodile Market at the mouth of Kulfo River (N06^{0}02'10.15"/E37^{0}34'02.4" elevation 1216 masl) and extend in the direction of the NechSar National Park in the north-eastern direction. The fate of hippopotamus in the Ethiopian Rift Valley lakes seems to be in a very precarious situation just like the reptiles.

Generally, the RV lakes can be grouped into two - Lakes Zwai, Hawassa, Langano, Abaya and Chamo make the freshwater series while Lakes Shala, Abijata and Chitu make the saline-alkaline series.

Water quality of the rift valley lakes

Extensive studies of the water chemistry of the Ethiopian Rift valley lakes have been made in the past. These studies resulted in the classification of the same according to their salinity-alkalinity series. Freshwater lakes with salinity < 0.5 g L^{-1} include Lake Zwai subsaline lakes with salinity between 0.5 – 3 g L^{-1} include Lakes Hawassa, Abaya, Chamo and Langano while the saline lakes, with salinity between 3–20 g L^{-1} include Lakes Shala, Abijata and Chitu. Detailed water chemistry data for the Rift Valley lakes, compiled from several sources, are given in Table 2.26. The salinity-alkalinity series of the Ethiopian Rift Valley lakes follows that of several authors (Elizabeth Kebede *et al.*, 1994; Tudorancea and Taylor, 2002) and figures in bracket are original data by Brook Lemma, 2011.

Table 2. 26: Water chemistry of lakes and rivers in the Ethiopian Rift Valley

(Sources: Bauman *et al.*, 1975; Wood and Talling, 1988; Elizabeth Kebede *et al.*, 1994; Haile Gashaw, 1999; Zinabu GebreMariam, 2002; Zinabu GebreMariam and Pearce, 2003; and Girum Tamire and Seyoum Mengistou, 2012) (nd: No data and bd: below detection and data with * are in mg L^{-1}).

Lakes/Rivers	Cond. (µScm^{-1})	pH	Salinity (gL^{-1})	Cations (meqL^{-1})	Anions (meqL^{-1})	Na^+ (meqL^{-1})	K^+ (meqL^{-1})	Ca^{++} (meqL^{-1})	HCO_3^- $+CO_3^{2-}$ (meqL^{-1})	Mg^{2+} (meqL^{-1})	Alkalinity (meqL^{-1})	Cl^- (meqL)	SO_4^{2-} (meqL)	NO_x^- (µgL)	NH_x^+ (µgL)	SRP (µgL)	SiO_2 (mgL)
L. Abaya	1000	8.8	0.833	10.695	10.788	9.344	0.397	0.621	9.37	0.333	8.655	1.736	0.397	47	32.3	187.9	18
L. Abijata	49100	9.9	19.049	328.08	320.392	326.442	7.484	0.092	325	0.024	231.551	83.404	5.437	9.5	36	1009.4	81.4
L. Chamo	1620	9.2	1.213	15.704	16.242	14.256	0.57	0.372	12	0.553	13.266	2.761	0.21	27.3	20.9	14.8	1.7
L. Chitu	50000	10.0	44.9	895	693	864	31.2	0.16	573	573	581	99	21.1	bd	35	2347	222
L. Hawassa	820	8.4	0.735	8.761	8.837	6.851	0.936	0.508	8.25	0.479	7.795	0.791	0.25	20.6	179.2	18.8	40.1
L. Langano	1750	9.3	1.461	17.267	17.449	16.284	0.535	0.251	12.5	0.197	12.249	4.792	0.409	64.8	8.5	16.4	30.7
L. Shala	23000	9.8	18.627	294.740	307.316	289.091	5.491	0.114	218	0.042	217.322	84.859	6.419	1.7	9.3	951.7	45.6
L. Zwai	400	9.0	0.375	4.514	4.61	2.745	0.277	0.802	4	0.69	4.098	0.387	0.124	13.6	297	59.1	22.9
R. Bilate	76	7.5	0.079	0.927	1.013	0.304	0.156	0.3	0.9	0.167	0.87	0.143	0	nd	nd	nd	nd
R. Bulbula	425	7.9	0.965	12.401	12.408	10.599	0.475	0.788	9.4	0.54	9.373	2.827	0.209	nd	nd	nd	nd
R. Horakelo	4462	9.1	2.323	35.52	38.933	34.3	0.778	0.269	27	0.174	27	9.244	1.048	nd	nd	nd	nd
R. Katar	203	7.9	Nd	nd	nd	5*	4*	30*	nd	3.67*	nd	4.6*	nd	33.8	56.5	29.1	nd
R. Kulfo	85	7.7	0.089	1.25	1.11	0.23	0.05	0.55	nd	0.42	1.02	0.09	0	nd	nd	nd	nd
R. Meki	451	7.8	0.285	nd	nd	2.3	0.2	1	3.4	0.8		0.5	0.3	nd	nd	nd	nd
R. Tikurwuha	743.2	7.2	0.46	6.81	7.066	5.405	0.506	0.586	6.1	0.312	6.077	0.733	0.204	nd	nd	nd	nd

2.10.1.1. Wetlands in the ONRS

Fig. 2.37 shows the lakes and rivers found in the RVL basin and the ones distributed in the Regions of Oromia and SNNP. The basin is dominated more by lakes which also constitute the majority of lakes found in Ethiopia.

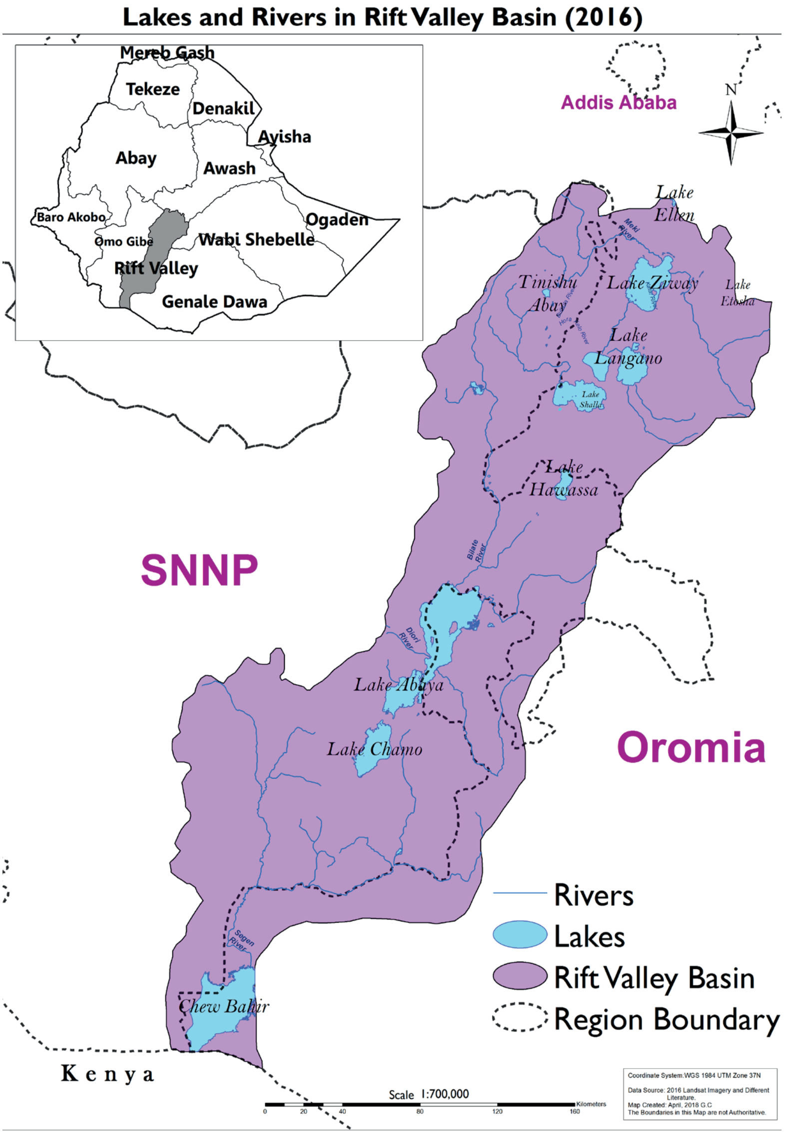


Figure 2. 37: Lakes and rivers in the RVL basin

2.10.1.1.1. Lakes and rivers in the ONRS

2.10.1.1.1.1. Lake Zwai

Located in the Ethiopian Rift Valley, Lake Zwai (also referred to as Zwai or Zeway in the literature) is a freshwater wetland that shares the shoreline of the lake with the woredas of Adami Tulu, Jido Kombolcha, Dugada Bora, and Zwai Dugda. The town of Zwai (now renamed as Batu) lies on the lake's western shore, extending along that shoreline and growing at a very fast rate in recent years. Besides seasonal runoffs and groundwater movement favoring the lake, it is also fed by two rivers, namely, the **Meki** from the west and the **Katar** from the east, and is drained by River Bulbula which feeds Lake Abijata to the south. The catchment of this lake has an area of 7025 km^2 (Mepham, *et al.*, 1992) and the lake lies at an altitude of 1,635 masl.

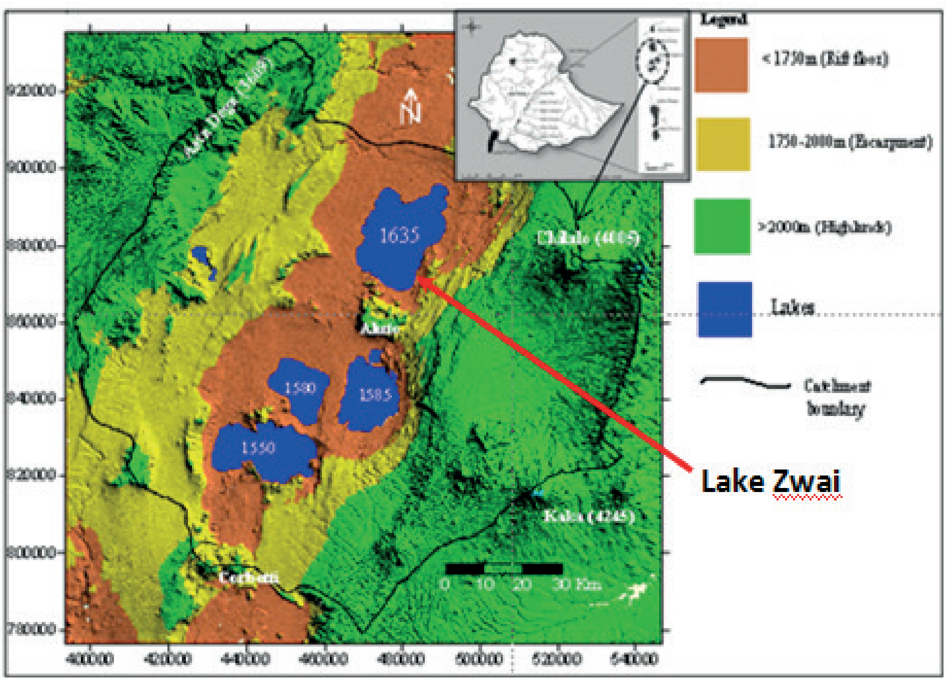


Figure 2. 38: Zwai-Shala Basin

Lake Zwai is shown at an altitude of 1635 masl, Lake Langano at 1585 masl, Lake Abijata at 1580 masl and Lake Shala at 1550 masl. The black line around the lake shows the watershed of the basin (Fig. 2.38).

Lake Zwai is 31 km long and 20 km wide, with a surface area of 440 km². It has a maximum depth of 9 meters (Seleshi Bekele Awulachew *et al.*, 2007; and NMSA, 1996). It has several islands which include Debre Sina, Galila, Birds' Island and Tulu Gudo. On the latter island, there is a monastery very recently renovated, which is believed to have housed the Ark of the Covenant around the ninth century during its plight from the Lake Tana islands (Hancock, 1992).

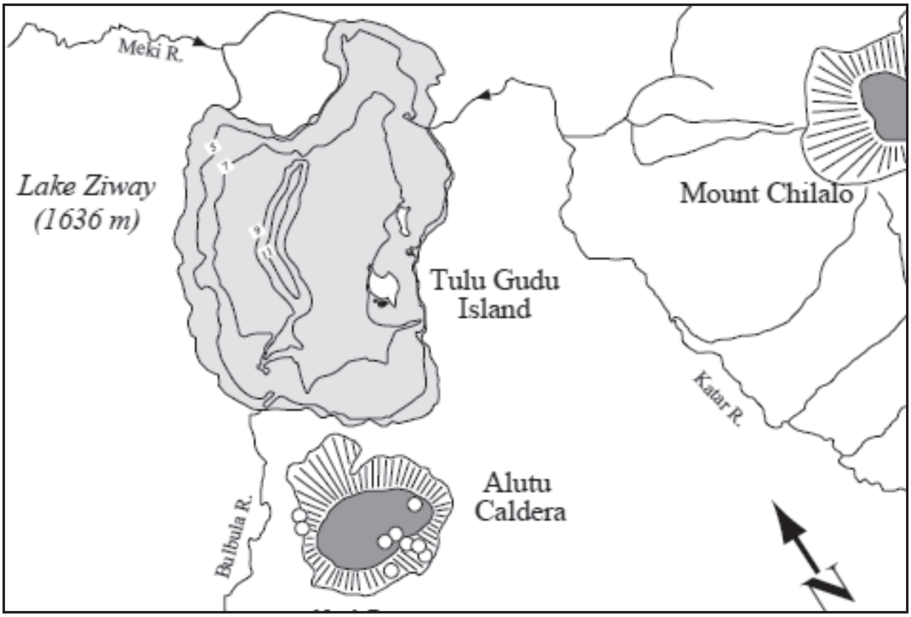


Figure 2. 39: Bathymetric map of Lake Zwai

(Hydrothermal springs in and around the lake discharge 10 to 0.25 L Sec^{-1}; after Turdu *et al.*, 1999).

As indicated above, this lake has attracted the attentions of many researchers such as historians, ornithologists, fishery biologists, limnologists and tourists with eyes of diverse interests. There are reports that numerous birds, hippopotamus, fish species and others thrive in it with generations of people making their livelihoods in and around it. The Ethiopian Department of Fisheries and Aquaculture at the Ministry of Agriculture reported that 2,454 tons of fish are landed each year, which the department estimates is 83% of its sustainable amount (Fisheries Management in the Federal Democratic Republic of Ethiopia, 2003; and Brook Lemma, 2012).

Lake Zwai has great geochemical and hydrological significance not only to its immediate watershed but also far beyond to the lakes, namely, Langano, Abijata and Shala (Shalla), which are all found at lower altitudes southwards along the main road into the Ethiopian Rift Valley (Fig. 2.37 and 2.38). River Bulbula is an overflow from L. Zwai feeding Lake Abijata with its volume very much decreasing during the dry season. The groundwater movement flows from Lake Zwai along the north-south gradient feeding Lakes Langano, Abijata and Shala, with the latter being the final recipient (Tenalem Ayenew, 1996 and Zerihun Woldu *et al.*, 2005). It has been shown that any event that may happen at L. Zwai and its watershed is felt in the other lakes due to these surface and underground hydrological linkages. For instance, recent water level fluctuations at L. Zwai (e.g. the drying of R. Meki resulted in the drop of the water level at L. Zwai far below the spillway to R. Bulbula) that resulted in complete drying of River Bulbula and hence the shrinking of the shallow and highly eutrophic saline-alkaline Lake Abijata (Falcon *et al.*, 1975; Jansen *et al.*, 2007) (see Fig 2.40).

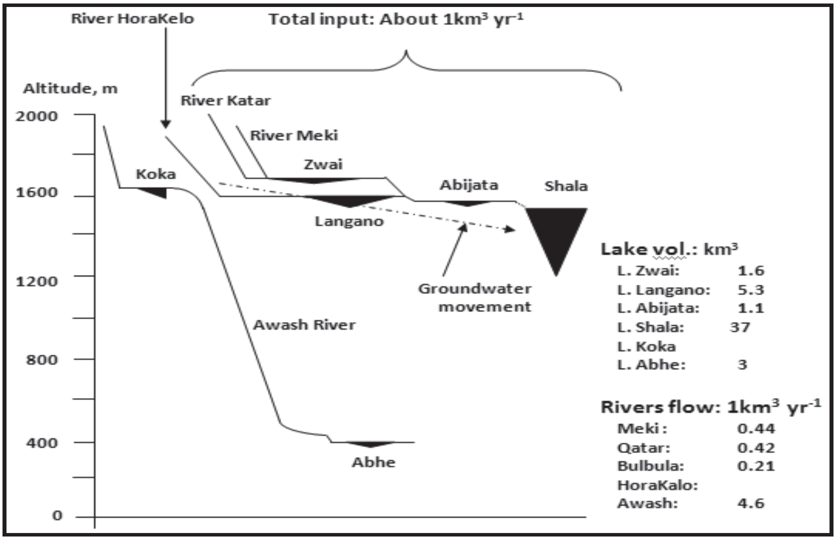


Figure 2. 40: Hydrological relations of the lakes in Zwai-Shala Basin and the role of Lake Zwai

The Koka-Abbe Basin does not seem to have hydrological relations with the Zwai-Shala Basin despite its seemingly geographical closeness (modified after Wood and Talling, 1988).

Plate 2. 34: One of the hot springs on the shores of Lake Zwai at Tulu Gudo Island, which is also used as holy water by the monastery on the same island Abaya (Photo credit: Brook Lemma)

A couple of the islands in Lake Zwai host monasteries that are historical and once sheltered the Arc of the Covenant that has allegedly come from Israel. This is particularly true for the monastery on Tulu Gudo Island. The monasteries in Zwai have become big attractions for national and international believers and tourists.

Water quality

Physically, Lake Zwai is highly turbid with Seechi depth less than 20 cm. This is mainly due to extensive agricultural practices that removed the land cover, in most cases right up to the shoreline (Tenalem Ayenew, 2007). As a result, light penetration is very low limiting phytoplankton productivity and encouraging the growth of macrophytes or large aquatic plants. This is highly encouraged by the silt deposit that is washed into the lake by runoff and which is highly loaded with nutrients and seepage with ground water. Water temperature ranged between 23^0C to 21.5^0C with the higher temperature measurement made at the water surface and the lowest at 3m depth[2].

Lake Zwai had dissolved oxygen ranging between 9.0 and 8.2 mgL^{-1} with the lowest measurement recorded at 3m depth. Electrical conductivity was low ranging between 400-480 $mScm^{-1}$ as expected for a freshwater system whose water has very short resident time as described above with the feeder and draining rivers (Meki, Katar and Bulbula). pH was 9.2 indicating the alkaline nature of the lake.

Among many, the most common phytoplankton in Lake Zeal are:

Phytoplankton
Cyanophyceae
Microcystis aeruginosa, Chroococus spp., Anabaena spp.
Chlorophyceae
Scenedesmus spp., Pediastrum spp.,
Charophyceae
Cosmarium spp.
Diatomophyceae
Aulacoseira spp. Nitzschia spp. Cyclotella spp., Navicula spp.
Euglinophyceae
Euglena spp. Phacus spp., Strambomonas spp., Thrachelomonas spp.
Dinophyceae
Peridinium spp.

This scenario is being changed by constant inflow of nutrients from the extensive agricultural practices in that watershed including the flower farms located on the western shore of Lake Zwai. In recent years the phytoplankton community is slowly changing to the dominance of Cyanobacteria such as *Microcystis* spp. This happens to be the case with most Ethiopian waters as situations are changing in

2 Coordinates of 3 measurement sites: N07^0 56.5' and E38^0 44.05' elevation 1636m; N07^0 56.510' and 07^0 54.7' E38^0 45.15'. Note: These coordinates corroborate with the seismic lines given in the concession map.

the country with extensive development work coupled with increasing population and variability in climate patterns (Elizabeth Kebede and Willen 1998, Willen 2011). In other words, the appearance of the above species is highly associated with the amount of nutrients and organic wastes entering the lake.

Zooplankton

The zooplankton community of Lake Zwai and the rest of the Ethiopian Rift Valley lakes in general are reflections of the tropical African freshwater systems modified by altitude and salinity-alkalinity series (Green and Seyoum Mengistu, 1991). In addition to that, the absence of cladocerans or their representation by the small-sized species is associated with the versatile feeding habits of the fish assemblages and their year-round predation assisted by high temperature (Brook Lemma, 1997; 2001; 2007). Despite this, one can rarely find *Daphnia barbata* in Lake Zwai and some other Ethiopian lakes where water turbidity has increased making Seechi depth as shallow as 20 cm or less. This provides macrozooplankton such as *D. barbata* refuge from visual predation by fishes such as *Oreochromis niloticus* (from Brook Lemma current research on Lake Zwai).

The major zooplankton species found in Lake Zwai belong to the following genera:

Cladocera
Daphnia barbata (very limited in biomass, limited to turbid periods and specific depths)
Diapohanosma, Ceriodaphnia, Moina
Copepoda
Thermocyclops, Eucyclops
Rotifera
Brachionus, Asplanchna, Lecane, Polyarthra, Hexarthra, Filinia

As with the phytoplankton, the diversity of zooplankton thins out as the salinity-alkalinity series increases from such freshwater systems as Zwai to the highly saline lakes, such as Chitu (Wood and Talling, 1988).

Fishes and fisheries

The fish species that are thriving in Lake Zwai are listed below (Vijverberg *et al.*, 2012). All of the these species, except *Tilapia zillii*, whose breeding habitats are associated with migration upstream into the feeder rivers of Meki and Katar are believed to have disappeared or severely in danger of disappearance due to disturbance of the riverine ecology by agricultural practices, excessive load of organic wastes and turbidity of the waters. *Tilapia zillii* is mostly a macrophyte feeder whose limnetic life is severely hampered by changes in the aquatic vegetation due to farming up to the shoreline, water abstraction and removal of aquatic vegetation for various human services that generate some immediate income (e.g. animal feed, making various handicrafts, etc.).

Oreochromis niloticus (Nile tilapia)

Clarius gariepinus (The African catfish)

Cyprinus carpio (Common carp)

*Tilapia zillii**

Carassius carassius

Carassius auratus

*Barbus ethiopicus**(endemic species)

*Barbus paludinosus**

*Barbus microterolepis**

*Garra dembecha**

*Garra makiensis** (endemic species)

*Labeobarbus intermidius**

Recent observations to the fishery at Lake Zwai indicate that *Carassius* spp., too, are appearing more frequently. Generally, fisheries practices are declining at Lake Zwai and it is not uncommon to see fishermen looking for other ways of livelihoods. For women, even in these specializations they are not property owners and their ability to compete and influence in decision-making is severely curtailed (Brook Lemma, 2012).

Other fauna of Lake Zwai

Lake Zwai is also popular for the numerous birds that visit it (see above discussion on general rift valley lakes). In addition to the high productivity of the lake, its position in the African rift valley system places it on the route of north-south bird migration route. As a result, the list of birds that can be encountered at Lake Zwai would be the highest from among the Ethiopian Rift Valley lakes, as this lake stands on the corridor of north-south migration routes. The fact that there is a bird sanctuary island in Lake Zwai by the name Birds' Island indicates that many birds reside in this system or transit by it.

Lake Zwai is also home for hippopotamus which are very easily seen at any time of day. Coupled with the birds, the hippopotamus also provide reason to attract tourists to visit it.

Aquatic vegetation

As indicated in Table 2.27, numerous aquatic vegetation ranging from grasses to vascular plants are found along the shores and on the islands of the lake (Girum Tamire and Seyoum Mengistou, 2012).

Table 2. 27: Macrophytes of Lake Zwai (Matagi 2005, Girum Tamire and Seyoum Mengistou, 2012)

Macrophyte groups	Identified species
Emergent macrophytes	*Arundo donax*
	Echinochloa colona
	Cyperus articulates
	C. papyrus
	Typha latifolia
	Schoenoplectus corymbosus
	Echinochloa stagnina
	Persicaria senegalensis
	Ludwigia erecta
	L. stolonifera
Rooted and free-floating macrophytes	*Nymphaea lotus*
	Nymphoides indica
	Pistia stratiotes
Submerged macrophyte	*Potamogeton schweinfurthii*

In addition to the above, there are a number of flowering-rooted trees in the shore areas forming mangroves. These trees dominated by *Aeschynomene elephroxylon* whose stems are under water in the rainy seasons when the lake-level rises. There are also times when the water regresses and the trees are left in the moist shorelines. These diverse higher plans provide sanctuary to many birds, fishes when the water level flows between the trees, and generally reduce soil erosion by firmly holding on the ground.

With increasing sediment inflow into the lake from the farmlands in the watershed, Lake Zwai is likely to get shallow allowing the growth of macrophytes further inwards into the pelagic zone.

The vegetation on the islands described by Haileab Zegeye *et al.* (2006) are very good indications of what was available in the watershed of Lake Zwai. With apparently all of the watershed vegetation replaced by agriculture fields, people are now turning to the islands for collection of construction and fire wood (Plate 2.36).

Plate 2. 35: A resident of Zwai town collecting firewood from Gelila Island of Zwai (Photo credit: Brook Lemma)

Ecosystem services and ecological status of Lake Zwai

In recent years, L. Zwai and its watershed are experiencing increasing investment in the direction of expansion of irrigated agriculture particularly in horticultural crops (cut-flowers, vegetables, etc.) that have quick returns with good accessible roads to the huge market in Addis Ababa. People seem to close in on the fresh waters of L. Zwai and the town of the same name in search of jobs. There is also remarkable increase in fresh water abstraction for irrigation and other industrial functions. With free access policy of the government to wetland resources (fishes, aquatic vegetation, water withdrawal, etc.), it is difficult to know exactly the quantity, types and sizes of fish caught each year. The same applies to the quantities of water abstracted and vegetation harvested by the local people and the agricultural and industrial ventures operating in the watershed. Service industries, such as hotels and resort centers, are rushing to get hold of land along the shoreline and on the islands of the lake that have attractive sceneries for tourists.

The lake water is also being pumped out to supply Zwai town for drinking and other household functions. Studies have shown that groundwater in the watershed is loaded with fluoride, making it unfit for drinking and cooking; mainly due to dissolution from volcanic rocks, magnetic fluids and low concentration of calcium ions (Haile Gashaw, 1999). The city administration has therefore shifted to the use of lake water for household supply. The lake also serves as treatment plant for all sorts of wastes that drain into it from the towns, villages and farm lands in the watershed. This same aquatic system is being used for animal watering, human consumption, bathing and recreational purposes.

2.10.1.1.1.2. Lake Langano

Lake Langano (Langeno) is located at 8 ^{0} 12’N, 37 ^{0} 23’ E and is one of the rift valley lakes frequented for recreational activities by people from Addis Ababa and other parts of the country.

Biophysical characteristics

By surface area, almost half the size of Lake Zwai Lake Langano has surface area of 230km^2 and a maximum depth of 46m. It has reddish brown water, which is attributed to high amount of silt containing iron compounds (Talling and Talling, 1965 and Wood and Talling, 1988). This lake is fed by five rivers (coming from the Arsi Mountains in the south eastern direction. It has an outflow through River Hora Kelo that feeds Lake Abijata.

Western shores of Lake Langano along the main Addis Ababa-Hawassa road have chains of resort hotels that are visited by guests very frequently. Although the merits or demerits of these resorts is yet to be seen, for now any development undertaking will have to reckon with them.

Plate 2. 36: Lake Langano (a) and human activities (b, c) (Photo credit: Brook Lemma)

(a) Lake Langano and surrounding Location: N07^{0}29'10.7"/E38^{0}43'27.9" elevation 1639 masl), (b) Restaurant of the resort with Lake Langano in the background. (c) and (d) Munissa Forest on the southeastern part of the watershed of Lake Langano.

Ecosystem services and ecological status

The south-eastern part of the watershed of Lake Langano has vast areas of forest plantations and natural forests known as Munissa Forest (Plate 2.37). These forests supply lumber to the woodwork industries in Addis Ababa and elsewhere. The lake also serves as an important recreational center and is habitat for some fish species. The littoral vegetation is poor. Lake Langano is not on high priority list for restoration but recreational pollution should be managed properly.

2.10.1.1.1.3. Lakes Abijata and Shala

Lake Abijata is located at coordinates 7°33'-7°43'N/38°27'-38°40'E and has an area of 150 km^2 whereas Lake Shala is very deep (266 m), is locate at coordinates

7⁰4'N, 38⁰ 6' E and has an area of 329 km ². Lake Shalla is reputed to be the largest caldera lake in Africa with a diameter of about 28 km (Tudorancea and Taylor, 2002).

Biophysical characteristics

Morphologically, Lakes Shala and Chitu lie in crater explosions with the former being the deepest lake in Ethiopia (Z_{max}=266m) (Fig. 2.41). Lakes Chitu and Abijata are shallow with depths of 20.5m and 14m, respectively (Turdu *et al.*, 1999). These shallow lakes tend to be highly productive due to frequent top-down mixing that brings nutrients from the sediment to the euphotic zone of the water column that contains almost a mono-culture of *A. fusiformis*. Lake Shala remains stratified both chemically and thermally owing to its depth, making the whole system poorly productive, as decomposed nutrients remain tied up in the depths of the lake (Bauman *et al.*, 1975). Because of these differences one sees the flamingos concentrated in the shallow lakes and makes their sanctuary on the islands of Lake Shala (Reaugh-Flower, 2011) where productivity is poor, human access is minimal, as humans have nothing to look for in the poorly productive Shala, at least for now.

The water chemistry of the three lakes shows some resemblance with each other at high salinity. This has impacted the kinds of plankton that thrive in the lakes and consequently the apparent non-existence of fishes and other vertebrates in their waters and even macrophytes that are highly dense on the shores of the other rift valley lakes.

Figure 2. 41: Abijata-Shala National Park (green circle) (After Reaugh-Flower, 2011)

(The three saline-alkaline lakes and other water-based institutions are shown. Note how Lake Abijata is regressing and the white spots in Lake Shala are islands where the flamingos roost; after Reaugh-Flower, 2011).

The four lakes in the Zwai-Shala Basin are remnants of a large fresh-water lake that existed during the Early-Mid Holocene and the Late Pleistocene wet periods (Street, 1979). The upstream lakes Zwai and Langano are mainly fed by rivers emanating from the highlands on either side of the rift, the Gurage Mountains on the west and the Arsi Mountains on the east. The major rivers flowing into Lake Zwai are the Katar and the Meki Rivers, which drain from the eastern and western plateaus, respectively. The catchment of these two rivers represents about 5610 km^2 (40% of the Zwai–Shala Basin). Lakes Zwai and Langano are open lakes, and overflow towards Lake Abijata to the south through the Bulbula and Hora Kelo Rivers, respectively. Lakes Abijata and Shala are closed lakes (Tenalem Ayenew, 2002).

Underground water flows in the direction of Lake Abijata with some percentage of the same ending up in Lake Shala. It is not well documented if Lake Chitu shares this groundwater.

With regard to lake water use, it is important to mention that the water of Lake Abijata is being abstracted to produce soda ash (Na_2CO_3 and $NaHCO_3$) by a Soda Ash Factory built on its northern shore. Lake Abijata is also being challenged by excessive water withdrawal from its feeder Rivers Bulbula and Hora Kelo for the purpose of development of irrigated agriculture (Tenalem Ayenew, 2002).

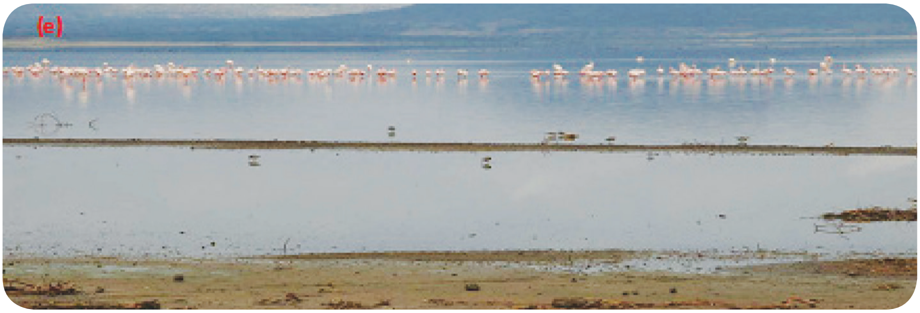


Plate 2. 37: Lakes Shala, Chitu and Abijata (Photo credit: Brook Lemma)

(a) Lake Shala viewed from the southern shore with the livestock drinking from the inflowing hot spring (b) from eastern shore of same lake (c) Lake Chitu viewed from the crater rim on the eastern side (d) from the shore of same side same lake (e) Lake Abijata and section taken from Reaugh-Flower, 2011.

(c)

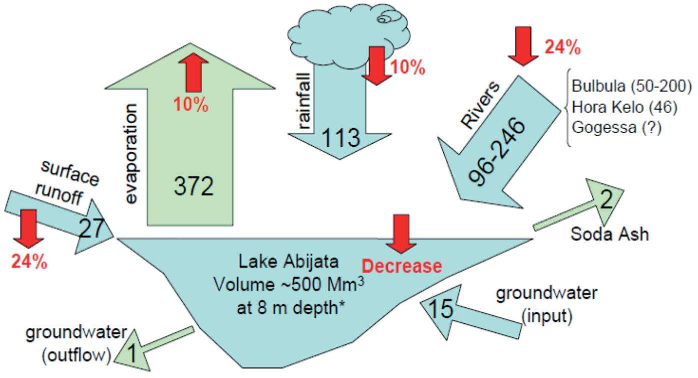


Figure 2. 42: Lake Abijata - Water Balance (unit: million m3 water per year - Mm3y-1) (after Reaugh-Flower, 2011).

The water balance of Lake Abijata has been estimated by several workers (e.g. Reaugh-Flower, 2011). The water inputs are outnumbered by outputs such as abstractions of lake water by the soda ash plant and the inflowing rivers, resulting in deficit water balance and lake level shrinkage (Fig. 2.42). If the trends described by Tenalem Ayenew (2002), Dagnachew Legesse *et al.* (2004), Reaugh-Flower (2011) and the development plans of the Ethiopian Government to enhance irrigated agriculture continues as documented in these sources, Lake Abijata will dry up by 2021 (Derege Tsegaye *et al.*, 2012).

Besides the need for increasing amounts of fresh water for development (irrigated agriculture, indoor farming, municipal use, livestock watering, etc.), waters of Lake Abijata are being used for soda ash. This trend would add the pressure on these saline alkaline lakes as described by Tenalem Ayenew (2002), Derege Tsegaye *et al.* (2012) and others.

There are several attempts to harvest *A. fusiformis* from the wild to supplement human needs for protein. This would be focused on the water resources of Lakes Abijata and Chitu for now and probably divert waters of Lake Shala, which now looks inexhaustible, into ponds to be constructed along the shore, for instance, the *Spirulina*-Mushroom Farm between Lakes Shala and Chitu (Reaugh-Flower, 2011).

Ecosystem services and ecological status of Lakes Abijata and Shala

Lake Abijata is highly degraded and on the verge of disappearance due to excessive water abstraction from the lake and its inflows (Hora Kelo and Bulbula Rivers). Restoration is of the highest priority and should focus on water use regulations, maintenance of inflows and best agricultural practices for irrigation of river waters. Lake Shala is relatively less encroached, but the recently proposed project to withdraw its water for soda ash extraction may have some impacts, which should be analyzed and rectified soonest.

2.10.1.1.1.4. Lake Chitu

Lake Chitu (7°24 0 N38°94 25 0 E and altitude of 1600 masl) is a tropical soda lake located about 1 km south-west of Lake Shala in the Abijata-Shala Lakes National Park (Tadesse Ogato *et al.*, 2015). It is a small (0.8 km^2), fairly deep (maximum depth 21 m) cup-shaped crater lake surrounded by a crater rim. The lake does not have surface outflows and inflows, being fed by direct precipitation and a few hot springs located at its shores, although the exact size of the catchment area and the theoretical renewal time of Lake Chitu are not known (Tadesse Ogato et al. 2015). Lakes Shala and Chitu morphologically lie in crater explosions, with the former being the deepest lake in Ethiopia (Z_{max}=266 m). Lakes Chitu and Abijata are shallow, with depths of 20.5 m and 14 m, respectively (Le Turdu *et al.* 1999). These shallow lakes tend to be highly productive because of frequent top down mixing that brings nutrients from the sediment to the euphotic zone, which contains almost a monoculture of *Arthrospira fusiformis* (=*Spirulina platensis sensu auct.),* which is the main diet of the flamingos and the alga has high nutritional value for humans.

Ecosystem services and ecological status

Lake Chitu is unique in providing the blue-green algal food (*Arthrospira fusiformis*) for the lesser flamingo, and one of the few lakes with an almost monoculture of the algae present most times of the year. The lake has shown water level decrease with time, which seems to be driven more by climate change as it has not been encroached by man due to its inaccessibility. Lake Chitu should be protected for its unique strain of *Arthrospira* algae, and the high population of lesser flamingos that present good opportunity for nature tourism.

2.10.1.1.1.5. Bulbula and Katar Rivers

Bulbula River is located at 7.899822 N and 38.743261 E. The Katar River mouth is found at N08^{0}01'58.6"/E39^{0}01'07.8" at an elevation of 1682 masl (Plate 2.39). According to Dessie Tibebe (2016), the Katar River has a large catchment of 3400 km^2 that includes the Arsi highlands to the eastern part of the lake. The main rivers that regulate the water volume of Lake Zwai are the inflowing Meki and Katar Rivers and the out flowing Bulbula River. Meki and Katar Rivers have a mean inflow of 6.62 and 11.10 m^3/s, while the mean outflow from Bulbula River is 4.92 m^3/s; with a balance of 12.8 m^3/s and a water residence time of 6.67 years in Lake Zwai (Desie Tibebe, 2016). According to the same author, the annual inflow of Lake Zwai from the Ketar River gauged at Abura (08^{0}02.019' N and 38^{0}49.340' E) was 302.0 MCM.

Plate 2. 38: River Meki (a) and River Katar (b) (Photo credit: Brook Lemma)

2.10.1.1.1.6. Meki River

The Meki River is located at N08°10'40.6" and E38°38'04.3" at an elevation 1796 masl. From a study conducted during 2014-2016, Dessie Tibebe (2016) concluded that the flow of the Meki River can dry out during severe dry years and the total annual contribution of Meki River to the Lake Zwai was 277.81 MCM. The Meki River is used for irrigation by riparian communities, although not on large scale as the Katar and Bulbula Rivers.

The Meki River catchment is severely degraded (Plate 2.39) and the river flow into Lake Zwai is turbid with high sediment load. It has been reported that the sediment carries a lot of nutrients from the catchment and the TN and TP values of sediment samples were found to be high (Dessie Tibebe. 2016). Annual net loading for TP and TN were 2693 and 20359 tonnes and the trophic condition of the lake was ascribed to the internal loading from sediment resuspension during mixing in the shallow lake. Fluoride concentrations in the Meki River were about 1.5 mg/l in some places, which presents health hazard to the local people.

2.10.2. Wetlands in the SNNPRS

2.10.2.1. Lakes and rivers in the SNNPRS

2.10.2.1.1. Lake Hawassa

Lake Hawassa (previously known as Awassa) is a lake near the fast-growing city of Hawassa**.** The waterfront of the same side of this lake is taken up by huge hotels and recreation centers that do not seem to pay much attention to the wastes that they release.

The drainage system of Lake Hawassa (Awassa) catchment depends on waters received from the Wondo Genet highlands and the extensive swamp of the Tikur Wuha (Fig. 2.43). In recent years, the Tikur Wuha wetlands have lost so much water and accumulated sediment and have turned into a vast marshy area with thick vegetation.

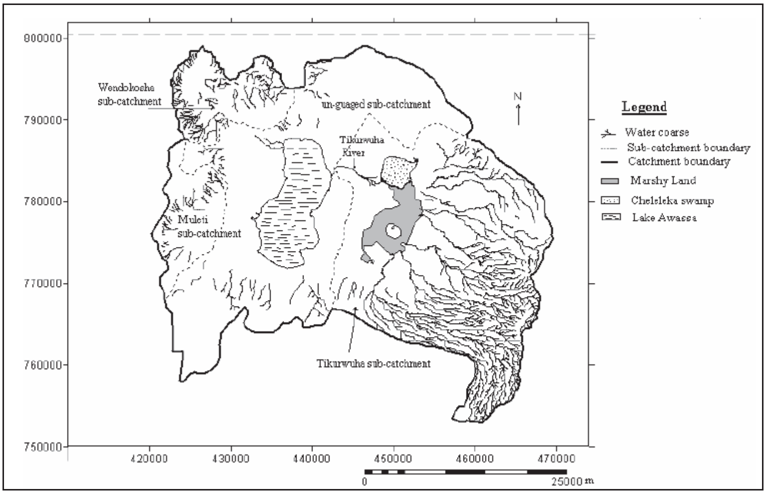


Figure 2. 43: Drainage system of Lake Hawassa (Awassa) catchment

Lake Hawassa waterfronts are found along the city of Hawassa and are occupied by farm lands and livestock grazing plots. People do fishing and collect water for household use directly from the lake. While all these livelihoods continue, there are no buffer zones that would protect the lake from siltation, inflow of agrochemicals, domestic and industrial/hospital wastes. The aquatic vegetation recorded in Lake Hawassa (submerged, floating and emergent) have become scanty both in species diversity and biomass and grasses continue to extend farther into the lake, indicating that the lake is getting shallower due to siltation and receiving high amount of nutrients from the farm inputs promoting the growth of the grasses (Plate 2.40).

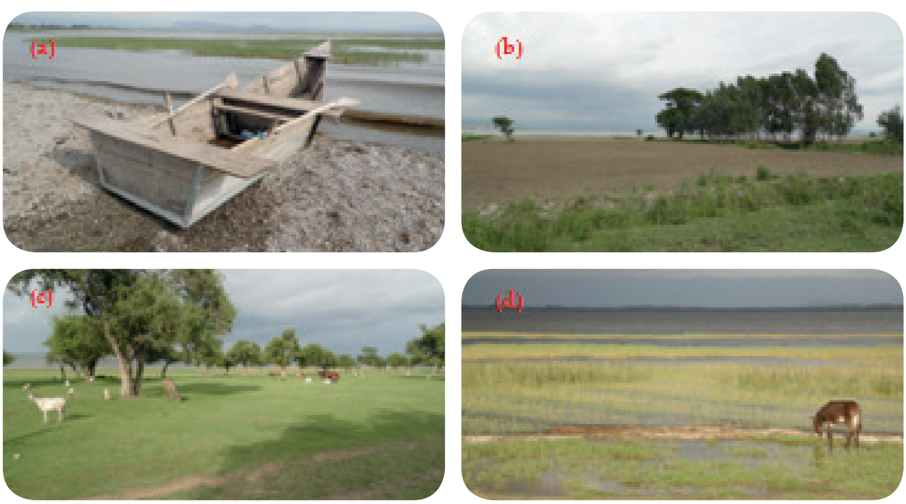


Plate 2. 39: Activities on the western shores of Lake Hawassa (Photo credit: Brook Lemma)

(a) Fishing community and the migration of aquatic grasses deep into the lake following siltation and external load of nutrients (b) Farming right along the shoreline contributing to siltation and external load of nutrients (c) remnant grazing areas serving as buffer zone to stabilize top soil and reduce nutrient loads into the lake (d) and (f) increasing siltation, nutrient loads followed by aquatic grasses growth that reduces water-holding capacity of the lake, increase evapo-transpiration and generally drying of the lake (e) Girls coming to the lake to fetch water for household use.

Plate 2. 40: Fertilizer use around Lake Hawassa (Photo credit: Brook Lemma)

A young farmer boy holding urea fertilizer in a metal bowl that he spreads in maize farms shown in the background (Plate 2.41) is an indication that there is not any optimization of fertilizer use.

River Tikur Wuha (N07^{0}05′29.2″/E38^{0}28′55.8″, elevation 1692 masl) enters the lake and on the eastern shore of which there is this small fenced and protected mini-forest inhabited by Colobus and other monkeys and birds such as owls, fish eagles and others (Plate. 2.42). It has huge ficus, acacia and other trees that serve as refuges for animals of the Lake Hawassa area. Similarly, this corner of the lake is also sanctuary to a highly limited number of hippopotamuses.

Plate 2. 41: Northeastern end of Lake Hawassa where animals get refuge (Photo credit: Brook Lemma)

(a) and (b) - blue arrow shows the entrance of River Tekur Wuha into the lake and green arrows show the last remnant forests on the lake shore (c) and (d) show sanctuary for monkeys and birds such as owls.

Ecosystem services and ecological status

Lake Hawassa supports a thriving fishery and its recreational amenities support the livelihoods of many people. Overexploitations of resources seem to be common due to lack of effective ownership of the lake. The lake shore shows signs of bank instability and pollution from several point and non-points sources have been documented. The ecological status of the lake is being investigated, while several workers have previously reported high pollution in the lake, including mercury intake by fish and consumers. All indications are that the lake's ecosystem services of provisioning, supporting and cultural values are being eroded. Urgent restoration programs should be in place before the lake is polluted beyond recovery. Some efforts are being made in this line by the Hawassa City Administration and Hawassa University.

2.10.2.1.2. Lake Abaya

Lake Abaya (also called Margherita) is located at coordinates 6 ^{0} 1'N and 37 ^{0} 4'E.

Biophysical characteristics

Lake Abaya is the second largest lake in Ethiopia after Lake Tana in the north. The shores are covered with dense bushes and tall acacia trees (N06^{0}31'47.0"/ E37^{0}50'00.6" elevation 1180 masl.) by the main roadside (N06^{0}07'27.9"/ E37^{0}37'56.2" elevation 1183 masl.**)** (Plate 2.43).

This lake is fed by a number of rivers that include Rivers **Greater Belate**, **Smaller Belate, Rai, Hamassa** (N06^{0}34'18.1"/E37^{0}49'23.0", elevation 1260 masl) and **Hareshew** and a few others that could be seasonal (Plate 2.43). These rivers tumble down with considerable velocity from the mountain peaks of the western escarpment of the rift valley (the Chencha-Ochello Mountain Ranges). As these rivers do so, they gather excessive amount of silt, cross the short distance between the mountains and the bushes and acacia forests and enter Lake Abaya before having the time to let the silt settle down in the forests. The waters of most of the rivers are loaded with very high amount of silt, except River Hareshew that meanders in the fields and flows on sands and gravels. An additional factor that adds wastes into Lake Abaya are the liquid wastes of the town that are directed into the rivers and people who directly wash clothes, bath and even wash their vehicles in the rivers that flow into the lake (Plate 2.43).

The silt load and the associated nutrient inflow into Lake Abaya have made the lake highly turbid with very shallow Seechi Depth measurements (less than 20 cm). The presence of these scenarios and the relatively high air temperature of the area have invited the appearance of invasive plants such as water hyacinth (Plate 2.44).

The south western tip of the lake hosts the so called Forty Springs (Arba Minch) from where a good number of springs (no one knows if they are exactly forty) start and directly flow into the lake feeding it with some heat, fresh water and at the same time providing breeding grounds to fish species such as *Barbus* spp. that migrate upstream into the springs for the same purpose.

The southern end of Lake Abaya where a peninsula having its tip formed into a beautiful hill makes part of the NechSar National Park. The area is completely covered with bushes and acacia trees. Numerous games and birds thrive in it. This isthmus makes a boundary between Lake Abaya and Lake Chamo to the south. Lake Abaya is located at about 66m above Lake Chamo. Historically, these two lakes used to be linked through a small corridor of low lying isthmus. Seleshi Bekele Awulachew (2006) has reported that in recent years these two lakes have no surface linkage whatsoever.

Fishing in Lake Abaya is one of the livelihood systems of hundreds of fishermen. There are numerous fish species in Lake Abaya that attract fishermen. Some of the commercially important fishes are *Lates niloticus*, *Oreochromis niloticus*, *Clarias gariepinus* and a number of *Barbus* spp. The presence of high populations of "dangerous" crocodiles and lack of accessibility with reasonably organized fish landing sites and lack of appropriate fishing gear has resulted in low fish production.

Ecosystem services and ecological status

Lake Abaya is an important habitat for crocodiles which thrive on its rich fish resources. Lake Abaya fisheries support the local fisher community. Due to its large size, it may also play some regulatory functions in moderating climate and hydrology in the lower Rift Valley basin. Its ecological status is good, although the threats from pollution and water weed infestation are on the rise (Plate 2.44).

Plate 2. 42: Rivers flowing into Lake Abaya (Photo credit: Brook Lemma)

(a) Greater Belate River seen from a bridge at a distance of 313 m from Addis Ababa (N07^{0}17′08′8″/E38^{0}04′21.5″ elevation 1718 masl) (b) Smaller Belate River, a short distance southwards in the direction of Arba Minch town (c) River Rai (N06^{0}27′27.9″/E37^{0}37′56.2″ elevation 1183 masl and (d) River Hareshew with relatively low silt contents (N06^{0}06′45.4″/E37^{0}33′39.9″ elevation 1254 masl.

Plate 2. 43: Lake Abaya with weed encroachment (Photo credit: Brook Lemma)

The threat of establishment of water hyacinth in Lake Abaya is shown in Plate 2.44. The red arrows indicate the infestation of the lake with water hyacinth, which seems to be just beginning but is also observed to drift from shore to shore. The drifting water hyacinth is seen to concentrate and establish itself in some of the less turbulent parts of the shore(c)

2.10.2.1.3. Lake Chamo

Lake Chamo lies at the southern tip of the Ethiopian rift valley at coordinates 5 ^{0} 50'N and 37 ^{0} 40'E at an altitude of 1233 masl.

Biophysical characteristics

River Kulfo (Plate 2.45) is the largest river inflow into Lake Chamo and serves as crocodile sanctuary, and hence it is today what is known as "Crocodile Market". The NechSar Park officers and managers of the Crocodile Farm at the shores of Lake Abaya stated that because the low lying fields around the two lakes (Abaya and Chamo) are changing very fast due to large scale plantations (banana, cotton, etc.) and construction of hotels and resort centers, sandy breeding grounds of crocodiles are being covered by alluvial soils. This has caused reduction in crocodile populations. According to them, female crocodiles find conducive sandy soils on the shores of River Kulfo only.

Ecosystem services and ecological status

Lake Chamo is clearly highly productive with fishes as records show it (Brook Lemma, 2012). The Nile perch (*Lates niloticus*) collected from this lake is very popular in big hotels in Addis Ababa and in 2012 one kg of Nile perch slice fetched 205 Birr (11.40 USD), which is very expensive for ordinary Ethiopians. Obviously, as in the case of Lake Zwai, one sees more fishermen and predatory birds in Lake Chamo than in Lake Abaya. Lake Chamo is currently subjected to overfishing according to fishery experts of the Ministry of Agriculture and leaders of fishery cooperatives in Arba Minch (Brook Lemma, 2012).

Plate 2. 44: Lake Chamo (Photo credit: Brook Lemma)

(a) River Kulfo entering Lake Chamo (b) Crocodile Market with wild crocodiles on the shores of the same river.

Threats to Lakes Abaya and Chamo

According to Fassil Eshetu Teferra (2016), the forest cover in the catchment area of Abaya and Chamo basin was already low in 2000 (0.1% and 3.4%, respectively), and further reduced during the period 2000 – 2012. The high sediment loading in the lakes is likely the result from the low vegetation cover in the catchments and is expected to further increase with the continuing conversion of natural vegetation to crop lands.

The excessive sediment loads and the profound nutrient enrichment in Lake Abaya and Lake Chamo are important anthropogenic disturbances that severely affect the ecological integrity of these lakes, and also undermine the delivery of vital ecosystem services to the region. Fassil E. Teferra *et al* (2017) stress about the urgent need for measures that prevent further environmental deterioration of these two iconic Ethiopian Rift Valley lakes.

2.10.2.1.4. Lake Chew Bahir (lacustrine salt marsh)

Lake Chew Bahir is located in the SNNPR and at coordinates 04°43’N 36°50’E and altitude 520 masl. It has an area of 112,500 ha and is a Wildlife Reserve.

Biophysical characteristics

Lake Chew Bahir is at the end of the Ethiopian section of the Great Rift Valley. It lies across the border of South Omo Zone of SNNPR to the west, and the Borena Zone of Oromia Region to the east. The southern tip of the lake crosses the border into Kenya. The lake lies in a basin primarily composed of the floodplains of the **Gelana Dulei river**, itself formed by the confluence of the **Segen** and **Weyto** Rivers. Chew Bahir Basin and the Gelana Dulei and Weyto Valleys are flanked on the west by steep, finely dissected, scarps rising to 1,600 m, the result of large-scale faulting. Lake Chew Bahir is subject to substantial changes in area as a result of variations in river discharge. It often dries out, but the lowest part in the northeast is always moist. As there is no outlet, all water entering the lake is lost by evaporation.

Over the past century, Chew Bahir has varied from swamp to shallow open water with a maximum depth of 7.5 m and a surface area of up to 2,000 km^2. The water of Chew Bahir is so highly saline that it cannot be used for either irrigation or domestic purposes. However, to the south-east across the mudflats lie a series of springs: some occur around the base of rock outcrops, but others are isolated on the flats where they support a dense growth of coarse and salt-tolerant sedge. The site supports a range of habitats, including marsh, open water, mudflats, springs, *Acacia–Euphorbia* bushland, mixed broadleaved scrub with *Terminalia* spp., scattered *Acacia* and *Acacia* scrub. There is a sparse vegetation of salt-tolerant plants throughout the basin. Particularly common is the tall coarse grass, *Sporobolus consimilis* and the mat-forming *Sporobolus spicatus*. There are a number of *Cyperus* species which are also highly salt-tolerant. However, where fresh water enters, there are rich swampy areas and pools, which are said to have tall *Echinochloa* spp., other *Cyperus* spp. and *Nymphaea* spp. The marshes support a high population of amphibians and snails. The Weyto valley has a very open, dry *Acacia savanna*, the main trees being *A. Senegal* and *A. polyacantha*, with *A. mellifera* forming dense stands along with spiny capparid species and *Cadaba rotundifolia*. Ground-cover is sparse, comprising a few perennial grasses, some interesting succulents such as *Caralluma spp.*, many opportunistic annuals and some geophytes such as *Pancratium tenuifolium* which only appears after heavy rain. The Arbore, Tsemay and Hamer peoples inhabit the Weyto valley and Chew Bahia Basin. They are basically pastoralists, but grow some crops opportunistically. Access to the freshwater springs in and beside the lake is disputed.

Ecosystem services

This is one of the few salt marshes in Ethiopia. It is pristine and needs no intervention at present.

2.10.2.1.5 Lake Tinshu Abaya

Lake Tinshu Abaya, which is interchangeably called Small Abaya to imply its size, is situated in the Siltie Zone (Siltie District, Kebet/Silttie Town) of the Southern Nations, Nationalities and Peoples Regional State of Ethiopia (Fig. 2.44). It is found in a small village called *Gebrie-Ber* located at about 15 km in the eastern direction from the town of Kebet/Silttie. The lake is located at 7^{0}29´03.65´´N latitude and 38^{0}03`17.79´´E longitude and at an altitude of 1835 masl.

Lake Tinishu Abaya is a small-sized inland freshwater system among the rift valley lakes of Ethiopia (Plate 2.46). The lake covers a total area of 1253 hectares (12.53 km^2) (Kassahun Asamine *et al.*, 2011). It is a shallow lake with a maximum and a mean depth of 3.7 m and 2.9 m, respectively and is almost an oval shape. Lake Tinishu Abaya has two major perennial rivers and a single outlet. **Rivers Dacha and Boboda** are the main tributaries for the lake in the northern and southern corners, respectively. **River Badober** (northern corner) is a small river which served as an outlet for the lake especially during the rainy season when the water level of the lake overflows. The lake has some commercially important fish species including Nile tilapia (*Oreiochromis niloticus), Tilapia zillii* and Barbus species. Barbus sp. and *T. zillii* are native for the lake, whilst *O. niloticus* was stocked from the nearby rift valley Lake Zwai in 1997 (Kassahun Asamine *et al.*, 2011).

Ecosystem services and ecological condition

Lake Tinshu Abay provides fish and water for irrigation. It has not been highly encroached by man and its ecological condition can be said to be good. The impact of stocked fish on the lake limnology has not been investigated.

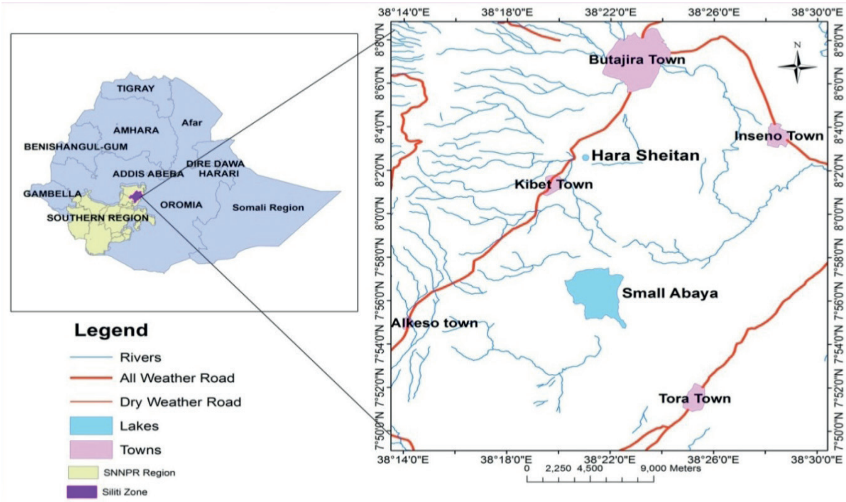


Figure 2. 44: Location of Lake Tinishu Abaya represented in this map as Small Abaya (Accessed at: www.earth.google.com and www.d- maps.com)

Plate 2. 45: Lake Tinishu Abaya (Google map, 2017)

2.10.2.1.6. Bilate River (Greater and Lesser)

The smaller rivers include the Bilate River (greater and smaller) and the Kulfo River, which have been described in earlier section.

Bilate River flows into Lake Abaya. It has been highly degraded by sediment loading.

The highly erosive mountains from which these rivers emerge need catchment restoration, which could improve the ecosystem services and sustainability of the large rivers in the SNNP.

2.10.2.1.7 Kulfo River

Kulfo River flows into Lake Chamo. The ecological condition of this river is also compromised due to heavy sedimentation, and abstraction for irrigation.

Other wetlands in the RVL basin

As indicated in Fig. 2.45, the wetlands consist mainly of fringe wetlands around the lakes. Tenalem Ayenew (2012) reported that these wetlands are likely formed as a result of neo-tectonic activities that result in formation of elongated depressions that eventually fill with cold springs and runoff from Ketar River. The Shetemata swamp north-east of Lake Zwai and the Abaya swamp complex on the western escarpment of Silte town are such wetlands. They are used for livestock grazing and seasonal cropping during the dry months. Some of the threats posed to these wetlands include deforestation, siltation and tectonic instability. The Shetemata **c**an completely dry up seasonally and become converted to grazing field.

swamp

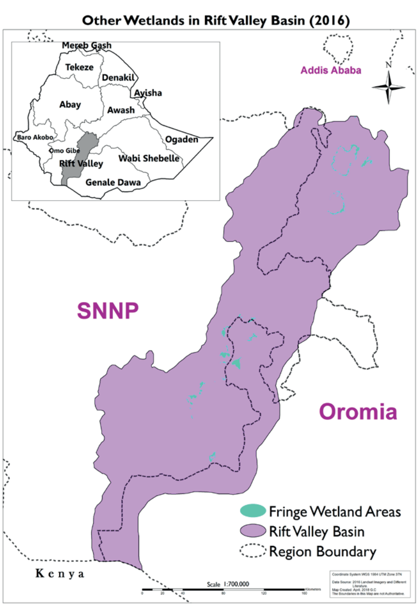


Figure 2. 45: Other wetlands in the RVL basin

2.11. Tekeze basin

The Tekeze River basin is located between 11 40` and 15 12` N, and 36 30` and 39 50` E. Tekeze river basin has an area of 82,350 Km^2, covering parts of the Amhara (4 zones) and Tigray (4 zones) and some parts in Eritrea (Fig. 2.46).

The Tekeze basin consists of three sub-basins: Tekeze, Angereb and Goang River sub-basins whose estimated annual flow is about 8.20 Bm^3. The ground water storage within the basin is not known but well yields vary between 3.6 and 1.6 l/s with median value of about 2.6 l/s. Potential for irrigation is about 450,000 ha for small scale and 207,781 ha for large scale. Tekeze basin has a potential for three large-scale irrigation sites with an estimated potential irrigable area of 83,368 hectares.

The Tekeze basin is highly eroded and devoid of vegetation, which could have reduced erosion into the reservoir. Watershed management is urgently called for to address this problem and ensure the long-term ecosystem services of the wetlands to continue. Because of the deep gorge and minimal human encroachment, the ecological status of the Tekeze River can be considered as good to moderate. Measures should be taken to reduce increasing levels of pollution and overfishing in the reservoir. There are reports of some tectonic instability, which might affect hydrological regimes and this should be addressed by hydrogeologists.

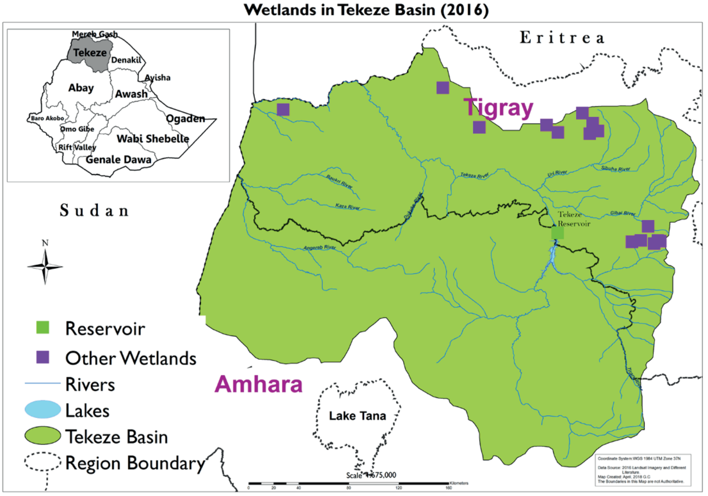


Figure 2. 46: Wetlands in the Tekeze basin

2.11.1. Wetlands in the TNRS

2.11.1.1. Lakes and rivers in the TNRS

2.11.1.1.1. Tekeze River

The length of the Tekeze River is more than 600 Km from its source down to the Sudanese border. The river basin has a lowest elevation of 536 m and a highest elevation of 4517 m (Ras Dashen). The total mean annual flow from the river basins is estimated to be 8.2 BMC. Over 70% of the basin area falls in the highlands. The population of the basin is about 6.4 million.

The soils on the basin are Eutric Vertisols on the level lands; Eutric Leptosols, Eutric Vertisols, Eutric and Calcric Cambisols and Halpi. Euric Vertisols with soil depths of more than 50 cm are dominant on the level lands while Leptisols are the most common soils on the sloping lands.

The climate of the basin can be divided into two; the west region of the Simien Mountains with wet season and the east region with dry (small rainy) and wet (main rainy) seasons. The mean temperatures in the basin vary from 10 ^{0}C in the Simien Mountains, to 22 ^{0}C in the highlands and to 26 ^{0}C in the lowlands. Minimum and maximum temperature ranges are 3-21 ^{0}C and 19-43 ^{0}C, respectively. These climatic differences have resulted in the classification of the basin into four agro-ecology zones, namely, Wurch, Dega, Woina Dega and Kolla. Semien mountain massifs may serve as recharge zone for the Tekeze basin.

Ecosystem services

Major ecosystem services of the rivers include provision of potable water, fish and irrigation water. Because most rivers flow in deep gorges, they are relatively less impacted by human and animal intrusions, but high sedimentation from degraded catchments is commonly observed. Restoration trials in SWC have yielded positive results in some catchments and some rivers have even recovered. This success story can best be gauged from the Geba catchment and should be replicated in other catchments.

2.11.1.1.2. Geba River

The Geba basin is bounded between latitudes 13⁰16′ and 14⁰16′ North and longitudes 38⁰38′ and 39⁰49′ East and is a tributary of the Tekeze River (also called Atbara by the Sudanese).

Biophysical characteristics

The Geba River originates from the Atsbi horst in the northeast and the Mugulat Mountains near Adigrat in the north and flows south and then westward to join Tekeze River on its way to Sudan. The basin has a total area of 5137 km^2. The Geba joins the Tekeze River at the confluence known as Chemoy.

The watershed receives two rainy seasons: the main rainy season (June to September) and the small rainy season (February to May). The annual rainfall totals between 500 to 800 mm. About 80 % of the annual rainfall in the Geba River basin occurs in the Kiremt (rainy) season from June to September, and 63 % of the annual rainfall is the peak which is recorded in July and August. The mean temperature varies from a minimum average of 6.5°C in the Atsbi plateaus to a maximum average of 32 °C at Agbe in the Abergele lowlands. The dominant land use in the study area is agricultural land about 40 % and shrub land (32 %), rangeland (11 %), bare land (8 %), and urban area, and forest land and water body covered 9 % of the total area.

The evaporation is maximum in April (10.4 mm per day) and May (10.1 mm per day), when daily temperatures are high and winds are comparatively stronger than during other months. The evaporation is minimum in July (4.1 mm per day) and August (3.8 mm per day) when the atmosphere is more humid, day temperatures are low and wind speeds are less compared to other months (Gebremedhin Kiros *et al.*, 2016).

The geology of the Geba basin is dominated by the Mekelle outlier, a basement complex plateau having an upper sedimentary rock layer with some doleritic intrusions and a basalt capping. Fluvial deposits occur along narrow incised river valleys. Leptosols area is widespread soil type in the Geba basin.

The daily stream flow shows high variable flows in the Geba River (119 m^3/s to 1445 m^3/), which indicates the flashy nature of the runoff. Very high floods within short time are also depending on the land cover and population density. The area is predominantly cropped corresponding to bare land except during the rainy seasons when the agricultural lands are covered by crops. This lack of vegetation cover reinforces the splash effect which, together with soil compaction by the movement of people and cattle, leads to a large reduction of infiltration rate and produces extensive overland flow.

Ecosystem services and ecological status

The Geba catchment provides few ecosystem services due to extreme degradation of the soil and vegetation. People use the river for potable water but the regulatory and supportive services of the rivers is poor. The analysis of Geba basin water balance indicates that the estimated annual precipitation falling on the basin is 640 mm and the evaporation loss from the basin is about 418 mm. The total water requirement shows that there is a high water demand during dry periods and surplus during the wet season. In addition, considerable water demand is expected due to the irrigation development and water supply for domestic purposes. Therefore, optimized water allocation tool is needed to balance the demand versus supply in the basin. This may be accomplished by establishment of water use associations in the catchment.

2.11.1.2. Other wetlands in the TNRS

2.11.1.2.1. Microdams

"Micro-dams are permanent bodies of water between five and 50 hectares in size, constructed by the government and used by villagers near the dams" (Amacher *et.al.*, 2004: 123).

There is some literature on micro dam projects in the Tigray NRS (e.g. Ersado *et al.*, 2004). The lack of empirical studies of local processes might be due to the fact that most micro dams are initiated by local communities and there are no project documents. Most of the micro dams were considered for water storage, irrigation and later as supplementary water bodies for fish production. Sileshi Awulachew *et al.* (2007) reported that from 2004 – 2007, a total of 370 000 ha of land was developed through irrigation by river diversion, river damming, collection of rain and flood waters in the Tigray, Amhara and Oromia regional states.

Micro-dams have both advantages and disadvantages. The most compelling impact of dry season irrigation is, of course, the increase of agricultural productivity. Further, micro dams may entail additional income generating opportunities and benefits, such as fruit tree cultivation, handicraft, fishing, livestock watering, as well as provide water for domestic uses. Moreover, small reservoirs may contribute to the increase of biodiversity and the decrease of land degradation. It was argued that micro dam development is also an attractive policy because it would be independent from international funding and hence not impact on Ethiopian interest and decision-making. Further, the downstream impact of hundreds of micro dams is much more difficult to estimate and quantify than of large dam projects.

However, it was also pointed out that cost and benefits of micro-dams have to be carefully balanced in water projects. A number of studies stated a significant increase of the risk and spread of malaria, schistosomiasis and other water vector diseases due to the creation of new insect habitats in the form of small reservoirs in the Amhara, Oromia and Beneshangul Gumuz regions (Amacher *et al.*, 2004). From an economic, but also social point of view, it is noteworthy that non-farm income generation activities were significantly reduced as one outcome of higher infection rates (Ersado *et al.*, 2004). Other typical technical problems associated with micro dams include the siltation of reservoirs and hydrological effects on downstream flows. But as most micro dams are the result of local, donor-independent initiatives, not all future consequences may be foreseen or their negative impact be mitigated by preventive measures. So far, no detailed field study is available focusing on local social–political processes during the acquisition of micro dams.

Ecosystem services and ecological status

Micro-dams provide drinking and irrigation water and improve livelihoods of farmers. Their provisioning and supportive services is the main drive for their construction on a large scale in Tigray and Amhara regions; however, their economic values have not been realized in full due to poor pre-planning and damming phases. Micro-dams could also moderate climate and regulate flows through their reservoir storage. They have also been used as meeting points for livestock watering and religious ceremonies. Still, most of the potential ecosystem services expected from micro dams have not been realized in Ethiopia. As many of the micro-dams were abandoned or destroyed beyond repair, there is little ground to plan for restoration and rehabilitation programs for micro dams. They remain a useful lesson to avert such ecological disasters in future. Perhaps better watershed management practices should be instituted in catchments where micro-dams are to be constructed in future in order to reduce or control such ecological calamities.

2.11.1.2.2. Tekeze dam and reservoir

The Tekeze dam (Plate 2.47) with hydropower production of 300 MW is a very high dam (188m) with the deepest gorge (canyon) in Africa, sometimes as deep as 2 000 m.

Water quality of Tekeze reservoir

The results indicate exceptionally high EC values of 1000 - 2029 us/cm from inflowing rivers in Tigray Region. This unusually high EC value of river water could be attributed to pollution of domestic waste around towns or low flow condition of the rivers. The Tekeze Basin surface water quality supports the use for domestic and irrigation purposes with the exception of **Illala River,** which has the highest TDS value and sediment load of all the basin rivers.

Plate 2.46: Tekeze River and Tekeze Dam in the Tekeze basin (Internet sources)

Ecosystem services and ecological status

- Provision of fish, water and hydroelectric power
- Regulatory services in moderating climate change in this arid environment

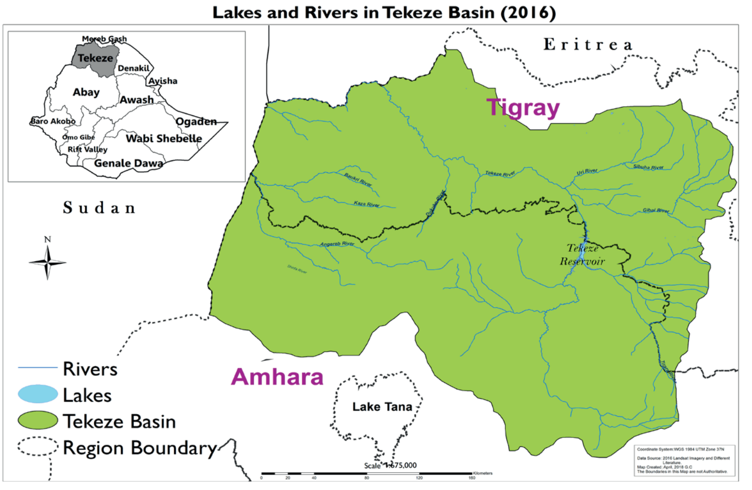


Figure 2. 47: Lakes and rivers in the Tekeze basin

2.11.2. Wetlands in the ANRS of the Tekeze basin

2.11.2.1 Lakes and rivers in the Tekeze basin

2.11.2.1.2. Shinfa sub-basin

The Shinfa catchment is located between 11^0 35'59'' to 13^0 49'12'' North and 35 ^{0} 09'45'' to 37 ^{0} 46'42'' East. Altitude varies from lowest altitude at about 441m above sea level to highest altitude of 2296 masl.

Biophysical characteristics

The Shinfa sub-basin has annual rainfall from 1200mm high to 900mm low. The Shinfa River drains a total of 8272.9 km ^{2} of catchment area. The sub-basin is dominantly covered by soil of loam and clay texture.

The minimum and the maximum rainfall values are 900 mm around Metema and Qaura and 1200 mm around Alefa and Chilga woreda, but can be less than 700 mm at the down tip of the basin. Monthly variations in rainfall and evapotranspiration for the basin are given in Table 2.27.

The Shinfa River sub-basin is endowed with annual surface yield of 13263.70m^3/sec and 496.4Mm^3 ground water resources. The surface and ground water flow of the basin is towards Sudan (Alitash Park).

Table 2. 28: Monthly rainfall (mm) and evapotranspiration (mm) in the Shinfa sub-basin (2011) (Source: Getnet Hunegnaw et al., 2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Area RF	0.74	2.63	3.78	15.73	79.48	163.12	233.45	244.37	174.83	71.98	7.10	0.93
Area PET	149.02	141.70	164.64	170.12	160.95	131.80	108.57	99.24	112.78	125.29	125.84	124.68

The surface water resources potential of the basin indicates that there are 16 perennial and 20 seasonal streams (Table 2.29), most of the streams are concentrated and emanate from the high lands of the basin. The seasonal streams can persist from June up to the dry month of December and may dry out for the rest of the six months of the year. Restoration efforts in the Shinfa sub-basin should focus on ways to lengthen the flow of the rivers beyond six months by hydrological intervention as opposed to unwise hydrological changes that are being done by the local community (Plate 2.48).

Table 2.29: Streams and Rivers in the Shinfa sub-basin (Abay Basin Authority)

No	Zone	Woreda	kebele	River Name	Remark
1	N.Gonder	Takusa	Chankie	Mariamwuha	All are used for diversion agriculture
2	N.Gonder	Takusa	Chankie	Basko	
3	N.Gonder	Takusa	Chankie	Sengue	
4	N.Gonder	Takusa	Arema	Demek	
5	N.Gonder	Takusa	Goay	Lenquatit	
6	N.Gonder	Takusa	Achera	Lenquatit	
7	N.Gonder	Takusa	Mekonta	Segie	
8	N.Gonder	Takusa	Chemera	Segie	
9	N.Gonder	Takusa	Chemera	Asratie	
10	N.Gonder	Takusa	Konta	Shinfa	
11	N.Gonder	Takusa	Abaye	Shinfa	
12	N.Gonder	Takusa	Konta	Baskura	
13	N.Gonder	Takusa	Jeree	Mirmir	
14	N.Gonder	Takusa	Dinblagiase	Mirmir	
15	N.Gonder	Takusa	Alisefer	Lomyie	
16	N.Gonder	Takusa	Boboh	Boboh	

The water table is shallow as determined from shallow water depth of the basin of about 20 m deep. But at the most downstream sites of the basin, the static water table values are relatively deep and reach from 90m to 120m depth. Thus, there are some efforts at Quara for modern irrigation (386.15 ha) on Gelegu River using motor pumps. The traditional rivers are potential sites for irrigation (861ha) also in Takusa Woreda.

The actual evapotranspiration of the catchment is estimated to be 864.0 mm/yr or 86.6% of the total input to the sub-basin. The inputs of the basin is long term mean monthly precipitation of 998 mm per annum, and the common losses/ out flow are actual evapotranspiration, direct run off and base flow as 864 mm, 75 mm and 6098.13m^3/ sec per annum, respectively. The annual replenishable recharge of 60 mm or 496.4Mm^3/yr is the safe ground water potential of basin that can be utilized in a few years. If there is excess utilization of water resource, the natural system of the area may be disturbed and land slide phenomena may occur.

Plate 2.47: Traditional stream diversion in Shinfa sub-basin

Ecosystem services and ecological status

The water budget of shinfa sub-basin is dominated by surface river inflows and groundwater. The high PET and the low total annual rainfall indicates that hydrological balances have to be managed by proper utilization of the river flows and groundwater; hence any restoration plan for this catchment should consider maintenance of the water table through planned extraction of flows for irrigation (Plate 2.48). The trans-boundary nature of the ground water flow should be considered. At present, the only ecosystem service from this sub-basin appears to be provision of fish and water and as habitat for fish and some migratory wildlife from the Alitash Park in the boarder of Sudan.

2.11.2.1.3. Gang river basin

The Guang River catchment (sub-basin) is located adjacent to Shinfa river sub-basin in the Abay Basin between 11^0 35′59″ to 13^0 49′12″ North and 35 ^{0} 09′45″ to 37 ^{0} 46′42″ East with coordinates Easting 194445 and Northing 1438826. The catchment area of the sub-basin is 5,919.17 km ^{2}.

Biophysical characteristics

The altitude of the Guang catchment varies from lowest altitude at about 608m above sea level to highest altitude of 2532 masl. Rainfall varies from 800 mm to 1253 mm of annual rainfall. The major streams and rivers in the Guang catchment are summarized in Table 2.30.

Table 2.30: Perennial streams in the Guang catchment (Getnet Hunegnaw et al., 2015)

No	Zone	Woreda	Kebele	River name
1	N/Gondar	Chilga	Nara Awederida	Wijiraba, Awega, Basikura, Kechin woniz
2	N/Gondar	Chilga	Kuak	Genbeliwa
3	N/Gondar	Chilga	Alemtshay	Guange
4	N/Gondar	Chilga	Chanidiba	Gabi kura
5	N/Gondar	Chilga	Dil aba	Awiga, Mez woniz
6	N/Gondar	Chilga	Ken wta	Tafite, balesmesik
7	N/Gondar	Chilga	Chaliya	Gunidira, Aba tikure
8	N/Gondar	Chilga	Shutera	Tsadikan
9	N/Gondar	Chilga	Leza buledige	Awiga
10	N/Gondar	Chilga	Negade bahir	Belwoha, Senikua
11	N/Gondar	Metema		Guange

The sub-basin has an area of 6,019.89 km^2, with maximum elevation of 2532 m and minimum elevation of 608 m, and mean elevation of 1569.59 m.

The Guang sub-basin is endowed with very shallow water depth which ranges from 20 up to 25 m deep and at the central part of the sub-basin, the static water table values reaches up to 50m deep. Generally in the sub-basin modern irrigation (motor pump) from different water sources is about 128 ha, from traditional irrigation river water source is 3373.23 ha, and from ground water well 24.6 ha. Water balance results show that the sub-basin receives 51.0 mm in the form of recharge and loses 131 mm and 879 mm in the form of surface runoff and actual evapotranspiration, respectively. Thus, evapo-transpiration is about 82% of the total annual input (rainfall). From this it can be concluded that most of the annual rainfall leave the catchment as actual evapotranspiration and surface runoff, and the local aquifer feeds the surroundings streams.

The minimum and the maximum value are greater than 27.5°C at Metema Woreda and from 16-21°C at the Chilga woreda. The Guang sub-basin is dominantly covered by silty clay and heavy clay texture. Rainfall varies erratically in the sub-basin with very low values in Nov–March and highest rainfall in July–Sept (kiremt). Evapo-transpiration is, however, rather uniform throughout the year with values between 124 – 155 mm/month (Table 2.31).

Table 2. 31: Monthly rainfall and potential evapo-transpiration in the Guang catchment (Source: Getnet Hunegnaw et al., 2015)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Area RF	0.97	0.68	6.35	16.96	90.34	175.66	249.20	254.25	180.33	75.48	9.35	1.28
Area PET	136.76	141.82	155.42	159.36	156.20	139.25	124.91	119.08	125.07	134.55	134.26	132.12

The surface water resources potential of the sub-basin includes 11 perennial and 14 seasonal streams. The seasonal streams fill up in June and can persist up to December. This means that they dry up completely for about 5 months (Jan–May). The perennial streams in the sub-basin include **Guang, Tsadikan, Awiga, Wijirba** and others (11 in total).

Ecosystem services and ecological status

Most of the perennial springs have fish stocks which are fished to some extent. Fishing activities of Guang River is mainly carried out by four permanent fishermen, and their market for the catch is Sudanese border town known as Gelabat, which is found at 34 km from Shehedi town. Other biodiversity abound in the rivers and wetlands but there is limited study done on it. The hydrological imbalance implies that the springs dry up for about half of the year. This may be due to uncontrolled extraction for irrigation, lowered water table as a result of groundwater withdrawal and high evaporation due to the arid environment and scant vegetation cover ("Serkin", "Banba", "Drgeja", "Lalo", "Kirkira", "Gaba" and "Kummer" are the most common flora). Restoration should focus of reducing withdrawal of surface and ground water through best agriculture practice and catchment forestation to increase water storage.

The status of the aquatic ecology of the Guang sub-basin appears to be good in that pollution is uncommon but rather the problem is hydrological imbalance caused by poor water management. Cooperation between the riparian countries of Ethiopia and Sudan is mandatory, as the Guang River eventually ends in Sudan as the Atbara River.

2.12. Wabe Shebelle basin - general

The Wabe Shebelle River Basin originates from the Bale Mountains in the Ethiopian highlands, at an altitude of about 4230 masl, and has a total catchment area of 297000 km^2. Nearly two-third (63.5%) of the basin area lies in Ethiopia and one-third in Somalia. Within Ethiopia, the river has several tributaries contributing to its runoff. Flowing generally south-easterly direction; the Shebelle River passes through an arid land in the eastern province of Ethiopia cutting wide valleys in southern Somalia. Running a distance of about 2526 km, of which 1290 km in Ethiopia, the river does not normally enter the Indian Ocean, but into a depression area, where it is finally lost in the sand in southern Somalia, feeding an ecologically sensitive area and recharging areas of groundwater aquifers. Only with exceptionally heavy rains does the Shebelle River break through to join the **Juba River** and thus succeed in reaching the Indian Ocean. With an average annual rainfall of 425 mm (over 1500 mm in the mountain areas and 200 mm near the border), mean annual runoff of the river at the town of Gode in Ethiopia is 3 387 Mm^3, and at the town of Beled-Weyne in Somalia is 2384 Mm^3. About 1,000 Mm^3 is lost in the Ogaden desert in eastern Ethiopia. The river runoff is totally generated by catchments within Ethiopia. The river has a high saline content even during high flows. Due to its climate conditions, the basin is frequently affected by droughts and floods causing major problems to mainly downstream communities in Somalia.

Wabe Shebelle has several major tributary rivers. The major tributary rivers include **Gobele** and **Erer** forming the bigger **Erer River, Mojo River, Ramis** and **Galeti River** forming a joint major tributary river. The Erer River is a perennial river of eastern Ethiopia, which arises near the city of Harar, and flows in a primarily southern direction to its confluence with the Shebelle. **Galetti River** is a tributary of the Shebelle River and it arises from the Chercher Mountains. Other tributaries include **Daketa, Madiso** and **Fafen**. The Fafen only reaches the Shebelle in times of heavy rainfall; its stream usually ends before reaching the main river. From Imi Town to the border around the town of Ferfer, the river moves gently and forms considerable delta along its length. These areas are very good breeding and feeding grounds for fishes and other aquatic organisms.

The Somali Region extends across 4 river basins – Aysha, Ogaden, Genale-Dawa and Wabe Shebelle. The first two basins are basically dry and do not harbor many wetlands. Still, description of their biophysical characteristics is given in this report. Most of the region is drained by the Wabe Shebelle River and the floodplains and irrigation fields of the river constitute the wetlands (Fig. 2.48).

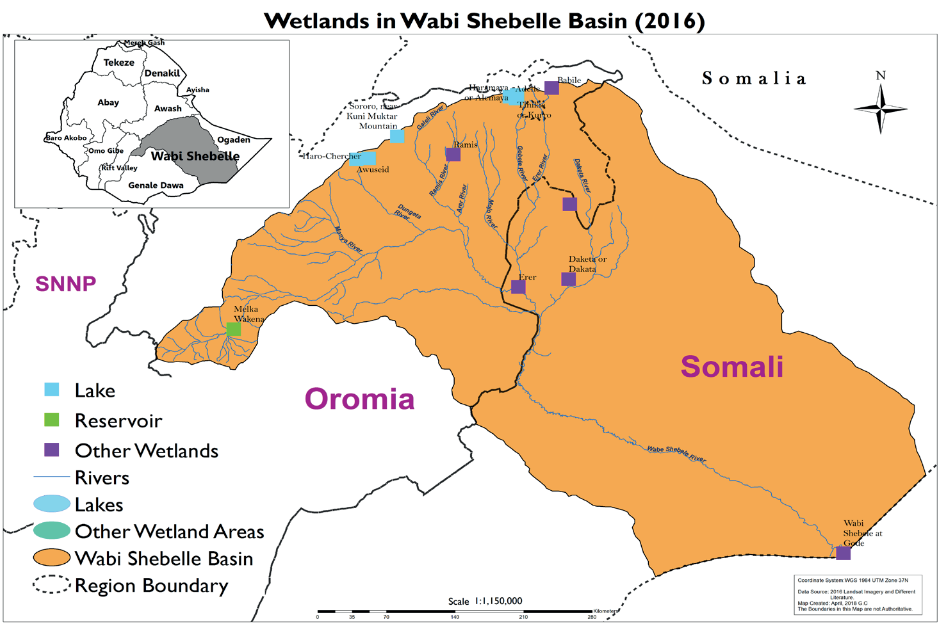


Figure 2. 48: Wetlands in the Wabe Shebelle River Basin

The large flood plain, which stretches from Kelafo to Mustahil, at the Ethio-Somalia border is about 600 km², and about 140 km² of these plains are flooded throughout the year and form a

permanent swamp; its estimated loss by evaporation alone is 560 Mm^3 (MoWR, 2005).

Around 41 small-scale, 77 medium-scale and 31 large-scale and a total of 149 **potential irrigation sites** are identified in the basin and it has an estimated potential of 237,905 hectares of irrigable area (Sileshi Awulachew *et al.*, 2007). The flow regime of the river is governed by two rainy seasons with different characteristics. The first from March to May that leads to high flood peak at Gode in April to May, and the second from July to September, that results in large flood volume, with generally modest peak around Gode area; the dry season extends from October to January (Agro Meteorology Team, Jijiga Meteorology Branch Office).

2.12.1. Wetlands in the Somali NRS

2.12.1.1 Lakes and rivers in the Somali NRS

2.12.1.1.1. Babile River and sanctuary

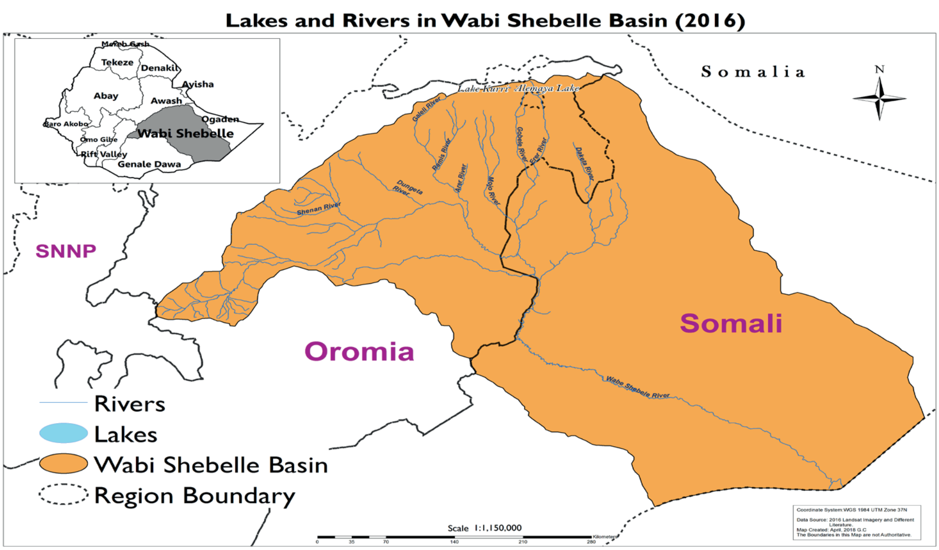


Figure 2. 49: Lakes and rivers in the Wabe Shebelle basin

Babille wetlands

The Babille wetlands (Elephant Sanctuary) is situated on the border between Oromia (Oromia) and the Somai Region at coordinates 08°45'N 42°38'E at an altitude between 1,000–1,750 masl, and has an area of 678,900 ha. It is delimited with coordinates of latitudes $08^0$22'20"- $09^0$30'30"N and longitudes $42^0$20'10" - $42^0$30'50"E and its elevation ranges between 940 m and 1585 masl.

Biophysical characteristics

Babile Wereda comprising of the Erer Valley (upper Erer and lower Erer) of in the eastern lowlands of Ethiopia (East Hararghe), is situated at the semi-arid trans-boundary of Oromia and Harari Regions, located at about 560 km southeast of Addis Ababa. The lower Erer Valley is part of the protected area for the African elephant (*Loxodonta Africana oleansie*) known as Babile Elephant Sanctuary (BES) (Anteneh Belayneh *et al*., 2012).

Five major rivers, namely: **the Gobele, Erer, Dakota, Borale** and **Fafen,** flow southwards through the sanctuary to drain into the Wabe Shebelle River (Fig. 2.50)**.** The valleys formed by the Erer, Dakota and Fafen rivers are significant physical features within the sanctuary. There are also ridges and small plateaus, or plains, between the watersheds. Most of the area comprises sandstone with limestone in places, as around Fik. The Fafen and other river valleys were apparently once covered in dense bush-land, but this has been cleared or much reduced as more and more pastoralists have taken up crop cultivation. The people in this area are traditionally pastoralists, but population pressure is forcing increasing numbers into a more sedentary existence. In the 1960s, there were some swampy patches beside the rivers, but a subsequent major lowering of the water-table in many of the valleys has probably adversely affected these wetlands. The hillsides and small plateaus are covered in *Acacia* bush-land mixed with succulents such as *Euphorbia* spp. and *Adenia aculeata*, particularly on the limestone. The plateaus are mainly covered in grasses with scattered bushes.

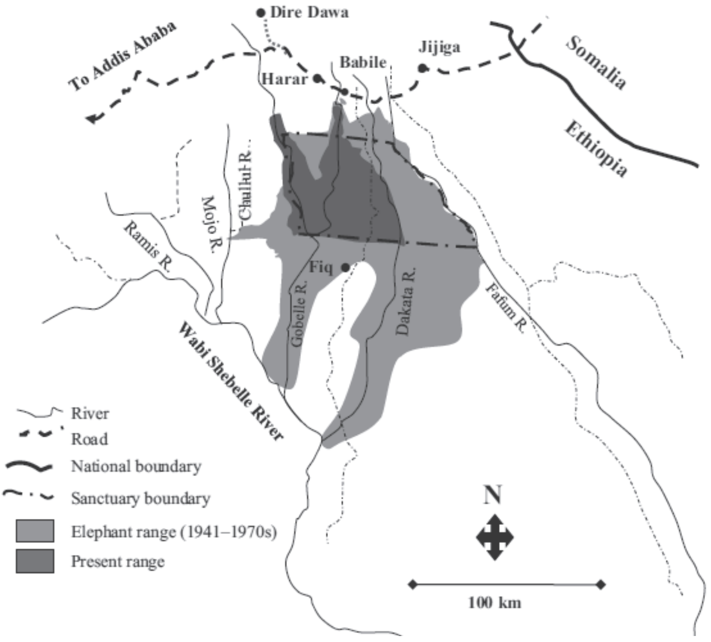


Figure 2. 50: Location of Babille (Babile) Wetlands where the Erer Valley and the associated rivers are found (after Yirmed Demeke et al. 2012).

Babille is also home to the hot thermal springs, used to supply much of eastern Ethiopia with the production of bottled mineral water in the same name. Just beyond the main entrance road into the park are the interesting geologic rock formations at Dakata's Rock Valley with a wonderful balancing rock as well as lower hoodoos. Other nearby attractions are the Prison House of Lij Eyasu in the Gara Mulleta Mountains, the Harar UNESCO World Heritage Site and the Kondudo mountain, which hosts a population of feral horses and a stalactite cave which rates among the 5 finest of Africa, locally know as the Gursum Pearl Cave.

The sanctuary was originally gazetted to protect a supposed elephant sub-species, *Loxodonta africanaoleansie*, but recent DNA tests showed that it is the regular African Elephant. Nonetheless, it is the most Northeastern population Elephant populations and with about 400 animals, the largest and most visible herd of the about 1000 animals remaining in Ethiopia.

Elephants can live in almost any habitat with sufficient food and water, but in the reserve, they prefer to stay in the Erer valley, where there is a lot of encroachment of Prickled Pear Cactus, an invasive species whose succulent leaves contain lots of water and food for the elephants. They often spend a lot of time in the gallery forest along the river, as food is more plentiful and the **Erer River.** It rises near the city of Harar reference at source: 9°19′30′′N; 42°04′43′′E), and flows in a primarily southern direction to its confluence with the Shabelle at 7°33′43′′N42°01′43′′E (from Wikipedia) and provides them with water, which in the dry season, they dig up from the sandy riverbed.

Plate 2. 48: Green trees along the Babile Elephant Sanctuary (Source: Ethiopian Tourist Organization)

The tall trees along the Erer River in Babile Elephant Sanctuary remain green through much of the dry season and they are frequented by elephants. The local people keep bees in the acacia trees in the gallery forest, which is an indication of persistence of wetness in the area that support regular supply of flowering plants for bees.

Other mammals living in the park are the Black-maned lion, Leopard, Cheetah, the Hamadryas Baboon, *Papio hamadryas*, Menelik's bushbuck, Soemmerring's Gazelle, and greater and lesser kudu. The bird list of 227 species includes the endemic Salvadori's serine. Of the reptiles, noteworthy are enormous tortoises and other animals.

Ecosystem services and ecological status

The Babille sanctuary serves indispensable provisioning and supportive ecosystem services as it serves as habitat for one of the few remaining elephant populations in the country, and several other wildlife and bird species (Plate 2.49). The area receives only 600 mm rainfall, yet the natural vegetation retains enough moisture to recharge the many rivers in the catchment. The local communities also use the sanctuary as source of wild fruits and cultivated crops. The rivers and hot springs are bottled as mineral water (Babile™)

2.12.1.1.2. Wabe Shebelle River (Riverine, floodplain)

The lower Wabe Shebelle River is found in the Somali NRS at coordinates 05°21'N 44°39'E, and altitude between 250–1,000 masl.

Biophysical characteristics

The Wabe Shebelle is the main river in central Somali Region. Rising between the Arsi and Bale mountains, it curves round the Bale massif and flows south-east to Somalia. The Wabe Shebelle and its main seasonal tributary from the east, the **Fafen**, cut through a series of wide, flat shelves of sedimentary rock. These are often overlain, as in the Gode valley, by deep, alluvial soils. The highest areas, at around 1,000 m, are east of the Fafen River. Between Imi and Kugno, *Tamarix* spp. and *Terminalia brevipes* grow together. Below this, and towards Kelafo, the river flows through a flat plain where the riverbanks and adjacent land are subject to seasonal inundation. Such areas are often covered in a tangled growth of small bushes and herbs that include wild relatives of cotton. At Kelafo, the river cuts through and runs parallel to a low limestone ridge with *Acacia–Commiphora–Boswellia* bush-land on it. In the Mustahil area, the river forms flood-plains: these are covered with tall herbaceous vegetation comprising various salt-tolerant species, e.g. *Schoenoplectus maritimus* and other sedges, *Limonium* spp., shrubby *Indigofera* spp., climbers, and various grasses. Grasses dominate the areas around the flood-plains. Away from the river basin, the vegetation is mostly *Acacia–Commiphora–Boswellia* bush-land. This association contains some interesting succulents, including several endemic species of *Jatropha* and *Euphorbia*.

Ecosystem services and ecological status

Without the Wabe Shebele, vast areas of the southwestern Somalia Region would be devoid of plants, animals and life-forms; as such the river and its numerous wetlands are the only source of biodiversity and livelihoods in the region. Due to recent practice of water abstraction for irrigation agriculture and storage, this wetland ecosystem will be degraded unless proper water management and best agriculture practice are put in place. It has been known (through recent survey) that farmers in the stretch of Wabe Shebelle, from Imi to Gode, catch fish using locally made fishing gears (hooks and lines and traps). Nearby open air markets are available for selling about 70 % of their catches and they keep the remaining 30% of the catch for household consumption. The fish species recorded from the Wabe Shebelle basin are listed in Appendix 3.

2.12.1.2. Other wetlands in the Somali NRSG

2.12.1.2.1. Wabe Shebelle floodplain

The diversity and distribution of wildlife resources in the basin is chiefly governed by diverse habitats and biomes. These habitat types range from highland forms to arid, hyperarid and to wetlands with their own vegetation types and compositions.

Information from local fishermen and farmers revealed that there are hippopotamuses ("Jer"), crocodiles ("Yease"), monitor lizards ("Debedejel"), snakes ("Mese"), lizards ("Mula"), different types of frogs and toads ("Rihe") as well as tortoises ("Kibdin") in and around Kelafo Woreda. The names given in parenthesis are in Somaligna - the language widely spoken in the region.

Plate 2. 49: Wetland at lower plain areas of Wabe Shebelle within Ethiopia (Fik/Hamero area)

Ecosystem services and ecological status

The Wabe Shebelle wetlands, although situated in an arid environment, provide much needed potable water, fish, vegetation and habitat for people, domestic animals and wildlife. The river and its floodplains are a rich source of biodiversity and have regulatory functions to maintain rainfall and moderate climate (Plate 2.50). Due to high evaporation, the basin has deficit water balance, which is compensated by flows from the rivers and floodplains. Much-needed irrigation projects are operating in the Somali Region, but these should also take environmental issues into consideration, including the loss of ecosystem services by wetlands.

2.12.2. Wetlands in the ONRS of the Wabe Shebelle basin

2.12.2.1. Lakes and rivers in the ONRS

2.12.2.1.1. Lake Haramaya

Lake Haramaya (also known as Alemaya in the literature) is located at 2000 masl, between $42^0 02'$E and $9^0 25'$N in the South-eastern Ethiopian Plateau about 525 km to the east of Addis Ababa.

Degradation history

Lake Haramaya is more of a catchment lake for an area of slightly more than 200 km^2 watershed (Brook Lemma, 1987; 1991). There were no streams or rivers that were flowing in or out of this lake, except the seasonal run off. An adjacent and northerly-located Lake Tinikie (Kurro) overflows into Haramaya during the rainy seasons, as it is located on a slightly higher ground. The watershed of these lakes is devoid of apparently all its natural vegetation and is highly populated, with the majority of the land being used for horticultural crops and a stimulant plant locally known as "*khat*" (*Catha edulis*) for export to neighbouring Djibuti and Somalia. Farmers in the watershed needed water for irrigation for about eight dry months of the year. Besides, the water of Lake Haramaya was also pumped for municipal uses to a town by the same name of about 30,000 people and the nearby town of Harar, 20 km in the eastern direction with a population of about 150,000. The latter town is outside of the lake watershed, posing additional water budget deficit on the lake. Eventually the demand for household water supply in Harar increased with increases in population and economic expansion of the city in recent years. This situation seems to be exacerbated by climatic change (warming up of the area and erratic rainfall) that increased the evapotranspiration rates of the area leading to extensive water budget deficit on the lake creating the scenario described below (see also Brook Lemma, 1987; 1991; 1994a and b; 1995; 2002 and 2003a and b).

Over the past 20 years L. Haramaya has been observed to shrink continuously. Some of the evidences in terms of morphomertric and physico-chemical changes are shown in the following figures and tables. By 2004, the lake has altogether disappeared and turned into an ephemeral lake where some water percolates at the lowest spot of the original lake basin.

Human demographic and climatic changes have contributed to the transformation of L. Haramaya to an ephemeral lake. The increase in population in Harar town and in the lake watershed demanded high municipal water supply over the years that has never considered any water budget scheme. The farmers in the watershed were pumping water out of the lake twenty-four hours a day. This was mainly to irrigate a commercial crop locally known as "*khat*" or scientifically, *Catha edulis*. Succulent leaves of this plant are chewed and the water extract swallowed as stimulant with the belief that it stimulates the brain to work harder, faster and longer. It is also exported to neighboring countries like Djibouti and Somalia. Farmers obtain quite satisfactory incomes as observed from the rate of conversion of food crop fields into "*khat*" fields.

Ecosystem services and ecological status

Lake Haramaya had significant provisioning services of water, fish, plants and livelihood means. It became degraded through unregulated overutilization of the water and fish resources, with the result that the lake receded and disappeared. According to this report, this lake is on the highest priority list for restoration (see Appendix 7).

2.12.2.1.2. Lake Adele

Lake Adelle (Adele) is located on coordinates $09^0$424759N, $41^0$950546E.

Biophysical characteristics

This is a shallow lake of not more than one meter at its deepest point. For long distances into the lake, aquatic grasses grow and during the dry seasons cattle walk into the water to feed on succulent fresh grasses, with the water barely reaching their bellies. Fishes are unknown in this lake and fish-eating birds such as cormorants are rarely seen. At the same time there are worms, algae and insect feeder-birds. During the peak periods of the lake it dries out. However, if the water persists the dry season, it appears that the water concentrates due to excessive evapotranspiration that some spoonbills and flamingoes appear following the change in the phytoplankton constellation.

The surrounding community uses this lake for household uses, as water supply to domestic animals, washing closes and bathing. The most important use probably is pumping the water of the lake for small scale irrigation to grow horticultural crops and *Catha edulis*, the stimulant plant locally known as "*Khat*" or "*Chat*". The products of the irrigation schemes are mostly exported to Djibouti or Hargessa or sold in Harar and Dire Dawa, both cities belonging to the Harari Regional state and the Dire Dawa Administrative Region, respectively.

Ecosystem services and ecological status

Lake Adele is a seasonal pan and serves as a stopover site for birds and provides livelihood amenities to local communities.

2.12.2.1.3. Lake Tinkie (Kuro)

Lake Tinikie or Kurro is located on coordinates 09^{0}440096N, 42^{0}017509E in Haramaya *Woreda*.

Biophysical characteristics

This is a shallow lake, but much deeper than Lake Adelle, with a maximum of 3.00 m, as measured back in 1987. It is very small as well but it is highly productive with rich harvest of two species of fish, namely, *Clarias gariepinus* and *Oreochromis niloticus*. As this lake is located at a slightly higher elevation than Lake Haramaya, the extra volume spills over into Lake Haramaya during the rainy season when the water overfills.

Like the cases of the lakes in the region, the water is abstracted for small scale irrigation purposes to grow horticultural crops and *C. edulis*. These products are again sold to the same destinations mentioned for Lakes Adelle and Haramaya. Besides providing household water to the local community, watering of domestic animals, two or three sizable pumps of the Harar Brewery collects water from the groundwater very close to the lake. The impact of these diverse water uses by humans and the variability in rainfall and increasing air temperatures in the region have strongly impacted these water systems, namely, Lake Haramaya, already dried out, Lake Adelle and Tinikie are on the verge of drying out..

Ecosystem services and ecological status

Provision of potable water and fish, supportive service as habitat for fish and plants. Lake Tinkie should be restored before it dries up like Lake Haramaya. Approaches such as forestation of the catchment and water use regulation should be used.

2.12.2.1.4. Lakes Haro-Chercher and Sororo

Lake Haro-Chercher is located at 8.820037 N; 40.656429E, which is further away from Gelemso on the way to Bedessa and Lake Sororo is loacted at 09.036212N; 40.916190E near Mt. Kuni Muktar where Nyala is found (see Figure Plate 2.51 below).

Plate 2. 50: Left: Lake Haro-Chercher and right: Lake Sororo (from Google Map, 2017)

The watershed of Lake Haro-Chercher tends to show some vegetation cover most likely due to its mountainous and difficult to farming nature. According to the Google image, there is a northern valley of wetlands which indicates that most of the runoff enters the lake from that side. On the other hand, Lake Sororo is crowded with farming communities, their village settlements with houses of tin-roofs and extensive small plots of farmlands. To the south of the lake there are extended wetlands, which are likely to be inundated in the rainy seasons, expanding the size of the lake. Much is not known whether these waters have been stocked with fishes.

Ecosystem services and ecological status

This small wetland has provisionary services to the local communities such as potable water, fish and aquatic plants.

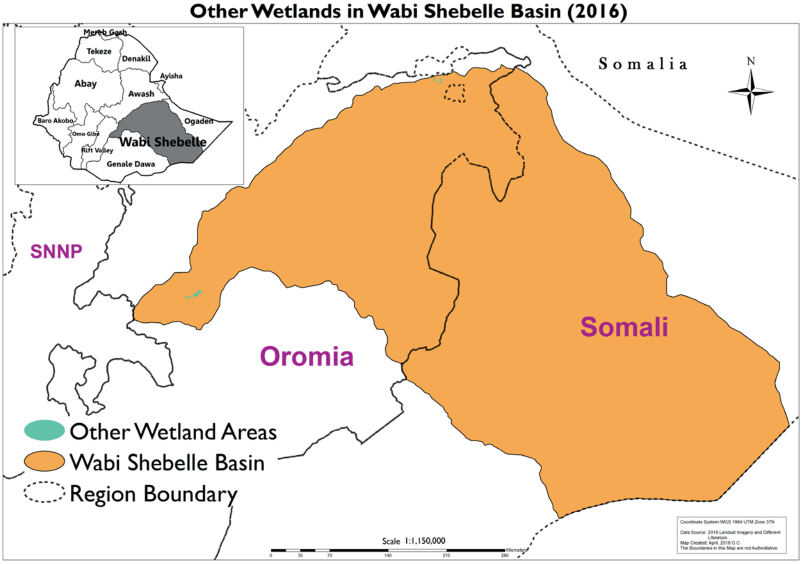


Figure 2. 51: Other wetlands in the Wabe Shebelle basin

2.12.2.2. Other wetlands in the ONRS

These include dams, reservoirs, flooded areas, floodplains, swamps, marshes, salt marshes, irrigation fields, plantations, seasonal pans, ponds, etc, as indicated in Fig. 2.51.

2.12.2.2.1. Awuseid wetland (pan)

Located at 8.809805N; 40.541515E, west of the town of Gelemso, West Hararghe (the red line indicates the road diverging from the main Addis-Ababa-Harar road to Mechara in the north-west (From Google Map, 2017, Plate 2.52).

Biophysical features

From past personal visits to the area and the map above, the area is highly populated with crowded farmers' plots and barren land devoid of natural land cover. Uncontrolled erosion and waste inflows from the surrounding farming communities and Gelemso town enter into the wetlands along the eastern shores of Lake Awuseid. There are reports that this wetland had dried out in some drought seasons of limited precipitation. It has also been reported that this same lake has been stocked with Nile-tilapia and common carp fingerings with the technical and financial support of The Catholic Development Agency located in Dire Dawa City.

Plate 2. 51: Lake Awuseid near Gelemso town, Hararge (Google map 2017)

Ecosystem services and ecological status

This is a seasonally drying wetland (pan) and perhaps the ecosystem services of provisioning that it gives at present should be maintained with more scientific and rational approaches, such as best agriculture practice. The upland catchments need to be rehabilitated.

2.12.2.2.2. Chelenko and Langue wetlands

Also referred to as Lake Langue, the Chelenko and langue wetlands are found in East Hararghe at 09.417531 and 41.61337 and langue Wetlands located at 9.404337 and 41.596765, both in East Hararghe along the main road from Addis Ababa to Harar, roughly at a distance of 100 km from each other (Plate 2.53).

Plate 2. 52: Chelenko and Langue Wetlands (from Google map, 2017)

Chelenko wetlands are mostly seasonal only appearing in the rainy seasons and lingering to stay for quite a long period into the dry season. This wetland is a major source of fresh water for the surrounding farming communities. When the water regresses, the wet ground converts itself into forage ground where cattle and small ruminants of the surrounding communities converge for communal grazing.

The Langue wetlands also serve the same purpose particularly for the small town on its northern shore that abstracts drinking water from it. Depending on the strength of the rainy season of that particular year, the water stays, however small, until the next rainy season, which has prompted people into naming it as a "lake".

Ecosystem services and ecological status

The small pan, which can dry up in some years, is still an important source of potable water, grazing area and recession agriculture for the local communities. It may be necessary to prolong the water storage of the pan through watershed forestation and water allocation schemes.

2.12.2.2.3. MelkaWakena reservoir

The Melka Wakana Reservoir is located about 336 km south-east of Addis Ababa in the Oromia Regional State at the upper part of the Wabe Shebelle river basin and was constructed for generating electric power. It is one of the South-East highland dams and was established in 1987. The reservoir has an area of 81.6 km^2 and shoreline length of 126 km at an elevation of 2376 masl; with maximum length of 37 km, maximum width of 18 km and mean depth of 10 m. There are major 6 inflowing rivers namely: **Burqa Hasassa** from North **Meribo**, **Nanesha, Leliso, Furona** and from south **Heraro River,** which flows to the reservoir in its western part.

Ecosystem services and ecological status

The Melka Wakena reservoir stores water which is used for hydropower production, besides its use as habitat for fish (carp) and aquatic plants. The inflowing rivers and the reservoir regulate flows and moderate climate in the catchment.

References

Abebe Damtew (2006). Evaluation of Gowa Worko small-scale irrigation scheme at Ada district, Oromia. A Thesis Submitted to the School of Graduate Studies through Department of Agricultural Engineering Graduate Council of Haramaya University, Ethiopia.

Abebe Getahun and Stiassny (1998). The Freshwater biodiversity crisis: The case of the Ethiopian Fish fauna. *SINET: Ethiopian Journal of Science*, 21 (2): 207-230.

Abile Teshita and Ayalew Wondie (2014). The impact of impoundment on downstream macro-invertebrate communities at Koga irrigation dam, West Gojam, Ethiopia. *Int. H. Sci. Res.* 3(6): 544 -552. Adugna Babu and Bogale Teferi (2015). Assessment of Human Induced Threats to Warameda Wetland, Dale Woreda, Southern Ethiopia. *International Journal of Fauna and Biological Studies*; 2(6): 25-33.

Afework Hailu (1998). An overview of wetland use in Illubabor Zone, southwest Ethiopia. Ethiopian Wetlands Research project, Metu, Illubabor.

Amacher, G.S., L. Ersado, W.S. Hyde and D. Grebro (2004). Diseases, microdams and natural resources in Tigray, Ethiopia: Impacts on productivity and labor supplies. *Journal of Development Studies,* 40(6):122-141.

Anteneh Belayneh, Zemede Asfaw, Sebsebe Demissew and Negussie F Bussa (2012). Medicinal plants potential and use by pastoral and agro-pastoral communities in Erer Valley of Babile Woreda, Eastern Ethiopia. *Journal of Ethnobiology and Ethnomedicine*, 8 (42):1-12 (http://www.ethnobiomed.com/content/8/1/42)

Argaw Ambelu, Mekonen S., G/Sellasiie, A., Mola, A and Karoumooti, K. (2013). Physico-chemical and biological characteristics of two Ethiopian wetlands. *Wetlands* 33 (6):69-79.

Balemwal Atnafu and Russo, A. (2004). Late Quaternary lacustrine ostracoda of the Zwai-Shala Basin (Ethiopia) as Paleo-environmental indicators. Bollettino delk Societh Paleontologica Italiana (Editors: Elsa Gliozzi and Antonio Russo), 43(1-2):235-266 (ISBN 0375-7633).

Bauman, A., Forster, U. and Rohde, R. (1975). Lake Shala: Water chemistry, mineralogy and geochemistry of sediments in an Ethiopian rift lake. *Geol. Rdsch,.* 64: 593-609.

Baxter, B.M and Golobitsch, D.L. (1970). A note on the limnology of Lake Hayq, Ethiopia. *Limnol. Oceaanogr.*, 15:144-148.

BCEOM. (1999). Abay Basin Integrated master plan study, main report Ministry of Water Resources, Addis Ababa. Phase two, Volume 3 Agriculture, 1-2.

Birdlife International (2013). Country profile: Ethiopia. http://www.birdlife.org / datazone/userfiles /file/IBAs/AfricaCntryPDFs/Ethiopia.pdf.

Briggs, P. (2010). *Ethiopia*, Global PWN, Warszawa.

Brook Lemma (1987). The present status and potentials for future development of inland fisheries in Ethiopia. In: S. Ouattar and J. Feyen (eds), Proceedings for the Management of Water and Natural Resources to Increase Food Production in Africa. Acco Press, Leuven, Belgium. pp. 18.1-18.16.

Brook Lemma (1991). Preliminary limnological studies on L. Haramaya, Ethiopia, and some questions arising. In: K. Koop (ed.), Aquaculture in Africa, held in Harare, Zimbabwe, 23-27 January 1991. IFS publication, Stockholm, pp. 134-148.

Brook Lemma (1994a). Changes in the limnological behaviour of a tropical African explosion crater lake: L. Hora-Kilole, Ethiopia. *Limnologica,* 24(1):57-70.

Brook Lemma (1994b). The influence of human water requirements on the limnological features of two tropical African lakes: Haramaya and Kilole, Ethiopia. In G. Friedrich (ed), Deutsche Gesellschaft für Limnologie e. V. Jahrestagung September 26-30, 1994; Vol. II; Hamburg, Germany. pp. 919-922.

Brook Lemma (1995). Seasonal limnological studies on Lake Haramaya: A tropical African lake, Ethiopia. Arch. *Hydrobiol.*, (Suppl.) 107:263-285.

Brook Lemma (1997). Der Einfluß zooplanktonfressender Fische auf die Größenfraktionen des Phytoplanktons und die Primärproduktion in gemäßigten und tropischen Seen (PhD Dissertation). pp 176.

Brook Lemma (2001). Fish predation pressure on and interactions between cladocerans: Observations using enclosures in tropical and temperate lakes, Ethiopia and Germany, *Limnologica,* 31:209 – 220.

Brook Lemma (2002). Contrasting effects of human activities on aquatic habitats and biodiversity of two Ethiopian lakes. *Ethiopian Journal of Natural Resources,* 4(1):127 – 148.

Brook Lemma (2003a). Ecological changes of two Ethiopian lakes as caused by contrasting human interventions. *Limnologica*, 33:44 - 53.

Brook Lemma (2003b). Aquatic habitats and biodiversity changes of two Ethiopian lakes. In: "*Wetlands and Aquatic Resources: Status, Challenges and Prospects*", Ethiopian Biological Society Conference, Addis Ababa University, Addis Ababa, 12 – 13 February 2003, pp. 27 - 31.

Brook Lemma (2007). Diel vertical migration of *Daphnia barbata* in a shallow tropical lake, Ethiopia. *SINET: Ethiop. J. Sci.* 30(2):117-126.

Brook Lemma (2008a). *Introduction to Lake Ecology, Aquaculture and Fisheries in Ethiopia*. Publisher: Haramaya University, Addis Ababa University Printing Press, Ethiopia, 416 pp. (*ISBN: 978-99944-819-0-3*).

Brook Lemma (2008b). Observations on the relations of some physico-chemical features and DVM of *Paradiaptomus africanus* in Lakes Bishoftu-Guda and Hora-Arsedi, Bishoftu, Ethiopia. *Limnologica* doi:10:1016/j.limno.2008.06.007.

Brook Lemma (2011). The impact of climate change and population increase on Lakes Haramaya and Hora-Kilole (1986 – 2006). In: Impacts of climate change and population on tropical aquatic resources. Proceedings of the Ethiopian Fisheries and Aquatic Sciences (EFASA); Haramaya University, 03-06 February 2011. pp. 11-36.

Brook Lemma (National Consultant) (2012). Report on the Value Chain (Marketing) Assessment of the Fishery Sector in Ethiopia. Publisher: Food and Agriculture Organization Sub-Regional Office for Eastern Africa (FAO/SFE), Addis Ababa. 131 pp.

Dagnachew Legesse, Vallet-Coulomb, Christine, V. C. and Gasse, F.C. (2004). Analysis of the hydrological response of a tropical terminal lake, Lake Abiyata (Main Ethiopian Rift Valley) to changes in climate and human activities. *Hydrol. Processes* 18: 487–504.

Defaye, D. (1988). Contribution à la connaissance des crustacés Copépodes d'Ethiopie. *Hydrobiologia,* 164:103-147.

Derege Tsegaye, Tsunekawa, A., and Tsubo, M. (2012). Continuing Land Degradation and Its Cause-Effect in Ethiopia's Central Rift Valley. Arid Land Research Center, Tottori University 1390, Hamasaka, Tottori, 680-0001, Japan (deremesh@yahoo.com); *Land Degradation and Development* XX:XXX.

Dagnachew Legesse, Vallet-Coulomb, Christine, V. C. and Gasse, F.C. (2004). Analysis of the hydrological response of a tropical terminal lake, Lake Abiyata (Main Ethiopian Rift Valley) to changes in climate and human activities. *Hydrol. Processes,* 18:487–504.

Daniel Elala (2011). Vulnerability assessment of surface water supply systems due to climate change and other impacts in Addis Ababa, Ethiopia. Disertation submitted to the Department of Earth Sciences, Aquatic Cliamatology, Uppsala University, 58pp.

Desale Kidane, Amanuel Mekonnen and Demel Teketay (2014). Contributions of Tendaho Irrigation Project to the Improvement of Livelihoods of Agro-pastoralists in the Lower Awash Basin, Northeastern Ethiopia. Ethiopian *e-Journal for Research and Innovation Foresight* (*Ee-JRIF*) 6(2): 1-19

Desalegn Chemeda Edossa, Babel, M, S. and Gupta, A. D. (2010). Drought Analysis in the Awash River Basin, Ethiopia. *Water Resour Manage* 24:1441–1460; DOI 10.1007/s11269-009-9508-0

Dessie Tibebe Ayele (2016). Internal and external agrochemical loads, dynamics and impacts of the freshwater ecosystem of Lake Zwai, Ethiopia: PhD Thesis, Department of Chemistry, Addis Ababa University**,** 195 pp.

Dikes Umbushe Gojamme. (2013). Wetland Vegetation Composition and Ecology of Abaya and Chamo in Southern and Fincha'a-Chomen and Dabus in Western Ethiopia. Addis Ababa University: Addis Ababa

Elizabeth Kebede and Willen, E. (1998). Phytoplankton in a salinity-alkalinity series of lakes in the Ethiopian rift Valley. *Algological Studies,* 89:63-96.

Elizabeth Kebede, Zinabu GebreMariam and Ahlgren, I. (1994) The Ethiopian Rift Valley lakes: chemical characteristics of a salinity-alkalinity series. *Hydrobiologia,* 288:1-12.

Ermias Deribe, Rosseland, B. O., Borgstrøm, R., Salbu, B., Zinabu Gebremariam, Elias Dadebo (2011) Bioaccumulation of persistent organic pollutants (POPs) in fish species from Lake Koka, Ethiopia: The influence of lipid content and trophic position. *Science of the Total Environment*, 410–411:136–145.

Ersado, L. G.S. Amacher and J. Awang (2004) Productivity and land enhancing technologies in northern Ethiopia: Health, public investments and sequential adoption. *American Journal of Agricultural Economics,* 86 (2):321-331.

Ethiopian Wildlife and Natural History Society (EWNHS) (1996). Important Bird Areas of Ethiopia. First inventory.

Eyualem Abebe and Coomans, A. (1996a-d). Aquatic nematodes from Ethiopia I, II, III and V. Hydrobiologia (a) 324:1-51; (b) 324: 53-77; (c) 324: 79-97; (d) 332:27-39.

EVDSA (Ethiopian Valleys Development Studies Authority) (1979). Amibara irrigation project II: Inception report for technical support services. Halcrow-ULG, UK

Falcon, N. L., Grove, A. T., Schove, D. J., Banister, K. E., Kingham, T. J., King, R. B., Lamb, H. H. Kent, P. and Peters, E. R. (1975). Former Lake Levels and Climatic Change in the Rift Valley of Southern Ethiopia: Discussion. The Geographical Journal 141 (2):194-202.

FAO (1965). Survey report on the Awash Basin: Genral Report. Submitted to the Imperial Government of Ethiopia by the Food and Agriculture Organization (FAO) of the United Nation, Rome. Technical Paper No. FAO/SF: 10 ETH, 180 pp.

Fasil Degefu, Aschalew Lakew, Yared Tigabu and Kibru Teshome (2013). The water quality degradation of Upper Awash River, Ethiopia. *Ethiopian Journal of Environmental Studies and Management*, 6 (1): 58-66 (http://dx.doi.org/10.4314/ejesm.v6i1.7)

Fasil Degefu, Herzig, A., Jirsa, F., and Schagerl, M. (2014). First limnological records of highly threatened tropical high-mountain crater lakes in Ethiopia. *Tropical Conservation Science* 7 (3):365-381.

Fassil E. Teffera, Pieter Lemmens, Arne Deriemaecker, Luc Brendonck,Stefaan Dondeyne, Jozef Deckers, Hans Bauer, Feleke W. Gamo & Luc De Meester (2017). A call to action: strong long-term limnological changes in the two largest Ethiopian Rift Valley lakes, Abaya and Chamo, Inland Waters

Fernando, C. H. (1994). Zooplankton, fish and fisheries in tropical freshwaters. *Hydrobiologia,* 272:105-123.

Gebrekidan Worku (2014). Assessment of the shrinkage and ecological importance of wetlands of Fogera plain, North West Ethiopia. *J. Env. Earth. Sci.*, 4, No. 14.

Gebremedhin Kiros, Amba Shetty and L. Nandageru (2016). Analysis of variability and trends in rainfall over northern Ethiopia. *Arab J. Geosci.*, 9: 451.

Getnet Hunegnaw, Habib Mengesha, Alemante Aimro and Biazin Ferede (2013). Wetlands Ecosystems Coverage, Status and Threats in the Abay River Basin. Abay Basin Authority, FRDE Abay Basin Authority, Report, 92 pp.

Girum Tamire and Seyoum Mengistou (2012). Macrophyte species composition, distribution and diversity in relation to some physicochemical factors in the littoral zone of Lake Zwai Ethiopia. Afr. J. Ecol., 51:66–77

Golubtsov, A. S. and Mina, M. V. (2003). Fish species diversity in the main drainage systems of Ethiopia: Current state of knowledge and research perspective. Eth. J. Nat. Res. 5:281-318.

Green, J. and Seyoum Mengistu (1991). Species diversity and community structure of Rotifera in a salinity series of Ethiopian inland waters. Hydrobiologia, 209: 95-106.

Groove, A. T., Street, F. A. and Goudie, A. S. (1975). Former lake levels and climate change in the rift valley of southern Ethiopia. Geographical Journal, 141: 177-194.

Habtamu Haile Tolera (2007). Suitability of local materials to purify Akaki Sub-basin water. PhD dissertation at the University of Karlsruhe, Germany.

Haile Gashaw (1999). Hydrogeochemistry of waters in Lake Zwai area. Paper presented at the 25th WEDC Conference on Integrated Development for Water Supply and Sanitation; pp. 286-189.

Haile Selassie Girmay and G. Assefa (1989). The Addis Ababa-Nazareth volcanic: A Miocene-Pleistocene volcanic succession in Ethiopian Rift. SINET: Ethiop. J. Sci. 12:1.

Haileab Zegeye, Demel Teketay and Ensermu Kelbessa (2006). Diversity, regeneration status and socio-economic importance of the vegetation in the islands of Lake Zwai south-central Ethiopia. Flora, 201: 483–498

Hancock, G. (1992). The Sign and the Seal. Crown Publishers Inc. New York. 600pp.

Harris, S. (2008): Salt Investment S.A.Z.F (SI SAZF), (2008) Lake Assal Salt Project, Djibouti. Geographic Environmental Solutions.

Jansen, H., Hengsdijk, H., Dagnachew Legesse, Tenalem Ayenew, Hellegers, P. and Spliethoff, P. (2007). Land and water resources assessment in the Ethiopian Central Rift Valley. Alterra-rapport 1587, Wageningen.83 pp.

JERBE (Ethio-Russian Biological Expedition) (2008). Twenty years of Biological Scientific Cooperation in ecological and faunitic studies in Ethiopia; Proceedings of Jubliee Meeting Addis Abeba, February 21-23, Moscow 2008.

Karlsson, J. (2015). Scoping study of water management in the textile industry in Ethiopia. SIWI Paper 23.SIWI, Stockholm.

Kassahun A, Fekadu T, Zenebe T (2011). Adaptability, growth and reproductive success of the Nile Tilapia, Oreochromisniloticus.(pisces: Cichlidae) stocked in Lake Tinshu Abaya (South Ethiopia). J. Biol. Sci. 10(2): 153-166.

Kinfe Hailemariam (1999). Impact of climate change on water resources of the Awash River basin, Ethiopia. Climate Change Research, 12: 91-96.

Klemperer, S. L. and Cash, M. D. (2007). Temporal geochemical variation in Ethiopian Lakes Shala, Arenguade, Hawassa, and Basaka: Possible environmental impacts from underwater and borehole detonations. Journal of African Earth Sciences, 48:174–198. doi:10.1016/j.jafrearsci.2006.10.006

Leykun Abune (2003). The distribution and status of Ethiopian wetlands: an overview. In: Wetlands of Ethiopia. Proceedings of a seminar on the resources and status of in Ethiopia's wetlands (Eds.Yilma D. Abebe and Kim Geheb). IUCN Wetlands and Water Resources Programme Blue Series.

Loiskanl, W., Ruffeis, G., Schoneridee, M., Spendingwinner, R., Awulachew, Sileshi Bekele and Boelee, E. (2008). Case study review of investigated irrigation systems in Ethiopia. Proceeding of symposium and exhibition, Addis Ababa, 27-29 November 2007. Colomobo, Sri Lanka, International Water Management Institute (IWMI), pp. 357-369.

Matagi, S. V. (2005). A biodiversity assessment of the Flamingo Lakes of eastern Africa. Biodiversity, 5(1):13-26.

McSweeney, C., New, M., and Lizcano, G. (2007). UNDP Climate Change Country Profiles Ethiopia, Available at: http://country-profiles.geog.ox.ac.uk, accessed 31-062011.

Megersa Dinka (2012) Analysing the extent (size and shape) of Lake Basaka expansion (main Ethiopian Rift Valley) using remote sensing and GIS. Lakes and Reservoirs: research and Management 17:131-141.

Megersa Olana Dinka., Loiskandl, W. & Ndambuki, J. M. (2014). Status of Groundwater Table Depth Under Long-Term Irrigation in Wonji Plain: Concerns for Sustainability of Wonji-Shoa Sugar Estate, Upper Awash Valley, Ethiopia.

Mepham, R., Hughes, R. H., and Hughes, J. S. (1992). A directory of African wetlands. Cambridge, IUCN, UNEP and WCMC, 158 p.

Moges Beletew (2007). The diversity, abundance and distribution of fishes in the Beshilo, Dura and Ardi Rivers, Abay Basin. MSc Thesis, Addis Ababa University, Addis Ababa.

Mohr, P. A. (1962). The Ethiopian Rift Rift System. Bulletin of Geophysics Observatory, 5:33-62.

Mulat Asmamaw, Ashenafi Haile and Gezai Abera (2018). Characterization and classification of salt affected soils and irrigation water in Tendaho sugarcane production farm, North-Eastern Rift Valley of Ethiopia. African Journal of Agricultural Research 13(9): 403-411, DOI: 10.5897/AJAR2018.12988

Nata Tadesse, D. Nadew, K. Woldearegay, T. G/yohannes and R. van Steerwegen (2015). Groundwater management for irrigation in the Raya and Kobo valleys, Northern Ethiopia. Int.J.Earth.Sci & Eng., 8(3):36-46.

Negash Atnafu, Eshete Dejen and Jacobus Vijverberg (2011). Assessment of the ecological status and threats of Welala and Shesher Wetlands, Lake Tana Sub-Basin (Ethiopia). Journal of Water Resource and Protection, 3:540-547.

Nilssen, J. P. (1984). Tropical lakes - Functional ecology and future development: The need for a process oriented approach. Hydobiologia, 113: 231-242.

NMSA (National Meteorological Services Agency) (2009). as reported in Table A.2. Central Statistical Agency website

Pattnaik, B. S. R. (2014). Species diversity of Lake Hawassa. International Journal of Science Research, 3(11): 33-35.

Prabu, C. P., Zerihun Teklemariam, Tadele Nigusse, Rajeshkumar, S., Lakew Wondimu, Alemayehu Negassa, Ephrem Debebe, Esayas Aga, Asfaw Andargie, and Asefa Keneni, (2008). Characterization of sewage wastewater and assessment of downstream pollution along Huluka River of Ambo, Ethiopia, Maejo International Journal of Science and Technology, 02(2):298-307.

Prabu, C. P., Wondimu L. and Tesso, M., (2011). Assessment of water quality of Huluka and Alaltu Rivers of Ambo, Ethiopia. Journal of Agricultural Science and Technology, 13:131-138.

Reaugh-Flower, K. (2010). Abijata Shala Lakes National park: Assessment of factors driving environmental change for management, decision-making, sustainable development of the protected area system of Ethiopia program, January.

Redeat Habteselassie (2012). Fishes of Ethiopia: Annotated Checklist with Pictorial Identification Guide. Austrian Development Cooperation and the Ethiopian Fisheries and aquatic Sciences association (EFASA), eclipse Printers, Addis Ababa. 250 pp.

Seifu Kebede, Travi, Y., Asfawossen Asrat, Tamiru Alemayehu, Tenalem Ayenew & Zenaw Tessema (2007). Groundwater origin and flow along selected transects in Ethiopian rift volcanic aquifers. Hydrological Journal DOI 10.1007/s10040-007-0210-0

Seleshi Bekele Awulachew (2006). Investigation of physical and bathymetric characteristics of Lakes Abaya and Chamo, Ethiopia and their management implications. Lakes and Reservoirs: Research and Management, 11:133–140.

Seleshi Bekele Awulachew, Aster Denekew Yilma, Makonnen Loulseged, Willibald Loiskandl, Mekonnen Ayana and Tena Alamirew (2007). Water Resources and Irrigation Development in Ethiopia. Colombo, Sri Lanka: International Water Management Institute (IWMI). 78p. (Working Paper 123) ISBN 978-92-9090-680-3

Seyoum Mengistou (2006). Status and challenges of aquatic invertebrate research in Ethiopia: A review. Eth. J. Biol. Sci., 5(1): 75-115.

Seyoum Mengistou (2016). Invertebrates of East African soda lakes. In: Schaegerl, M. (ed.). Soda Lakes of East Africa. Springer

Solomon Kebede (2005). Preliminary environmental impact assessment for the development of Tendaho geothermal area, Ethiopia. geothermal Training Program Orkustofnun, Grensásvegur 9, Reports 2005, Number 11, The United Nations UniversityIS-108 Reykjavík, Iceland

Stave, K., Goraw Goshu & Shimellis Aynalem, (eds.) (2017). Social and ecological system dynamics.: Characteristics, trends and integration in the Lake Tana basin, Ethiopia. AESS Interdisciplinary Environmental Studies and Sciences Series. Springer.

Street, F. A. (1979). Late Quaternary lakes in the Zwai-Shala Basin, Southern Ethiopia. PhD Thesis submitted to the University of Cambridge. 457 pp.

Tadesse Gobena Shonka (2017). Performance Evaluation of Field Water Application at Tendaho Sugar Estate, Ethiopia. Irrigat Drainage Sys Eng 6: 199. doi: 10.4172/2168-9768.1000199.

Tadesse Mumicha, (2010). Assessment of land use impact on the water quality of Huluka River Ambo district, Oromia region, Ethiopia, M. Sc Thesis, Ambo University, 79pp.

Tewolde Tekle Giorgis (2009). Regional groundwater flow modeling of the Gebabasin, Northern Ethiopia, PhD Thesis. VUB, Belgium, 274 pp.

Talling, J. F. and Talling, I. (1965). The chemical composition of African lake waters. Int. Revue ges. Hydrobiol., 50:421-463.

Tenalem Ayenew (1996). Application of TM band 6 for the study of groundwater and surface water interaction with the lakes of Zwai-Shala basin. Abstracts, programs of the third Ethiopian Geoscience and Mineral Engineering Congress, 15-17 November 1996, Addis Ababa.

Tenalem Ayenew (2002). Recent changes in the level of Lake Abiyata, central main Ethiopian Rift. Hydrological Sciences, 47(3): 493-503

Tenalem Ayenew (2007). Some improper water resources utilization practices and environmental problems in the Ethiopian Rift. Africa Water Journal, 1(1):83-108.

Tenalem Ayenew (2009). Natural Lakes of Ethiopia. Addis Ababa University Press, Eclipse Printers, Addis Ababa. 206 pp.

Tenalem Ayenew (2012). Status and threats to selected Ethiopian wetlands in 2016. In: Ethiopian Environment Review. Sue Edwards (ed.) Forum for Environment, No. 2, 2012.

Tenalem Ayenew., Molla Demlie, and Wohnlich, S. (2008). Application of Numerical Modeling for Groundwater Flow System Analysis in the Akaki Catchment, Central Ethiopia Mathematical Geoscience, 40:887–906, DOI 10.1007/s11004-008-9144-x

Tilahun Kibret and Harrison, A. D. (1989). The benthic and weed-bed faunas of Lake Awassa (Rift Valley, Ethiopia). Hydrobiologia, 174: 1-15.

Tudorancea, C. and Taylor, W. D. (eds.) (2002). Ethiopian Rift Valley lakes. Backhuys Publishers, Leiden, The Netherlands, ISBN: 90-5782-114-1. 289 pp.

Tudorancea, C., Baxter, R. M. and Fernando, C. H. (1989). A comparative limnological study of zoobenthic associations in lakes of the Ethiopian Rift Valley. Arch. Hydrobiol. Suppl., 83: 121-174.

Turdu, C. L., Tiercelin, J. J., Gilbert, E., Travi, Y., Lessar, K. E., Richert, J. P., Massault, M., Gasse, F., Bonnefille, R., Decobert, M., Gensous, B., Jeudy, V., Tamirat, E., Mohammed, M. U., Martens, K., Atnafu, B., Cherenet, T., Williamson, D. and Taieb, M. (1999). The Zwai-Shala lake basin system, Main Ethiopian Rift: Influence of Volcanism, techtonics, and climate forcing on basin formation and sedimentation. Paleogeography, Paleoclimatology, Paleoecology, 150: 135-177.

Uhlenbrook, S., Y. Mohemmed and A.S. Gragne (2010). Analyzing catchment behavior through catchment modeling in the Gilgel Abay, Upper Abay Basin, Ethiopia. Hydrol. EarthSyst. Sci, 14: 2153-2165.

USAID (2006). Agro-climatic monitoring famine early warning system (FEWSNET)

Vijverberg, J., Eshete Dejen, Abebe Getahun and Nagelkerke, L. A.J. (2012). Animal Biology 62: 315-335.

Waltham T. (2005). Extension tectonics in the Afar Triangle. Geology Today, 21 (3):101–107.

Waltham T. (2010). Afar Triangle: Rift Valleys and Volcanoes over Plate Divergence. In: Migoń P. (ed.), Geomorphological landscapes of the world. Springer Science + Business Media, Dordrecht: 183–190.

Water Governance Center (2013). Issues Paper: Water Governance Capacity Awash Basin, Central Ethiopia - A review on content, Institutional, Relational layer. Hague, The Netherlands. 18 pp.

Willén, E., Ahlgren, G., Girma Tilahun, Spoof, L., Neffling, M. R., and Meriluoto, J. (2011). Cyanotoxin production in seven Ethiopian Rift Valley lakes. Inland Waters, 1:81-91.

Wood, R. B. & Talling, J. F. (1988). Chemical and algal relations in a salinity series of Ethiopian inland waters. Hydrobiologia, 158:29-67.

Worku Legesse, (2000). Physico-chemical and biological assessment of the Kebena River, Addis Ababa, Ethiopia. PhD Thesis, Department of Zoology and Animal Ecology, National University of Ireland, Cork.

Yilma Delelegn and Geheb, K. (2003). Wetlands of Ethiopia: Proceedings of a Seminar on the Resources and Status of Ethiopia's Wetlands. International Union Conservation of Nature and Natural resource, Nairobi. pp.116.

Yirmed Demeke, Renfree, M. B. and Short, R. V. (2012). Historical range and movements of the Elephants in Babile Elephant Sanctuary, Ethiopia. Afr. J. Ecol., 50:439–445.

Zerihun Woldu and Kumelachew Yeshitela (1999). Plant Biodiversity Annual Report for 1998-99. Ethiopian Wetland Research Program, Metu. pp.25.

Zerihun Woldu and Kumilachew Yeshitila (2003). Wetlands in Ethiopia with examples from Ilubabor, southwestern Ethiopia. In: Yilma Delelegn and Geheb, K. (eds). Wetlands of Ethiopia: Proceedings of a Seminar on the Resources and Status of Ethiopia's Wetlands. IUCN, Nairobi.

Zerihun Woldu, Assefa Mebrate, Seyoum Mengistou, Tenalem Ayenew, Dagnachew Legesse (2005). A review of the current status and an outline of a future management plan for Lakes Abijata and Zwai. Oromia Environmental Protection Burea. Unpublished Technical Report. Addis Ababa, Ethiopia. 80 pp.

Zinabu GebreMariam (2002). The effect of wet and dry seasons on concentrations of solutes and phytoplankton biomass in seven Ethiopian rift valley lakes. Limnologica, 32:169-179.

Zinabu GebreMariam and Pearce, J. G. (2003). Concentrations of heavy metals and related trace elements in some Ethiopian Rift-Valley lakes and their in-flows. Hydrobiologia, 429:171–178.

Zinabu GebreMariam and Taylor (1997). Bacteria-chlorophyll relationships in Ethiopian lakes of varying salinity: Are soda lakes different? Journal of Plankton Research, 19(5):647-654.

Zinabu GebreMariam, Chapman, L. J. and Chapman, C. A. (2002). Conductivity as a predictor of a total cations and salinity in Ethiopian lakes and rivers: revisiting earlier models. Limnologica, 32:21-26.

CHAPTER 3

CAUSES OF WETLAND DEGRADATION

The major causes of wetland degradation in developing nations are similar and we may categorize the causes of wetland degradation into two - the ultimate and proximate causes.

The **ultimate causes** are related to population growth and bad governance that ultimately lead to poverty. When poverty prevails, it would be very difficult, if not impossible, to conserve biodiversity and their habitats. Therefore, the ultimate solution rests in tackling these root causes of the problem, which have socio-economic implications and require political will and commitment to resolve.

The **proximate causes** are mainly related to habitat destruction (alteration), introduction of alien species, pollution and overexploitation, which are usually abbreviated as HIPO.

The major cause of wetland degradation is habitat destruction, which is related to several factors that include excessive water abstraction for various purposes, including irrigation, watershed perturbation (sedimentation), damming, diversions and channelization.

3.1 Excessive water abstractions

Alteration can reduce or increase the natural amount of water recharging wetlands and extent of saturation and may cause changes in the ecosystem functions. Any excessive withdrawal of water either directly from the wetlands or from Feeder Rivers and other water bodies associated with the wetlands reduces their size and ultimately leads to their disappearance; Lake Haramaya is a typical example for this case.

Excessive withdrawal of water for various purposes is now becoming a serious problem all along the rift valley lakes starting from Lake Afdera in the north to

Lake Turkana in the south. This is more serious in the case of the Zwai-Shala basin (Tenalem Ayenew, 2012). The effect of water diversion from feeder rivers is better reflected in the larger lakes than in the wetlands. However, as the lakes start to recede the associated wetlands will start to shrink. The flood plains are also seriously affected by abstraction of water from rivers for irrigation purposes. Obviously, the flood plains are recharged by overflow of water from the adjoining rivers.

Plate 3.1. Lake Abijata in 2017 (Photo credit: Solomon Wagaw)

Plate 3.2. "Lake" Haramya in 2011

According to Tenalem Ayenew (2012) the above consequences are aggravated by the following factors:

a. *Habitat loss and fragmentation*

Habitat fragmentation, as wetlands are drained or hydrologically altered, may result in changes in species composition as wetlands species are replaced by others adapted to drier environments; loss of large, wide-ranging species; loss of genetic integrity when isolated habitats are too small to support viable populations; reduced populations of interior species that can only reproduce in large tracts; and increased number of competitors, predator, and parasite species tolerant of disturbed environments.

b. *Water diversion structures*

Water diversion structures, such as canals (channels), ditches, and levees have been used to modify wetlands to achieve flood control, drainage, mosquito control, irrigation, and industrial activities (Mitsch and Gosselink, 2007). Canals and channelization change the hydrology of wetlands and increase the speed with which water moves into and through wetlands. As a result, patterns of sedimentation are altered and wetland functions and values that depend on the normal slow flow of water through a wetland can be affected. High sediment loads entering wetlands through channels, irrigation ditches and drainage ditches can smother aquatic vegetation and contribute to increased turbidity and also alter the water temperature and diminish habitat suitable for aquatic organisms.

Traditional river diversion for small-scale and micro-scale irrigation can be found in all regions of Ethiopia. Over the last decade, an increase in traditionally irrigated areas has been observed due to the growing pressure to intensify agricultural production as a result of high population growth and shortage of arable land and recurrence of drought. Traditional river diversions are physical structures built with local materials. The diversion structures are normally destroyed by floods during the rainy seasons and have to be built each year. The unregulated way in which diversion of water from rivers, lakes and streams is going on indicates that the process is not sustainable and has to be managed.

In the Ethiopian context, the irrigation sub-sector is classified as small (less than 200 ha), medium (200 to 300 ha) and large-scale (over 300 ha) schemes. Ethiopia's irrigation potential has been estimated to be in the order of 3.5

million hectares. The total area currently irrigated by modern irrigation schemes in Ethiopia is approximately in the order of 160,000 ha. In addition, there are traditional schemes in the order of 120,000 ha of traditional schemes in the Amhara, Southern Nations and Nationalities, and Oromia regions. Currently, irrigated agriculture produces less than 3% of the total cereal production. Despite the importance of irrigation agriculture for the country, rarely has attempt been made to assess the impact of irrigation abstraction on the hydrological balance and water table lowering, and the ability of wetlands to recharge rivers and lakes.

Besides traditional diversions, relatively better engineered canals and culverts are being built all over the country (e.g. Plate 3.3). While the merit of such activities to bolster food security is commendable, the disorganized and speedy way by which canals are constructed all over the country calls for serious planning and management intervention.

Plate 3.3. Shini canal around Addis Zemen Town (Lake Tana sub-basin)

c. *Impoundments*

Impoundment of natural wetlands for storm water management or wildlife and habitat management may exploit one function of wetlands at the expense of others (Mitsch and Gosselink, 2007). Impoundment alters the natural wetlands' hydrology and decreases water circulation. Decreased water circulation causes increased water temperature, lower dissolved oxygen levels, and changes in salinity and pH; prevents nutrient outflow; and increases sedimentation. Sedimentation reduces the water storage capacity, smothers vegetation, reduces light penetration, reduces oxygen content and affects the entire ecosystem richness, diversity, and productivity. Toxic substances, adhering to sediments, may accumulate in impoundments as a result of decreased water circulation and bioaccumulation of contaminants by wetland biota may occur.

Plate 3.4. Koga Reservoir, near Merawi (Lake Tana sub-basin) with potential sediment fill-up

d. *Sedimentation*

Sedimentation of storage reservoirs is a major problem of dams. All micro-dams and large dams lose important portion of their storage capacities to sedimentation every year. There are even cases where reservoir capacities were filled with sediment within less than five years of operation. A case in point is Koka Dam in the rift valley and Koga Reservoir (Plate 3.4) in the Abay basin, both of which are in danger of fill-up with sediment load from degraded catchments.

3.2 Habitat changes due to agricultural practices

Historically, agriculture has been the major factor in freshwater and estuarine wetland loss and degradation through:

- Harvesting food, fiber, or forest products;
- Minor drainage;
- Maintenance of drainage ditches;
- Construction and maintenance of irrigation ditches;
- Construction and maintenance of farm or forest roads;
- Maintenance of dams, dikes, and levees;
- Direct and aerial application of damaging pesticides (herbicides, fungicides, insecticides, fumigants); and ground water withdrawals.

The above activities can alter a wetland's hydrology, water quality, and species composition. Excessive amounts of fertilizers and animal waste reaching wetlands in runoff from agricultural operations, including confined animal facilities, can cause eutrophication.

The debate about the future of wetlands tends to divide between those seeking to develop these areas for agricultural production (crop producers and livestock husbandry) and those who believe that wetlands must be preserved as much as possible in a stable state to maintain their ecological contributions to the ecological system (Ecologists). The perception of the former extends up to assuming wetlands as waste lands. In concentrating on the first big argument, it is very serious issue especially in developing countries that dominate the balance of debate.

The flat topography, fertile soil and reliable provision of water at dry season etc. of wetlands are some of the attracting factors. In Ethiopia, the debate is between consequences on one side and the government and the farmers on the other side. The government and farmers are in need of converting the wetlands in order to gain more products at a time. The highlands of south west Ethiopia (Illu Aba Bora) and swamps of Awash valley are good examples on where the government and farmers are engaged in producing more than seeing sustainable use of the resources (Dixon, 2002; Dixon and Wood, 2007). According to Afework Hailu (1998), in Illu Aba Bora zone, south west Ethiopia, where many swampy wetlands are located, there was no act of cultivation around the periphery of the wetlands before the beginning of the 20th century. But, in the years 1911-1918, wetland cultivation has extended beyond the use of wetland margins to include much larger areas. Nowadays, the complete drainage and cultivation of wetlands has become a common phenomenon throughout the area (Afework Hailu, 1998; Dixon and Wood, 2007).

Recently, irrigated agriculture comprising both open-field horticulture small holders and large scale greenhouse growers has expanded rapidly around the rift lakes of Zwai, Abijata and Langeno. Release of the various agricultural fertilizers and pesticides into the lakes is a real threat to the lakes' habitat and the biota within. It has, currently, become common to grow eucalyptus, banana, sugarcane and 'chat' on the periphery of the wetlands.

Resettlement and villagization in the rural areas have the effect of increasing demand upon the natural resources in some localities. Needs for thatching houses put a heavy demand upon the wetlands near the new villages and affects the quality of the reed beds. In addition, the need for more accessible farm and grazing land leads to the drainage of wetland in the vicinity of these new settlements.

Degradation of floodplains is exacerbated by unrestricted encroachment by squatters, landless farmers and unemployed who simply grab land portions and use them for sowing crops, grazing, removing vegetation for building houses, etc, with little impunity and oversight. As a result, many floodplains around the Omo delta, Gilgel Abay delta, Awash River delta near Lake Abe and fringe wetlands such as Shesher and Welela wetlands, are affected by disorderly settlements, landscape degradation and loss of ecosystem services of providing fish, fertile soil and habitats due to overexploitation.

Plate 3.5. Cheffa wetland and poor agricultural practice.

Drainage agriculture: There are cases where wetlands have been drained and used for agriculture (e.g. Plate 3.5). Wetlands play significant role in attenuating floods and acting as temporary storages during the wet season. This situation helps in reducing peak flows in the major rivers during the rainy season and also contributes to the base flow during the dry season by releasing what is stored during the wet season. This creates a situation where the flows in the wet and dry seasons do not show much variation. Drainage of the wetlands in some areas in the western part of the country is now affecting the flow regime in the Baro River. The wet season flows are increasing from time to time while the dry season flow has been reduced significantly over the past years.

Plate 3.6. Farming to the edge of the lake (Lake Hayq)

Land use changes: Shortage of farm land has forced many farmers to use land near lake shores (Plate 3.6). The impacts of land use patterns in Lake Zwai watershed has led to its degradation. The land use pattern in the watershed of Lake Zwai is dominated by agricultural practices. Most of it is dependent on rain-fed system, while in recent years irrigated agriculture to grow horticultural crops for Addis Ababa market and flowers for export are flourishing. This is highly motivated by increased population and livestock growth beyond the carrying capacity of the watershed (Derege Tsegaye *et al.*, 2012) and the policy of the Ethiopian Government to enhance development, create jobs and make the country self-sufficient in food production. The policy of enhanced development has also brought in extensive flower farms that draw a lot of water from the lake and discharge high quantities of effluents loaded with nutrients and other agrochemicals.

The major factors to land degradation and decrease in wetlands are cited as increase in human and livestock population as shown in Table 3.1 and 3.2 below. This scenario is aggravated by increase in temperature and trends of decreasing rainfall for the same period (1970-2006).

Land use/cover	1973		1985		2006		Change (%)		
	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)	1973–1985	1985–2006	1973-2006
Water	1258.14	7.69	1158.56	7.09	1065.09	6.51	–7.90	–8.58	–15.34
Forest	2512.15	15.37	2276.04	13.92	848.72	5.19	–9.51	–62.71	–66.26
Woodland	4681.01	28.61	3245.47	19.85	1442.59	8.82	–30.68	–55.55	–69.19
Intensive cultivation	5090.39	31.17	4459.65	27.28	6854.91	41.93	–12.58	53.71	34.48
Mixed cultivation	1681.63	10.28	3119.17	19.08	3021.45	18.48	85.48	-3.13	79.67
Degraded land	972.76	5.95	1918.34	11.72	2924.85	17.89	96.90	52.71	200.67
Marsh area	152.37	0.93	171.51	1.05	191.06	1.17	12.57	11.40	25.39
Total	16,348.45	100	16,348.74	100.	16,348.67	100			

Table 3. 1: Land use data for the central rift valley region (Source: Derege Tsegaye et al., 2012)

According to Derege Tsegaye *et al*. (2012), the increase in human and livestock population in the central rift valley is staggering and more than 100% increase was documented between 1965 and 2008 (Table 3.2).

Year	Population	Livestock	Population density	Livestock density
1965	1,078,719	85,120	66.1	5.2
1975	1,541,027	1,020,000	94.4	62.5
1985	2,201,468	1,058,000	134.9	64.8
1995	3,144,955	1,560,000	192.7	95.6
2008	4,897,145	1,850,000	300.2	113.3

Table 3. 2: Human and livestock population in the central rift valley region (Derege Tsegaye et al., 2012),

Overgrazing: Overgrazing is a serious problem around all wetlands of Ethiopia due to the high population of livestock in the country. Grazing livestock can degrade wetlands that they use as food and water source. Compaction of soil by livestock trampling is a common consequence in overcrowded wetlands (Plate 3.7). Urea and manure can result in high nutrient inputs. Overgrazing of riparian areas by livestock reduces streamside vegetation, preventing runoff filtration, increasing stream temperatures, and eliminating food and cover for fish and wildlife. Stream bank destabilization and erosion then cause downstream sedimentation. Sedimentation reduces stream and lake capacity, resulting in decreased water supply, irrigation water, flood control, hydropower production, water quality, and impairment of aquatic life and wetland habitat.

Plate 3.7. Grazing in Cheffa and Gerima wetlands, Amhara Region (note soil compaction)

3.3 Watershed perturbation

Clearance of forests and the resultant erosion from surrounding catchments would seriously affect the biological and physico-chemical situations in water bodies. This is especially aggravated in the absence of wetlands.

In Ethiopia, there is rapid land use land cover change, especially the conversion of natural forests to cultivated land and grazing lands hold the widest part. Food and agricultural organization of the United Nations (FAO, 2005) illustrated that, in the year between1990–2000, the total natural forest cover of the country has decreased by 9% with the estimated rate of 40,000 ha per year while plantations have increased only by 1%.

Fertilizers from agricultural fields surrounding water bodies may cause, through erosion, excess loadings of nutrients that could cause eutrophication in the water body. In turn, eutrophication is the main cause of fish kills and deaths of other aquatic organisms by causing depletion of oxygen. Fish kills, caused by the above problems, have been observed in Lakes Chamo, Hayq, Babogaya and Hashenge in Ethiopia in the past years.

Due to unwise utilization of land, deforestation and overgrazing of watershed, soil erosion is increasing from time to time and causes siltation of lakes, reservoirs and rivers. Lake Haramaya, Hawassa and Koka Reservoir are live examples affected by siltation problems, which emanates from degradation of the wetlands. The worst scenarios are observed in Lakes Abaya and Chamo.

Plate 3.8. Collection and transporting fuel wood from Lake Tana surroundings

Deforestation is one main cause of land degradation (See Plate 3.8). It is estimated that some 1900 million tons of soil is being eroded annually in the highlands. This is equivalent to an average of 35 tons from every hectare in the highlands. However, most losses are from croplands, totaling an estimated 22% of the land area of the highlands and the remaining 20% is from overgrazed grasslands and little from waste and other lands. Most of this is deposited as sediment on grass and forest land, but the part that is carried into rivers is lost, carrying away from the highlands some 1900 million tons of soil every year.

Aggradation of river channels is another problem resulting from sedimentation. For example, the stretches of the Awash in the lower valley is a case in example. As a result of aggradations of these stretches, the channels have lost their natural capacity to carry floods of even much less than peak flows. Consequently, flooding in these areas has now become a yearly phenomenon.

3.4 Mining activities

Sand mining is the process of removal of sand and gravel from inside and around wetlands, usually rivers and flood plains. As the demand for sand increases in industry and construction, the issue has become very serious. Unscientific mining has caused degradation of land, accompanied by subsidence and consequential disturbance of the water table leading to topographic disorder, severe ecological imbalance and damage to land use patterns in and around mining regions. Stream sand and gravel dredging directly alters riverine fish habitat through the removal of sediment, which increases turbidity and creates deep pools. The erosion caused by dredging can incise beds, erode banks, reduce the number of sandbars and islands, and undermine bridges and other structures all of which have potential to impact aquatic biota

In-stream sand and gravel dredging is an invasive process that can influence fish and habitat both directly and indirectly. It is especially critical for migratory fish species and other aquatic organisms that use gravels and sand for depositing and protecting their eggs and developing embryos. For example, it is known that the migratory *Labeobarbus* species of Lake Tana require an area with gravel beds and clear, fast-flowing and well-oxygenated water for spawning/breeding. Some reports indicate that sand mining activities (e.g. Plate 3.9) and irrigation canals could severely affect spawning grounds and migratory routes of these fishes. Sand mining may reduce suitable breeding grounds by removing the sand and gravel bed from the main channel of the rivers and disturbing both the quantity and quality of water. These activities, in extreme cases, can cause species decline and extinction.

Salt mining is widely practiced in the Afar wetlands and this will eventually result in complete drying up of the lakes. Lakes Afdera and others are in danger of such crisis but the deeper Lake Asal appears to be less vulnerable.

Soda Ash mining has been taking place in Lake Abijata, and with exacerbated abstraction from feeder rivers, the lake has now lost so much water and is on the verge of complete dry-up.

Phosphate mining has resulted in the loss of thousands of acres of wetlands in central Florida (Mitsch and Gosselink, 1993). Other types of mining operations can also degrade wetlands through hydrologic alterations, high metal concentrations, and/or decreased pH. A case in point in Ethiopia is phosphate mining in Lake Asal which requires lots of fresh waters from the upland springs and this will affect the water table and hydrology of the lowland wetlands.

Plate 3.9. Sand excavation from Shini River (Tana sub-basin)

3.5 Introduction of non-native (exotic) plants and animals

As a result of disturbance and habitat degradation, wetlands can be invaded by aggressive, highly-tolerant, non-native vegetation, such as water hyacinth *(Eichhornia crassipes)*, and salvinia *(Salvinia molesta)*, or can be dominated by a monoculture of cattails *(Typha* spp.*)* or common reed *(Phragmites* spp.*)*.

Water hyacinth and similar species can rapidly fill a wetland and are a threat to water quality in some areas. The invasion of water hyacinth *(Eichhornia crassipes)* is very much noted in Lake Tana (Plate 3.10) from the highland lakes, Koka Reservoir in the rift valley and Lake Tata in Gambella. It appears that currently it is spreading to other water bodies including Lake Zwai in the rift valley.

Non-native species may be introduced on purpose. For example, water hyacinth has been noted for its ability to sequester nutrients and is used for wastewater purification.

Carps are exotic fish species that degrade wetlands. Carps, introduced for various purposes, are known for severely increasing the turbidity of water resources. These species have been introduced, for example, into Lakes Zwai and Langeno as well as Koka Reservoir and are dominating the fisheries (Plate 3.11).

Plate 3.10. Water hyacinth in Lake Tana (Photo credit: Wassie Aneteneh)

Plate 3.11. Cyprinus carpio and Carassius carassius introduced into Lake Zwai and other water bodies (Photo credit: Abebe Getahun).

3.6 Urbanization and pollution

Cities and towns are expanding in Ethiopia and these expansions create pressure on the surrounding environment. It is not uncommon that most of these are established around water bodies and wetlands. The importance of water for urban construction and dwellers is indispensable. They are not only source of water, but also provide many economic, social and environmental services (see Plate 3.12). Obviously, most of these cities and towns are with no proper sewerage systems and many of the households and industries release their wastes into the surrounding water bodies.

Urbanization has resulted in direct loss of wetlands as well as degradation of wetlands. Degradation is due to changes in water quality, quantity, and flow rates; increases in pollutant inputs; and changes in species composition as a result of introduction of non-native species and disturbance. The major pollutants associated with urbanization are sediment, nutrients, oxygen-demanding substances, heavy metals, hydrocarbons, bacteria, and viruses. These pollutants may enter wetlands from point sources or from nonpoint sources.

As urbanization expands, roads, buildings, and parking lots are constructed and hence the amount of impervious surface increases. Impervious surfaces prevent rainfall from percolating into the soil. Rainfall and snowmelt carry sediments; organic matter; animal wastes; pesticides and fertilizers from lawns, gardens, and golf courses; heavy metals; hydrocarbons; road salts; and debris into urban streams and wetlands.

Obviously, a considerable number of Ethiopian towns are close to wetlands (e.g. Bishoftu, Hawassa, Zwai (Batu), Bahir Dar, Hayq, Arba Minch, etc). These wetlands near urban centers are suffering from negative consequences from the expanding development activities and infrastructures in the towns/cities (e.g. hotels, health centers, households and factories; see Plate 3.14). These urban centers release different solid and liquid effluents to their respective nearby wetlands. The illegal settlements in and around wetlands also affect the health and size of the wetlands significantly.

Urbanization requires landfills and these landfills can pose an ecological risk to wetlands. Landfill construction may alter the hydrology of nearby wetlands. Sanitary landfills may receive household hazardous waste and some hazardous waste from small quantity operators, as well as sewage sludge and industrial waste.

Mosquito control efforts in urbanized and resort communities has resulted in wetlands loss and degradation through drainage, channelization, and use of toxic pesticides. Urban and sub-urban agriculture using irrigation ditching can increase contamination of wetlands receiving irrigation drainage water, particularly where soil is alkaline or contains selenium or other heavy metals. Agricultural pesticides entering wetlands in runoff, as well as through atmospheric deposition, may bioaccumulate in fish and other aquatic organisms.

Industrial pollution is an area that has drawn little attention in Ethiopia. The majority of industries in Ethiopia are located along the banks of rivers and streams from where they draw water for their processes. Most of the high water consuming industries in Ethiopia discharge their wastewaters directly into the streams and water courses without any kind of treatment whatsoever. Added to this, so far there is no strict restriction on industrial plants discharging their wastewater into the rivers and water courses. Most industries directly discharge their wastes into the nearby water course because they have no waste water treatment facilities (see Plate 3.13). On the other hand, however, the few industries in the city of Addis Ababa, which are equipped with treatment facilities, divert their raw waste water into the storm water drainage system or the water course. The reason could be either for technical reasons related to the waste water treatment plant operation or for practical reasons since there are no regulations and effective control regarding industrial and domestic discharges by concerned bodies.

Plate 3.12. Fish market near Lake Hawassa

Plate 3.13: Flower farm near Lake Zwai

Polluting substances introduced as a result of agricultural activities include: chemical fertilizers, insecticides, herbicides and organic matters. These pollutants enter into the water bodies mainly through surface run-off and irrigation return flows. In the Ethiopian context, pesticides and herbicides are common agricultural inputs on large scale farms while fertilizers serve as major inputs on both large scale farms and in the peasant agriculture plots. Pesticides mostly used include chlorinated hydrocarbons, organo-phosphorus compounds and carbamate compounds. Fertilizers in use are basically of nitrogen and phosphorus origin.

Furthermore, control of disease vectors are carried out using pesticides like DDT and Lindane whose residues are persistent for long periods, which are toxic and whose use has been banned in many countries. Apart from the significant benefits of the large scale irrigation projects for instance in the Awash valley, there are some adverse effects inflicted on the environment such as salinity problem, problems due to agricultural inputs (fertilizers and pesticides), health related problems (malaria, shistosomiasis) and municipal and domestic pollutions.

Industrial pollution: A number of studies have confirmed that about 90% of industries in Addis Ababa simply discharge their effluent into nearby water bodies, streams and open land without any form of treatment. In the 1992 to 1994 wastewater facilities master plan project study, it was reported that out of 70 factories, 56 (80%) were dumping their untreated effluent into nearby watercourses and urban streams. Added to this, so far there is no strict restriction on industrial plants discharging their wastewater into the rivers and water courses. In 1997, Environmental Protection Agency conducted a survey on the kinds of waste generated by industries and the number of factories with treatment plant, only 3 (about 8%) of them have any form of treatment plant. The extent and severity of industrial pollution has not received the attention it deserves, because of laxity from the regulatory bodies and problems of implementing the regulations when violations occur.

Plate 3.14. Resort hotels around Lake Tana

3.7 Overexploitation of resources

This basically includes the overexploitation of fishery resources from the water bodies and also macrophytes from lake near shores. In many of the freshwater bodies of Ethiopia especially in highland lakes such as Lakes Tana and Hayq and Rift Valley lakes such as Lakes Zwai, Hawassa, Langeno and Chamo, from where the majority of the fish catch is coming from, there is overexploitation of the fishery resources. This is mainly caused by increased number of fishermen that created pressures beyond the sustainable production level of the lakes. The fishermen operating in these lakes are not all registered and the fishing gears they use are not regulated (Plate 3.15). Some of the fishing gears are so destructive that smaller fingerlings below the table size are caught and some are wasted. Fishing during the breeding seasons of the fishes is not prohibited in some regions; even though it is legally prohibited in some, enforcement of the legislation has become a daunting task and could not be realized.

Plate 3.15. Illegal monofilament gill net used in Lake Tana (Photo credit: Abebe Getahun).

3.8 Climate change

Climate change and recurrent droughts are threats to wetland ecosystems of Ethiopia. Nitrous oxides, sulfurous oxides, heavy metals, volatilized pesticides, hydrocarbons, radionuclides, and other organics and inorganics are released into the atmosphere by industrial and agricultural activities, and from vehicles. These compounds can enter wetlands through wet and dry atmospheric deposition and can adversely affect aquatic organisms and the terrestrial organisms that feed on them. There is also an increase in temperature due to climate change, which is generally affecting wetlands and other ecosystems. Such phenomena adversely affect hydrological cycles, which in turn affect the biodiversity resources and various services of wetlands (see also chapter 1).

Obviously in times of recurrent drought and dry times, the pressures that would be exerted on wetlands is huge since they are the only major sources of water, fodder, and crop production, and contribute to saving lives of humans, livestock and wild biodiversity.

3.9 Neo-tectonism (Seismic events)

According to Tenalem Ayenew (2012), the Ethiopian rift experiences frequent tectonic activity manifested as earthquakes and rarely also by volcanism. New ground cracks are being created and these cracks result in the disappearance and /or reduction of the sizes of wetlands as evidenced in the Main Ethiopian Rift. The case of Tendaho Reservoir in the Awash valley is a good example to show the effects of seismic activities on the nature of wetlands.

3.10 Absence of appropriate policy and Institutional arrangement

In Ethiopia, wetland related concepts are incorporated in different policies and strategies (e.g. Ethiopian Water Resources, Agriculture and Environmental policies). The Conservation Strategy of Ethiopia, which forms the basis for the Environmental Policy of the country, has also mentioned wetland-related issues. Unlike the national environmental strategy, the Gambella region's Conservation

Strategy contains a separate section devoted to wetlands. But, Ethiopia generally lacks a specified policy on wetlands. There appear to be strategy documents that favor irrigation agriculture through drainage at the expense of wetland ecosystems. These documents encourage draining and conversion of wetlands into other forms of land use particularly for improving agricultural yield. The Environmental Policy in its general aim of protecting the environment highlights only the importance of wetlands for water resources management.

For instance, agriculturalists see moist fertile soil with vast potential for growing grain; fishery managers find a support base for producing fish; hydrologists calculate capacities to provide water for industry, agriculture, and domestic use; public health specialists may not see them as regulators of water quality but in contrary as transmitters of diseases such as malaria and so on. Investment in wetland management is rarely integrated. Instead, wetlands are invariably viewed by each user as single-product systems, precluding other values, while single-purpose returns fall far short of expectations. The absence of an institution duly empowered to issue and implement wetland laws and coordinate management activities is the underlying cause for the deterioration of the wetlands of Ethiopia.

Wetland management in Ethiopia also suffers from capacity limitations such as lack of skilled manpower, finance and technology. Wetland focused training programmes are very scarce in higher learning institutions of the country. Programmes are not implemented to fill this gap nationally. As a result, there is shortage of wetland specialists. There is also awareness problem from grassroots up to decision maker levels. The scarcity of wetland focused institutions and weak relation of the country to wetland affiliated global institutions such as the Ramsar Secretariat has hampered its capacity building opportunities.

The basic principle laid down in the Helsinki Rules on **transboundary waters** was that they have to be shared equitably and reasonably among the riparian countries. One of the most difficult hurdles in dealing with the Nile waters and which is dictating against any form of negotiation is the reluctance to recognize this basic principle of law which has gained universal acceptance. Riparian nations sharing wetlands in common should respect the Helsinki Rules and work together for the common conservation of the wetlands and their ecosystem services.

3.11 Ownership of land tenure

This factor also contributes to further degradation of natural resources including wetlands, as the farmers try to draw short term benefits, although destructive, rather than thinking of long term returns because of lack of security in ownership. As a result, there is intensive cultivation by draining the wetlands, especially with limited knowledge about wetland management.

References:

Afework Hailu (1998). An overview of wetland use in Illubabor Zone, southwest Ethiopia. Ethiopian Wetlands Research Project, Metu, Illubabor.

Derege Tsegaye, Tsunekawa, A., and Tsubo, M. (2012). Continuing Land Degradation and Its Cause-Effect in Ethiopia's Central Rift Valley.Arid Land Research Center, Tottori University 1390, Hamasaka, Tottori, 680-0001, Japan.

Dixon Aand Wood A., (2007). Eight local institutions for wetland management in Ethiopia: Sustainability and state intervention. CAB International. 134 pages.

Dixon, A. (2002). The hydrological impacts and sustainability of wetlands drainage cultivation in Illubabor, Ethiopia.*Land degradation and development*, 13 (1):17-31.

FAO (2005). Global Forest Resources Assessment 2005: progress Towards Sustainable Forest Management. FAO, Rome, IT

FAO (2006). Country Pasture/Forage Resource Profile. Compiled by Alemayehu Mengistu. Publishing Policy and Support Branch, Office of Knowledge Exchange, Research and Extension, FAO, Viale delle Terme di Caracalla, 00153 Rome, Italy.36 pp.

Mitsch W.J. and Gosselink, J.G. (2007). *Wetlands*. New York: Wiley

Tenalem Ayenew (2012). Current status and threats to selected Ethiopian wetlands. In: *Ethiopian Environment review* No. 2; Editor; Sue Edwards; Forum for Environment, Addis Ababa, Ethiopia.

CHAPTER 4

DEGRADATION STATUS AND PRIORITIZATION FOR RESTORATION

The most highly degraded wetlands in need of definitive restoration actions are listed in their order of priority below. The major causes for the degradation are illustrated with supporting plates. Only the causes for degradation and the degree of stress faced by the wetlands is described in this chapter, while restoration actions are suggested for clusters of these degraded wetlands in the next chapter.

The 16 degraded wetlands are listed based on the degree of degradation and the priority for restoration (prioritization matrix given as Appendix 7 in the order – Lake Haramaya, Lake Zwai, Akaki-Aba Samuel sub-basin, Lake Abijata, Afar lakes, Lake Hawassa, Koka (Gelila), Lake Hayq, Lake Basaka (Metehara), Cheffa wetlands, Lake Chamo, Boye and Kito wetlands, Fogera plains (Shesher and Wellela), Lake Hashenge, Lake Hora-Kilole and Lake Chelekleka. Appendix 8 lists the approach and criteria used to prioritize the wetlands, which was largely modified from Wheller et al., (1995).

4.1 Haramaya sub-watershed

The major issue in the Wabe Shebele Basin is the drying up of a number of lakes in the Eastern Highlands of Hararghe focused on Lake Haramaya. The details of the drying of Lake Haramaya are available in sizable amounts in the literature. It has also been of considerable coverage in the Ethiopian media and conferences. Some highlights are given below.

Over the past 20 years, Lake Haramaya has been observed to shrink continuously. Some of the evidences in terms of morphomertric and physico-chemical changes are shown in Table 4.1 and Fig. 4.1. By 2004, the lake has altogether disappeared and turned into an ephemeral lake where some water percolates at the lowest spot of the original lake basin.

Human demographic and climatic changes have contributed to the transformation of L. Haramaya to an ephemeral lake (Brook Lemma, 2011). The increase in population in Harar town and in the lake watershed demanded high municipal water supply over the years that has never considered any water budget scheme. The farmers in the watershed were pumping water out of the lake twenty-four hours a day. This was mainly to irrigate a commercial crop locally known as "*khat*" or scientifically, *Catha edulis*. Succulent leaves of this plant are chewed and the water extract swallowed as stimulant with the belief that it stimulates the brain to work harder, faster and longer. It is also exported to neighboring countries like Djibouti and Somalia. Farmers obtain quite satisfactory incomes as observed from the rate of conversion of food crop fields into "*khat*" fields.

Table 4. 1: Morphological changes of Lake Haramaya from 1986 to 2006 (Brook Lemma 2011)

Parameters	Upto 1987	1988 – 2000	After 2004
Altitude	2000 masl	2000 masl	2000 masl
Surface area	4.72 km2	2.17 km2	Total transformation from aquatic to a terrestrial environment
Maximum depth	7.0 m	3.5 m	
Mean depth	3.13 m	1.33 m	
Volume	0.15 km3	0.005 km3	

There is a marked increase of about 3^{0}C in the air temperature of the region between 1960 and 2006 (Fig. 4.1). The rainfall pattern over the years has not changed much except that it is highly erratic. However, when rainfall of the region is viewed in comparison with the increase in air temperature and the change in human demography, it is obvious that the lake was operating at water budget deficit.

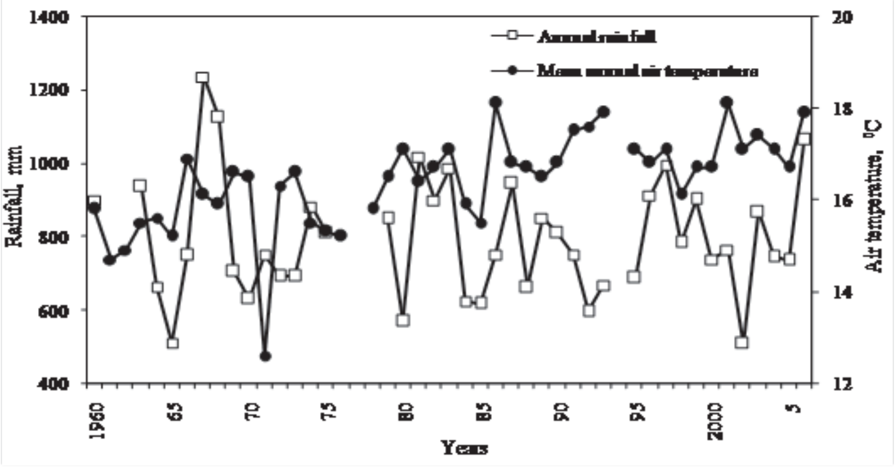


Figure 4. 1: Meteorology of Lake Haramaya area, 1960 – 2006 (Brook Lemma 2011)

At the same time, the household wastes dumped in the watershed and all that comes from Haramaya town are washed into the lake with torrential rains that are followed by runoff that brings into the lake high amounts of top soil and organic wastes. These have greatly influenced the plankton community in favour of those species, particularly *Peridinium* spp., that proliferate on such food sources (Brook Lemma, 2011). The zooplankton communities have gone in the direction of small cladocerans, copepods and mostly rotifers that are small-bodied, such as, *Brachionus* spp., *Filinia* spp. and *Lecane* spp.

As observed in many tropical lakes, these trends are sufficient indicators of lake water quality deterioration and progressive loss of the assimilative power of lakes of the organic and other wastes that come in by wind, runoff or direct dumping of wastes into the lake.

As the operation of water collectors, municipalities and irrigation schemes continued unabated, the lake size continued to decrease, fishermen had to follow the retreating water edge and the water below their boat continued to disappear.

Plate 4. 1: Lake Haramaya: gradual drying up by 2000 (Photo credit: Brook Lemma).

Today it has completely disappeared with grasses gradually covering the sediments. The image below (Fig. 4.2) collected from a South African environmental group shows the size of Haramaya nd adjacent lakes (Tinikie and Adelle) in 1986, followed by an image from 2005 that shows how Lake Haramaya disappeared and the other two lakes, namely, Tinikie and Adelle shrank.

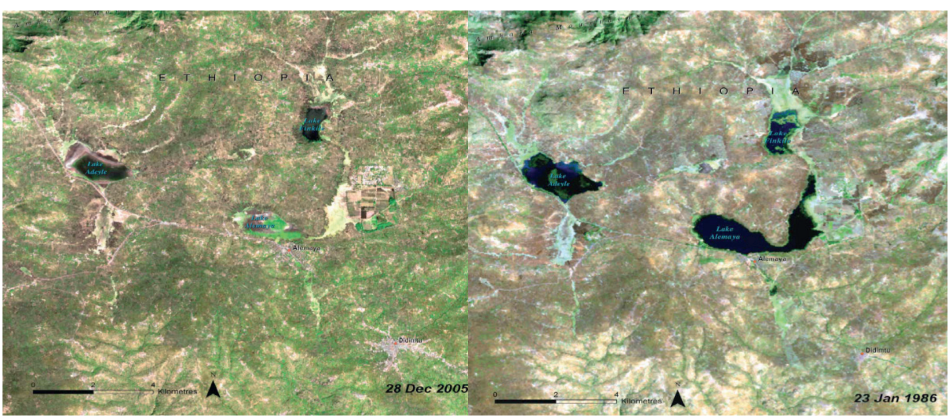


Figure 4. 2: Contrasting images of the changes in Haramaya and adjacent lakes between 1986 and 2005 (Image from an environmental group in South Africa)

4.2 Lake Zwai

In recent years, L. Zwai and its watershed are experiencing increasing investment in the direction of expansion of irrigated agriculture particularly in horticultural crops (flowers, vegetables, etc.) that have quick returns with good accessible roads to the huge market in Addis Ababa. People seem to close in on the fresh waters of L. Zwai and the town of the same name in search of jobs. There is also remarkable increase in fresh water abstraction for irrigation and other industrial functions. With free access policy of the government to wetland resources (fishes, aquatic vegetation, water withdrawal, etc.), it is difficult to know exactly the quantity, types and sizes of fish caught each year. The same applies to the quantities of water abstracted and vegetation harvested by the local people (Plate 4.2) and the agricultural and industrial ventures operating in the watershed. Service industries, such as hotels and resort centers, are rushing to get hold of land along the shoreline and on the islands of the lake that have attractive sceneries for tourists.

Plate 4. 2: Water abstraction from Lake Zwai

Some cases of water abstraction besides hundreds of pumps owned by small farmers: (a) and (b) two of the big pumps owned by Sher Flower Farm established right on the eastern shore of Lake Zwai locations N07^{0}54’56.0”/E38^{0}43’51.1” elevation 1664 masl and N07^{0}54’22.6”/ E38^{0}44’08.6” elevation 1647 masl, respectively; (c) Pumps owned by Bochessa Small Scale Irrigation Farm location

N^{0}7053’37.7”/E38^{0}45’29.7” elevation 1650 masl; (d) Water abstraction and treatment plant owned by Zwai Town Municipality location N07^{0}54’04.7”/ E38^{0}44’07.6” elevation 1642 masl (Images by Brook Lemma, 2012).

It is, therefore, safe to assume that with development comes the need to use more and more fresh water for household, agricultural and industrial purposes; and at the same time release of solid and liquid wastes (Plates 4.3 - 4.5) that enter Lake Zwai in much unplanned and uncontrolled ways. It is also obvious that there will be use of excessive fertilizers (Fig. 4.3), pesticides and other chemicals that may contain heavy metals (e.g. Chromium from leather factories), in a setting where much of the planning and control measures are not in place.

Plate 4. 3: Solid waste dumping site of Zwai town

(a) The waste dumping site with Gelila Island of Lake Zwai in the background **(b)** Small ruminants scavenging on the waste and **(c)** scavenging storks kicked out of the waste deposits by the small ruminants and basking in the sun (Images by Brook Lemma, 2012).

Plate 4. 4: Floriculture effluent into Lake Zwai

(a) Liquid wastes collected in canals from each greenhouse of Sher Flower Farm **(b)** canal leading to Lake Zwai and **(c)** finally the liquid waste directly entering into Lake Zwai. These canals are located between the two water abstraction pumps of the same flower farm (Images by Brook Lemma, 2012).

Plate 4. 5: Human encroachment on the Zwai-Shala National Park

(a) Electric power line poles to cross the land corridor between Lakes Shala and Abijata to supply a town called Chelle within the park **(b)** Harooressaa Elementary School (Grades 1 to 8) located at N07^{0}31’75”/E38^{0}35’78.3” at elevation of 1585 masl is one of three sprouting schools, built for children whose families reside in the park **(C)** Grazing livestock and farmlands of the park located at N07^{0}32’54.3”/ E38^{0}34’59.3” at an elevation of 1595 masl.

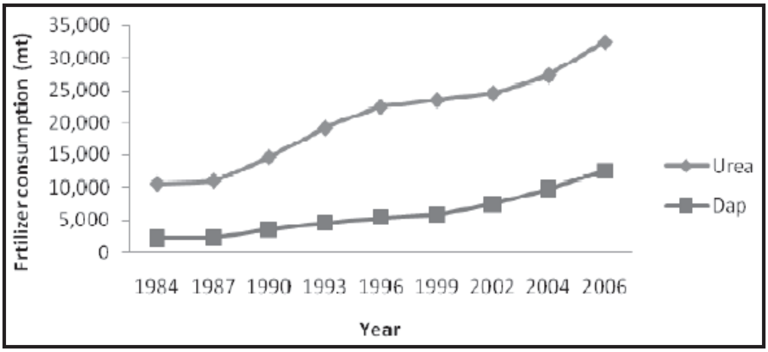


Figure 4. 3: Trends in fertilizer consumption in the Ethiopian Central Rift Valley (1984-2006) (Derege Tsegaye et al., 2012)

It is also understandable that impacts observed on L. Zwai are also found on the other lakes of the rift valley basin. Such impacts could be like failure of or reduction in rainfall, excessive abstraction of water for irrigation directly from the lakes and their rivers that come into and go out of them, excessive nutrient load, etc. that can result in the drying of inputs or outputs of the lake. The release of pollutants like pesticides, heavy metals and fertilizers in the watershed that can eventually be washed into the lakes, which are already being felt in the fishes examined or the water that is being used directly by the local community (e.g. Dsikowitzky *et al.* 2012). Such events are not uncommon in Ethiopia while the events that occurred at Lakes Haramaya (Alemaya) and Hora-Kilole are vivid examples of the recent past (Brook Lemma, 2011).

4.3. Akaki sub-basin and plantations

This sub-basin comprises the rivers that cross the city of Addis Ababa and the reservoirs built along their lengths. Rivers Big and Little Akaki originating from the Intoto Mountains transect the city of Addis Ababa.

The water quality of the rivers in Addis Ababa and the associated wetlands and reservoirs is polluted with household liquid wastes, industrial effluents and plastics of all sorts as there is no canalization system and desegregation of wastes. This obviously suggests that all sorts of wastes are dumped or directed into the rivers that flow through the city. In the Akaki sub-basin the weathering products of volcanic rocks and the circulation of thermal water that is found at the centre of Addis Ababa significantly affect the concentrations of chemical components in surface water and groundwater. The other factor contributing to the change in physico-chemical characteristics of the water are anthropogenic inputs of domestic and industrial wastes, which enrich certain anions and cations such as Na+, Cl^-, NO_3^-, SO_4^- and some heavy metals. Water parameters data showed that though most of the groundwater in AkakiSub-basin has fairly normal values of dissolved solutes, while surface waters revealed higher values due to the influence of anthropogenic pollutions. Dissolved oxygen as low as 0.2 mgL^{-1} is by itself an indication of high load of polluting materials, particularly organic matter as measured by high BOD and COD (see Habtamu Haile Tolera, 2007).

The type of water in the Akaki Basin is alkaline with high contents of the alkalis, with hydrogen carbonates prevailing. Among anionic measurement NO_3^- showed very high concentrations, exceeding US EPA standards. This has been reflected in the groundwater as well. Within this basin the concentration of heavy metals is lower in the surface waters than in the groundwater, where in the latter accumulation and concentrations take place over time, while the residence time in the former is very short as the water moves down the gradient all the way into River Awash.

The dams built to capture water for the city of Addis Ababa, namely, Dire, Legedadi, Gefersa I and III are located in the upstream sections of Akaki River. Their location out of the city of Addis Ababa is a protection against the household and industrial wastes of the city. However, parts of the watershed above these dams are increasingly devoid of vegetation cover and farm lands that use fertilizers and pesticides are threats to the quality of the water in the reservoirs and hence to the dwellers of Addis Ababa city that drink their waters. The cost of treatment of the water supplies for the city from these reservoirs is a consistent problem for the city administration.

Besides, the same waters with household wastes including direct releases of latrine wastes and industrial refuses enter the Akaki Rivers (Plate 4.6) whose loaded waters are used for growing horticultural crops to supply the city (see Girma Kebede, 2004).

Plate 4. 6: Pollution of Akaki Rivers

Solid and liquid industrial and household wastes draining from Addis Ababa join the Akaki Rivers to eventually go through Lake Aba Samuel and Awash River to end up in Lake Koka (Karlsson, 2015). Similarly, the groundwater quality of the Akaki sub-basin is also affected as various hydrological studies indicate..

The Akaki sub-basin is also impacted by climate factors such as rising temperature, erratic and decreasing rainfall patterns as reported by the meteorology station in Addis Ababa (Conway *et al.*, 2004).

At the southern end of the sub-basin, Aba Samuel Dam is the final recipient of all these wastes of Addis Ababa city. This dam basically developed for hydropower generation has been abandoned for a long period until very recently when it is being rehabilitated to do the same function of supplementing the electricity demand of Addis Ababa. However, the water quality has remained the same and yet considerable amount of it is used for irrigation of horticultural crops for the same city. The resulting contamination from the horticultural crops of the Aba-Samuel farm lands supplied to dwellers of Addis Ababa remains largely unknown (Girma Kebede, 2004).

Awash Basin beyond Lake Koka: Wonji, Tendaho and other irrigation schemes

This water sub-basin is known for the large scale plantations for cotton, sugarcane and other crops. As these areas are known for their arid climate with severe rainfall deficiencies, water had to be brought in from River Awash to convert the naturally dry but fertile plains into irrigation schemes. Many people coming from different corners of the country make their living here in direct or indirect activities related to the plantations.

When the plantations were first established, the natural vegetation, mainly Acacia trees and grasses were completely removed, the native pastoralist population living in the area was pushed aside and the animals migrated or were killed for various purposes (for food, horns, skins or just for pleasure). Today the systems support monocultures of sugarcane or cotton plantations and settlement areas with factories that process the agricultural products and release wastes into the environment (see also Shimellis Abdi Assefa, 2016, Mousseau and Martin-Prével, 2016 and others).

The problems associated with these large-scale irrigation schemes and the expansion of the plantations come in the form of water logging, salinization and hence the associated loss of biodiversity. Currently, the irrigation schemes are waterlogged with the water table in the ground reaching within 20 cm from the surface. Despite the drainage canals built, the water still remains close to the surface. This water is believed to move underground to Lake Besaka becoming one of the major reasons for the lake increase in volume.

A more serious case maybe salinization of the soil. With salts coming in with the river water, the addition of different chemicals including fertilizers to improve agricultural productivity and most of all the high arid temperature of the area associated with poor annual rainfall, the evapotranspiration process has left behind the salts in the soil. The irrigation schemes have started to abandon those fields with increasing salinity and started to claim new grounds by moving away the local populations, the vegetation and the wildlife. From the agricultural productivity point of view, the fields have become increasingly less productive as a consequence of salinization of the soil (Figure 4.4).

Much the same way as in Wonji Sugarcane Plantation, salinity has come to bite the irrigated land over time.

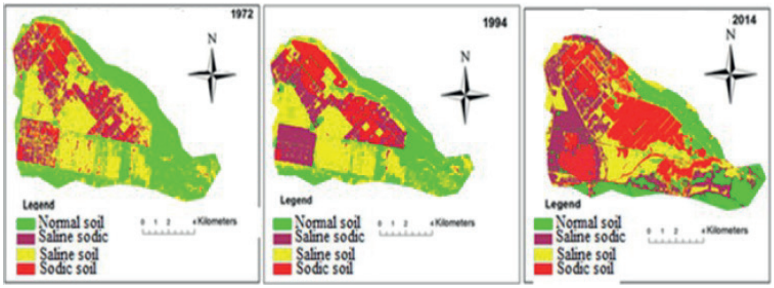


Figure 4. 4: Satelite images indicating salt affected soils of Dubti/Tendaho state farm for the three time periods (1972, 1994 and 2014) (Shimellis Abdi Assefa, 2016).

Saline level	1972		1994		2014		1972-1994		1994-2014		1972-2014	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Normal soil	3782.8	35.05	2930.3	27.15	2189.4	20.29	-652.5	-7.90	-740.9	-6.86	-1593.4	-14.76
Saline-sodic soil	2177.5	20.18	2423.3	22.45	3153.6	29.22	+245.8	+2.27	+730.3	+6.77	+976.1	+9.04
Saline soil	4035.0	37.39	4138.2	38.34	2928.7	27.14	+203.2	+0.95	-1209.5	-11.2	-1106.3	-10.25
Sodic soil	797.4	7.39	1301.2	12.06	2521.2	23.36	+503.8	+4.67	+1220	+11.3	+1723.8	+15.97
Total	10,793	100	10,793	100	10,793	100	-	-	-	-	-	-

Table 4. 2: Changes in hectares and percent coverage of salt affected soils from the year 1972 to 2014 at Dubti/Tendaho state farm (Shimellis Abdi Assefa, 2016)

Associated with the increased salinity of the soil, the water logging status of the Tendaho Plantation is also worrying as in Wonji. The following image indicates the relations between elevation of the irrigation land and its water logging status.

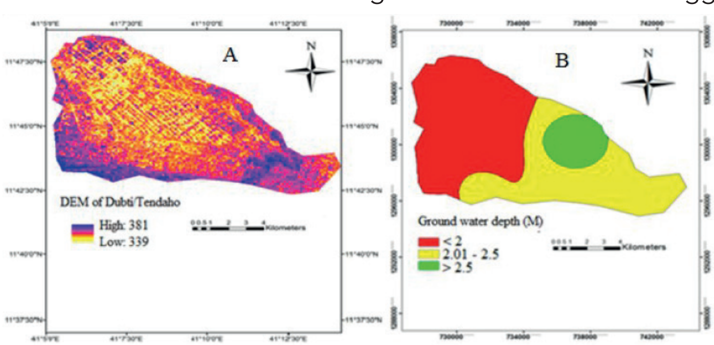


Figure 4. 5: (A) Digital elevation model in meters above sea level and (B) groundwater depth and its spatial extent at Dubti/Tendaho state farm (Shimellis Abdi Assefa, 2016)

Shimellis Abdi Assefa (2016) concludes that the expansion rates of salt affected soils, particularly saline sodic and sodic soils have increased with time at the expense of normal soils and nowadays some plots of the state farm are becoming unproductive. Poor irrigation water quality, inappropriate irrigation practices, inadequate drainage, and the development of shallow groundwater table are the major factors for the development of salt affected soils in the area. If the present irrigation practice continues, it is expected that most of the cultivated lands will become sterile within a short period of time. This conclusion is not much different from what was observed at Wonji Sugarcane Plantation.

The expansion and hence conversion of the arid land of the pastoralists in the Awash Basin into wetlands by constructions of dams and irrigation farms with sugar, cotton and other factories has created thousands of jobs. According to Piguet (2007) and Mousseau and Martin-Prével (2016), the Afar Region has faced complex migration movements: pastoralists have been forced to change the pattern of the transhumance after their eviction from the fertile banks of the Awash River and, in a way parallel, thousands of highlander farmers have settled into the region. Such migratory movements have occasioned destitution among pastoralists; cultural waste linked to colonization by non-Afar civil servants, traders and farm workers, resulting in micro-conflicts; opposing pastoralists groups in competition for water and pasture; and/or afar pastoralists and highlander settlers considered as foreign occupants.

While attempting to circumvent poverty and hunger and bringing Ethiopia to middle-income country by 2025, such development plans should not bring about environmental degradation and social conflicts. It is therefore suggested by Piguet (2007) and Mousseau and Martin-Prével (2016) that in order to avert such long-term impacts, the Ethiopian federal and regional governments need to set up a migration policy which will look ahead from resettlement programs moving people with all the authoritarian risks linked with such (so-called) voluntary programs. Push and pull factors analysis should be the prerequisite to implement migration programs as well as the interests of native populations. Is voluntary migration essentially linked with "push" factors regarding the poor living standard and the risk of destitution balanced with attracting factors (pull) by developing infrastructure (health, education, etc.) and economic opportunities, even when those are limited to seasonal employment as daily workers? Mousseau and Martin-Prével (2016) also suggest that upgrading pastoralism that is compatible to what the Afar Region provides is likely to make better returns than sugar production that results in removal of the natural vegetation, causing intensive evapotranspiration, salinization of the soil and creating migration of the natives to poorer grazing/watering grounds and deserting their homes to migrate to towns.

4.4. Lake Abijata

Owing to its terminal position in the drainage area and its shallow depth, Lake Abijata is especially susceptible to changes in rainfall in the surrounding plateaus and escarpments, general climate variability, as well as to human water use in the Zwai-Shala Basin (Dagnachew Legesse *et al.*, 2004).

The major problem associated with the two lakes is withdrawal of water for soda ash extraction (from Lake Abijata at present but also Lake Shala in future). These activities have profoundly affected the water balance in Lake Abijata, which has resulted in its shrinkage to very low and apprehensive size in recent years (Fig. 4.6).

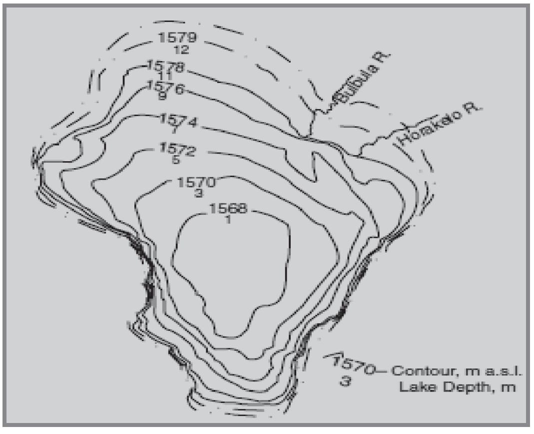


Figure 4. 6: Bathymetry of Lake Abijata

(Broken lines indicate the shoreline as the lake regressed with time; after Dagnachew Legesse *et al.* 2004).

If the trends described by Tenalem Ayenew (2002), Dagnachew Legesse *et al.* (2004), and the development plans of the Ethiopian Government to enhance irrigated agriculture continues as documented, Lake Abijata will dry up by 2021 (Derege Tsegaye *et al.*, 2012).

Besides the need for increasing amounts of fresh water for development (irrigated agriculture, indoor farming, municipal use, livestock watering, etc.), the water of Lake Abijata is being used for soda ash. This trend would add the pressure on these saline alkaline lakes as described by Tenalem Ayenew (2002), Derege Tsegaye *et al*. (2012) and others.

4.5. Afar Sub-Basin (Afar Depression)

This sub-basin extends all the way into Djibouti. It covers the lowest points in the country with areas below sea-level up to 125m. In these area, there are a series of saline acidic lakes and small hot streams that harbour some specially adapted fishes, e.g. *Aphanius dispar, Aphanius stiassnyae,* and *Danakilia franchettii* in Lake Afdera (Abebe Getahun, 2001; Abebe Getahun and Lazara, 2001).

Besides increasing visitors in the form of tourists and researchers in the fields of archaeology and geology, there are no appreciable human interferences in the area. After all, the area is climatically hostile for highland people to move in as in the case of the plantations of Wonji and Tendaho. The major risk of the area is natural disaster in the form of seismic impacts that may alter the situation in split seconds if and when it occurs (Yohannes Lemma *et al*., 2010).

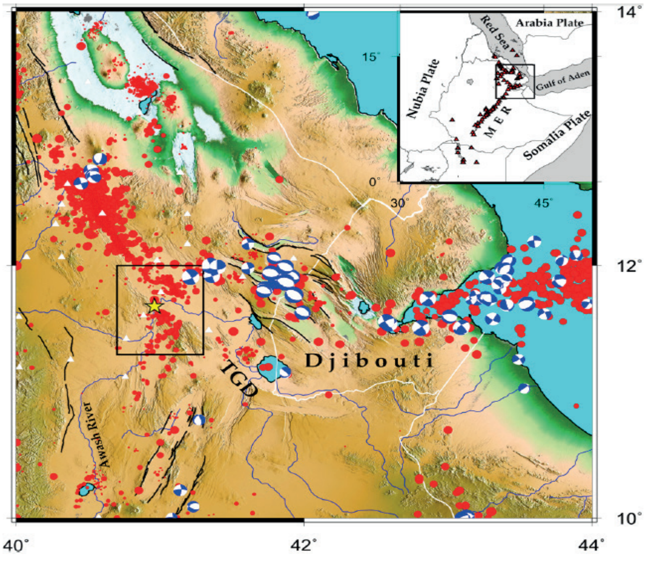


Figure 4. 7: Tectonic impact on Afar lakes (After Atalay Ayele et al., 2016)

Inset shows Red Sea and Gulf of Aden oceanic rifts forming a triple junction with the Ethiopian rift in the Afar Depression where red triangles show distribution of active volcanoes in the region. Red dots show seismicity in the Afar Depression region with size of the circle being proportional to earthquake magnitude. The white and blue 'beach balls' show fault plane solutions of some major earthquakes from GCMT solutions. The black rectangle shows the location of the Tendaho Dam in the Depression with the yellow star showing the location of the earth filled Dam body. The black lines show fault traces while the white lines show national boundaries.

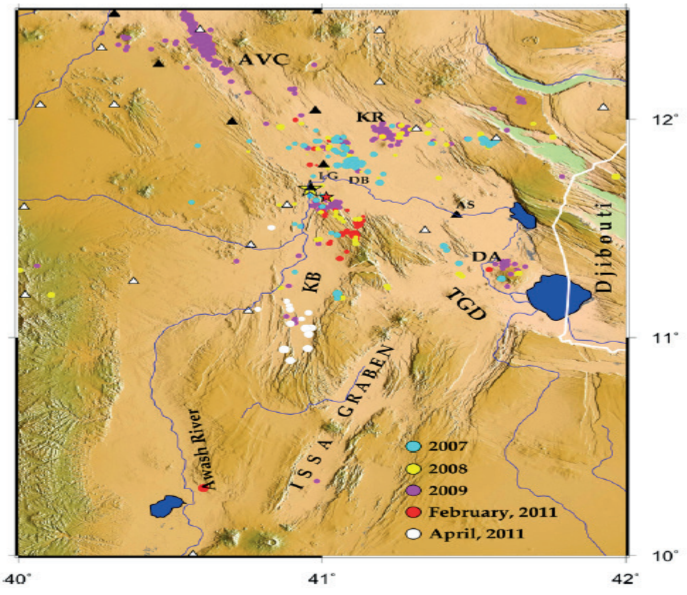


Figure 4. 8: Detailed topography and seismicity of the Tendaho dam region from 2007 to 2011 (After Atalay Ayele et al., 2016)

This is a zoomed version of the black box shown in Figure 4.7. The circles represent earthquakes, with the size of the circle being proportional to the earthquake magnitude. The seismicity of the corresponding years is detailed in the legend. Black triangles represent the distribution of the seismic stations for the post-2009 deployment, while the grey ones represent both the US and UK seismic station networks after the Dabbahu activity. The black line segments are fault traces while the white traces are national boundaries. (NOTE: AVC, Ado Ale Volcanic Complex; KR, Kurub Volcano; DA, Dam Ale Volcano; KB, Karrayu Basin. The yellow star shows the location of the intake tower while the red star shows the location of the Allalobeda Hot Springs).

The Afar region is the most seismically and volcanically active part of the Eastern African Rift System. The most notable recent earthquake activities that occurred not far from the location of the Tendaho Dam are the 1969 and 1989 earthquake sequences at Serdo and Dobigraben, respectively. The March and April 1969 earthquake sequence (maximum surface wave magnitude MS 6.3), which occurred in Central Afar, destroyed the town of Serdo with significant casualties of 40 dead and 160 wounded from a total population of 420 (Gouin, 1979). All the masonry structures including the highway authority compound, the school and the police headquarters buildings were completely destroyed. The reinforced concrete water tower was the only structure that survived the shaking. The epicentre for the main shock of the Serdo sequence was only 40 km away from the current Tendaho Dam site, all indicating that the Tendaho Dam is located in a tectonically and geothermally active region of Afar.

The combined effect of increased vertical load of water in dams and pore pressure on the ground will have the greatest tendency to increase seismic activity in regions where the maximum compressive stress is vertical (Allen 1982, Atalay Ayele *et al.*, 2016). The Tendaho dam site is located close to the Afar triple junction (the Nubia, Arabia and Somalia Plates) where the East African Rift System (EARS) meets the Gulf of Aden and Red Sea oceanic rifts as shown in Fig. 4.7. The Tendaho dam reservoir lies in a seismically and volcanically active rift zone at the intersection between the NNE-striking Karrayu Basin of the Ethiopian rift and the NW-striking Tendaho Graben of the southern Red Sea Rift

It is, however, challenging to distinguish whether the increase in earthquake activity and changes in hydrothermal systems are dam-induced or the result of stress transfer southward from rapid rift opening in the DMH segment to the north. Regardless of the causative mechanisms, it is observed that:

1. High levels of seismicity coincide with conjugate fault systems;
2. Major changes have occurred in the Allalobeda Hydrothermal System after dam impoundment;
3. The time–space pattern of seismicity and hydrothermal activity suggest the NW-striking and North–South-striking conjugate fault sets of the Tendaho-Goba'ad fault zone are partially open for hydraulic flow (Atalay Ayele *et al.*, 2016).

If the increased levels of seismicity are indeed induced by dam loading, the very short time period between impoundment and induced seismicity indicates that a very weak crust underlies the dam site (e.g. Simpson, 1976). Results document that fault, magmatic and hydrothermal systems beneath and near the Tendaho dam site are active (Atalay Ayele *et al.*, 2016).

In general, the dam construction was implemented without detailed subsurface geophysical and geological investigation and up-to-date information regarding volcanic and earthquake hazards. The supports for the earth-filled dam were drilled into hydrothermally altered mafic volcanic rocks along a zone of coeval NW- and NNE-striking normal fault systems, near hot water seeps and geysers of Allalobeda. Therefore, if a multifaceted development activity is to be planned and executed in the area in an environmentally friendly manner, close follow-up of the background activity with state-of-the-art geophysical and geological activities is highly recommended (Atalay Ayele *et al.*, 2016).

4.6. Lake Hawassa

The shores of Lake Hawassa (formerly Awassa) were rich with huge trees and dense aquatic macrophytes. These were visited by numerous birds and wild animals and the open waters were inhabited by various fish species and hippopotamuses (Plate 4.7).

Hawassa city lying in the east in SNNP Region is expanding so fast that it is possible that the western shores of the lake under the administration of Oromia Region would eventually turn into flourishing city. That would be multiplying the problems of the lake many times over.

Another danger for the Lake Hawassa is the abstraction of groundwater from the source of River Tikur Woha, the only feeder river to the lake. This is taken as an alternative since the ground water in Hawassa area is loaded with fluoride; the city gets its water supply from the base of Wondo Guenet Mountains where River Tikur Woha originates.

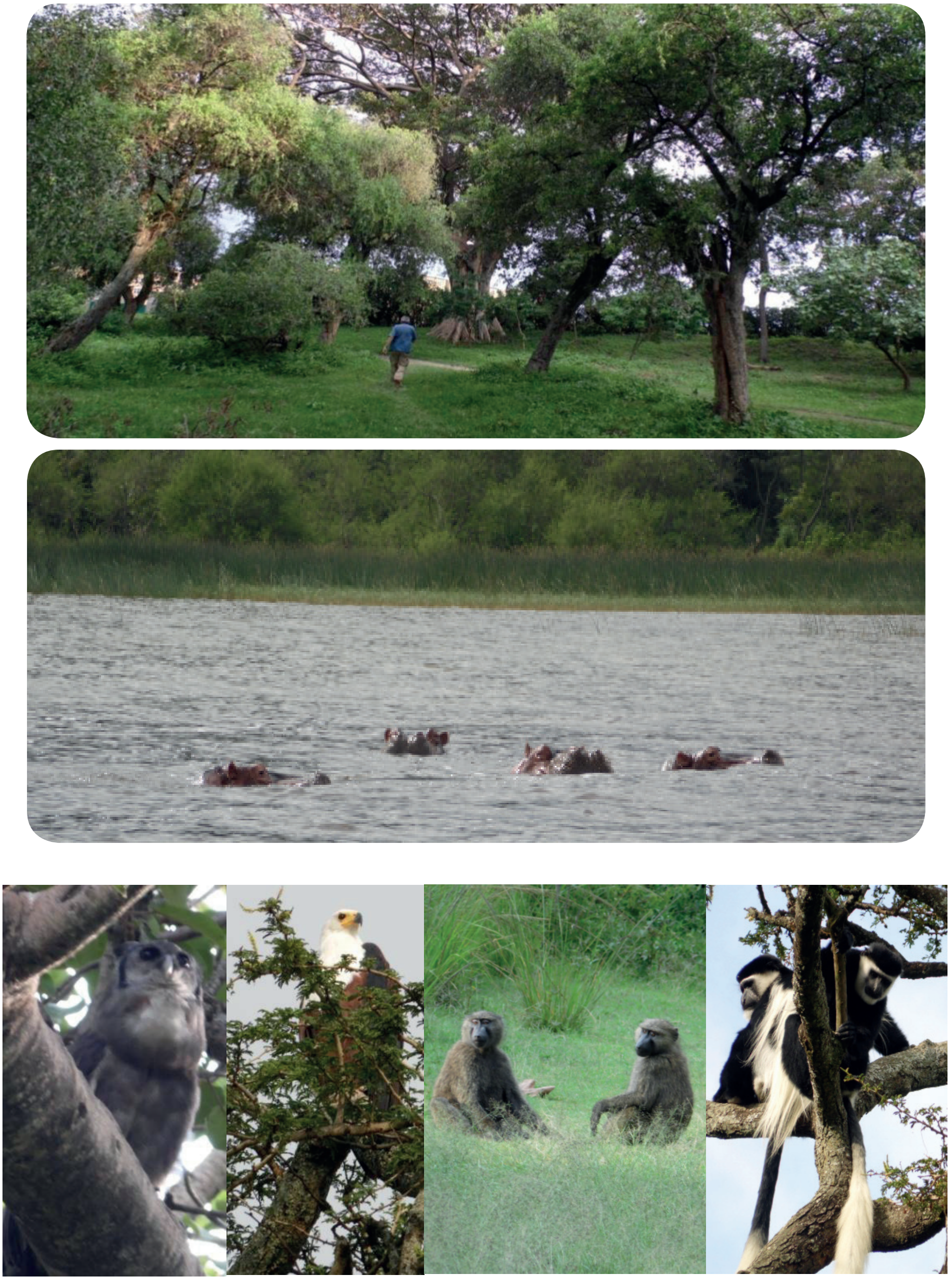


Plate 4. 7: Habitat degradation around Lake Hawassa (Photo credit: Brook Lemma)

Top: The last refuge for the remnant wildlife in and around Lake Hawassa, a forested small patch between River Tekur Woha and Haile Resort. The wild animals shown in the above images were once common in and around Lake Hawassa. Toady these are restricted to the trees in the above specified place (Images: Brook Lemma 2012).

Lake Hawassa is also confronted with more direct problems, as shown in Plate 4.8. The municipal, industrial and hospital wastes flowing directly into the lake are regular topics of research by national and international researchers. The heavy metal and pesticide loads of the fishes have been reported in many journals internationally.

Plate 4. 8: Recreational pollution in Lake Hawassa.

(Sprouting hotels and recreation centers on the shores of Lake Hawassa: some are suspended on the water surface with the wastes directly dropped into the water: (Images: Brook Lemma, 2012).

4.7. Lake Koka sub-watershed

Lake Koka, constructed on the course of Awash River, is used for household water consumption, fishing, irrigation (mostly vegetable farming), power generation, transportation and recreation. In due course it has been exposed to multiple human impacts. The most exemplary case is the waste coming from the Akaki sub-water basin that contains wastes from Addis Ababa city and all the industrial zones in and around it. The following image (Fig. 4.9) presents how the drainage basin collects and directs the wastes down to Lake Koka.

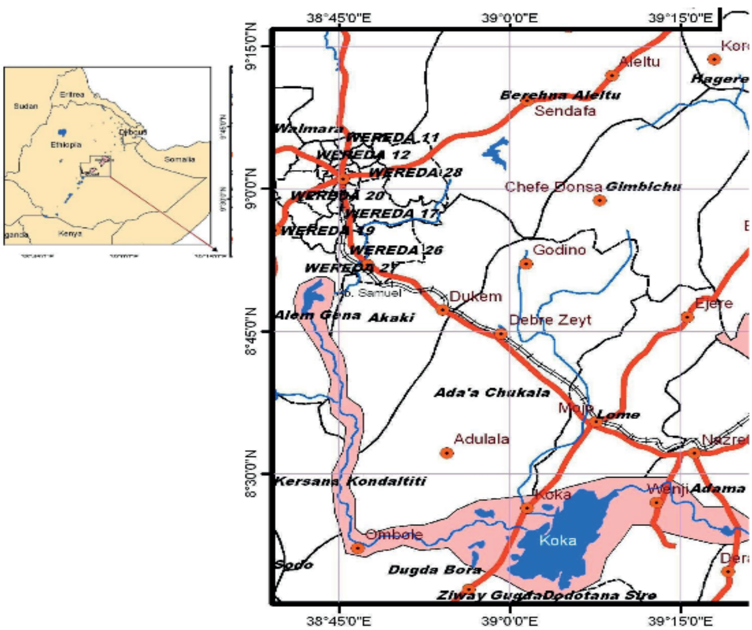


Figure 4. 9: Direct link in movement of household and industrial wastes from the cosmopolitan center, Addis Ababa, all the way to Lake Koka (also known as reservoir) (Image from http://www.oired.vt.edu/ipmil/wp-content/uploads/2014/07/10-Fessehaie.pdf)

Another aspect of Lake Koka is the uncontrolled soil erosion and land degradation of the Awash River catchment (Plate 4.9) resulting in heavy sediment transport in streams and rivers, which has caused significant reduction of the capacity of the Koka reservoir, which serves as the only impoundment for Awash flows. Water supply for irrigation and hydropower generation downstream depends on releases from this reservoir. The reservoir also serves as means of flood retention to protect downstream developments.

Plate 4. 9: Farming right up to the shoreline of Lake Koka (Photo credit: Brook Lemma)

This allows erosion of the top soil directly into the lake by small rain shower and wind action. This is in addition to the removal of plant cover in the watershed by the increasing population density.

The fishery harvest from this lake is of substantial amount. Owing to its high productivity and the fishing activity that capitalizes on the lake close proximity to the lucrative markets of Addis Ababa (less than 150 km) with super highways; fishes collected at dawn are marketed for lunch in Adds Ababa, despite reports for heavy metals and pesticide contaminations. The water hyacinth infestation is also a crtical issue for Lake Koka (Plate 4.10), as in other water bodies such as Lake Tana.

At present, Lake Koka however useful it is to the surrounding communities and beyond (e.g. power, fish and vegetable users in Addis Ababa and elsewhere), the quality of its water and food products is deteriorating by the year as the rush for food production and development in the watershed expands and at the same time, the effort to put control measures for anthropogenic impacts remains unheeded (Karlsson, 2015).

Plate 4. 10: Infestation of Lake Koka with water hyacinth and cattle feeding on it (Photo credit: Abebe Getahun)

4.8. Lake Hayq

Lake Hayq has been facing increasing threats from human and livestock encroachment, with farming extending right to the lake shore. This leads to extreme sedimentation as silt from the inflowing Ankerkeha River causes lake water to appear muddy and unsightly for recreational purposes. Also, the lake suffers from recreational pollution from the nearby towns of Hayq and Dessie. The degraded watershed enhances the siltation problem. Recently, Lake Hayq is facing problems of infestation by the exotic weed water hyacinth, which has covered a large portion of the southern lake shore (Fig. 4.10). Over-exploitation of the fish resource has become so serious that Wollo University and the local churches have embarked on a project to restock the lake by raising fingerlings in artificial ponds. This promising beginning to restore some of the ecosystem services of the lake should continue strongly.

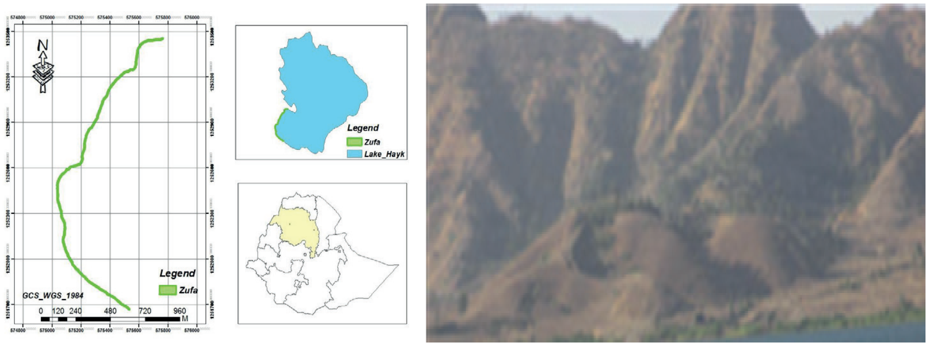


Figure 4. 10: Lake Hayq showing infestation with water hyacinth and degraded catchment (Source: Assefa Tessema et al., 2015)

4.9. Lake Basaka sub-watershed

The watershed of Lake Basaka covers 505 km^2 of which the lake covers 10% of the area. The climate condition of the area is semi-arid with mean rainfall of 534 mm and mean temperature of 25^{0}C with the potential evapotranspiration of the lake exceeding the monthly rainfalls.

This is a unique feature of the Awash basin, where the expected trend with freshwater systems is shrinking and eventual disappearance in the tropics, but Lake Basaka is continuously on the rise.

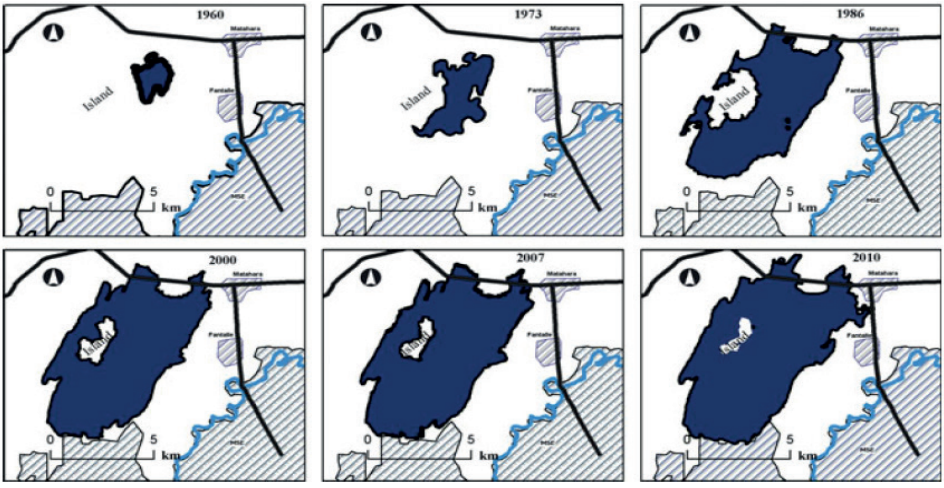


Figure 4. 11: Spatio-temporal dynamics of Besaka Lake (1960–2010) (Megersa Dinka, 2010)

Lake Basaka is located in a sub-basin that is known to be rainfall deficient. Despite that, the lake is increasing in volume covering large surface areas. The main highway and railway connecting Djibouti and Addis Ababa (the bloodline of the Ethiopian economy) had to be abandoned and re-routed.

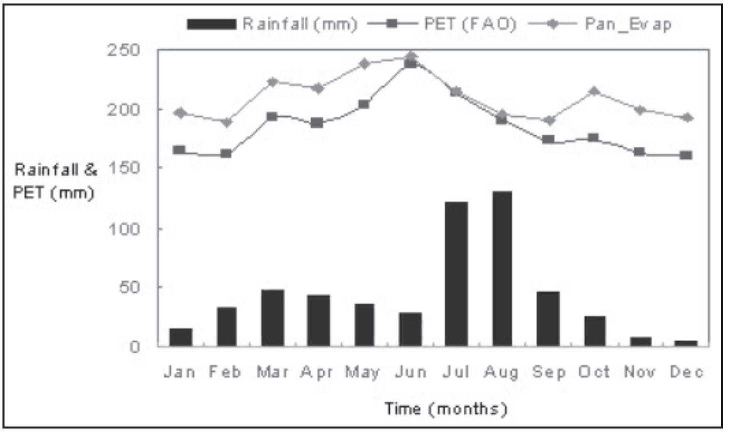


Figure 4. 12: Long-term (1966-2007) mean monthly potential evapotranspiration of Lake Basaka (Source: Eleni Ayalew Belay, 2009)

Compared with monthly precipitation, the potential evapotranspiration (PET) and pan-evaporation (Pan_evap) exceeds rainfall, which indicates that the lake would have dried if there were no other sources of water inflows:

Plate 4. 11: Expanding Lake Basaka (Source: Eleni Ayalew Belay, 2009)

As indicated in Plate 4.11, Lake Basaka is shown taking over the railway and the tarmac road indicated in the left lower corner of the image. In a recent study, the lake completely flooded both the railroad and asphalt road, which had to be abandoned and a new transport line built close to the Yerer Mountain.

4.10. Cheffa wetlands

Chefa wetland receives fertile soil from highlands during rainy season every year when Borkena floods; therefore farmers plough the wetland for subsistence and commercial agricultural production. Recently, the number of farmers participating in both traditional and modern irrigation has increased in Cheffa wetland at alarming rate due to good price of crops and fruit and vegetables at Kemissie, Kombolcha and Dessie Towns. The dominant crops harvested from the wetland are: - Sorghum, tomato, onion, green pepper, cabbage and salad, banana and papaya. Sugar cane cultivation by some 11 investors is highly intensified in the wetland (Assefa Tessema *et al.*, 2015).

In Cheffa wetland, although local farmers mainly focus on subsistence farming, more than 15 investors with 4-1750 hectares of land are engaged in mechanized farming in five Kebeles (Gerbi, Tuche, Shekla, Belida and Woledi) (Assefa Tessema *et al.*, 2015)

Plate 4. 12: Cheffa wetland and farming activities (Source: Assefa Tessema et al., 2015)

4.11. Lake Chamo

Lake Chamo is among diversified, productive, and economically important lakes in the Ethiopian rift valley. According to Alemayehu Hailemichael and Solomon Raju (2010), the ecosystem is facing threats associated with destructive and over-fishing, shrinking of lake size, changes in water chemistry, and poor waste management that resulted in eco-degradation and, ultimately, loss of biodiversity.

Woody species, climbers, shrubs, herbs, and grasses characterize the vegetation composition of the surroundings of Lake Chamo. The vegetation composition varies based on altitudinal differences and proximity to water bodies and could be classified as lacustrine, riverine, palustrine, and terrestrial.

This diverse aquatic habitat serves as breeding, feeding and roosting sites for a large number of resident birds. Moreover, the lake is a place where we find crocodiles and hippopotamuses and a variety of birds living in harmony. Lake Chamo is known for its diversified ichthyofauna of Nilo-Sudanic forms consisting of about 18 fish species.

Pressures on the wetland environment emanate from extended cultivation for staple as well as cash crops to over-fishing and removal of vegetation cover. Due to uncontrolled human population growth, there is huge encroachment around the lake shore and unregulated abstraction of water from the lake for irrigation purposes. There is unabated conversion of the fringe wetlands for recession agriculture. This situation has brought heavy erosion and sedimentation in the lake. There is also growing number of livestock and overgrazing has exacerbated the sedimentation process and increased organic loading. Firewood collection, charcoal production and timber logging has removed much of the riparian vegetation.

It has also been reported that there is lake level reduction through the years. Long time spatio-temporal analysis of lake size indicated that there is a general decline in lake area coverage since 1960s (Alemayehu Hailemichael and Solomon Raju, 2010). This decrease in the water level is accompanied by increase in ionic concentration and nutrient load. Significant changes in water chemistry and general limnology of the lake may be a great challenge to maintain the existing biodiversity. Such limnological changes would have contribution to algal blooming, recurrent mass fish kill, and deaths of zebra, which have also been witnessed in the past in the rift valley. There is also overfishing in the lake in which the lake's fishery resources are being depleted.

4.12. Boye and Kito wetlands

These two wetlands serve as a habitat for a variety of plants, birds, and mammal species, and are water sources for human and livestock populations. It has also been reported that hippopotamus inhabits the middle of the Boye wetland, but it has been highly degraded and under the risk of loss due to poor watershed management, solid and liquid waste disposal, rapid expansion of Jimma Town towards the wetlands, and conversion to agricultural land (Tariku Mekonnen and Abebayehu Aticho, 2012).

According to Seid *et al.* (2013), a total of 36 bird species were recorded during their survey of Boye wetlands. Among these, two species, *Poicephalus flavifronsis* is endemic to Ethiopia. Some of the species that are limited only to Ethiopia and Eritrea also inhabit Boye wetland such as *Bostrychia carunculata, Dioptrornis chocolatinus* and *Corvus crassirostris. A*mong the recorded species *Baleari capavonina* and *Baleari caregulorum*are vulnerable while *M. flavicollis* was near threatened. These species will be endangered within a short period of time, unless the necessary actions are taken.

Argaw Ambelu *et al.* (2013) identified forty-four macro invertebrates belonging to 19 families from the Boye sites, whereas, in the Kitto sites 366 MIs from 26 families were collected. The relatively higher load of pollution correlated closely with decreased pollution sensitive species diversity (like EPT) and increased abundance of number of certain pollution tolerant macro-invertebrates like Chironomidae in Boye wetland.

Generally there is a high level of anthropogenic threat to both the wetlands. The more intense agricultural practices and waste discharge was closely associated with higher phosphate concentration and low level of dissolved oxygen (DO). The biological analysis reveals a notable reduction of the diversity of macro-invertebrates in the downstream direction. Kitto wetland has significantly better MI diversity than Boye). Overall, Boye wetland was relatively more polluted than Kitto due to intensive pollutant input mostly from Jimma Town as well as intensive agriculture related practices around the Boye wetland (except at downstream sites).

The Boye wetland drainage for agricultural and other land use types has an adverse effect on the bird species due to the alteration of the ecosystem.

4.13. Lake Tana wetlands (Fogera plains, Shesher and Welella wetlands)

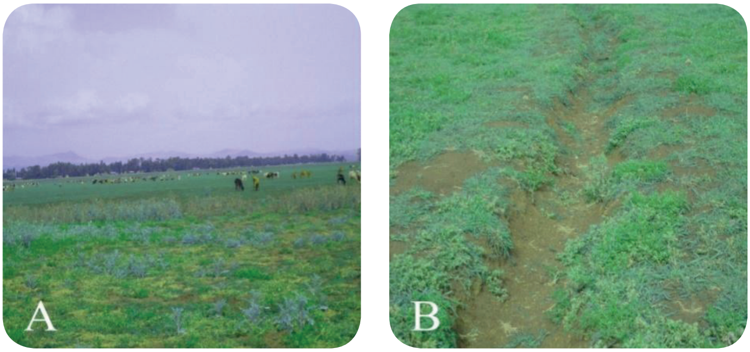
Fogera floodplain lies on the eastern side of Lake Tana in Libo Kemkem and Fogera Woredas of Southern Gondar Administrative Zone. It is surrounded by five Kebeles, i.e., Nabega, Shaga, Abuana Kokit, Shina and Kidist Hana. This floodplain was historically used for grazing of the renowned Fogera breed but is being now used for cultivation of various kinds of crops such as rice, maize, chickpea, Bukri teff (early maturing local farmers variety) and partly for grazing (mainly before the onset of the major flooding season). The plain is flooded by the overflow of two major rivers feeding Lake Tana, i.e., **Rib and Gumara Rivers** during the rainy season. There are also several tributaries of these major rivers contributing to the flooding of the Fogera floodplain. Noteworthy is that there is no rock in the floodplain and it is a major habitat for local resident birds and major destination for intercontinental seasonal migratory birds for wintering and feeding. The major soil type of the plain is black clay soil although this has been altered by the extent of soil erosion from the catchments of Rib and Gumara Rivers where the subsoil (mainly sands) are deposited following overflow of these rivers (Sileshi Nemomissa, 2008). The Fogera plains have faced critical ecological changes, with the major one being conversion into rice fields.

The current extent of **Shesher, Welela and Daga-Takua wetlands** is given in Table 4.3. The wetlands have been significantly reduced in size due to expansion of agriculture and drainage for irrigation. Although highly reduced in area, they are still the major destination for intercontinental seasonal migratory birds and provide habitats for resident bird species. Owing to remarkable anthropogenic impacts on the wetlands, the latter are infested with weeds and only few wetland species remain. Furthermore, the areas of the wetlands have continued to significantly reduce in size. It is to be noted that Daga wetland was divided into two fragments (Daga and Takua) because of the settlement (cultivation) which runs almost on its middle part.

Table 4. 3: Areas of Shesher, Welela and Daga-Takua wetlands based on 1987 and 2008 topographic map of Ethiopian Mapping Authority (Sileshi Nemomissa, 2008)

Wetland	Area (ha)	Area (ha)
	1987	**2008**
Shesher	1557.27	1405.31
Welela	298.26	139.26
Daga-Taqua	247.71	180.61

The reduction of these fringe wetlands depends on the rate of their abstraction during the dry season. Due to high influx of landless farmers from the surrounding areas, this problem will continue as long as poverty and lack of other livelihoods remain a challenge in the area. Unregulated abstraction and recession agriculture will eventually disrupt the water balance and these fringes may revert to dry agricultural land, a phenomenon frequently observed in valley bottom wetlands and irrigation fields.



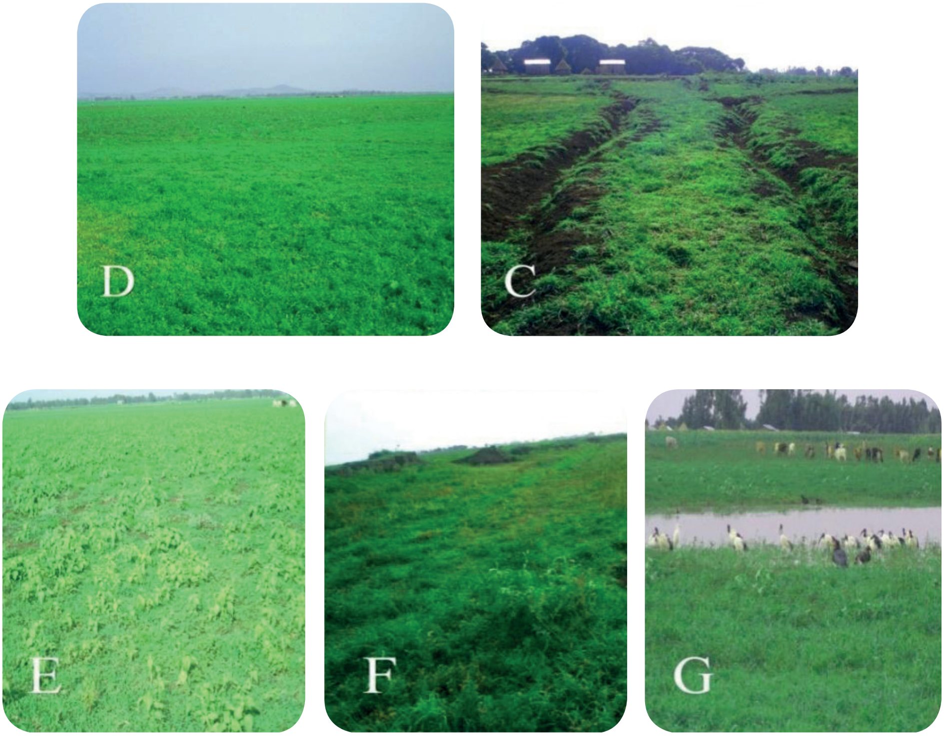


Plate 4. 13: Welala (Welela) wetland (Source: Sileshi Nemomissa, 2008)

(A), overview of the wetland with cattle grazing and exotic invasive weed (*Argemone mexicana*, Papaveraceae); (B-C), artificial canals used to drain water following the end of the rainy season for small scale irrigation; (D), the wetland is dominated with *Sacciolepis africana* (square) and invasive weed (Brassicaceae); (E), *Sacciolepis africana* – Periscaria community; (F), Hydrological connection of Welala wetland drains to Lake Tana and Welela-Shesher-Lake Tana connections and back flow of Lake Tana during peak period via Ginder Canal to both wetlands; (G), small pond formed following the onset of the rainy season in the middle of the Welala wetland attracting many water birds such as Sacred Ibis and Geese.

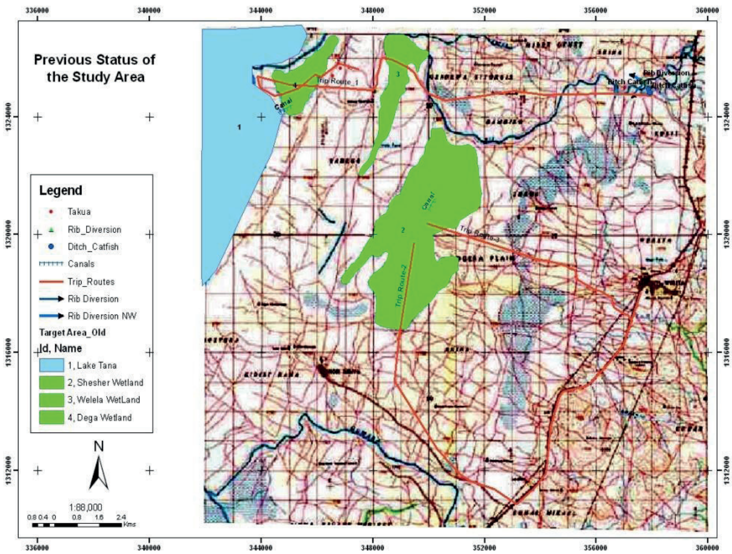


Figure 4. 13: Extent of Shesher, Welela and Daga-Takua wetlands of Fogera Plain in 1987 (upper panel) and in 2008 (Sources: Ethiopian Mapping Authority, Sileshi Nemomissa, 2008)

The dramatic changes in the areas of Shesher, Welela and Daga-Takua wetlands, as shown in recent maps (Figures 4.13 & 4.14) indicates changes in other land use features also. This apparent decrease will have severe consequences on the carrying capacity and habitat diversity of the wetlands. It is to be noted that Welela wetland has exhibited the least value of change in area over 1987 – 2008 period (Table 4.4). The present condition of the Welela, Shesher and Takua wetlands is shocking (Table 4.4 and Figure 4.14), with over more than 10-fold decrease on the wetlands during the course of three decades. This indicates that fringe wetlands could disappear within the lifetime of the surrounding community members, leaving them with no alternative means of livelihood. In all three wetlands, the driving forces for reduction of their extent (area) are expansion of agriculture and extensive drainage irrigation. This calls for urgent rehabilitation actions to restore the provisioning and other services of these wetlands to the communities.

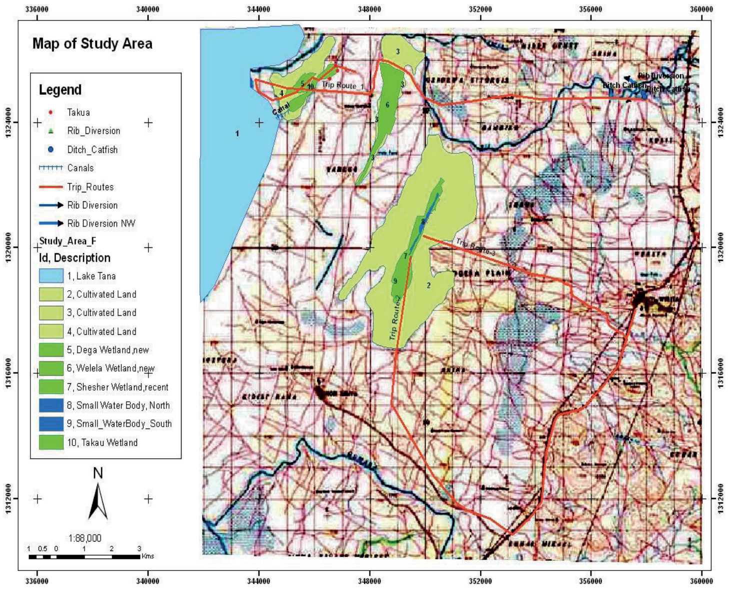


Figure 4. 14: The magnitude of change in areas of Shesher, Welela and Daga-Takua wetlands (Source: Sileshi Nemomissa, 2008)

The ecological status of these wetlands was also investigated during a study commissioned by the Nile Trans-boundary Environmental Action Plan (NTEAP) in 2008 and the result is presented in Table 4.4. It can be concluded that the condition of most wetlands some two decades ago was still not in the excellent category, but rather in good and even lower status (good-fair). Most of the low scores are due to altered geomorphologies of the wetlands because of drainage, agriculture (rice farming), overgrazing and land degradation. Although no score was given at that time for restorability, it is evident that most wetlands around Lake Tana are in dire need of restoration.

The same study also included assessment of the ecosystem services rendered by the wetlands and found that except for Delgi-Takusa wetland, no other wetland in the LTSB was giving full expected ecosystem services. The worst score was obtained for Fogera and Gilgel Abay wetlands, where it was concluded that these wetlands were impaired and in need of intervention. The major threats observed were rice cultivation and hydrological alterations in Fogera and silt accumulation, bank erosion and loss, and human encroachment in the Gilgel Abay floodplain wetland.

Table 4. 4: Ecological status of LTSB wetlands during 2008 (Source: NTEAP, 2008)

Wetland name/ index score	Bahir Dar Zuria	Zeghe	Delgi	Takua	Fogera	GilgelAbay
Hydrogeomorphic (HGM) condition index	8	20	20	14	4	14
Vegetation condition index	27	40	24	38	23	31
Water quality index	40	40	40	50	40	40
Buffer condition index	14	11	15	8	13	11
Restorability	ND	ND	ND	ND	ND	ND
Overall condition index	89 **(0.66)**	111 **(0.82)**	99 **(0.73)**	110 **(0.81)**	88 **(0.60)**	96 **(0.71)**
Narrative ecological condition	Good	Good	Good	Good	Fair	Fair-Good

4.14. Lake Hashenge

It is located at coordinates 12°35′N 39°30′E and altitude of 2,400–3,000 masl. Named also as Lake Ashangi/ Ashenge, it is a lake in the southern Tigrai Region of the Ethiopian highlands and has no outlet. The British explorer Henry Salt has noted that the Tigrigna name of the lake is Tsada Bahri ("White Sea") from the number of birds which cover its surface, Lake Hashenge is five kilometers long and four wide, with a surface area of 20 square kilometers.

The lake is showing some signs of degradation such as overharvesting of shore vegetation and its ecological integrity should be protected so that it can continue to give ecosystem services, including climate moderation. This lake harbours a variety of waterbirds and provide a wintering habitat for Palaearctic and other migratory birds. However, the importance of the lake as a temporary site for migrant bird populations has not been adequately studied. A total of 36 species belonging to 14 water bird families were encountered in the lake (Alemayehu Yismaw *et al.*, 2017). Fifteen of the species were resident birds, including the endemic Wattled Ibis (*Bostrychia carunculata*), and 14 of the species were Palaearctic migrants, including the globally Near-Threatened Ferruginous Duck (*Ayithya nyroca*) and Maccoa Duck (*Oxyura maccoa*). Increased abundance of Palaearctic species towards the dry season increased species diversity, but may have caused displacement of resident birds resulting in lower overall abundance in this season.

4.15. Hora Kilole

Lake Hora Kilole (Bishoftu-Kilole) has changed dramatically due to diversion of Mojo River into its volume for irrigation and these changes are discussed in Brook Lemma (2014) and Figures below (Plate 4.14).

Plate 4. 14: Degradation of Hora Kilole and Wedecha River
(Photo credit: Brook Lemma)

Above: Currently Lake Hora-Kilole has reverted to maximum depth of 6.5 m with the ground on its eastern shore that received alluvial sediments from the regressing water has turned into farms. **Below**: The two images present expansion of flower farms using River Wedecha as source of water and in return recipient of untreated liquid wastes, mostly loaded with fertilizers, pesticides and organic matter, as refuse from flower harvests (Photo credit: Brook Lemma)

4.16. Lake Chelekleka

The topographic feature of Lake Chelekleka was made up of rolling terrain (a rugged topography) with the average altitude 1920 masl. The common soil type in the area includes luvisols, lepthosols, nithosols, vertisols and cambisols (Daniel Assefa, 2015).

Chelekleka Lake supports different bird species (Plate 4.15) including endemic birds like Wattled ibis (*Bostrychia carunculata).* Wetland birds recorded at Chelekleka Lake include a variety of storks, herons, ducks, geese, waders, ibises and birds of prey (Kalkidan Esayas, 2017). The site holds more than 20,000 water birds seasonally. The shallow waters form significant roosting site for more than 18,000 common cranes from October to March (Baxter, 2002).

According to Kalkidan Esayas, 2017, aquatic plants found at Chelekleka Lake include *Typha* spp., sedges, rushes, *Potamogeton* spp., *Persicaria* spp. and *Odontelytrum abyssinicum*. Around the lake, some remnant natural forests comprising tree species: *Afrocarpus falcatus*, *Prunus africana, Albizia gummifera*, *Aningeria adolfi-friederici*, *Cordia africana*, and *Croton macrostachus* occure. Plantation woodlots with exotic tree species such as *Eucalyptus* species, *Gravilea robusta*, and *Cuprunus lustanica* are common.

Major cause for degradation is relentless and unregulated abstraction and land grab for commercial and residential purposes. This shallow pan has dried up completely in recent years. The lake is intensively cultivated on the fringes by local farmers who grow chick peas and different kinds of vegetables like tomatoes and cabbages. Besides the local farmers, various agro-industrial enterprises have land holdings around the wetland. These industries use different pesticides and fertilizers during their production processes. Effluents enter surface or underground into the wetlands. The wetland, over time, has accumulated toxic substances in its substrate. The wetland and all life forms that depend on the area are at great risk of being contaminated (Daniel Assefa, 2015)

Plate 4. 15: Lake Chelekleka (Photo credit: Kalkidan Esayas, 2015)

References

Abebe Getahun (2001). Lake Afdera: a threatened saline lake in Ethiopia. SINET: EthiopianJournal of Science, 24 (1): 127-131

Abebe Getahun and Lazara, K.J. (2001). Lebias stiassnyae: a new species of killifish from Lake Afdera, Ethiopia (Teleostei: Cyprinodontidae). Copeia 1: 150-153

Abebe Getahun and Stiassny (1998). The Freshwater biodiversity crisis: The case of the Ethiopian Fish fauna. SINET: Ethiopian Journal of Science, 21 (2): 207-230.

Alemayehu Hailemicael and A.J. Solomon Raju (2010). Challenges and opportunities of Chamo Lake-wetland biodiversity, Ethiopia.

Alemayehu Yismaw, Woldegerima Kiros and Mihretu Yonas (2017). Importance of Lake Ashenge, a small Important Bird Area in Northern Ethiopia, to Palaearctic and other migratory birds. African Journal of Wildlife Research; 47 (1): 1-9.

Allen, C. R. (1982). Reservoir-induced earthquakes and engineering policy. California Geology, 35, 248–250.

Argaw Ambelu, Mekonen S., G/Sellasiie, A., Mola, A and Karoumooti, K. (2013). Physico-chemical and biological characteristics of two Ethiopian wetlands.Wetlands33(6): 69-79.

Assefa Tessema, Nuria Abdurohman and K.S Goudar (2015). Role of Cheffa wetland to the local communities around Kemissie, Oromia Zone, Amhara region, Ethiopia.Direct Research Journal of Agriculture and Food Science (DRJAFS).Vol.3 (7), pp. 148-156, July 2015

Atalay Ayele, Ebinger, C. J., Van Alstyne, C.2, KEIR, D. Nixon, C. W., Belachew Manahloh and Hammond, J. O. S. (2016). Seismicity of the central Afar rift and implications for Tendaho Dam hazards. Geological Society, London, Special Publications420: 341-354; doi: 10.1144/SP420.9,

Baxter, R.M., (2002). Lake morphology and chemistry. In: Tudorancea, C., Taylor, W.D. (Eds.), Ethiopian Rift Valley Lakes. Backhuys, Leiden, pp. 45–60.

Brook Lemma (2011). The impact of climate change and population increase on Lakes Haramaya and Hora-Kilole (1986 – 2006). In: Impacts of climate change and population on tropical aquatic resources. Proceedings of the Ethiopian Fisheries and Aquatic Sciences (EFASA); Haramaya University, 03-06 February 2011. pp. 11-36.

Brook Lemma (National Consultant) (2012). Report on the Value Chain (Marketing) Assessment of the Fishery Sector in Ethiopia. Publisher: Food and Agriculture Organization Sub-Regional Office for Eastern Africa (FAO/ SFE), Addis Ababa. 131 pp.

Brook Lemma (2014). Baseline Studies on Climate Change Research in Ethiopia. Published by the Ethiopian Academy of Sciences, Addis Ababa, Ethiopia, 125pp.

Brook Lemma and Hayal Desta (2014). Review of the Natural Conditions and Anthropogenic Threats on the Ethiopian Rift Valley Rivers and Lakes. International Journal of Water Resources Development submitted URL: http://mc.manuscriptcentral. com/cijw

Conway, D., Mould, C. and Bewket, W. (2004). Over one century of rainfall and temperature observations in Addis Ababa, Ethiopia, International Journal of Climatology24: 77-91.

Dagnachew Legesse, Vallet-Coulomb, Christine, V. C. and Gasse, F.C. (2004). Analysis of the hydrological response of a tropical terminal lake, Lake Abiyata (Main Ethiopian Rift Valley) to changes in climate and human activities. Hydrol. Processes18: 487–504.

Daniel Assefa (2015). Causes and effects of diminishing water volume in Lake Chelekleka, Bishoftu, Ethiopia and strategy for conservation, MSc. Thesis (Unpublished), Addis Ababa University, 106pp.

Derege Tsegaye, Tsunekawa, A., and Tsubo, M. (2012). Continuing Land Degradation and Its Cause-Effect in Ethiopia's Central Rift Valley. Arid Land Research Center, Tottori University 1390, Hamasaka, Tottori, 680-0001, Japan, Land Degradation and Development .

Dsikowitzky, L. Mesfin Mengesha, Elias Dadebo, Carlos Eduardo Veiga de Carvalho, C. E. V. and Sindern S. (2012). Assessment of heavy metals in water samples and tissues of edible fish species from Awassa and Koka Rift Valley Lakes, Ethiopia. Environ.Monit. Assess. DOI 10.1007 /s10661-012-2777-8.

Eleni Ayalew Belay (2009). Growing lake with growing problems: integrated hydrogeological investigation on Lake Beseka, Ethiopia. Ecology and Development Series No. 64, 2009, pp.186

Girma Kebede (2004). Living with urban environmental health risks: The case of Ethiopia. Ashgate Publishing Company, Burlington, USA, pp. 251; ISBN: 0 7546 4306 9

Gouin, P. (1979). Earthquake history of Ethiopia and the Horn of Africa. International Development Research Center (IDRC), Ottawa, Ontario.

Habtamu Haile Tolera (2007). Suitability of local materials to purify Akaki Sub-basin water. PhD dissertation at the University of Karlsruhe, Germany

Kalkidan Esayas (2017). The ecology of Wattled Ibis (Bostrychia carunculata) in relation to landuse/cover change of Chelekleka Lake, Bishoftu. Unpublished PhD Dissertation, Addis Ababa University, Addis Ababa, Ethiopia.

Karlsson, J. (2015). Scoping study of water management in the textile industry in Ethiopia. SIWI Paper 23.SIWI, Stockholm.

Mousseau, F. and Martin-Prével, A (2016). Miracle or mirage? Manufacturing hanger and poverty in Ethiopia? Published by The Oakland Institute, Oakland, CA 94619 USA, www.oaklandinstitute.org and info@ oaklandinstitute.org, 28pp.

NTEAP (Nile Transboundary Environmental Action Plan) (2008). The biodiversity, wetlands and water quality of the Lake Tana sub-basin (LTSB), Compiled report to the NBI.

Piguet, F. (2007). Complex development-induced migration in the Afar pastoral area (North-East Ethiopia. Paper Prepared for the Migration and Refugee Movements in the Middle East and North Africa; The Forced Migration & Refugee Studies Program The American University in Cairo, Egypt, October 23-25, 2007, 19pp.

Seid Tiku Mereta, Boets, P., Argaw Anbelu Bayih, Asgedom Malu, Zewdu Ephrem, Addisu Sisay, Hailu Endale, Menberu Yitbarek, Amana Jemal, De Meester, L. and Goethals, P.L.M. (2012). Analysis of environmental factors determining the abundance and diversity of macroinvertebrate taxa in natural wetlands of southwest Ethiopia. Ecological Informatics 7: 52-61.

Shimellis Abdi Assefa (2016). Status of salt affected soils, irrigation water quality and land suitability of Dubti/Tendaho Area, North Eastern Ethiopia. PhD Dissertation submitted to Haramaya University, Ethiopia, 149pp.

Sileshi Nemomissa (2008). Delineation of wetlands of Fogera floodplain and scaling their biological and physical connections to Rib River and Lake Tana. A consultancy study.

Simpson, D. W. (1976). Seismicity changes associated with reservoir impounding. Engineering Geology, 10, 371–385.

Tariku Mekonnen and Abebayehu Aticho (2011). The driving forces of Boye wetland degradation and its bird species composition, Jimma, Southwestern Ethiopia. Journal of Ecology and the Natural Environment, Vol. 3(11): 365-369.

Tenalem Ayenew (2002). Recent changes in the level of Lake Abiyata, central main Ethiopian Rift. Hydrological Sciences 47(3): 493-503

Wheeler, B.D., Shaw, S.C., Fotj, W.J. and Robertson, R.A. (1995). Restoration of temperate wetlands. Wiley, Chichester, UK. 562 pp.

Yohannes Lemma, Aklilu Hailu, Mohammednur Desissa, Kalberkamp, U. (2010). Integrated Geophysical Surveys to Characterize Tendaho Geothermal Field in North Eastern Ethiopia. Proceedings World Geothermal Congress, Bali, Indonesia, 25-29 April 2010

CHAPTER 5

ALTERATION HISTORY AND PRACTICAL RECOMMENDATIONS FOR RESTORATION OF WETLANDS

5.1. Introduction

Several workers have reported on the anthropogenic pressures and threats posed to Ethiopian wetlands, with main focus on the rift valley lakes (Tudorancea and Taylor, 2002; Tenalem Ayenew and Dagnachew Legesse, 2007; Brook Lemma and Hayal Desta 2016). However, a few have ventured forward to analyze the causes for the degradations and to suggest mitigation measures.

The major causes for degradation of Ethiopian wetlands can be classified into four categories, aside from specific causes that apply to each wetland. These causes are not different from the global causes for deterioration of wetlands, abbreviated as HIPO, i.e.,

Habitat alteration

Invasive species

Pollution, and

Over-exploitation

In this chapter, the alteration history of each of the 16 degraded wetlands will be reviewed using two approaches:

- Maps to show hydrological and areal changes of the wetlands
- Secondary sources (literature, data, and reports) to indicate level of changes

In this report, the broad causes for wetland degradation can be grouped into 3 categories, with a lot of overlap between them.

In **Category 1**, wetlands degraded due to hydrological alterations induced by human activities (and climate change) and drainage agriculture can be included. Accordingly, the main wetlands included are the following:

- Lake Haramaya
- Lake Chelekleka
- Lake Zwai
- Lake Basaka
- Hora Kilole
- Lake Abijata
- Lake Chamo
- Lake Hayq

Hydrological changes are also induced by agricultural drainage for recession farming and seasonal grazing, and in this class, the following wetlands can be included:

- Fogera plains;
- Sheher and Welella wetlands,
- Boye and Kito wetlands,
- Cheffa and Kemisse wetlands**,** and numerous wetlands in the Amhara and Oromia regions.
- Valley bottom wetlands.

In Category 2, which might also include several members in the first category, we might place wetlands degraded due to pollution and improper (unwise) use of resources, including over-exploitation. Such wetlands are common in urban areas and in rural areas where livelihoods hinge on using the natural resources from the wetlands in an intensive manner, and include wetlands such as:

- Lake Hawassa
- Lake Zwai
- Lake Tana
- Awash River Basin including Koka Reservoir and Aba Samuel dam,
- Rivers crossing the City of Addis Ababa (Akaki, Kebena)

Improper extraction of lake and river resources degrades the habitat quality and erodes biodiversity values of ecosystems. Unwise extraction of soda ash, common salt and potash, sand mining and gold panning are observed in the following lakes and rivers:

- Lake Abijata
- Lake Afdera
- Lake Asal
- Lake Tana
- Abay River tributaires (Beles, Dabus, Didessa, etc.)

In Category 3, wetlands degraded due to natural causes are discussed. Some of these wetlands are located in geologically unstable areas such as fault lines and are vulnerable to natural hazards like earthquakes, landslides and seismic cracking. Water enclosed in the lake or dam basin can be completely lost by seepage such as the Tendaho Dam and micro-dams in Tigray Region, while groundwater intrusion may inflate lake volume and area in others (Lake Basaka). Some of the large wetlands in Gambella Region are prone to seasonal flooding which affects peoples' livelihoods and ecosystem services, while others such as the shallow wetlands like Chelekleka may completely dry out as a result of natural desiccation compounded with human mismanagement.

5.2. General restoration approaches

The major restoration approaches to wetlands degraded due to hydrological changes induced by anthropogenic activities mainly (but also exacerbated by climate change) include, among others:

5.2.1. Water use regulations

Because the major reason for degradation of such wetlands is unregulated use of water by different actors in the catchment - with everyone abstracting water to capacity, and therefore with much wastage and impunity - it appears that regulations with focus on water use efficiency, payment for water used, reducing wastage and ensuring flow allocation to the natural system, should be enacted so that such wetlands can be restored to their original conditions in time.

Water tariffs and water costing should be put into practice in all watersheds of the country, provided that the annual water budgets of the wetlands is studied counter to the annual community and evaportanspiration needs of the area and consultations are made with water users and all other stakeholders. Once an agreement is reached covering a number of years, the implementation plan must be regulated to have severe penalties for those who violate the agreements. A good start has been made in the Awash River Basin and this experience should be replicated in these degraded basins also. Water allocation committees and regulatory bodies should be in charge of water distribution based on need and efficiency. In many Woredas and Kebeles, there are water use associations, but their performances have not been successful. The several water use associations around the wetlands of Lake Zwai could be mentioned in this regard. Improving the capacity of such associations will help to allocate water in more efficient and sustainable ways.

Besides regulatory approaches, and because most of the misuse of water is due to lack of awareness by local communities, concerted efforts should be made to raise awareness of watershed communities through local trainings and outreach programs.

5.2.2. Watershed management to restore hydrological balance in the long term.

The Ethiopian Government has already embarked on a massive campaign to restore catchments degraded due to deforestation and poor land use practices using established SWC approaches, such as:

- Soil water conservation and enhancement programs by re-planting catchments with native trees and shrubs that can retain moisture and minimize soil erosion. Preference can be given to trees with added value such as fruit trees and all-purpose trees.

- Hydrophytic vegetation restoration shall be of species typical for the wetland type(s) being established and the varying hydrologic regimes and soil types within the wetland. Preference shall be given to native wetland plants with local genetic material.

- Increase water content of uplands with terraces and bunding practices that can maintain saturated soils for long period of time during the year. Although labor-intensive, construction of wide terrace floors and vegetation that allow slow percolation of water into the uplands should be practiced. It is not uncommon to see such terraced uplands remaining as wetlands for most of the year in well-managed catchments in Asia (Plate 5.1)

- Maintenance of water logged terraces will also uplift the water table and recharge rivers and lakes in downstream river valleys (Plate 5.1 left)

Plate 5. 1: Water retention in wide terraces in Ethiopia (left) and Asia (right)

(Note how wetlands are maintained by long retention of water in the terraces)

- Revegetation of bare uplands is enhanced by forestation followed by restricted access or complete access denial to closed areas. Fencing and protection of such exclosues should be continued for a minimum of 5 years to allow the natural vegetation to establish, and the hydrological conditions to restore flows and come-back of streams and rivers in the river valleys. Some success stories have been documented in this line in the regional states of Tigray and SNNPR.

- Where natural colonization of acceptable species can realistically be expected to occur within 5 years, sites may be left to revegetate naturally. If not, the appropriate species will be established by seeding or planting.

- Rehabilitated wetlands should be protected from human and livestock encroachments through community ownership and custodianship. The lessons from indigenous practices of the Oromia and SNNP communities in forest and water conservation customs should be emulated and expanded.

On a smaller scale, it has been successfully demonstrated in Addis Alem that forestation with indigenous (or other trees with same qualities of soil and water retention) can restore the hydrological balance and restore river flow and vegetation recovery. There was no need to remove entire farms or people to achieve this result, which indicates that the same operation can be successful on a wider scale at watershed level. But, a lot of political will and mobilization of local communities is necessary to ensure success of such action. This remains a big challenge, given that SWC efforts have not yielded the desired results in northern Ethiopia,

5.2.3. Buffer zone demarcation

Buffer zone delineation around rivers and lakes reduces pressure on removal of riparian vegetation. The extent of buffer zone should take local conditions into account and should not be fixed at certain distance from river banks and lake shores. Wide ranging experience indicate that 15 m buffer zone around lakeshores is quite effective to protect against further degradation of lake shores. Buffer zones around river banks could be much less, given that people have high contact with rivers to meet their livelihoods in rural Ethiopia, and the difficulty of implementing the actual guidelines of such buffer zones elsewhere.

Primary and secondary zones should be marked around lakes for setting development and conservation priority areas. No incursions for development should be allowed in primary zones while limited development and conservation schemes should be allowed in secondary zones. The extent of such zones should be determined by local wetland restoration committees.

The buffer zones around lake shores, river banks and fringe wetlands should not be exaggerated at the cost of financial and ecological benefits they give. Exclosures should be fenced and protected for at least 5 years and the regenerated vegetation should be allowed to attain perennial status again. The extent of buffer zones around lakes and rivers should be delineated for streams, rivers, lakes and wetlands separately, following experiences of other countries. Buffer zones will also ensure that nutrients do not enter into lakes and reduce the development of eutrophication and degradation of the littoral regions.

5.2.4. Upstream diversion

In many instances, such as Lakes Zwai and Tana, the lowering of lake levels is a result of abstractions taking place not in the lake, but from Feeder Rivers through diversions and pumping for irrigation purposes. Such actions should be regulated and used only when planned for sustainable use.

Uncontrolled exploitation of a wetland that is the source of a river or other forms of water at upstream causes serious problems to the people using it downstream. Excessive consumptive use or pollution of water by upstream users may deprive the downstream users of their legitimate use of the shared resource. Therefore, upstream users must recognize the legitimate demands of downstream users to share the available water resources. This clearly implies that dialogue or conflict resolution mechanisms are needed in order to reconcile the needs of upstream and downstream users. To this end, any initiatives and development plans should take the linkages between upstream and downstream users of water into account so that the activities will not lead to disastrous consequences.

5.2.5. Hydrological restoration

The major restoration approach for such wetlands is to restore hydrological balance through the long dry season by catchment management such as vegetation, which retains soil moisture for long periods, removing eucalyptus, SWC to increase percolation and regulations to manage drainage and water allocation in a sustainable manner. As such wetlands have been the bulwark of peoples' livelihoods for centuries and their long term restoration implies that alternative livelihood strategies have to be developed for the communities affected.

The Cheffa wetlands in the Amhara Region have been used for agricultural purposes for a long time and showed irregular fluctuation in area. In 1991, the area of the Cheffa wetlands was 60.61 km^2, and it slightly increased in area in the next decade in 2001 to 64.1 km^2. Then it decreased to 48.9 km^2 in 2011and then increased to 54.2 km^2 in 2016. Most of these changes were due to drainage practices by the state farm and the private owners of the wetlands, who have all the time put their cropping and husbandry interests first at the expense of the wetland's well being. Recently, these wetlands are facing additional threats, including overgrazing, settlements by squatters and tribal conflicts over water and grazing rights (Assefa Tessema *et al.*, 2014). Such wetlands require a suite of approaches and strategies, as the causes for their degradation span across several actors and processes.

Several practical approaches should be considered in the restoration of wetlands degraded because of excessive drainage, deforestation of catchment and water table lowering.

a. Prohibit drainage of wetlands by legislation

One could take the example of some African countries such as Uganda where draining wetlands for agricultural, residential or industrial purposes is prohibited by law. Even airport terminals have to do with coexistence with wetlands.

b. Regulating draining and water allocation

Proclamation No. 456/2005 issued by the Federal Rural Land Administration in 2005 appears ambivalent on the issue of wetland draining for agriculture purposes. While it does not explicitly encourage draining wetlands, some people have interpreted it as doing so. It appears that the greatest threat to wetlands appears to be land use policy and planning (Mengistu Wondafrash, 2003). It targets land set aside for social services, in particular grazing and other communal land use to be carried out in accordance with a location's peculiarities and through communal participation, in which wetlands could be part of that.

c. Catchment forestation with trees

Trees having desirable qualities to conserve soil and water, such as those with high root moisture storage and low evaporate-transpiration are preferable. Often, better results are achieved with native wetland plants with indigenous genetic material. This action will allow delayed percolation and long period to recharge wetlands from the uplands

d. Best agricultural practices

BAP reduces water wastage and minimizes pollution from excess nutrients and pesticides. Ground water should be abstracted according to crop water demand, which reduce water wastage for irrigated wetlands sourced from ground water, thereby allowing recharge or discharge as the case may be. For wetlands sourced from surface waters, better methods of water storage and prolongation of the water retention capacity of the soils during the long dry seasons is recommended. Drip irrigation practices reduce water loss and planting crops and tress with less water demand should also be adopted.

e. Human settlements

Human villages and abodes should be restricted to lowlands and uplands should be managed to conserve soil and water so that the lowland wetlands can be restored sustainably. Wetlands are being encroached for temporary settlements by nomadic communities, and while this is unavoidable, it should be managed and regulated on sustainable basis.

5.2.6. Restoration approaches to valley bottom wetlands (VBW)

Many of the valley bottom wetlands in northern, western and eastern parts of the country, appear to be of the minimal effect wetlands (MEW), i.e. they are wetlands with saturated soils due to natural infiltration and horizontal flow, or artificial irrigation withdrawal.

When the wetland features of these types of wetlands is further degraded and the agricultural features are prominent, then it can be said that the original wetlands have been compromised and totally converted into "cropland". It may be possible to re-convert such croplands into their original wetland features. The steps through which wetlands such as MEW become converted to agricultural land may involve the following anthropogenic activities and ecological changes.

How deep or shallow the water table is determines whether a wetland or river may form (Fig. 5.1). Where the water table is shallow, wetlands develop. The sources of the wetland waters are infiltration, which is enhanced by vegetated mountain catchments (slow infiltration, little runoff, high storage) such as river valleys (RV) or mountain seepage (MS) areas.

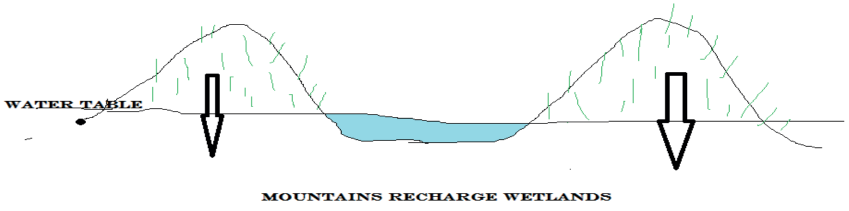


Figure 5. 1: Water table and wetland formation

Because water is present year round and the vegetation is rich (whether natural such as grass or planted such as rice), these wetlands are productive, highly populated and support many livelihoods such as fisheries, food, medicines, cultural amenities. Such examples include the Fogera and Dembia plains (wetlands) around Lake Tana, where the source of their waters is not from overflow of Lake Tana, but from base flow and infiltration of surface flows, which recharge the wetlands.

Surface-dominated wetlands

A distinction can be made between wetlands and lakes dominated by water coming from surface sources (runoff from precipitation or rivers) and subsurface sources (base flow and ground water flow). Some hydrologists further divide each category into two types – based on residence time of the water for the major part of the year.

The contribution of ground water flow to lakes and wetlands has not been adequately studied in Ethiopia, except for deep lakes such as Shalla. It can be simplified that the major wetlands and lakes dominated by surface water in the northern part of Ethiopia are of the type with surface water contributing the major share of the water budget and intermediate water residence time due to through flows. Many of the lakes in this category may store large volume of water during the 3-months 'kiremt' months and lose most of it by evaporation and evapotranspiration during the long dry months (Fig. 5.2). Besides lakes, rivers also have higher discharges during the kiremt months and may remain low or completely dry out during the dry months. Swamps and marshes also store most of their waters during the kiremt months, and depending on the level of withdrawal (drainage for farming, evapotranspiration, rice farming), they may remain as wetlands for the rest of the year, or resort to dry croplands for the rest of the year. The dynamics of how much water remain in lakes, rivers and palustrine wetlands is thus, a feature of how much of it is lost during the 7 dry months of the year.

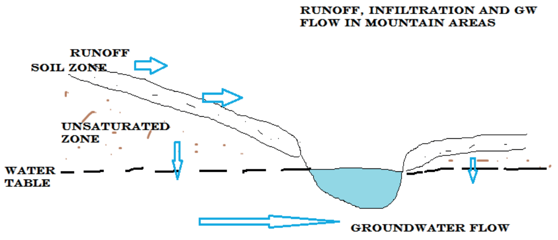


Figure 5. 2: Surface runoff as main water source for valley bottom wetlands

In a mountain seepage wetland, the water source could be surface runoff. In the Ethiopian context, the torrential rains during the three months of '*kiremt*' can supply such water which could last for a considerable part of the year due to slow percolation and moisture-retaining soil and vegetation (and thus persist as wetland through most of the year). In time, due to intensive agricultural pressure, the duration of such wetlands has diminished considerably that they continue as wetlands for only a few months after *kiremt*, after which they become converted to full agricultural crop lands and grazing fields. Such wetlands could be completely converted to agricultural and even to dry lands in time. This is the sad story of much of the northern part of Ethiopia, where remnants of the once robust MS and VB wetlands are now seen as wet and moist patches or complete dry lands, utterly degraded and their wetland functions entirely lost (Plate 5.2).

Plate 5. 2: Once thriving river valley wetland converted to degraded cropland (left) and partially restored to wetland through SWC activities (ANRS areas)

The ecological deterioration of such wetlands can be accelerated by human activities such as deforestation of the mountains (Fig. 5.3), which increases runoff, slows infiltration and depletes stored water and eliminates base flows, resulting in lowered water table. The reason why people move to uplands could be to escape the devastating effects of malaria in the lowlands, and to use the extensive lowlands for agriculture and the uplands for settlements. High population pressure is a driving cause in such cases. In time, such wetlands converted to crop lands will further degrade and deteriorate as useless dry lands.

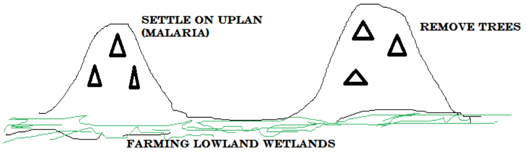


Figure 5. 3: Deforestation of uplands and intensive agriculture in lowland mountain seepage (MS) and Valley Bottom wetlands (VBW)

Examples of such wetlands include the extensive valley bottom wetlands in large parts of southern and northern Gojjam and others in the ANRS. The wetland features could be preserved in such lowlands when the surface waters are replenished with rivers and streams that prolong the season with high water presence in the soil, such as the Borkena wetlands (Plate 5.3).

Plate 5. 3: Borkena wetland with water lasting for most months of the year

Because of sustained flow, this riverine wetland is wet throughout the year. However, with long-term unregulated use, such as high livestock watering, abstraction for irrigation, fill-up by sediment from the river bank, such wetlands may slowly be degraded to isolated patches of waterlogged and dry river beds through the river stretch. It is not uncommon to see such types of wetlands in mountain seepage and valley bottom areas.

Groundwater and wetlands

When the water source of a wetland is from ground water, then the water table and the groundwater table should be close and ground water should charge the wetlands. Because the GW source is perennial and reliable, then the wetlands formed in such areas as mountain seepage and river valley bottoms will last the whole year and are visible as wetlands the whole year round.

If the recharge amount from GW is low, then such wetlands may not last the whole year, especially if water abstraction from GW is also done, as is most often the case to supply drinking water to settlements. In such case, the wetlands may lose more water every year as recharge from GW decreases, and at some point revert to agriculture land. If further abstraction of GW continues, such wetlands can be completely converted to drylands and eventually degraded into bare lands.

This is especially true, if the recharge zone of the GW table is deep and deforestation has further degraded the situation by lifting the water table up (Plate 5.4)

Plate 5. 4: Degraded dry land due to ground water abstraction and deforestation

This is the unfortunate situation one observes in the northern part of Ethiopia, where once thriving wetlands in river valleys and mountain bottoms have been degraded beyond recognition due to deforestation and draining of wetlands for agricultural purposes and concomitant abstraction of ground water beyond the rechargeability of the wetlands. Examples include the Raya and Kobo wetlands where GW is now abstracted for irrigation and the wetlands are giving their ecological services until the rechargeability is gone. Such wetlands can be restored only through hydrological intervention.

If the GW source is assisted by surface and base flows, then the wetlands will persist for longer periods during the year, and can even be perennial wetlands if abstraction and deforestation are regulated. It is evident that river valley and mountain seepage wetlands, which constitute the largest mass of land in northern Ethiopia, can be restored favorably through the following measures:

1) Soil and water conservation (SWC) to retain moisture and increase infiltration and storage, which will lengthen the recharge of the wetland for longer period during the year,

2) Groundwater and base flow management to maintain GW table close to the wetland water table,

3) Hydrological intervention including managed water usage to prolong water residence time until next surface inflows.

Afforestation with exotic trees (e.g. Eucalyptus)

The main reason for the forestation of the mountains around Addis Ababa was to restore the depleted firewood demand of the society. The traditional trees with their deep root systems able to hold moisture and soil particles during the torrential kiremt months were now replaced with the fast-growing, yet voracious water demanders and with root systems that were not deep enough.

The forestation program met to some extent the firewood demand of the then low population of the country. Evidently, the hydrological impacts of raised water tables and depleted aquifers were not realized until the coverage of eucalyptus plantations reached high proportions. By then, most of the indigenous tree species were completely replaced with eucalyptus, which continued to satisfy also other wood demands for timber, construction and roofing. However, as in other parts of Africa and Australia itself, the sad result was that rivers started drying up and mountains ceased recharging wetlands and rivers. Agriculture in the river valleys also faced setback in that water availability for cropping throughout the year became unattainable.

Restoration approach to Eucalyptus-dominated catchments

There has been much controversy about the role of eucalyptus in Ethiopian agriculture landscape. It has been suggested that given its indispensable role in providing timber, it should be maintained in catchments that do not suffer from water shortage. However, removing eucalyptus plantations in water stressed catchments has also been suggested by many environmentalists. Such catchments should be replenished with vegetation that can retain soil moisture and reduce soil erosion. Some people recommend the pioneer indigenous trees that were earlier removed by people while others argue that any tree or shrub with the desired features could be good candidates. In the Wollo valley bottom and mountain seepage wetlands around the Borkena valley, it has been observed that the mountains covered with *Lantana* shrubs had better hydrological flows of rivers and streams, while the ones covered with eucalyptus had dry river beds. Thus a simple restoration approach to eucalyptus-dominated RV and MS wetlands appear to re-vegetate with desirable trees and shrubs. This calls for massive mobilization of local communities and could be incorporated in the current campaign that the Government has undertaken for SWC activities. SWC further enhances nutrient retention in terraces, and then the excess nutrient should be removed using multi-purpose trees such as fruit trees and species with deep root moisture storage and low evapo-transpiration. There should be sound scientific study to identify and raise such trees in local nurseries.

5.2.7. Restoration of polluted wetlands

Among several approaches to combat pollution of wetlands, perhaps the best approach is to strengthen regulatory and enforcement institutions within the catchment and the wetland itself. The experience of the developed countries such as Europe and USA will be useful here.

There are regulations requiring any developmental projects to conduct Environmental Impact Assessment (EIA) studies before their implementations. All such projects should be obliged to have waste treatment plants and they need to pay for the quantity of water they abstract from the water bodies and the waste they discharge into them.

The Ministry of Environment**,** Forest and Climate Change **(MEFCC)** has the mandate to follow up and monitor the presence of these studies and proper implementation of the concerns and mitigation measures suggested in the EIA studies. Those projects that are not strictly following the guidelines need to be penalized and **MEFCC** has to be capacitated and strengthened to make sure that its guidelines are properly implemented. Any project that abstracts water needs to pay according to the **water tariff** that would be set in regulations. Moreover, the principle of **"polluter pays"** has to be enacted to make the party responsible for producing pollution pay for the damage done to the natural environment.

In most cases the land around any water body is tilled to the edge of the latter. Keeping **riparian vegetation (watershed)** around water bodies and a **buffer**

zone between the water body and the agricultural fields is the best way to properly combat non-point pollution.

A non-or less protected water body is also prone to invasions by **exotic (non-native) species**, now observed in several water bodies such as Lakes Tana, Zwai and Koka Reservoir. These water bodies are seriously threatened by water hyacinth invasion and in the latter two cases there is also domination of exotic fish species in the fisheries. Once any water body has been invaded by exotic species, it may be difficult and costly to make it free from the invasion. It may be appropriate, thus, to use a combination of **biological and mechanical methods**, especially, in the control of the invasive weeds. However, it is recommended that any type of appropriate use of the invader for economic benefits is very feasible and will, ultimately, help in reducing, if not eliminating, the population of the invader.

In order to realistically implement all the above suggested actions, there need to be **awareness creation and education movements** at all levels (community, development workers, administrators, and policy makers).

Last but most importantly, there must be the **political will and commitment on the part of the government**, at all levels, to go ahead with setting policies and regulations and look after, seriously, their effective implementations for conservation and restoration of wetlands.

5.2.8. Proper use of resources

Unwise exploitation of fishes and macrophytes and other riparian vegetation has been a serious problem in most, if not all, of Ethiopian lakes and their environs (including floodplains). This problem is closely associated with overpopulation, unemployment, poverty and increased demand for the resources. Moreover, absence of regulation on the use of these resources has aggravated the situation.

Therefore, proper **regulatory mechanisms** have to be in place in order to reduce the effects. The fishermen operating in a certain lake have to be limited, licensed and regulated. Any illegal fishermen have to be penalized and the legal ones should be protected. The fishing gears used need to be monitored and the **mesh sizes of the gill nets** (major fishing gears) should not be below the standard (not less than 8 cm). **Illegal and damaging fishing gears** (such as monofilament nets, poisoning with plant products and chemicals) should be avoided. Fishing during breeding (spawning) seasons should be prohibited. It appears that the Federal Government and some regions have **Fishery Proclamations** that prohibit the above actions. The limiting factor remains on setting implementation regulations and mechanisms of their enforcement. The active **involvement of the community** in managing these resources is highly recommended.

In all of the above mentioned water bodies there is **excessive use of macrophytes** and riparian vegetation for various purposes (house and boat constructions, ceremonials, animal feed, etc.) and this has to be **properly regulated and managed** in order for the latter to serve their roles as **breeding sites, refuges,** for fishes and other organisms in the water body.

Extraction of salts and minerals

Some lakes are exploited for the salts they contain, such as common salt from Lake Afdera, soda ash (Sodium Carbonate-Bicarbonate) from Lake Abijata, Chitu and Shala or potash (Potassium Chloride) from Lake Asal. The lake water often has to be drained and evaporated to extract the salts, as a result, there is risk of complete draining of lakes in the long term, unless sustainable abstraction methods are used (which do not seem to be economically sound).

The water level of Lake Afdera has been changing erratically partly due to unregulated abstraction of common salt by investors and the government (Fig. 5.24). It varied from an area of 114.7 km^2 in 1991 to increase to 119.3 km^2 in 2001, then decreased to 117.9 km^2 in 2011 and again recently increased to 119.2 km^2 in 2016. Although the changes in the lake area and volume appear to be small, the long-term impact of such unsustainable means of exploitation may be severe to the lake ecology, and ultimately to the commercial enterprises as well.

In addition to salt extraction, Lake Afdera has been subjected to dilution from freshwater springs around the lake. Even if such restricted habitats have been suitable for colonization and survival of some fish species, the long-term effect of lake dilution is difficult to predict.

5.2.9. Restoration of wetlands degraded due to natural causes

Although these wetlands are the least prioritized for restoration, still some measures can be taken to buffer the effect of natural disasters and reduce impacts on ecosystem services and peoples' livelihoods.

Some of the wetlands (such as Tendaho Reservoir) are prone and exposed to natural hazards like seismic events and drought while some such as Chelekleka and Gambella wetlands are affected by drought (in the former case) and over-flooding (in the latter case).

Tendaho Dam is an earth-filled dam in the eastern Afar Region of Ethiopia. It is situated on the Awash River, between Dubti and Mille and its reservoir also receives the output of Mille River. The purpose of the reservoir is to provide irrigation primarily for the sugar cane plantation for the Tendaho Sugar Factory and also providing drinking water for humans and animals.

Tendaho dam is a site characterized by a network of intersecting NNE and NE-trending faults and both faults are active and are potential sources of seismogenic hazards (Atalay Ayele *et al.*, 2016). As a result, it has been recommended that the Tendaho Dam site and the surrounding region require continuous monitoring for the safety of downstream populations and development infrastructures.

This large reservoir has faced a great problem being highly vulnerable for evaporation and drought as well as with a problem of seepage in which it has dried, at least, once in the last two years (it totally dried out in 2016) with a total loss of its fish fauna (Plates 5.5 to 5.7, below).Water flow and volume decrease during drought typically leads to increase in salinity. This also enhances algal production, promoted toxic cyanobacterial blooms, and lowered dissolved oxygen concentration. Nutrients, turbidity and algal levels also often increased in the reservoir.

Plate 5. 5: Normal level of the Tendaho reservoir (upper) and after it has dried out (lower) (Photo credit: Gizachew Teshome)

Plate 5. 6: The course of the Awash River at the reservoir during the time of drought (Photo credit: Gizachew Teshome).

Plate 5. 7: Mass death of fishes during drought in Tendaho Reservoir (Photo credit: Gizachew Teshome).

Lake Basaka

Although very difficult to manage, the effects in both instances, increasing the water storage capacity of the wetlands in those affected by drought (through various methods including plastic linings) may be a mitigation measure. Moreover, watershed management and preventing draining of the water for uses including agriculture and urbanization may facilitate the water holding capacity of these wetlands. Proper management and regulation of the stored water in the case of Tendaho Reservoir may be useful to reduce the total loss of water from the reservoir.

The **Gambella wetlands** are over-flooded during the rainy seasons and they remain so for some months (Plate 5.8). It is possible to use these flooded areas for aquaculture purposes, especially for catfish or lungfish aquaculture, which could tolerate lowered water level and decreased oxygen level. The flooded area could also be used as rice farms when the water is lowered to some extent.

Plate 5. 8: Over flooding in Gambella Nuer Region during light rains period (October, 2015)

5.2.10. Knowledge and Legislation

5.2.10.1. Awareness and concern creation

Often, people abstract water beyond their immediate use because of the perception that it is inexhaustible. It is the duty of the Government and experts to teach communities about sustainable ways of using water without degrading wetlands.

Building knowledge and awareness about wetlands

It is very important that policy and decision makers, development workers, academia and the public, including grassroot communities know about the functions and values of wetlands and the consequential negative effects that would accrue if they are not sustainably utilized.

According to Mengistu Wondafrash (2008), in order to manage wetlands effectively and make informed and sound decisions that improve the livelihoods of local people dependent on wetland areas while safeguarding wetland functions, values and attributes (including biodiversity), it is necessary to have adequate knowledge of their status and functioning. In this regard, it is of high priority to assess, carry out national inventory of wetlands and compile a National Directory of Wetlands, which is partially addressed in this publication. The desired information on wetlands has been suggested to be attained through resource base assessment, which involves survey, inventory, compilation of national directory of wetlands and construction of updatable computer database. According to Mengistu Wondafrash (2008), this objective can be achieved through a series of public awareness raising campaigns which include:

(a) Production and distribution of awareness raising materials (posters, flyers, fact sheets, booklets),

(b) Making use of mass media to put out features on wetlands,

(c) Series of awareness raising seminars and workshops on identified knowledge gaps,

(d) Promotion of environmental education, and

(e) Establishment of wetland clubs/support groups.

Furthermore, it has been emphasized that the value and role of indigenous knowledge/practices should not be left out when setting up awareness, advocacy and capacity building programmes

5.2.10.2. Policy and Regulatory approaches

Developing Land use policy and management Plans

- An appropriate institution should be created with mandate to implement policies, provide alternatives to actions that cause wetland degradation and to formulate modalities for a national wetland management program. This would provide an understanding of wetland values and problems, as well as filling gaps to support the protection and wise use of wetland ecosystems in the country
- Delineation and registration of wetland areas
- Preparing conservation and management plan for selected and important wetland areas
- To gain technical support and development assistance, the country must ratify international wetland agreement, Ramsar Convention and register Ramsar Sites, with conservation and management plan
- Conduct inventory study of wetland areas of the country using Land Sat imagery.
- Enhance awareness of stakeholders through programs in the media, workshops, short courses, outreaches, etc.
- Empower local communities to conserve and protect their wetlands.

Developing an independent wetland policy

Successful wetland conservation in Ethiopia is being challenged by absence of Wetland Policy and lack of suitable legislative frameworks as a result of insufficient political conviction to formalize wetland conservation (Yilma Delelegn and Geheb, 2003). Accordingly, there seems to be a strong need to develop a stand-alone National Wetlands Policy that could be practical as soon as possible.

In addition to the national policy, government is earnestly urged to ratify the Ramsar Convention on Wetlands. Most importantly, priority should be given to designate at least one wetland for inclusion in the list of wetlands of international importance, promote the wise use of wetlands and create wetland reserves, as per the requirement of Ramsar Convention.

Prioritization and management plans for wetlands

Undertaking a prioritization process through consultation and full involvement of all concerned stakeholders including local communities to identify wetlands that need immediate conservation actions is important. The process helps to target limited resources or options for conservation to those wetlands in most urgent need of conservation attention. Once priority wetlands for immediate conservation actions are identified, there is a need to prepare management plans for each of the priority wetlands.

Impact assessments and Continuous Monitoring of Wetlands

It is imperative to undertake Environmental Impact Assessment (EIA) studies before implementation of any development activities (e.g. draining, damming, diversion or using for irrigation). The most important aspect is the follow up of the study and making sure that mitigation recommendations are properly implemented (environmental auditing). It also involves implementing integrated management plans covering every aspect of the wetlands and their relationships with their catchments. It is only through monitoring programmes that the extent and causes of loss and degradation of wetlands can be determined, and the success of conservation actions be measured. Monitoring methods include simple field observations, remote sensing, quantitative sampling techniques such as annual counting of observable animals (e.g. birds), like it was conducted for 12 years in the row by EWNHS in the past and is being carried out currently by EWCA, and where changes in social values and uses are concerned, participatory observation.

Building partnerships with stakeholders

Conservation efforts in general and that of wetlands in particular, require working together and reconciling different interests. Some of the many stakeholders of Ethiopian wetlands are the Ministry of Agriculture and Animal Resources, the Ministry of Water, Irrigation and Electricity, MEFCC, Ethiopian Institute of

Agricultural Research, EWCA, the Regional States, the communities living around the wetlands, and as well as all the Civil Society Organizations, such as EWNRA and EWNHS, among others, that are engaged in wetland related activities, These should all work together for the common goal of promoting wetlands.

5.3. Alteration History and Restoration Approaches

5.3.1. Lake Haramaya

Up until 2004, L. Haramaya was observed to shrink progressively. Some of the evidences in terms of morphometric changes are shown in Fig. 5.4. By 2004, the lake disappeared altogether and turned into an ephemeral lake, where some water percolated at the lowest spot of the original lake basin during the wet seasons and dried up as the dry spell creeps during the dry season (Brook Lemma references cited in this report).

In section 2.3.3.4, it was indicated that human demographic and climatic changes contributed to the transformation of L. Haramaya to an ephemeral lake. The increase in population in Harar town and in the lake watershed demanded high municipal water supply over the years. In addition, the farmers in the watershed were pumping water out of the lake to grow horticultural crops to the lucrative markets of Dire Dawa, Harar, Hargessa and Djibouti. The horticultural crops includes the crop locally known as "*khat*" (*Catha edulis)*, which is a stimulant that is said to activate people when the succulent fresh leaves are chewed. As this crop generates a much higher income than any other horticultural crop, farmers have been observed to change their farm plots into *Khat* farms.

There was a marked increase of about 3^{0}C in the air temperature of the region between 1960 and 2006. The rainfall pattern over the years has not changed much except that it is highly erratic. However, when rainfall of the region is viewed in comparison with the increase in air temperature and the change in human demography, it is obvious that the lake was operating at water budget deficit.

At the same time, the household wastes dumped in the watershed and all that comes from Haramaya town are blown by wind or washed into the lake with torrential rains that are followed by runoffs that bring into the lake high amounts of top soil, organic wastes, fertilizer, pesticides and other pollutants. As observed in many tropical lakes, these trends are sufficient indicators of lake water quality deterioration and progressive loss of the assimilative power of lakes of the organic and other wastes that come into them by wind, runoff or direct dumping of wastes into the lake.

As the operation of water collectors, municipalities and irrigation schemes continued unabated, the lake size continued to decrease, fishermen had to follow the retreating water edge and the water below their boat continued to disappear.

Lake Haramaya appears to have changed dramatically from an aquatic system to a terrestrial one, mainly due to human mismanagement of water use and also by natural processes, such as climate change (Brook Lemma, 2011).

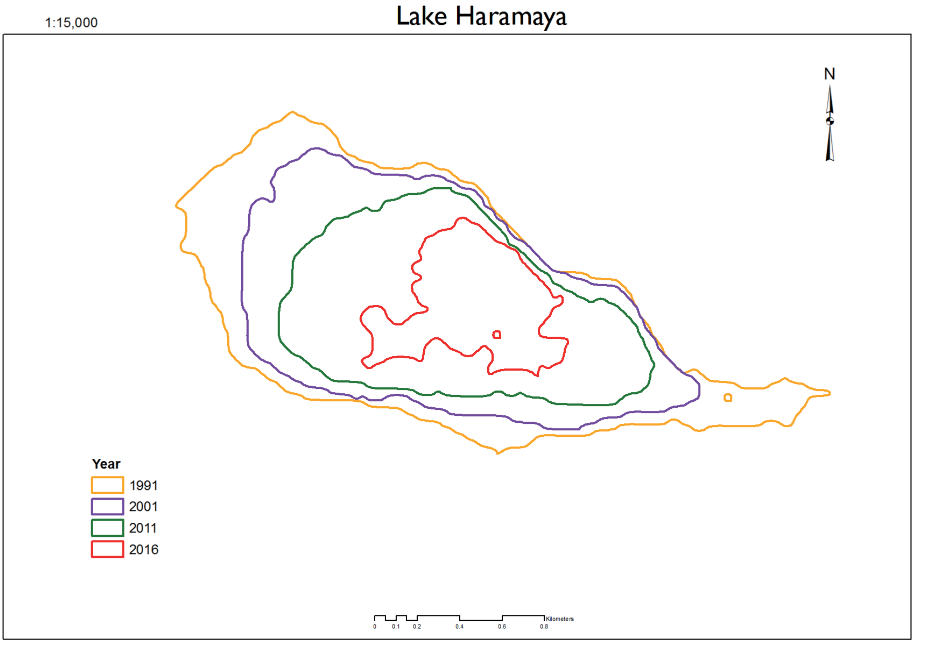


Figure 5. 4: Changes in the surface area of L. Haramaya from 1991 to 2016 (Surface areas by 1991: 2.34, by 2001: 1.77, by 2011: 1.195 and by 2016 it was 0.398km2).

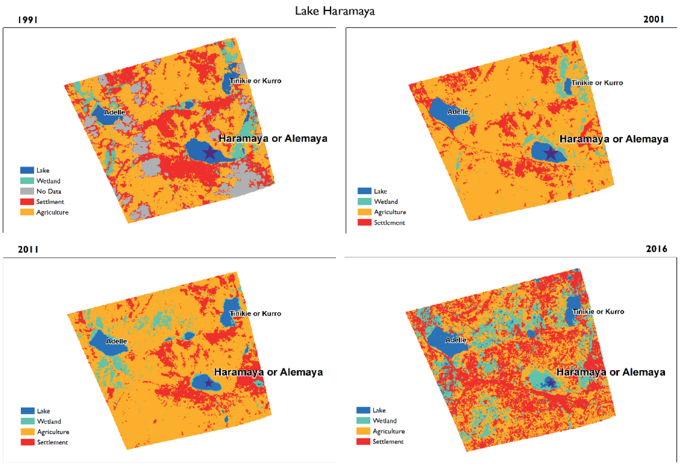


Figure 5. 5: Areal and hydrological changes in Lake Haramaya (1991-2016)

Restoration approaches for Lake Haramaya

Water use regulation

- The major reason for degradation of Lake Haramaya is unregulated use of water by different actors in the catchment, with everyone abstracting water at will and with impunity. Regulations which focus on water use efficiency, payment for water used, reducing wastage and ensuring flow allocation to the natural system also, should be enacted. Water use associations should be strengthened and water wastage reduced.

Watershed management to restore hydrological balance

- Afforestation of degraded catchment with indigenous (or other trees with same qualities of soil and water retention) can restore the hydrological balance and restore water table to previous level. A lot of political will and mobilization of local communities is necessary to ensure success of such actions. This remains a big challenge, given that SWC efforts have not yielded the desired results in northern Ethiopia.

Buffer zone demarcation

- This action should help to prevent human and livestock encroachment, and reduce sediment loading into the lake. Exclosures and buffers should be fenced and protected for 5 years and the regenerated vegetation should be allowed to attain perennial status again.

Awareness and concern creation

- It is very important that policy and decision makers, development workers, academia and the public including grass root communities know about the functions and values of wetlands and the consequential negative effects that would accrue if they are not sustainably utilized. To that end, Mengistu Wondafrash (2008) argues that awareness creation and raised sense of concern on wetlands can be achieved through a series of public awareness raising campaigns which include:

(a) Production and distribution of awareness raising materials (posters, flyers, fact sheets, booklets),

(b) Making use of the various mass media to spread out adequate information on wetlands,

(c) Series of awareness raising seminars and workshops on identified knowledge gaps,

(d) Promotion of environmental education,

(e) Establishment of wetland clubs/support groups,

(f) Promotion of values of indigenous knowledge/practices in conservation of wetlands, and

(g) Establishing Think-Thank that will enhance the knowledge base on wetlands and provide technical backstopping to concerned stakeholders

5.3.2. Lake Zwai

The lake is shallow and has an open water area of 434 km^2 and shoreline length of 137 km, a maximum depth of 8.9 m and an average depth of 2.5 m. Given its smaller size and depth, the lake is susceptible for degradation due to, mainly, changes in the water level of its feeder rivers, namely Katar and Meki Rivers, which are currently being heavily affected by the degraded watershed and also unregulated abstraction of water for irrigation purposes. Tenalem Ayenew (2007) indicated that the annual inflows from Meki and Katar Rivers into Lake Zwai were 264.5 and 392 million m^3, respectively, and there is considerable reduction of inflows from those rivers into Lake Zwai; the situation may have been aggravated due to uncontrolled expansion of farmlands by removing forests, bushes and grazing lands during recent years and the future has to be cautiously considered.

At present, there is no significant change in water level (Fig. 5.6), and hence the most pressing problem appears to be pollution pressure from several point and non-point sources, including floriculture effluents, municipal wastes, resorts, farm effluents, urban garbage, recreational waste and livestock waste. However, it should be noted that the slow rate in the reduction of the surface area of lake Zwai should not deceive readers that it is not shrinking, since the depth of the lake has progressively decreased due to the high rate of sedimentation that emanated from the removal of the land cover (stated above) exposing the top soil for wind, rain, etc. erosions.

Figure 5. 6: Hydrological and land use changes in Lake Zwai, 1996-2016
(Changes in surface area of the lake by 1991: 414.99km2, by 2001: 415.20 km2, by 2011: 415.20 km2and by 2016: 415.20 km2 , after Shimellis Girma, 2016).

Lake Zwai fishery supports livelihood of more than a thousand fishers. The catch has not approached the fishery potential of 3000 tons/year except during 1997 (Megersa Endebu *et al.*, 2016) and has shown changes in species composition and lower catches in time. This is blamed on habitat degradation, human-induced pressure and climate change. The changes in the lake shore of Lake Zwai mainly impacts the fringe wetlands that surround the lake, especially the Shetamata swamp located on the northeastern part of the Katar inflowing River (Tenalem Ayenew, 2012). It has been reported that this wetland has been severely degraded due to clearance of vegetation for charcoal production and conversion into grazing land. Further, it is suspected that neo-tectonism with formation of new ground cracks is also responsible for the decline of the swamp (Tenalem Ayenew 2012).

Restoration approaches

- Sedimentation can be reduced or arrested by catchment management which should consider the highlands of Arsi to the east and Gurage to the west from which most of the inflowing rivers into the lake come from. There are some promising projects started by the universities of Arsi, Wolkite and Wachamo in this line and these efforts should be strengthened. The Zwai Fishery Research Center has executed projects involving planting and expansion of macrophyte beds to arrest sediment and nutrient influx, and use of multi-purpose trees such as *Sesbania sesban* and *Aeshnemone* spp. which has shown promising results in rehabilitating wide portions of the lake shore (shoreline length – 137 km).

- Pollution from Batu (Zwai) City, commercial farms and cut-flower plants should be controlled through strict regulations and policy enforcement by regulatory institutions from *Woreda*, Regional and Federal governments.

- The expansion of water hyacinth from the intake canal into the main lake should be controlled through integrated approach using physical, biological and chemical means.

- There should be regulatory planning for abstraction of lake water for irrigation by investors, wineries and state farms. These farms use wasteful irrigation methods, which have to be revised and regulated. The riparian communities also abstract water for domestic use and farming through their water use associations. While the effort to organize the communities into such associations is laudable, it is noted that the associations lack scientific know-how and training; it remains the task of the local and regional governments to empower the associations with such enabling tools.

5.3.3. Akaki–Aba-Samuel Wetlands

(Oromia R. S., Coordinates 08°52'N 38°04'E, Area 12,068 ha, Altitude 1,900 m)

The Akaki–Aba-Samuel Wetlands are part of the Awash River catchment, c.20 km south-east of Addis Ababa and receive most of the flood and wastes from the city. The wetlands consist of Aba-Samuel reservoir and an adjacent area that is inundated most of the year (Plate 5.7). The Akaki river consists of two main branches which rise from north-west and north-east of Addis Ababa and meet at the Aba-Samuel reservoir. Aba Samuel reservoir was created in 1939 to produce electricity for Addis Ababa, and production continued until 1970 when the machinery became too old to maintain and the plant stopped working. Aba-Samuel reservoir catchment area is 1,495 km^2, and includes the catchment of the Lege Dadi Dam. The reservoir originally had an area of 12,068 km^2, but the catchment has suffered much erosion resulting in silt deposition in the reservoir that was facilitated by water hyacinth (*Eichhornia crassipes)* infestation of almost half the reservoir (46%) (Firehun *et al.,* 2014). Recently the reservoir has been rehabilitated and is partly active. The fringe wetlands surrounding the reservoir are home for some aquatic birds.

The Aba Samuel Reservoir used to receive most of the waste from Addis Ababa, and as a result become extremely productive (hyper-eutrophic). The lake area was reduced from 1.32 km^2 in 1991 to a mere 0.39 km^2 in 2001 mainly because of chocking by the water hyacinth and other wastes (Fig. 5.8). Since then, some restoration works were done including construction changes; as a result the reservoir area increased to 3.34.km^2 in 2006 and was almost full during the sighting of the dam in Aug. 2017 (Plate 5.7).

Figure 5. 7: Aba Samuel dam and reservoir and adjoining wetlands in Aug. 2017

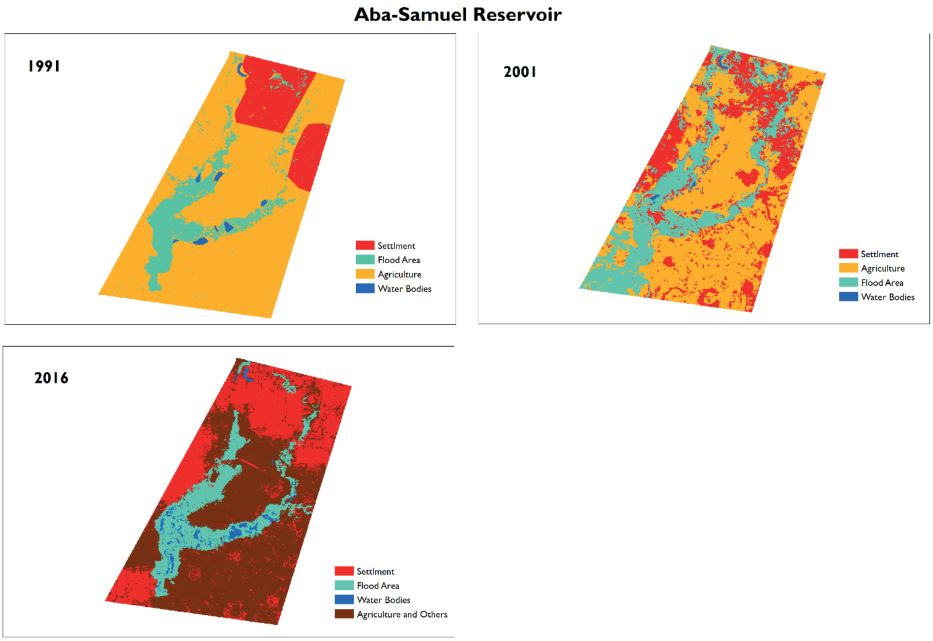


Figure 5. 8: Aba Samuel dam and reservoir and adjoining wetlands in Aug. 2017
(By 1991: 163.86 km2, by 2003: 107.81 km2, by 2011: 158.98 km2 and by 2016: 143.361km2).

The flooded wetlands adjoining Aba Samuel have been changing erratically (Fig. 5.8). In 1991, the flood wetlands had an area of 20.95 km^2 which increased drastically to 38.15 in 2011. Since then, these flood wetlands have decreased to 24.07 km^2. These wetlands have provisioning service for many wetland migratory birds en route to the rift valley lakes. During Aug. 2017, such extensive flooded wetlands were observed near Aba Samuel dam (Fig 5.7). However, these seasonal wetlands are being degraded by channelization of the flood water for agricultural purposes.

Restoration approaches

Restoration of Koka dam is a difficult challenge given the high sediment already deposited in the reservoir. Still, the longevity of the dam can be extended by catchment restoration as far upstream as the source of the Awash in the Shoa highlands. Control of water hyacinth has been successful in the Wonji Shoa Sugar Estate plantation area (Rezene Fissehaye 2005) and this exercise should be replicated in the Koka reservoir, as the infestation level is only about a third of the lake area (Firehun *et al.*, 2014) and it should be manageable to effect control measures as for the plantation canals.

5.3.4. Lake Abijata

The water level of the shallow Lake Abijata has been lowered so much that what was open lake some years ago is now grazing ground for cattle and can be driven at ease by vehicles (Fig 5.9). The last remaining patch of the lake in the southern end has been a refuge for the last remaining flocks of flamingos. A few cormorants were also observed at the southern end of the retreating lake during a field visit in 2016. The fate of Lake Abijata now rests on whether it can be recouped from its fatal state by rehydration of the lost water (for example, pumping from Lake Shala by the new Shala Abijata soda ash project), or stopping abstractions by all parties for a few years until the lake recovers.

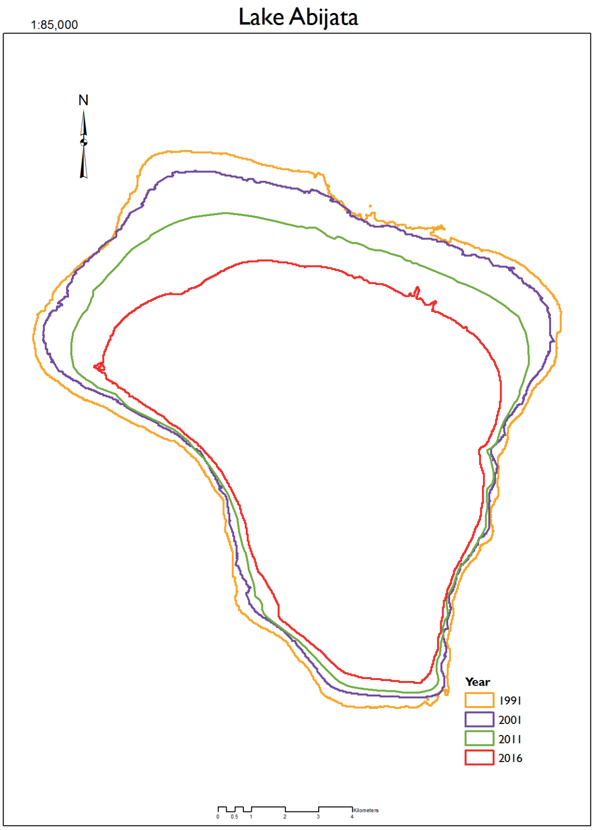


Figure 5. 9: Hydrological changes in Lake Abijata, 1991-2016
(Changes in surface area by 1991: 151.49km2, by 2001: 138.52km2, by 2011: 117.60 km2 by 2016: 915km2).

Restoration approaches

Lake Abijata is a typical example of how an aquatic ecosystem can be completely degraded before one's eye in one generation due to reckless abstraction and mismanagement and institutional discord. Thus, besides the hydrological and watershed interventions, the lake can be salvaged only if strict political and institutional actions are enforced by all stakeholders, including the soda ash factory (both old and new one), the regional water bureau, the federal ministry of water resources, lakeshore communities and local governments.

5.3.5. Lake Afdera

Lake Afdera is located some 700 km north of Addis Ababa (12.6°N and 41°E) at an altitude of 80 meters below sea level. "Afdera" by the local language (Afar) means "inaccessible". The depression is under active volcanic and tectonic activities (Williams *et. al.*, 1977).

The surface area of Lake Afdera is 70 km^2; maximum depth is about 80 m; salinity is about 160 g per litre; conductivity of 250000 K_{20} ($\mu^s cm^{-1}$); pH=6.55 (Wood and Talling, 1988) (Fig. 5.10). The very high salinity is accounted to the high evaporative concentration and the lake's geological history of having marine inputs from the Red Sea (Gionfiantini *et al.*, 1973). There are several hot springs that are coming into the lake, although the exact number of these springs is not well known.

There are three species of fishes so far identified from the lake: *Aphanius dispar*, *Aphanius stiassnyae* and *Danakilia franchettii* (Abebe Getahun and Lazara, 2001). These fishes inhabit a very small segment of the lake at the shore where the hot springs join the lake. At this juncture the fishes compromise the high temperature of the hot springs with the salinity of the lake. Although the lake is reported to be biologically unproductive (Wood and Talling, 1988), no further mention was made as to the extent of its life forms (Abebe Getahun, 2001).

The threats include presumably unregulated abstraction of water for salt production and non-sustainable use of the fresh water from the hot springs for various domestic purposes. From Fig. 5.10, it is evident that the lake area has not shown drastic reduction in line with the overexploitation of salt from the water. The hydrogeology of the lake basement needs to be investigated in detail.

Restoration actions:

- Awareness creations in the community working and living around Lake Afdera about the unique biota in the lake and the extent of the threat looming over these species.
- Conservation of the hot springs and the vegetation around the hot springs and keeping their environmental flow.
- Sustainable management of abstraction of the lake's water for salt production, as well as water from the hot springs

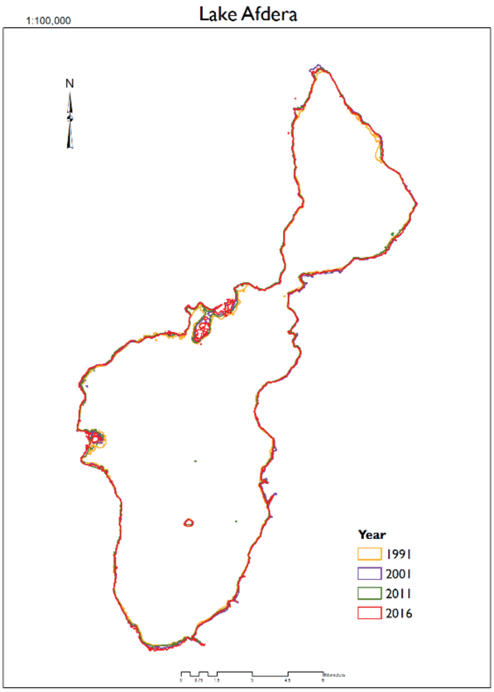


Figure 5. 10: Hydrological changes in Lake Afdera, 1991-2016

5.3.6. Lake Hawassa

Lake Hawassa is in the lowest portion of a caldera, along with a previously extensive wetland, Lake Chelelek (Shallo) swamp. According to Shimellis Girma (2016), this extensive swamp (shallow lake) used to drain into Lake Hawassa from north east before 2000. Due to excessive sediment deposition and poor land use, this swamp gradually declined from an area of 10.3 km^2 to 3.62 km^2 during 1972-1988, and almost completely disappeared by 2000 (Fig. 5.11). Lake Hawassa has therefore no outlet (water may seep away through the underlying volcanic ash and pumice) and has become a closed endorhheic system. As a result, ecological impacts on this closed lake are expected to be of severe consequence. The lake level rise has caused relocation of settlements near the lake to uplands, and incurred much economic loss.

The major causes for degradation of Lake Hawassa have been discussed in Chapter 4, section 4.2, and include urban and industrial pollution and groundwater abstraction. Further, Lake Hawassa has also been facing erratic changes in area increasing from 93.2 km ^{2} in 1991 to 95.1 km^2 in 2001, and then showing consistent decline since then, to 93.4 km^2 in 2011 to 88.9 km^2 in 2016 (Fig. 5.11). The decline in water level has been partly attributed to the disappearance of the Shallo swamp (Lake Cheleklek), according to Shimellis Girma (2016; Fig. 5.13), and withdrawal for irrigation. Also, groundwater abstraction has lowered GW table and depleted aquifers which may have long term effect on a growing urban population of Hawassa City in the future. There are reports of flooding of lake shore during the rainy months which has forced people to move to upland areas in the city (Fig. 5.13, upper panel).

Lake Hawassa

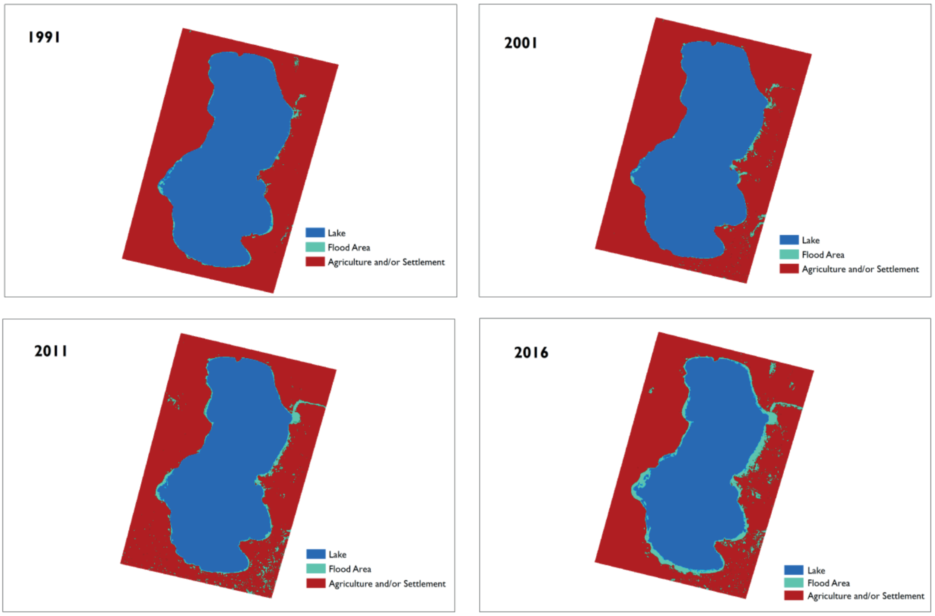


Figure 5. 11: Changes in surface area of Lake Cheleklek
(By 1991: 93.25, by 2001: 95.01, by 2011: 93.47 and by 2016: 88.85 km2).

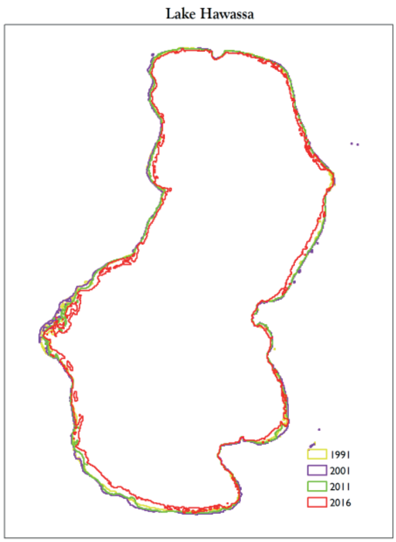


Figure 5. 12: Hydrological changes in Lake Hawassa, 1991 – 2016

According to several researchers, pollution from industrial, residential and agricultural discharges from the city of Hawassa and environs have become a serious concern. For instance, Zinabu Gebremariam and Zerihun Desta (2002) reported that the effluent from Hawassa textile factory had effect on aquatic biota in experimental studies. Birinesh Abay (2007) noted that the industrial zone area around Hawasaa City had many parameters exceeding the maximum permissible limit (MPL) set by the Ethiopian EPA standards. Behailu Berehun *et al.* (2015) reported that industrial effluents discharged from textile and ceramic plants had unusually high levels of some physico-chemical parameters such as COD, TDS, Phosphate and Zinc. Worst still, recent studies have shown that Mercury levels in fish from Lake Hawasaa were very high due to bioaccumulation in the food chain, and concentrations even exceed health limit set by international standards (Dsikowitzky *et al.*, 2012; Zerihun Desta *et al*, 2008). Ermias Deribe *et al.* (2011) reported that persistent organic pollutant (POP) levels were higher than normal in fish from the rift valley lakes, including Lake Hawassa.

It is also reported that absence of buffer zone restriction and hence habitat degradation of the lakeshore and riparian habitats of Lake Hawassa has resultant impact on loss of livelihoods and ecotourism (Tenalem Ayenew 2007);

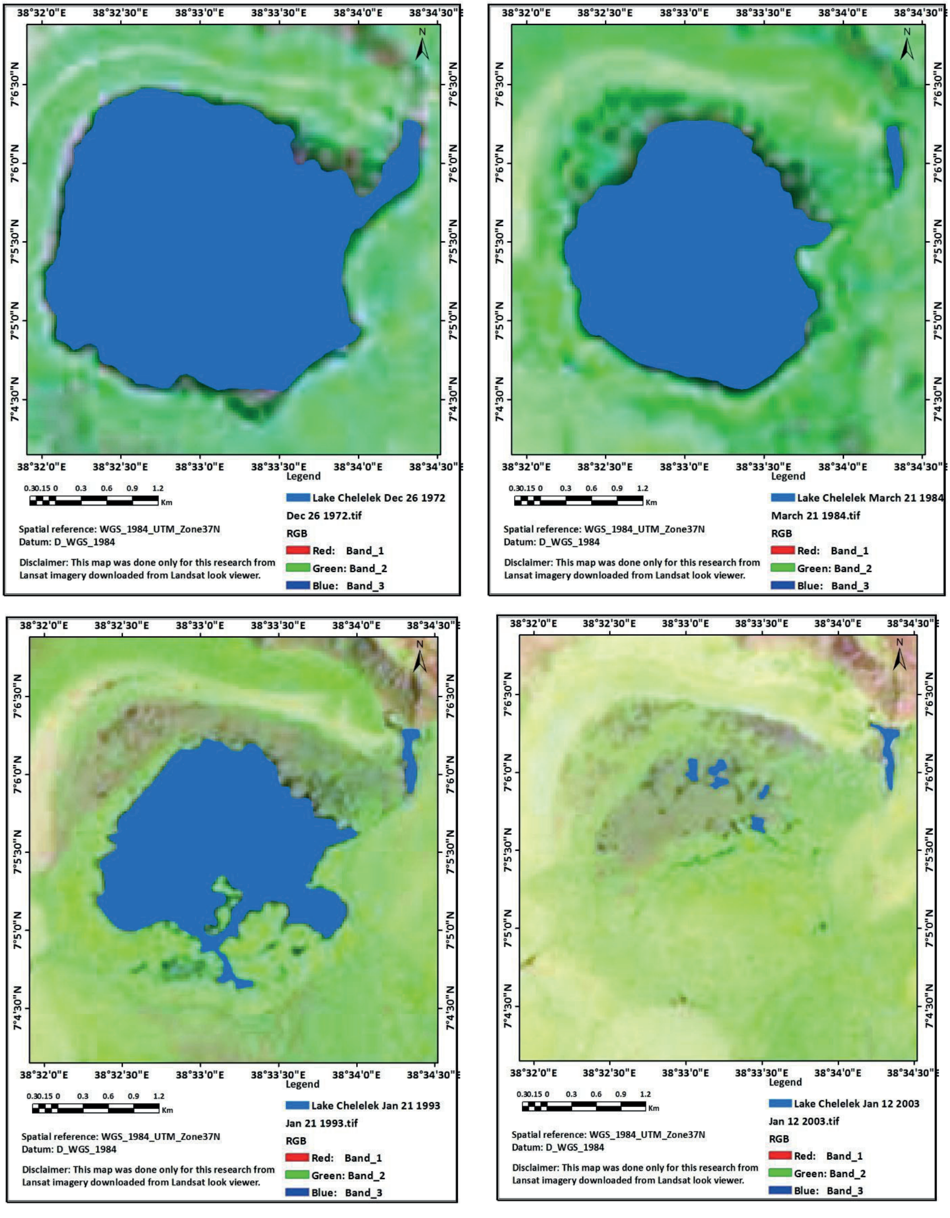


Figure 5. 13: Water level changes in Lake Chelelek (after Shimellis Girma, 2016)

Restoration approaches

Restoration efforts for Lake Hawassa should focus on stakeholders' consultations, formulation of regulations that are acceptable to all and formulate implementing body to eliminate point-source polluters through fines ("polluter pay principle") and strict bylaws to inhibit non-point source polluters. Exchange of experience from other cities that have conducted successful arrest of pollution should be adopted, instead of starting from scratch. The habitat changes and pollution of lake shore and river banks should be tackled through buffer zone delineation. This will be a serious challenge because of rampant settlement in the Lake Hawassa littorals by squatters, resorts, fisher folks and farms; therefore a more realistic approach would be to designate buffer strips and put strict regulations (including penalties) on use and misuse of littoral resources.

More scientific studies need to continue to understand the extreme hydrological variations of Lake Hawassa, which could be due to both anthropogenic and natural factors, including climate change (Tenalem Ayenew and Dagnachew Legesse, 2007). Ground water abstraction should be regulated in the Hawassa area and good agricultural practice (GAP) should be enforced on large commercial and state farms in the catchment.

5.3.7. Lake Koka

(Oromia Regional State, Coordinates 08°30'N 39°00'E, Area 18,400 ha, Altitude 1,750 masl)

Koka Dam was built to provide hydroelectric power and came into operation in 1960. The resulting freshwater lake, Lake Gelila or also known as Koka, has an area of c.180 km^2, and originally had a storage capacity of 1,850 million m^3, although sedimentation has reduced this by 35% (Fig. 5.15). It is estimated that more than 30% of the total volume and almost 96% of the dead volume of the reservoir has been lost to sedimentation. The shoreline used to be fairly clear of vegetation, but *Eichhornia crassipes* has invaded the area and is spreading rapidly. The Awash basin supports a total irrigated area of some 69000 ha with the only means of regulation being provided by a single reservoir – Koka. The erosion rates in the Awash basin as a whole and in the Koka catchment in particular are high with values generally in excess of 6000 t/km2/yr (SMEC 2008). These high rates of erosion are attributed mainly to the lack of appropriate cultivation and land management practices.

The erratic fluctuations in the area of the Koka reservoir has been documented (Fig. 5.14). The lake area showed decline from 1991 to 2003 (from 163.8 to 107.8 km^2), and then a sudden increase in the next decade until 2011 (to 158.9 km^2) and persistent decline since then until 1996 (143.4 km^2). These changes are believed to be due to evapotranspiration loss from water hyacinth infestation, reduction in volume due to sediment fill-up and unpredictable flow changes in the Awash River exacerbated by climate change (SMEC 2008), which has caused flooding and economic damage to much of the lakeshore communities (Fig. 5.15).

A secondary impact in Koka is the reduction in the reservoir's capacity to attenuate flood peaks and operational problems (such as the blockage of the low level outlet and obstruction of the powerhouse intakes), which have already been encountered. The extreme sediment deposit may require the hydropower station to be shut down completely and an expensive and time consuming clearing undertaken. The major degradation in the Koka catchment is due to population pressure, deforestation, poor farming system, etc. in the upper catchments.

Restoration approaches

Restoration of Koka dam is a difficult challenge given the high sediment load already deposited in the reservoir. Still, the longevity of the dam can be extended by catchment restoration as far upstream as the source of the Awash in the Shewa highlands. The elimination of water hyacinth has been successful in the Wonji Shewa Sugar Estate plantation area (Rezene Fissehaye, 2005) and this exercise should be replicated in the Koka reservoir, as the infestation level is only about a third of the lake area (Firehun *et al.*, 2014). The erratic changes in lake area and volume can be partly curbed by flow management of the Awash River from upstream dams.

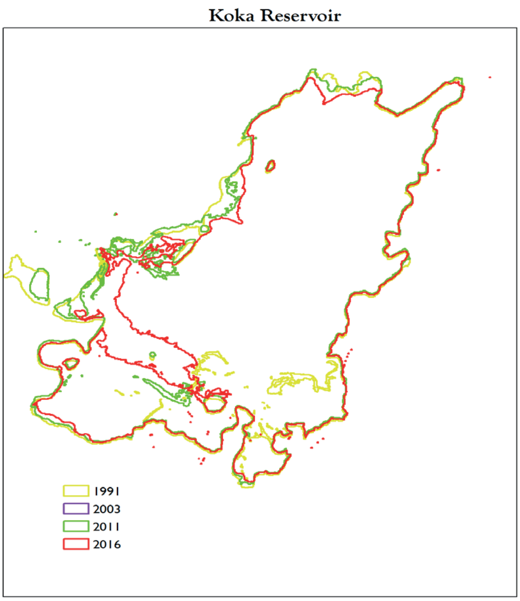


Figure 5. 14: Changes in surface area of Lake Koka by 1991: 163.86, by 2003: 107.81, by 2011: 158.98 and by 2016: 143.361 km2

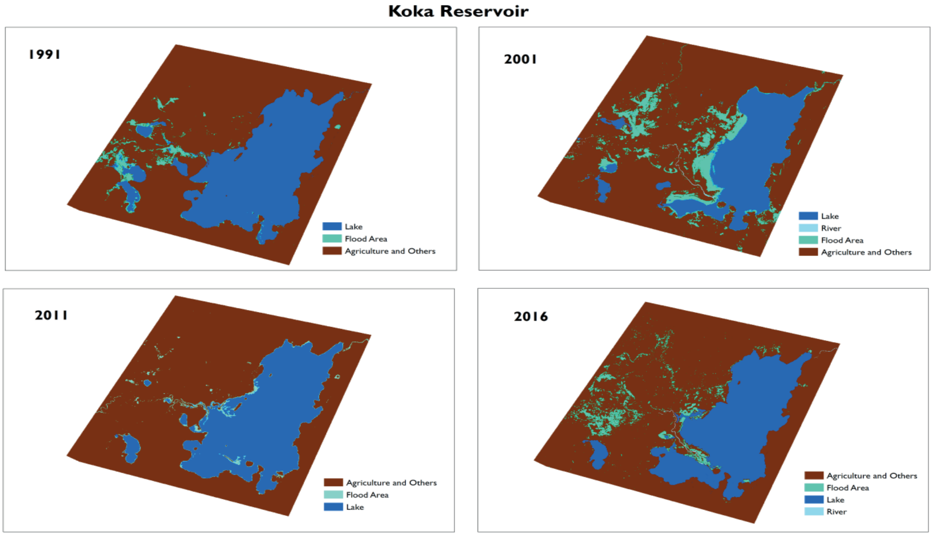


Figure 5. 15: Hydrological changes in Lake Koka, 1996 – 2016 (Note increase of flooded areas in recent times)

5.3.8. Lake Hayq

Although there appears to be no significant change in water level of Lake Hayq through the years (Fig. 5.16), there is an increased encroachment towards the shore of the lake by humans for agricultural purposes, leaving, in most instances, no buffer zones. These activities will cause sedimentation and, thereby, reduction of the quantity of water of the lake. There is also a possibility of the water being polluted from non-point sources; i.e. agricultural inputs (fertilizers, pesticides, etc.).

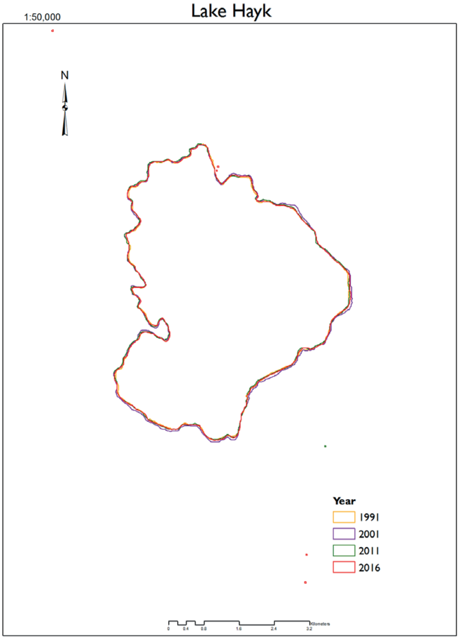


Figure 5. 16: Hydrological changes in Lake Hayq, 1991-2016 (Changes in surface area by 1991: 22.03, by 2001: 22.61, by 2011: 22.27 and by 2016: 22. 22 km2)

Several researchers have documented that Lake Hayq is being highly impacted by anthropogenic and natural factors such as invasive species (Girum Tamrie *et al.*, 2016), overfishing (Dereje Tewabe *et al.*, 2015; Zuriash Seid, 2016) , pollution (Ruchi *et al.,* 2016), land use land cover change and reduction in water volume and siltation (Hassen Mohammed *et al.*, 2013; Dagnachew Melaku and Abate

Shiferaw, 2014) and rainfall variability and change in temperature (Dagnachew Melaku and Abate Shiferaw, 2014).

Restoration approaches

As indicated in Asefa Tesemma (2017), restoration efforts have to focus on actions that will mitigate or eliminate the threats mentioned by different researchers. These include:

- Control of water hyacinth expansion using experience gathered from successful operations in the Awash basin (Rezene Fissehaye, 2005),
- Regulations to arrest illegal fishing in the lake,
- Pollution abatement programs,
- Land use planning and implementation of buffer zones,
- Catchment SWC actions to reduce sedimentation and nutrient pollution

5.3.9. Lake Basaka

The increase in the water level and area of Lake Basaka has been well documented. The lake has increased almost twice between 1991 and 2016 (Fig. 5.17.).

This rise in the water table of the Wonji Sugar Estate that came as close as 20 cm to the surface of the ground eventually found its outlet in Lake Basaka (Metehara), whose surface area has increased enormously by the year between the main Addis Ababa-Djibouti highway and railway. This increase is recorded irrespective of climate factors such as rainfall and evapo-transpiration, which otherwise could have resulted in the drying of the lake.

Despite the potential evapotranspiration that exceeded the annual rainfall budget of the watershed, Lake Basaka has increased in volumes and surface coverage by infiltration of groundwater that mainly comes from the Awash River, be it from the irrigation for sugarcane plantation and the natural subsurface infiltration of water through the porous nature of the geological formation of the area (Seifu Kebede *et al.* 2007) (Fig. 5.17 and 5.18). The consequences of such increase in the lake volume on the aquatic biota have not been investigated. The overgrown lake has however affected the railroad and asphalt road from Addis to Djibouti in that an alternative route had to be newly constructed and the present one had to be abandoned (see Section 2.2.3.1.2.).

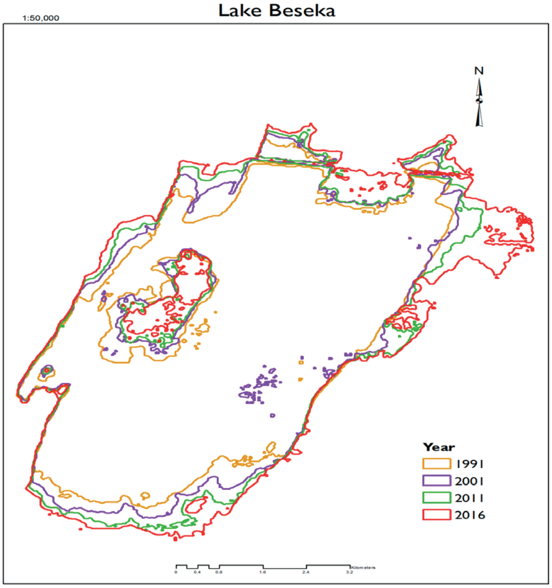


Figure 5. 17: The expansion of the surface area of Lake Basaka from 1991 – 2016 (Changes in surface area by 1991: 35.33 km2, by 2001: 39.92 km2, by 2011: 43.68 km2 and by 2016: 49.60 km2 , after Shimellis Girma, 2016).

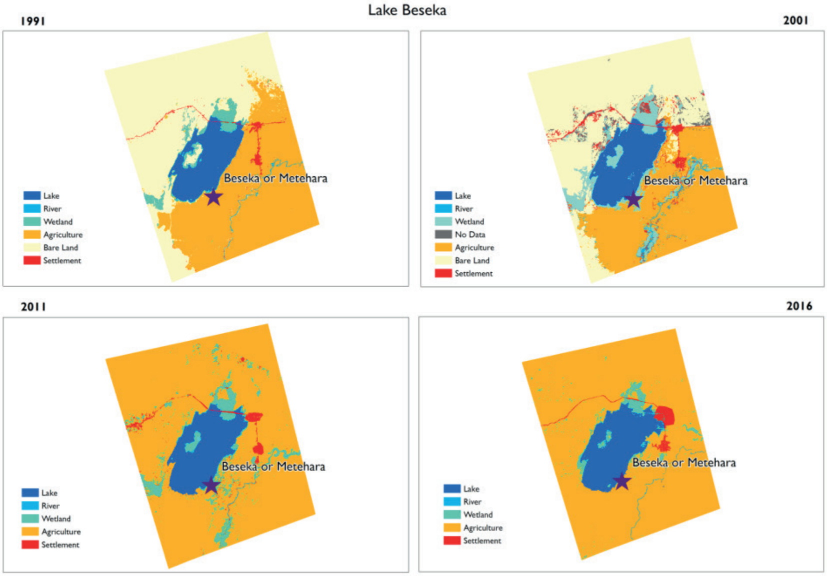


Figure 5. 18: Summary of the areal and hydrological changes in Lake Basaka, 1991-2016

Restoration approaches

It is evident that besides the expansion of Lake Basaka (Fig. 5.17), other ecological changes have taken their toll in other wetlands including the Awash River and several plantations. Thus a holistic approach that takes all wetlands into consideration will have to be planned for the eventual restoration of the wetlands and salvation of any ecosystem services that they might render in future.

Some years ago, the then Ministry of Water Resources attempted hydrological intervention to arrest the lake area expansion by pumping the lake water into Awash River through adjoining canals. This project was stopped later due to its possible negative impact on river biodiversity. As the lake continued to expand, the train and road lines running close to Lake Beseka (also known as Metehara) were abandoned and a new transportation route was started further upland near the Yerer Mountains.

5.3.10. Cheffa wetlands

The Cheffa wetlands, through the years, have been under heavy pressure from anthropogenic impacts (agricultural practices, overgrazing, settlements, abstraction of water etc.).

During the rainy season there is serious flood problem, which displaces several hundreds of people and livestock from the wetlands every year. Moreover, several residents are denied access to market and the main road during the rainy season. When the water level recedes after the rains, increasing sand mining activities, greatly affect the wetland ecosystem.

The pressure is even more alarming during the dry season since pastoralists from Afar and Oromia Zone of the Amhara Region move, with their herds, into these wetlands for prolonged period of time. Water is also diverted upstream during the dry season for agricultural and domestic purposes and there is acute shortage of water in and around the wetlands. There are about 15 investors in Dewachefa locality competing for water, although creating temporary and permanent jobs for several people in the area. Moreover, it remains to be a source of conflict between farmers and pastoralists.

Water quality, bird and macro-invertebrate diversity and habitat conditions of Cheffa wetland were affected by the above pressures. Accordingly, there has been recorded low DO, high COD, turbidity and chloride values which appear to be mainly associated with organic pollution from animal excrements and sewage discharges from towns and villages (Melaku Getachew *et al.*, 2010). The loss of *Cyperus papyrus,* an effective species in reducing nitrogen and phosphorus levels in water, undermines the service of the wetland in mitigating pollution.

So, there must be a proper management program to make sure that water is available during the dry season and mitigate the flood during wet season. However, the poverty level in the area and natural disasters particularly periodic droughts, the complexity of existing land tenure systems, the lack of infrastructure and administrative hurdles make the implementation of an effective and sustainable wetland conservation and restoration plan difficult (Melaku Getachew *et al.*, 2012).

There are some five species of fishes (*Labeobarbus intermedius*, *L. nedgia, Labeohoreii, Garra dembecha* and *Clarias gariepinus*); Nile monitor (*Varanus niloticus*), snakes and some ten species of birds (Cattle egrets (*Bulbulcus ibis*), Egyptian goose (*Alopochen aegyptiacus*), Grey hereon (*Arde acinerea*), Hadada Ibis (*Bostrichia hagedash*), Sacred Ibis (*Threskiornis aethiopicus*), Yellow billed Duck (*Anas undulate*), African Jacana (*Actophilornis africana*) and Great white pelican (*Pelecanusono crotalus*)), in which their habitats are compromised due to the pressure exerted on Cheffa wetland (Asseffa Tessema *et al.*, 2015).

Some recommendations (including those provided by Seifu Bekele, 2011) for restoration of this wetland include:

- Establishing farming management body (advisory committee), especially focused on water use, that consists of the community, EPA, MoWR, MoArd and representatives of the local Government to coordinate different activities.
- Engaging all stakeholders in the decision making process and creating appropriate channel for information flow and communications.
- Harmonizing activities of the different users, state and non-state actors (ORDA, World Vision and other NGOs, the local government offices, etc.).
- Water budgeting and monitoring.
- Defining ownership status by giving priority to the local people.

- Raising awareness of the local people, experts and policy makers on wetland values and functions.
- Constructing small dikes or berms where flooding is a threat.
- Finding both financial and human resources required to restore the wetlands.

5.3.11. Lake Chamo

Degradation of Lake Chamo has two major causes:

1. Hydrological fluctuations - erratic changes during 25 years indicate fluctuations in surface area by 1991: 311.85763, by 2001: 302.78218, by 2011: 297.87984 and by 2016: 306.11231km^2 (Fig. 5.19). On the other hand, Shimellis Girma (2016) documented 9% decline of lake level in Chamo from the 1970's 327.84 km^2 to 298.40 km^2 in 2010's (Fig. 5.20) and attributed the decrease to land use changes involving intensive irrigation from the lake and tributary rivers. Tibebu Kassawmar (2007) earlier reported that there was rapid expansion of farmland and irrigation per farm in the Lakes Abaya-Chamo area from 1973 – 2000. The causes for decreased water level in both lakes are both due to natural climate change and man-induced changes (irrigation and abstraction).
2. Sedimentation and nutrient pollution. - According to Fasil Eshetu (2016), Lakes Abaya and Chamo have deteriorated during the last decades due to nutrient input from fertilizer use and decline in water transparency because of sediment loading from inflowing rivers, enhanced by the high erodibility of the soil structure and the sparse woodland vegetation of the watershed. Such degradation negatively impacts ecosystem services and peoples' livelihoods, which depend mainly on agriculture and fisheries.

Restoration approaches:

Lake Chamo and Abaya are large lakes in a complex rift valley setting, with intensive agricultural and urban pressure from all sides. Fasil Eshetu *et al.*, (2017) have called for immediate intervention to stop degradation processes and start restoration activities of the lakes. They emphasize that land restoration measures should be undertaken to prevent further ecological degradation of these two important Rift Valley lakes. Restoration programs should focus on reducing soil erosion and developing guidelines for fertilizer application on poorly managed degraded marginal lands. Fish stocks that are showing sign of depletion such as nile perch and tilapia should be enhanced though regulating the fisheries and aquaculture practices. Some projects are ongoing to empower fishermen associations of Lake Chamo to start pond cultures around the lakes.

Regulations on water use of irrigation from both the lakes and inflowing tributaries are called for. The extreme sedimentation of the rivers and Lake Abaya should be curbed through sustained SWC planning in the uplands and the rift escarpment. Pollution sources from the fast sprawling Arba Minch Town and commercial farms should be curbed through implementation of strict guidelines by EPA. There is an urban sanitation project by WASH that plans to treat domestic wastes through use of designed toilets and awareness creation drives, the success of which still awaits to be seen.

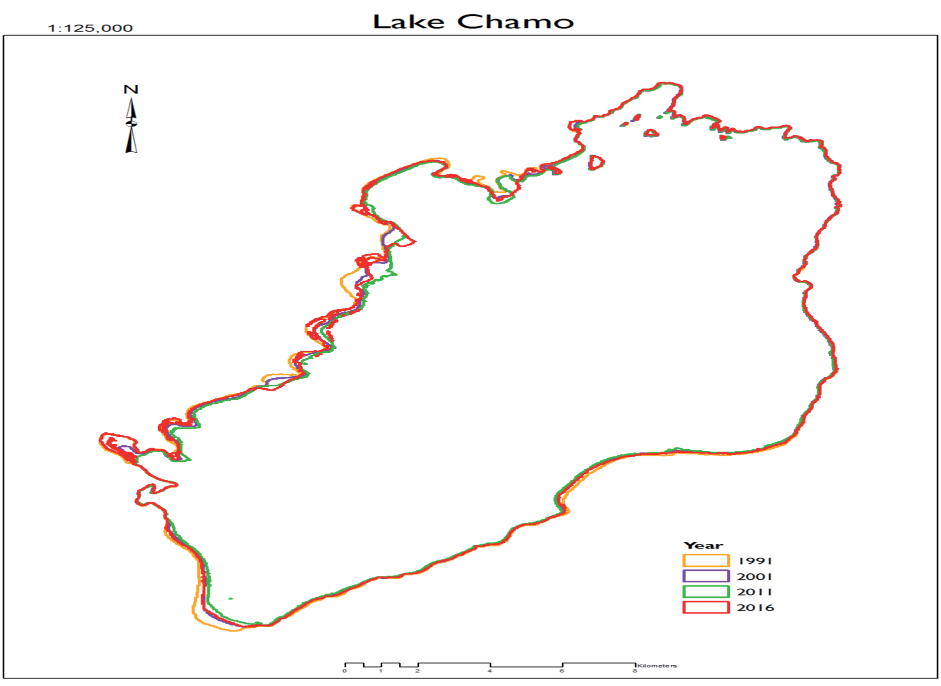


Figure 5. 19: Hydrological changes in Lake Chamo, 1991-2016: Changes in surface area by 1991: 311.85 km2 by 2001: 302.78 km2 by 2011: 297.87 km2 and by 2016: 306.11 km2.)

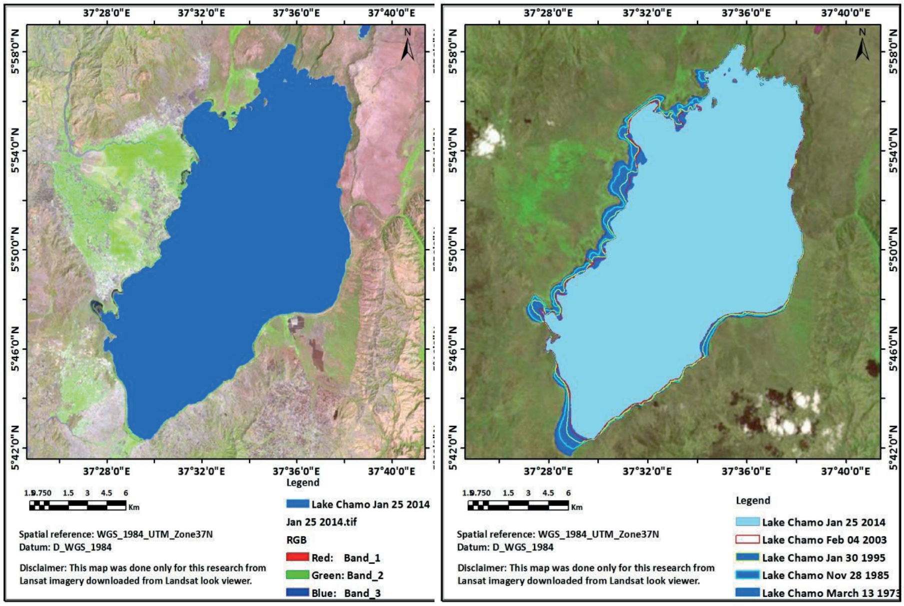


Figure 5. 20: Summary of the hydrological changes in Lake Chamo 2014 and 1975 – 2014 (after Shimellis Girma, 2016).

5.3.12. Boye and Kito wetlands

The location of these two riverine wetlands in the Gilgel Gibe watershed is shown in Fig. 5.21. Kitto stream passes through Kitto wetland. At the downstream direction, Awetu stream, which is known to carry Jimma Town's domestic solid and liquid wastes, joins with the Kitto stream. Boye wetland is located some 4 km from Jimma Town after the confluence of Kitto and Awetu streams and is continuously fed by that stream, which is passing through this wetland and finally joins the Gilgel Gibe River (Chewaka *et al.* 2017).

The area is characterized by a warm temperate and rainy climate. The average annual temperature in the area ranges between 15 °C and 22 °C, whereas the mean annual precipitation ranges between 180 cm and 230 cm (National Meteorological Agency 2014).

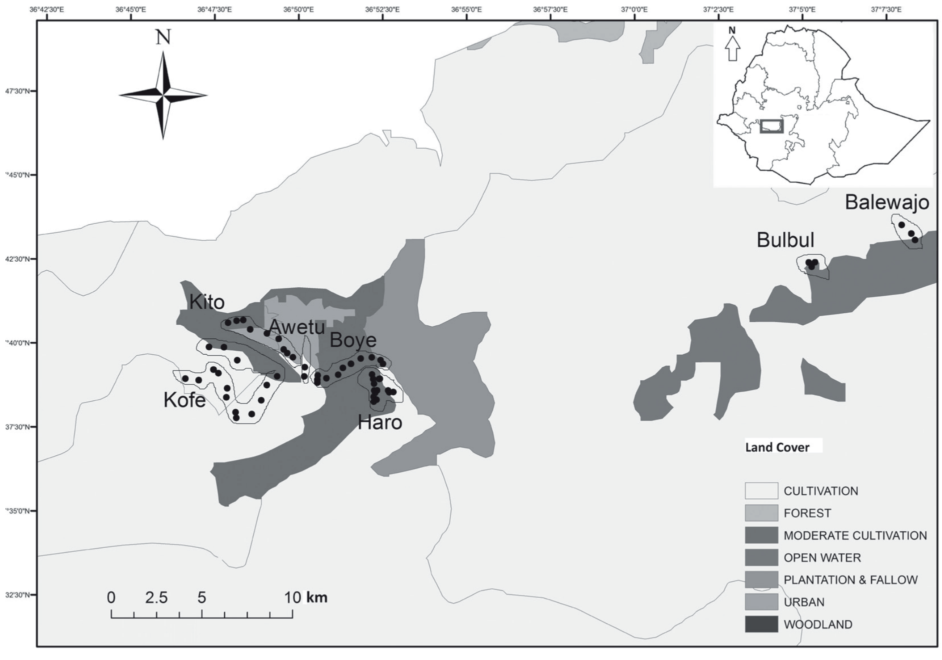


Figure 5. 21: Location of Boye and Kito wetlands in the Gilgel Gibe watershed (after Selamawit Chewaka et al., 2017)

The two wetlands serve as habitats for a variety of plants, birds, and mammal species and are a water source for human and livestock consumption. Boye wetland is, especially, a very suitable habitat for birds. There are about 35 species of birds recorded, of which 2 are *endemic* (Yellow fronted parrot *Poicephalus flavifrons* and Abyssinian long claw*Macronyx flavicollis*), while three are near-endemic (Wattled ibis *Bostrychia carunculata*, Abyssinian Slaty fly catcher *Dioptornis chocolatinus* and Thick-billed Raven *Corvuscras sirostris*). Two of the species (Black crowned crane *Balearica pavonina* and Wattled crane *Bugeranus carunculatus*) are "Vulnerable", while one species (Abyssinian Longclaw *Macronyx flavicollis*) is "Near threatened" (Tariku Mekonnen and Abebayehu Aticho, 2011). There is also reportedly hippopotamus inhabiting the Boye wetland.

Anthropogenic activities that take place in the area include cattle grazing, tillage, brick construction, pottery making and eucalyptus plantation. The more intense agricultural practices and waste discharge were closely associated with higher phosphate concentration and low level of dissolved oxygen. Maize (*Zea mays*) cultivation is a common practice in and around these wetlands (Seid Tiku *et al.*, 2012, Chewaka *et al.*, 2017). It has been noted that there is a significant reduction of the diversity of macro-invertebrates in the downstream part of the two streams (Argaw Ambelu *et al.*, 2013). Studies also indicated that wetland structure and function can be impacted by agricultural activities due to increased sedimentation associated with tillage practices, increased pesticide runoff and altered hydrological regimes (Seid Tiku *et al.*, 2013).

Boye wetland is more polluted than Kitto due to intensive pollutant input mostly from the Jimma Town as well as intensive agriculture related practices around the wetland.

Despite intense agricultural pressure, Boye wetland has been increasing in area consistently from 0.109 km^2 in 1991 to 0.26 km^2 in 2001, 1.23 km^2 in 2011 and to 1.26 km^2 in 2018. In contrast, the flooded area adjoining the wetland has slightly decreased from an area of 19.71 km^2 in 1991 to 18.82 km^2 in 2016 (Fig. 5.22). The causes for such related fluctuations in the area of the wetlands and its feeder flooded area need to be investigated in detail.

Restoration actions include:

- Properly manage and treat/reduce the waste from Jimma Town that is getting into the rivers and ultimately into the wetlands.
- Regulate brick making, recession agriculture and eucalyptus plantations in and around the wetlands.
- Designate and protect the core areas of the wetlands and establish buffer zones.
- Properly establish selected indigenous plant species suitable for the area.
- Avoid draining and farming the middle vulnerable parts of the wetlands, which store and maintain residual water during the dry season.

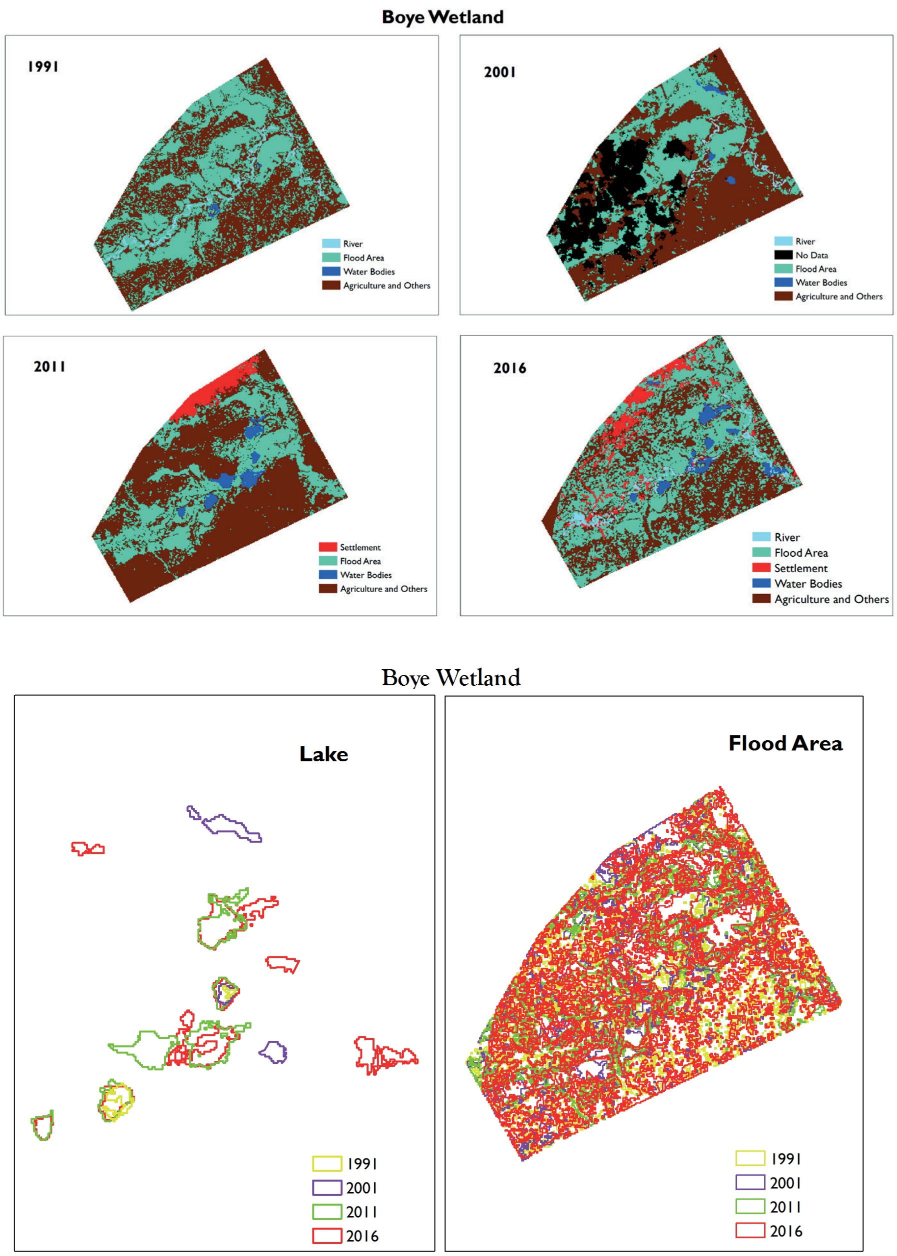


Figure 5. 22: Changes in the wetland area and flooded areas of Boye wetland, 1996-2016

5.3.13. Fogera plains and Shesher Wellela wetlands

(Lake Tana fringe wetlands in Amhara NRS, Coordinates 11°57'N 37°42'E, altitude 1,750 masl**)**

The Fogera plain consists of a flat, open plain across which the Rib River flows into Lake Tana. The Gumera River forms the southern boundary. Both rivers originate on the high plateau to the east, and as they reach the plains the gradient decreases and they form meanders. During and after the rainy season, as the Rib River approaches the level of Lake Tana, water overflows its banks and floods the surrounding area (fringe wetlands). A perennial swamp has been formed around the mouths of these rivers. During the dry season, the water retreats and the flooded area are used for seasonal grazing and retreat (recession) cultivation. The extent of the marsh depends on the amount of rain, as no other surface water feeds it.

The shoreline of the lake supports well-established papyrus beds 4 m tall. Further inland the vegetation is dominated by sedges, reed grasses and bulrushes, along with swamp grasses such as *Echinochloa* spp. and *Cynodon aethiopicus* that make very good grazing in the dry season. Patches of mixed small and broadleaved trees and bushes are found around churches on small, rocky hills near the lake shore.

Erratic fluctuations in the lake level and area of Lake Tana have been documented (Fig. 5.23), associated with the erratic flow changes on the numerous rivers and streams that feed and drain the lake. Degradation of upstream catchments such as the Choke Mountains, source of several inflowing rivers such as Gilgel Abay, exacerbates the deterioration of the fringe wetlands.

The plains support a large population of an indigenous breed of cattle, *Fogera*, named after the area. Cattle-farming is still a major activity, but crop cultivation has become increasingly important. In the 1970s, an agricultural research station was established at Woreta to promote rice as a crop. Although the rice grew well, there was little market for it, as local mills were not equipped to husk it. However, farmers have expanded cultivation of other crops, particularly shallots and other vegetables, which are otherwise traditionally grown with supplementary irrigation.

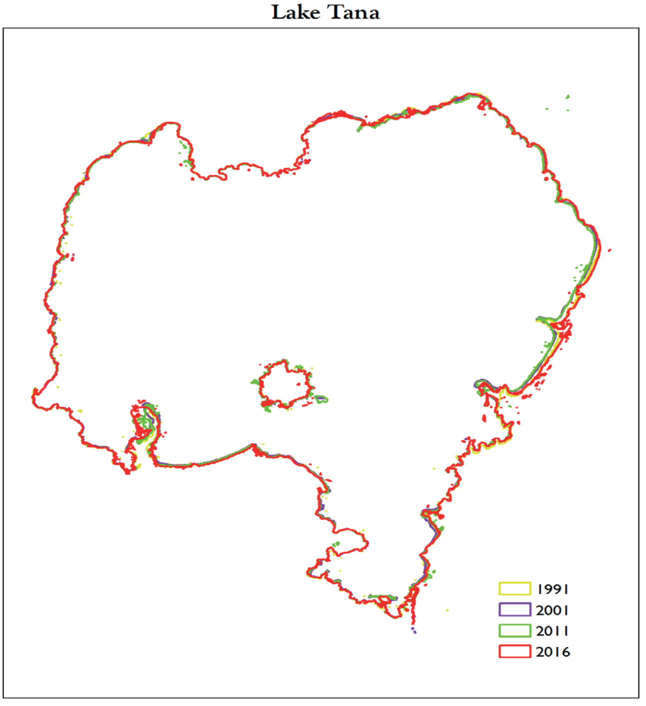


Figure 5. 23: Hydrological changes in Lake Tana, 1996-2016

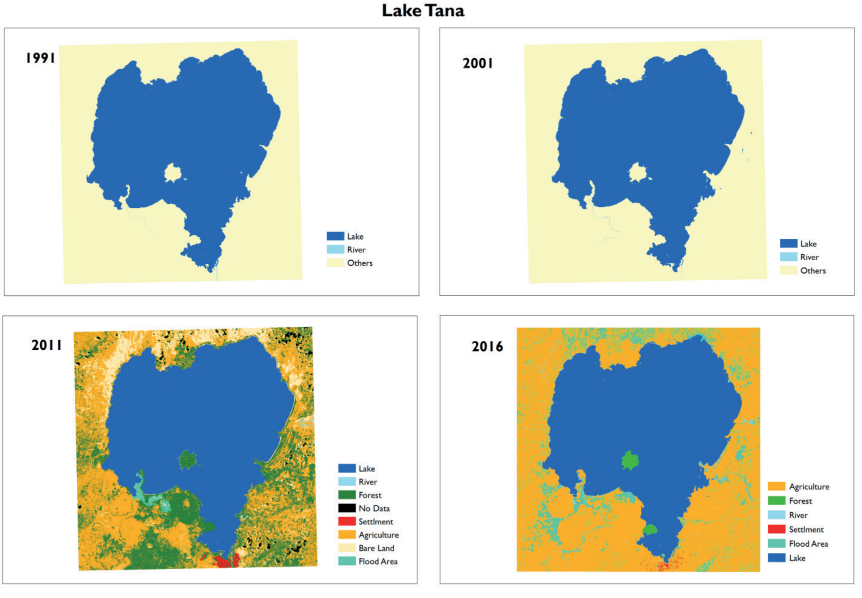


Figure 5. 24: Land use changes in the Lake Tana sub-basin, 1996 – 2016

The land use changes that have resulted in deterioration of the lacustrine wetland and associated fringe wetlands indicate the major causes to be deforestation and increased farm lands, mainly due to population pressure from people and livestock (Fig. 5.24). The flooded areas along lake shores show erratic changes, with some fringe wetlands like Fogera plains and Shesher and Welella wetlands shrinking and transforming to bare ground (Fig. 5.25).

Restoration approaches

Fogera plains have degraded in time due to long-term unsustainable farming practices, adaptation of rice farming with unsustainable water use practices, livestock compaction and nutrient loading of the wetlands (Sileshi Nemomisa, 2008). Regulatory interventions are needed to curb the rapid rate of degradation of the wetlands with strict adherence to best practices in agriculture and animal husbandry in the wetlands.

Shesher and Wellela fringe wetlands

The limnological characteristics of these two wetlands were described by Tarekegn Wondimagegn (2010). Negash Atnafu*et al* (2011) made further studies on these two wetlands, which are formed from overflow of the Ribb and Gumara Rivers and Lake Tana during the flooding months of July-September each year. The wetlands have been shrinking very fast due to reclamation of land for recession farming during the dry months and another irrigation project on the Ribb River, which diverts water all year round. The wetlands have receded so fast that they have lost the natural connection with Lake Tana and are presently isolated patches of pans.

The extent of hydrological shrinking of the two wetlands (Table 4.3 and Fig. 5.22) indicates that Shesher wetlands lost almost a tenth of its volume in a decade (1987-2008), while Welela wetland lost almost a fifth of its volume within the same time. These wetlands harbor high diversity of aquatic birds, including Palearctic migrants (Shimellis Aynalem 2007); thus their loss also affects global biodiversity and ecotourism potential of the Lake Tana area.

Restoration approaches

Restoration of these fringe wetlands should follow procedures that will restore connection between the rivers and Lake Tana, and hence hydrological interventions are in line. The natural water supply should be maintained in order to approximate the original hydrologic condition of the wetlands. This means that draining the wetlands for recession agriculture should be curtailed and free grazing during the dry season should be regulated with the carrying capacity of the wetlands taken into consideration.

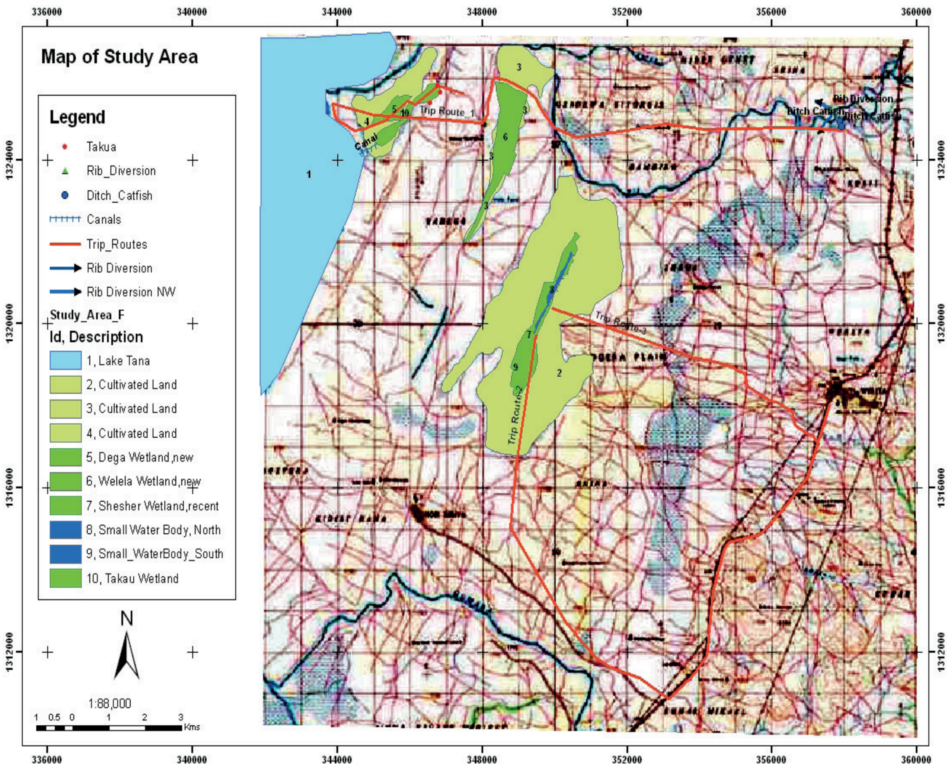


Figure 5. 25: The magnitude of change in areas of Shesher, Welela and Daga-Takua wetlands (Source: Sileshi Nemomissa, 2008)

5.3.14. Lake Hashenge

Lake Hashsnge resides in a deep crater and there are no reports of hydrological changes over time. The lake is a closed basin and the long-term effect of evaporation on the water balance of the lake has not been investigated. The effect of nutrient and silt inflow from the catchment could be serious in such closed lakes. The surrounding catchment has been intensively cultivated for centuries and the area has high livestock density. These activities accelerate pollution and eutrophication of the lake. However, the major challenges in Lake Hashange include overfishing and siltation, and lakeshore pollution from fertilizer use and encroachment.

Restoration of Lake Hashenge should focus on catchment rehabilitation, regulation of the fisheries, buffer zone demarcation of the lakeshore and best agriculture practice.

5.3.15. Hora Kilole

Hydrological changes in Hora-Kilole near Bishoftu crater lakes has been well documented by the study of Brook Lemma (2004, 2011, 2016, Fig. 5.26). In 1989, the Ministry of Agriculture diverted River Mojo into the saline-alkaline Lake Kilole with the intention of converting it into a reservoir to use the captured water for gravitational irrigation to the south and west of the lake. With the water column rising from 6.4 m in pre-1989 years to 29-30 m in the rainy seasons that completely diluted the lake with complete changes in the constellation of the lake chemistry and the biota

In the course of time around 2005 within less than a month the water of the lake sunk into the ground only to reappear in Lake Hora-Arsedi, a lake located at the lowest point among a chain of Bishoftu Crater lakes only 13 km to the west of Lake Hora-Kilole. This event is documented in Brook Lemma (2011). Since 2005 the project has been abandoned and the lake has changed from its natural saline-alkaline nature to ordinary tropical freshwater system, maybe never to revert to its original nature. Today, horticultural crops are harvested along the shores using the freshwater and some fishermen operate to supplement their daily incomes.

Restoration approaches

Restoration of Hora Kilole requires hydrological intervention to re-establish the lake volume to its original condition. This has implicit engineering and economic challenges.

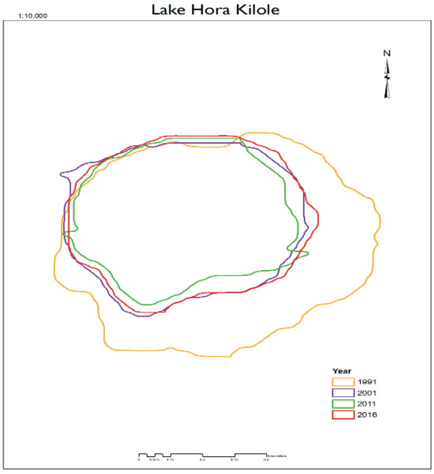


Figure 5. 26: Hydrological changes in Hora Kilole, 1991-2016.
(Changes in surface area by 1991: 1.55 km2, by 2001: 0.92 km2, by 2011: 0.80 km2 and by 2016: 0.95 km2 ; see also Brook Lemma 1994 and 2011).

5.3.16. Lake Chelekleka

Chelekleka is in a shallow pan into which fresh water seeps and flows from the surrounding cultivated slopes. Water fills the muddy depression during the rainy season and persists well into the dry season. The two highland ranges of Teltele and Sofa, on the north-eastern side of the swamp, are the main catchments for Chelekleka. Because of its shallow nature, the lake's shoreline is wide. The size of the inundated area varies dramatically from year to year, although recently the size of the swamp has been reduced through the construction of flood-control dykes in the feeder streams, and channeling run-off from the town into Bishoftu

This small lake (pan) near Bishoftu used to sustain the water volume for the whole of the year in past times. The source of the lake water was surface runoff during the *kiremt* months. However, in recent years, due to real estate development, recession agriculture and natural causes, the water level started to decrease and recently, it was observed that the pan has dried completely and taken over by urban settlement. The lake area changes between 1991 and 2016 are shown in Figure 5.27 and 5.28. The area and volume of the lake have decreased consistently during the last two and a half decades and what remains now is a seasonally filling depression of negligible size.

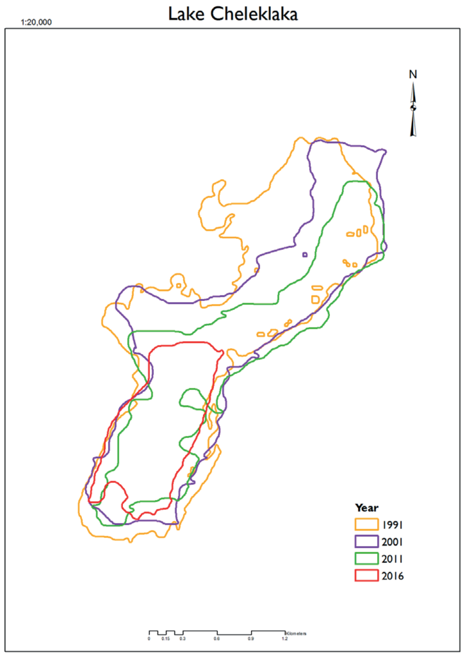


Figure 5. 27: Changes in the surface area of L. Cheleklaka: 1991 – 2016. (Surface area changes by 1991: 3.59 km2, by 2001: 2.96 km2 by 2011: 1.96 km2 and by 2016: 0.98 km2)

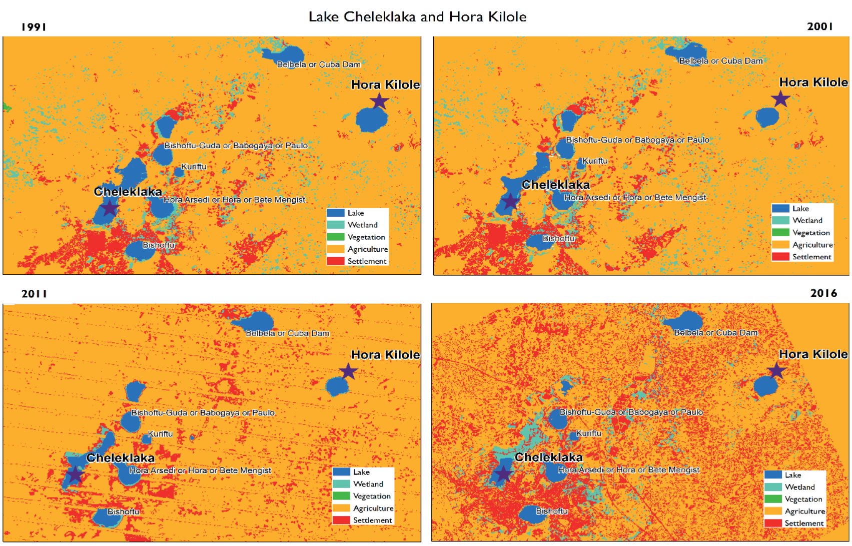


Figure 5. 28: Summary of the changes in the water level and area of Lake Chelekleka from 1991 to 2016

Restoration approaches

From the figures above, it appears that Lake Chelekleka has been severely affected due to the pressures from land use changes, expansion of settlements and other human activities. The wetland has completely dried up in recent years due to the compounded effects of drought in the area. The dry-up process has been accelerated because of the shallowness of the wetland and its highly-prized amenities and land-grabbing by residential and real estate property developers. As such pressures are difficult to control, it can be concluded that restoration of Lake Chelekleka is almost impossible, or very difficult at best. It requires political decision and good will of the city administration to outweigh the cost benefit scenario of maintaining the system with the consideration of preserving the rights of future generations.

References

Abebe Getahun (2001). Lake Afdera: A threatened saline lake in Ethiopia. SINET: Ethiopian Journal of Science, 24 (1):127-131.

Abebe Getahun and Lazara, K. J. (2001). Lebias stiassnyae: A new species of killifish from Lake Afdera, Ethiopia (Teleostei: Cyprinodontidae). Copeia, (1):150-153

Argaw Ambelu, Seblework Mekonnen, Azeb G/Selassie, Asgdom Malu and Kaliaperumal Karunamoorthi, (2013). Physicochemical and biological characteristics of two Ethiopian wetlands.Wetlands,33:691-698

Assefa Tessema and Kelemework Geleta (2013). Assessment of Challenges and Opportunities of Fisheries of South Wollo Lakes, Ethiopia Journal of fisheries International.,8: 69-73

Assefa Tessema, Nuria Abdurahman and K.S. Goudar (2015). Role of Cheffa wetland to the local communities around Kemise, Oromia Zone, Amhara Region, Ethiopia. Direct Research Journal of Agriculture and Food Science, 3(7):148-156.

Atalay Ayele, Ebinger, C. J., Van Alstyne, C. Keir, D. Nixon, C. W., Belachew Manahloh and Hammond, J. O. S. (2016). Seismicity of the central Afar rift and implications for Tendaho Dam hazards. Geological Society, London, Special Publications 420:341-354; doi: 10.1144/SP420.9.

Behailu Berehun, Bekele Lemma and Josef Tekle-Giorgis (2015). Chemical composition of industrial effluents and their effect on the survival of fish and eutrophication of Lake Hawassa, Southern Ethiopia. Jour. Environ. Protect. 6:792-803.

Birinesh Abay (2007). Assessment of downstream profiles of Hawassa textile effluent along Tikur Wuha River using physico-chemical and maco-invertebrate indicators. MSc Thesis. Addis Ababa University.

Brook Lemma (1995). Seasonal limnological studies on Lake Haramaya: A tropical African lake, Ethiopia. Arch. Hydrobiol. (Suppl.) 107:263-285.

Brook Lemma (2003). Ecological changes of two Ethiopian lakes as caused by contrasting human interventions. Limnologica, 33:44 - 53.

Brook Lemma (2011). The impact of climate change and population increase on Lakes Haramaya and Hora-Kilole (1986 – 2006). In: Impacts of climate change and population on tropical aquatic resources. Proceedings of the Ethiopian Fisheries and Aquatic Sciences (EFASA); Haramaya University, 03-06 February 2011. pp. 11-36.

Brook Lemma and Hayal Desta (2016). Review of the natural conditions and anthropogenic threats to the Ethiopian Rift Valley rivers and lakes. Lakes and Reservoirs: Res. and Mang't,21: 133–151.

Dagnachew Melaku and Abate Shiferaw (2014). GIS and Remote Sensing Based Water Level Change Detection of Lake Logo, North Central Ethiopia. Journal of Environment and Earth Science, 4 (5):70-88

Dereje Tewabe, Birhan Mohamed and Binyam Hailu (2015). Impacts of anthropogenic activities on fish habitat, breeding ground and macrophytes of lake Logo. Global Research Journal of Fishery Science and Aquaculture, 3 (1): 20-27

Dsikowitzky, L. Mesfin Mengesha, Elias Dadebo, de Carvalho, C.E. and Sindern, S (2012). Assessment of heavy metals in water samples and tissues of edible fish species from Awassa and Koka Rift Valley Lakes, Ethiopia. Environ. Monit. Assess. 185: 3117-3131.

Ermias Deribe, Rosseland, B.O., Borstrom, R, Salbu, B., Gebremariam, Z and Dadebo, E. (2011). Bioaccumulation of persistent organic pollutants (POP's) in fish species from Lake Koka, Ethiopia: The influence of lipid content and trophic position. Science of the Total Environment, 410-411: 136-145.

Fasil Eshetu (2016). The ecology of the major Ethiopian Rift Valley lakes Abaya and Chamo, with special reference to water quality and food web structure. PhD dissertation. KuLeuven, Belgium.

Fasil Eshetu, and 8 others (2017). A call to action: strong long-term limnological changes in the two largest Ethiopian Rift Valley lakes, Abaya and Chamo. Inland Waters.Doi.Stated.

Firehun, T, Struik, P.C., Lantiga, E.A and Taye, T. (2014). Water hyacinth in the Rift Valley water bodies of Ethiopia: Its distribution, socio-economic importance and management. Int. J. Current Agr. Res., 3: 67-75.

Girum Tamrie, Tadesse Ogato and Tadlo Awoke (2016). Report on field survey on macrophytes and phytoplankton composition of Lakes Logo, Ardibo and Mybar. Report Submitted to Amhara Region Universities Forum Research Group

Gionfiantini R.S., Ferrara, G. and Panichi, C. (1973). Isotopic compositions of waters from the Danakil depression (Ethiopia).Earth Planet. Sci. Lett. 18: 13-21.

Hassen, Mohammed, Tena Alamirew, Assefa M. Melesse, and Mohammed Assen (2013). Bathymetric study of Lake Logo, Ethiopia. Research and Management, 18: 155–165.

Megerssa Endebu, Alemu Lema, Tilahun Genet, Assefa Mitike, Bulbula Regassa, Eshete Dejen and Husein Abegaz (2016). Fisheries Baseline Survey Describing Status of Fisheries in Lake Zeway, Ethiopia. Fisheries Livest Prod 3: 129.

Melaku Getachew, Argaw Ambelu, Seid Tiku, Worku Legesse, Aynalem Adugna and Helmut Kloos (2012). Ecological assessment of Cheffa wetland in the Borkena valley, northeast Ethiopia: Macroinvertebrates and bird communities. Ecological Indicators, 15: 63-71.

Mengistu Wondafrash (2008). The role of wetlands in Biodiversity conservation and management in Ethiopia: A case study of Berga Floodplain. Ethiopian Wildlife and Natural History Society (EWNHS), Ethiopia.

Negash Atnafu, Eshete Dejen and J. Vijverberg (2011). Assessment of the ecological status and threats of Welela and Shesher wetlands, Lake Tana sib-basin (Ethiopia). Journal of Water Resources and Protection, 3: 540-547.

Rezene Fissehaye (2005). Water hyacinth (Eichhornia crassipes): A review of its weed status in Ethiopia. Arem,6: 105-111.

Ruchi, K., Assefa Tessema, Belete Tesfaw and Fikadu Chekol (2016). Assessment of water quality of Lake Logo, South Wollo, Ethiopia. International Journal of Fisheries and Aquatic Studies, 4(6):95-100.

Seid Tiku, Boets, P., Argaw Ambelu, Asgedom Malu, Zewdu Ephrem, Addisu Sisay, Hailu Endale, Menberu Yitbarek, Amana Jemal, de Meester, L., Goethals, P.L.M. (2012). Analysis of environmental factors determining the abundance and diversity of macroinvertebartae taxa in natural wetlands of southwest Ethiopia. Ecological informatics, 7: 52-61

Seid Tiku, Boets, P., de Meester, L., Goethals, P.L.M. (2013). Development of multimetric index based on benthic macroinvertebrates for the assessment of natural wetlands in southwest Ethiopia. Ecological Indicators, 29: 510-521.

Seifu Bekele (2011). Matching socioeconomic and ecological need in wetland management using systems approach: The case of Cheffa wetland in Ethiopia. MSc Thesis, Swedish University of Agricultural Sciences, Sweden

Seifu Kebede, Travi, Y., Asfawossen Asrat, Tamiru Alemayehu, Tenalem Ayenew & Zenaw Tessema (2007). Groundwater origin and flow along selected transects in Ethiopian rift volcanic aquifers. Hydrological Journal DOI 10.1007/s10040-007-0210-0

Selamawit Chewaka, Seid Tiku, Goethals, P.L.M., Lens, L. and Boets, P (2017). Effects of human-induced environmental changes on bird diversity and abundance in natural wetlands of southwest Ethiopia. Wetlands,40(2): 129-143.

Shimellis Aynalem (2007). Species composition, distribution, relative abundance and habitat association of the bird fauna of Bahir Dar, Zeghe peninsula and nearby islands. MSc Thesis, Addis Ababa University.

Shimellis Girma (2016). Assessment of Ethiopian lakes level change and identification of endangered lakes for the four decades using Landsat satellite images. MSc Thesis. Addis Ababa University.

Sileshi Nemomissa (2008). Delineation of wetlands of Fogera floodplain and scaling their biological and physical connections with Rib River and Lake Tana. Report.

SMEC (2008) Hydrological study of the Tana-Beles sub-basins. Report

Tarekegne Wondimagegne (2010). Limnological study of Shesher and Wolala wetlands, Fogera floodplain. MSc Thesis. Bahir Dar University, 77 pp.

Tariku Mekonnen and Abebayehu Aticho (2011). The driving forces of Boye wetland degradation and its bird species composition, Jimma, southwestern Ethiopia. Journal of Ecology and the Natural Environment,31: 365-369.

Tenalem Ayenew (2003). Environmental isotope- based integrated hydrogeological study of some Ethiopian Rift Lakes. J. Radioanal. Nucl.,257:11-16.

Tenalem Ayenew (2004). Environmental implications of changes in the levels of lakes in the Ethiopian Rift since 1970. Reg. Environ. Change.,4: 192-204.

Tenalem Ayenew (2007). Water management problems in the Ethiopian rift: challenges for development. Afr. Earth Sci.,48:222-226.

Tenalem Ayenew and Dagnachew Legesse (2007). The changing face of the Ethiopian rift lakes and their environs: call of the time. Lakes and Reservoirs: Research and Management,12: 149-165.

Tenalem Ayenew (2012). Status and threats of selected Ethiopian wetlands in 2010. In: Sue Edwards (ed.) Ethiopian Environment Review. No.2 , Forum for Environment.

Tibebu Kassawmar (2007). Integrated approach for spatio-temporal variability analysis of wetlands: a case of wetlands of Abaya-Chamo Lakes, Southern Ethiopia. MSc Thesis, Addis Ababa University.

Tudorancea, C. and Taylor, W. D. (2002). Ethiopian Rift Valley lakes. Backhuys Publishers, Leiden, The Netherlands, ISBN: 90-5782-114-1. 289 pp.

Williams, M.A.J., Bishop, P.M. and Dakin, F.M. (1977). Late quaternary lake levels in southern Afar and the adjacent Ethiopian rift. Nature, 267: 690-693.

Wood, R.B. and Talling, J.F. (1988). Chemical and algal relationships in a salinity series of Ethiopian inland waters. Hydrobiologia, 158: 29-67.

Zerihun Desta, Borgstrom, B., Gebremariam, Z. and Rosseland, B.O (2008). Habitat use and trophic position determine mercury concentration straight fin barb Labeobarbus paludinosus, a small fish species in Lake Awassa, Ethiopia. J. Fish Biol, 73:477-497.

Zinabu Gebremariam and Zerihun Desta (2002) The chemical composition of the effluent from Hawassa textile factory and its effect on aquatic biota. SINET: Eth.J.Sci. 25:263-274.

Zuriash Seid (2016). Fish Diversity, Abundance, Socioeconomic Importance and the Status of the Fisheries of Lake Logo, South Wollo, Ethiopia. MSc thesis, Department of Zoological Sciences, Addis Ababa University.

CHAPTER 6
NATIONAL WETLAND RESTORATION GUIDELINES

6.1 General

6.1.1. Historical background

Most of the content in this introductory section is excerpted from Girma Hailu (2000)

Ethiopia is the oldest independent nation in Africa. From the sixteen centuries onwards, Ethiopian rulers had a legal document similar to the modern day Constitution called "Feteha Negest" meaning Rule of Kings. The Feteha Negest was basically the guiding document for the Emperors who used to rule over their subjects until it was replaced by the first Constitution of 1923.

Emperor Menlik II who led the country during the 19th century transformed the country into a modern state. The era of modernization of Ethiopia was started by the introduction of a government administration backed by a cabinet of ministers, the first executive organ of the Ethiopian State. According to Articles 8 and 14 of the 1893 Regulation for the establishment of the Ministry of Agriculture, ' the Ministry of Agriculture is responsible to assess the number of farms, forests, grass, cultivated/uncultivated or spoiled lands of each Nobel's territorial jurisdiction. The Ministry of Agriculture is responsible to keep up the country's forest, the failure of which causes drought. In doing so, the Ministry shall order the public not to cut many trees without payment of taxes, not to cut small growing trees and reward persons who grow many trees. The Ministry furthermore determines the number of big trees to be cut and also consults Governors for keeping such trees, as they are present in their territories.

These Articles indicate the level of environmental awareness of the time and mechanisms of implementation, which called on the Nobility and Governors personal attention to look into the protection of forest resources in their administrative jurisdiction.

Subsequent rulers of Ethiopia also made some efforts to contain the environmental concerns of the nation during their reign of power. However, Emperor Minilik II was the first ruler of Ethiopia who established the first protected forest known as Menagesha Forest 30 kms west of Addis Ababa.

The 1992 Rio Earth Summit has been an important event in the Ethiopian environment debate. The Ethiopian government came back from Rio de Janeiro convinced about the multi sectoral nature of the environment and commitment to establish a focal environment agency and appropriate legal regime for the protection of the environment in the country.

The national Conservation Strategy of Ethiopia document is another landmark exercise initiated by the government and accepted by the Council of Ministers' in 1997 as a blue print for sustainable development in Ethiopia. The five volume National Conservation Strategy documents include baseline information on the potential natural resources, identifies the environmental challenges of the country, policy gaps, intervention areas and also investment requirements to address the said environmental problems in the short and long term.

Until the establishment of the Environmental Protection Authority in 1997, sectoral ministries handled environmental issues of the country as it related to their particular mandate. But still, the line ministries retain the same mandate and cause some difficulties in implementation, especially in coordination of federal environmental affairs.

6.1.2. Operational definitions: Wetlands and their contextual definition

Defining what wetlands are has always been a challenge, as the importance of wetlands and the services they provide to society vary by the nations one is dealing with. Making perceptions and policies thereof complex, there are many cases that such wetlands are shared directly, as these systems may lie across borders, or indirectly, as these resources connect countries by surface or groundwater flow.

In the booklet entitled *Wetlands of Ethiopia* (Yilma Abebe and Geheb, 2003), wetlands are ecosystems or units of the landscape that are found on the interface between land and water. The same booklet contends that it is difficult to find one universal definition for wetlands and suggested that today there are over 50 definitions for the same. Putting aside whether nations have ratified the Ramsar Convention or not, the overriding and the contemporary and operational definition of wetlands is the Ramsar definition for wetlands, which is stated that "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters" (RCS 1997, 2013, 2016). This definition of the Ramsar Convention upholds that wetlands are areas where water is the primary factor controlling such environments and their associated plant and animal lives.

The function of a Wetland Restoration Implementation Plan (WRIP) and the Wetland Management Plans (WMPs) are to help the implementing nation achieve its goals for undertaking the exercise of restoring impacted wetlands, as much close as possible, to the conditions the wetland was before the impacts. Such plans need not be complex, instead among others they should include (modified after Peters and Clarkson 2010):

- Serve as the road map for wetland restoration
- Streamline the actions of the restoration implementation parties (Government, NGOs, donors, local communities, etc.)
- Help clarify issues
- Suggest solutions
- Put in place the modality of proposal developments, negotiate with funding organization by way of estimating the likely costs
    - Record the best time for fieldwork and
    - Help the responsible offices keep track of results and the timely reporting of the same.

A cohesive plan is one of the necessary steps for developing a robust monitoring program to determine whether the restoration is successful or which aspects may need modifying. A Plan is also useful for bringing together funding applications, for example, by providing timelines and detailed costs for activities and equipment. Additionally, new volunteers are more likely to donate their time to a project that is well thought out and can demonstrate some positive results.

6.1.3. The need for wetland management and policy

The concept of wetland management is obtaining centre stage in Ethiopia due to the threats of extensive population pressure and increasing climate change impacts on them. Particularly the former comes into play due to the increasing desire to reduce the threat of hunger, poverty reduction and the desire to enhance job creation for a growing population, now reaching 100 million and the desired economic growth the country to reach to compatible stage in global trade and fair international interactions. This calls for intensive resource use that is currently converting wetland resources into production of all sorts, be it in agricultural or industrial.

At the same time, it is also important to look at wetland resources that are intimately connected to the Ethiopian way of life, particularly to the majority that live in the countryside. The majority of the Ethiopian population, unlike the case of the developed nations, rely on wetlands all the way from using the poor quality water for direct drinking to bathing in them, washing clothes and to watering of livestock. The same people use the wetlands for agriculture; currently for irrigated farming at off seasons, as their means of waste disposals and assimilating the same and moderation of climate and flood impacts; these latter services remaining mostly unnoticed.

As a consequence, the effort of enhanced development of sustainable wetland management is a timely action that must be undertaken before things go out of hand and wetlands in Ethiopia become sources of diseases, due to uncontrolled pollution, and maybe also complete disappearance. as witnessed in the case of Lake Haramaya or excessively expanding as in the case of Lake Basaka.

Given the above annotated background, every nation needs a policy that safeguards the wise use, conservation, and when damaged or degraded, restoration of wetlands to ensure the continuity of benefits of wetlands for human wellbeing.

6.1.4. Strategic vision for wetland restoration
(modified after MBWSR, 2009)

Wetlands provide important functions in Ethiopia as elsewhere in the world including drinking water, livestock watering, agriculture, industrial use, assimilating organic wastes, fish and wildlife habitat, improving water quality, flood damage reduction and groundwater recharge. In the past 30 years or so, many of the wetlands in most of Ethiopia have been converted to agricultural fields, settlements or drained to combat diseases like malaria or new ones were created in the form of dams altering the natural course of the hydrology of the area.

Following the article concerning the protection of safe environment in the Ethiopian Constitution, this strategy was developed to provide a statewide perspective and improved approach for restoration of wetlands. The Ethiopian Government and federal states, local government units and non-governmental organizations (NGOs) combine and coordinate their efforts to achieve the shared goal of greater net gains in wetland functional benefits.

6.1.5. Strategic approach to restoration of wetlands

(modified after MBWSR, 2009)

Key elements of this statewide wetlands restoration strategy are:

- Prioritize restorations based on desired outcomes, specifically water quality improvements, habitat gains, flood damage reduction, and other hydrologic benefits
- Improve coordination of wetlands restoration efforts
- Design and produce better wetland restorations that stand the test of time, and provide lasting functional benefits
- Empowering local stakeholders for the wise use, protection and restoration of wetlands with accountability to the society they live in.

Prioritization starts with identifying desired outcomes (functional benefits gained by restoring wetlands) and potentially restorable sites. That information will inform the decisions of government officials, project partners, and landowners, along with other decision tools like local and state plans for land use, water and economic development. This strategy recommends prioritizing restoration opportunities that will produce the greatest singular or multiple benefits and focuses on the functional benefit categories of water quality, wildlife habitat, and hydrologic functions. Other outcomes may also be factored depending on the circumstances and preferences (e.g., climate change; carbon sequestration).

6.2 Guidelines for wetland restoration in Ethiopia

6.2.1 Establishing the responsible institution and their responsibilities

(Guidance for environmental implementation and management plans (Draft 3rd edition, 2013)

6.2.1.1. The responsibilities of every organ of state are to:

- Exercise every function it may have or that has been assigned or delegated to it, by or under any law, and that may significantly affect the protection of wetlands, substantially in accordance with the wetland restoration and implementation plan or the wetland management plan prepared, submitted and adopted by that organ of state in accordance with this federal government proclamations and directives, provided that any substantial deviation from any wetland management plan or wetland implementation plan is reported to the Ministry of Environment, Forest and Climate Change (MEFCC) and the subordinate subcommittees on wetland restoration implementation plans (WRIPs) and wetland management plans (WMPs); and

- Report annually within two months of the end of the financial year on the implementation of its adopted WRIPs or WMPs to the MEFCC and the subordinate subcommittees on WRPPs and WMPs.

6.2.1.2. The responsibilities of every regional government are, amongst others, to ensure that:

- The relevant regional environmental implementation plan is complied by each municipality within its region; and

- Municipalities adhere to the relevant wetland protection implementation and management plans, and the principles contained in the federal government proclamations and directives in the preparation of any policy, program or plan, including the establishment of integrated development plans and land development objectives.

6.2.1.3. The responsibilities of the MEFCC are, amongst others, to:

- Keep a record of all wetland restoration implementation plans and wetland management plans, relevant agreements between organs of state and any annual reports related to wetland implementation and management plans, as well as make such plans, reports and agreements available for inspection by the public;
- Monitor compliance with the federal wetland restoration implementation and management plans;
- Receive annual reports from organs of federal government or regional states on the implementation of their adopted wetland restoration implementation and management plans;

6.2.1.4. The responsibilities of the subordinate subcommittee on WRIPs and WMPs, are, amongst others, to:

- Consider any substantial deviation from WRIPs or WMPs that is reported to it by any federal or regional organs of the states;
- Consider WRIPs and WMPs and annual reports submitted by the above in compliance with Federal and regional proclamations and directives; and
- Consider and provide advice on any matter incidental to the WRIPs or WMPs.

(Note: More detailed procedures for these steps is attached in Appendix 6).

6.2.2. Considerations for a national wetland council and subcouncils (modified after RCS, 2013a)

- The guidelines for WRIP and WMP encourage responsible federal and regional responsible parties or stakeholders to establish National Wetland Council (NWC), which can provide a broader focus at national level for the implementation of the plans, involving relevant government agencies, scientific and technical institutions, regional and local authorities, local communities, NGOs, and the private sector, to deal with such issues as: national wetland policies; management of sites; application of international convention mechanism of national and international importance; inclusion of new sites of similar importance; and submissions to the Ministry of Environment, Forest and Climate Change of the Federal Government of Ethiopia (MoEFCC).

- The NWC is primarily mandated to develop a national wetland definition and designates wetland environments as wetland systems and monitor their wellbeing through reports of subcommittees, field visits and international benchmarking visits and reports.

- It is the duty of the NWC to issue statement and background papers on wetlands on past and present statuses and follows up the implementation plans and the achievements of the desired outcomes of the WRIPs and WMPs.

- The NWC develops proposals for funding for wetland restoration schemes from national, regional and international sources and assists others that do the same; thereby it is expected to network itself with national and international institutions that share the same objectives.

- In addition, the NWC can have cascading Regional Wetland Subtonics (RWSC) that may provide expert input to national reports for meetings of the conference of the parties or stakeholders at national and regional levels, and review implementation of resolutions and recommendations adopted by the conference of the institutional (governmental and non-governmental) and individual stakeholders.

- Most importantly, the NWC provides a mechanism for spreading the guidelines principal approaches to wetland and water issues beyond the individuals and branches of government that are officially charged with its implementation. Ideally, the NWC should include as many sectors of government and representatives of stakeholders as possible.

- The NWC should consider already existing committees with experiences for the establishment of the regional subcommittees though they have to be revisited for compatibility and completeness for the tasks demanded by the WRIP and WMP of the country. For example, some committees consist of representatives of several relevant government agencies and appropriate non-governmental organizations, sometimes also including academics and other individuals with relevant expertise, whilst others may be organized as governmental committees (including regional governments in federal states) or as essentially non-governmental advisory bodies.

6.2.3. Defining stakeholders: Harmonization of responsible institutions (modified after RCS, 2013)

The NWC, through its secretariat and its other bodies, maintains close working links with other international, intergovernmental, and non-governmental organizations within Ethiopia and outside to achieve a strategic alliance for wetland conservation and restoration.

International Organization Partners (IOPs) can include the global non-governmental organizations (NGOs) that have the track record of working in wetland conservation and restoration, which were confirmed in the formal status of the IOPs. Such exemplary institutions as listed below could be starting references:

- Bird Life International (formerly ICBP)
- IUCN – International Union for Conservation of Nature
- International Water Management Institute (IWMI)
- Wetlands International (formerly IWRB, the Asian Wetlands Bureau, and Wetlands for the Americas)
- World Wildlife Fund International (WWF)

The IOPs provide invaluable support for the work of the wetland conservation and restoration at global, regional, national, and local levels, chiefly by providing expert technical advice, field level implementation assistance, and financial support, both from their headquarters units and from their national and regional offices and affiliates and from their expert networks. The Ramsar International Organization Partners (IOPs) can also participate regularly as observers in all meetings of the conference of the members of the NWCs and as full members of the Scientific and Technical Review Panels of the NWC, upon request.

Other non-governmental organizations and related bodies: In many countries, there is also an "NGO constituency" that works with the government and is active in promoting and implementing the goals of the WRIPs and WMPs. The NWC and its secretariat should try to maintain as much contacts as possible with as many local, national, and international NGOs (in addition to the five partners listed above) as are in sympathy with wetland systems and the principles of conservation and restoration of the same.

Specifically, the NWC should benefit from formal cooperative agreements of various kinds of international organizations, such as, the International Association for Impact Assessment (IAIA), the International Ocean Institute (IOI), LakeNet, the Society of Wetland Scientists (SWS), The Nature Conservancy (TNC), the Wetland Link network of the Wildfowl and Wetlands Trust (WWT), the Society for Ecological Restoration, the ASEAN Centre for Biodiversity, and the World Association of Zoos and Aquariums (WAZA).

Moreover, several additional organizations should be invited to participate as observers in the works of the NWC, including the Business and Biodiversity Offsets Program (BBOP)**,** Conservation International (CI), the European Space Agency – ESRIN and the Japanese Aerospace Exploration Agency (JAXA), the Global Water Partnership, the Coordinating Committee for the Guidelines for Global Action on Peatlands (GGAP-CoCo), ICLEI – Local Governments for Sustainability, the Institute for European Environmental Policy (IEEP), the Interim Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), the International Crane Foundation (ICF), the International Network of Basin Organizations (INBO), and the International Society for Ecological Economics (ISEE).

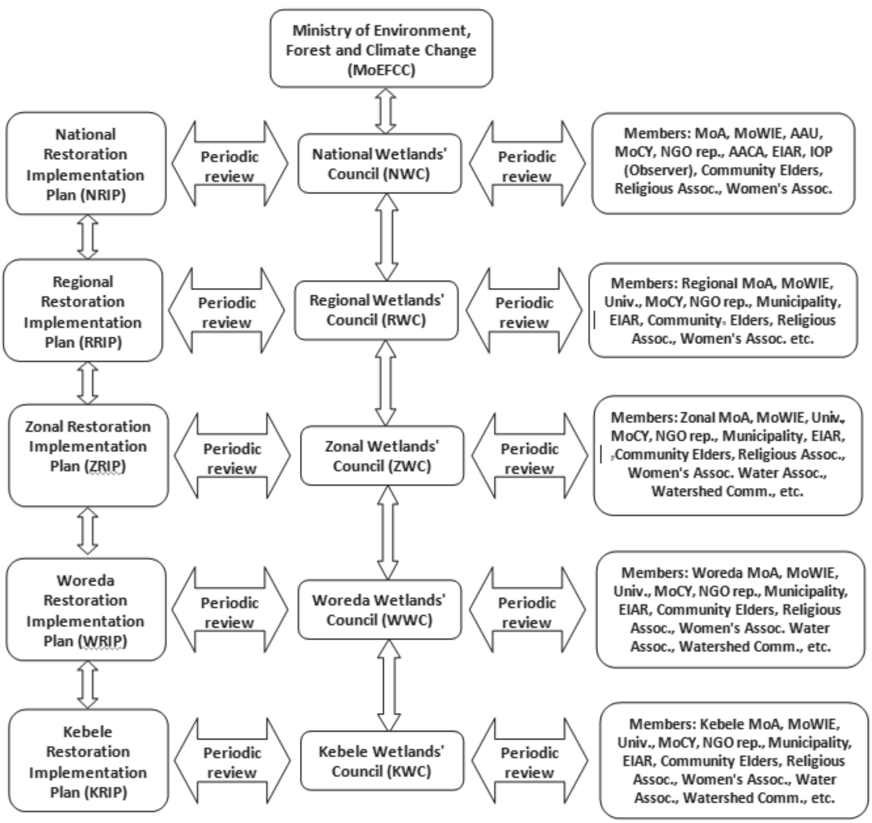
It must be made a point to invite national and international NGOs to participate in meetings for the implementation of the WRIPs and WMPs of Ethiopia, which are perceived as good opportunities for networking and influencing government policies and actions.

External and internal support agencies and the private sector: The NWC should maintain active contacts with a number of external support agencies, such as the World Bank and the regional development banks, and possibly be given observer status with the Council of the Global Environment Facility (GEF). All of them provide funding both for wetland projects and for projects that affect wetlands. Contacts should also be maintained with the Development Assistance

Committee of the Organization for Economic Cooperation and Development (OECD) and with the European Commission. Financial assistance for projects, meetings, reports, and wetland-related work on the ground in the developing world have frequently been provided by a number of national development assistance agencies with which the NWC should maintain close contacts.

Contacts with federal and regional responsible offices, local community leaders and associations should be established and maintained to provide baseline information and monitor the implementation of WRIPs and WMPs of the country.

National to Kebele level councils network and workflow chart with cascading Restoration Implementation Plans



6.2.4. Training: Communication, Education, Participation and Awareness (CEPA) program (RCS, 2010a)

To begin with, all interested parties or stakeholders should have common understanding of what constitutes the CEPA, training and capacity building in this section of this wetland restoration guidelines.

- **Communication** is a two-way exchange of information leading to mutual and enhanced understanding. It can be used to gain the involvement of 'actors' and stakeholders and is a means to encourage cooperation of groups in society by listening to them first and clarifying why and how decisions are made. In an instrumental approach, communication is used with other instruments to support wetland conservation, to address economic constraints and to motivate action.

- **Awareness** brings the issues relating to wetlands to the attention of individuals and key groups who have the power to influence outcomes. Awareness is an agenda-setting and advocacy exercise that helps people to know what and why this is an important issue, the aspirations for the targets, and what is being and can be done to achieve these.

- **Education** is a process that can inform, motivate, and empower people to support wetland conservation, not only by fostering changes in the way that individuals, institutions, business and governments operate, but also by inducing lifestyle changes. It may take place in both formal and informal settings. Education in the broadest sense is a life-long process.

- **Training** is the process of increasing or strengthening specific knowledge, skills, attitudes and behaviors that can be taken back to the workplace. It may take place in both formal and informal settings.

- **Capacity-building** includes a range of processes by which individuals, organizations and institutions develop abilities for effective implementation of wise use of wetlands. Abilities include, among others, facilities, funding and resources, infrastructure, enabling environments, etc

- **Participation** is the active involvement of "stakeholders" in the common development, implementation and evaluation of strategies and actions for the wise use of wetlands. Levels and kinds of participation can be highly variable, depending upon both the specific context and the decisions of the individuals and institutions leading the process. Participation comes in many forms such as passive, active or interactive participation, or participation by delegation, providing financial incentives or even participation by consultation.

The purpose of this section is, therefore, to organize guidance material from relevant decisions adopted by the stakeholders over the years, for the protection and wise use of Ethiopian wetlands. This helps practitioners of the respective stakeholders to implement the best wetland restoration practices in a way that is convenient to handle and more naturally matches their own everyday working environment.

The intended readership includes national and local staff members of the government departments, ministries and agencies that act as administrative authorities of wetlands of the country. Equally important are users in many cases who are managers of individual wetland areas, as some aspects of the guidance relate specifically to site management. It is important that these guidelines are used by all whose actions may benefit from or impact upon the wise use of wetlands. Last, but not least, the guidelines should be accessible to students so that they have prior knowledge of the damages that could be made on wetlands.

The major tasks to be achieved by these sub-guidelines include, among others, the following:

- All stakeholders involved in the restoration of Ethiopian wetlands need to establish national (or sub-national, catchment or local level, as appropriate) WRIP and WMP action plans.

- All stakeholders need to establish at least one wetland education centre in the area.

- All stakeholders need to establish practices that ensure the participation in the development and implementation of wetland management plans of stakeholder groups with cultural or economic links to wetlands or those communities that depend on the wetlands for their livelihoods.

- All stakeholders need to assess their national and local training needs with respect to the conservation and wise use of wetlands.

- All stakeholders need to collect circulars, periodic publications and exchanges of information vertically to the MoWIE and its central committee and horizontally across all regional and zonal similar reports and sharing of experiences to reach a wide range of target groups, including such products as decision-making frameworks, networks, and technical documents.

Vision and guiding principles

- **Vision:** The vision of this restoration guideline is to motivate people to become responsible of their actions regarding the wise use of wetland resources.

- **Guiding principles:** The guiding principles that underpin this restoration guideline for Ethiopia are:

    - The CEPA Program offers tools to help people understand the values of wetlands so that they are motivated to become advocates for wetland conservation and wise use and may act to become involved in relevant policy formulation, planning and management. This should be implemented by the stakeholders identified by the main council at the MoEFCC.

    - The CEPA Program fosters the production of effective CEPA tools and expertise to engage participation of major stakeholders in the wise use of wetlands and to convey appropriate messages in order to promote the wise use principle throughout society.

    - This guideline upholds that CEPA should form a central part of implementing WRIPs and WMPs by each stakeholder. Investment in CEPA will increase the number of informed advocates, actors and networks involved in wetland issues and build an informed decision-making and public constituency.

Goals and strategies to pursue the Vision

The CEPA program identifies the **goals** (what needs to be achieved), the **strategies** (how these goals can be realized), and the **results** (what outputs should be achieved). An overview of the desired goals and strategies are listed below.

Goal 1: Communication, education, participation and awareness (CEPA) are used effectively at all levels of federal and regional administrative bodies to promote the value of wetlands.

This goal includes recommendations that relate to using CEPA to enhance awareness of wetland values, promotion of CEPA as a valuable process, and integration of CEPA into policies and planning at multi-scalar levels from global and national to basin and to site levels.

Strategy 1.1: Foster sustained national and sub-national campaigns, programs and projects to raise community awareness of the important ecosystem services provided by wetlands, including their social, economic and cultural values.

Indicators of results of Strategy 1.1:

- Campaign, programs or projects undertaken with key partners to raise awareness, build community support, and promote stewardship approaches and attitudes towards wetlands.
- Celebrating national and international Wetlands' Day with appropriate national and local events and promotions and distribution of resource materials, in order to raise awareness of wetland values and functions
- Collaborating with the media to inform decision-makers, key wetland users, and the broader society about the values and benefits of wetlands.
- Identifying and promoting wetlands of national and international importance and celebrating achievements
- Indicating areas of noted problems of degradation and converging stakeholders to commit themselves to restore the damages.

Strategy 1.2: Demonstrate that CEPA processes are effective in achieving WRIPs and WMPs and wetland wise use objectives at the global, national and local levels.

Indicators of results of Strategy 1.2:

- Developing and evaluating pilot projects for a range of approaches for applying CEPA in promoting the wise use of wetlands, in particular involving those who make a direct use of wetland resources.
- Reviewing existing CEPA programs and case studies and learning the lessons from these experiences regarding effective approaches and document them
- Making available the findings and conclusions drawn from the above two points to stakeholders and the broader community through appropriate mechanisms

Strategy 1.3: Integrate CEPA processes into all levels of policy development, planning and implementation of this guideline.

Indicators of results of Strategy 1.3:

Integrating CEPA into all relevant work programs, including joint work plans with other organizations, and included in the development of all further wetland guidelines

- Where appropriate, wetland CEPA has been integrated into the business of national and regional wetland, biodiversity, forestry, agriculture, irrigation, power generation, mining, tourism, and fisheries committees and other relevant policy and planning committees where they exist.
- Encouraging to synergize collaboration globally and nationally, with the CEPA activities under other international conventions and programs
- Integrating collaborations of major stakeholders with wetland CEPA into all relevant regional (where applicable), national, catchment and local wetland and other appropriate sectoral

policies, strategies, plans and programs, such as those for biodiversity conservation, water management, fisheries, poverty reduction, educational policies and curricula, etc.

Strategy 1.4: Support and develop mechanisms to ensure that CEPA processes are incorporated into wetland site management plans.

Indicators of results of Strategy 1.4:

- Documenting case studies that show the positive role of CEPA in local management activities and the critical role of CEPA tools and skills in effective participatory wetland management, and making these case studies available to stakeholders and other interested bodies

- Demonstrating readiness of multi-stakeholder bodies to guide and inform catchment/river basin and local wetland-related planning and management, and these bodies include appropriate expertise in CEPA.

- Documenting catchment/river basin planning and management including communication, education, participation, awareness, and capacity building as central processes in the delivery of overall water and wetland management objectives

- Developing appropriate strategies and actions, where they do not already exist, for communication, education, participation, and awareness to introduce into site management plans

Goal 2: Provide support and tools for the effective implementation of national and local wetland-related CEPA activities.

This goal is focused on establishing the enabling environment for the effective implementation of CEPA. This includes mechanisms such as frameworks and action plans, the establishment of CEPA focal points, including individuals, organizations and centers, and mechanisms such as networks for information exchange and access to resources, experts and training.

Strategy 2.1: Ensure that national and local leadership, networks and cohesive frameworks are developed to support and catalyze CEPA for the wise use of wetlands.

Indicators of results of Strategy 2.1:

- Appointing suitably qualified persons to fulfill the roles of national Government and Non-governmental Organization (NGO) Focal Points for wetland CEPA, and advising the national committee of the persons fulfilling these roles and their contact details
- Establishing a national Wetland CEPA Task Force (if no other mechanisms exist for this purpose), including CEPA Focal Points, key stakeholders and NGO participation, and a review of needs, skills, expertise and options undertaking and prioritizing set for the co-development and implementation of this program of work.
- Collaborating with the national CEPA Focal Points to work with wetland and other environmental education centers and, as appropriate, a representative of such centers including on the Wetland CEPA Task Force or other planning bodies.
- Formulating a national (or, as appropriate, a sub-national, catchment or local) CEPA Action Plan, drawing upon the CEPA toolkit for this purpose and for the restoration guidelines on participatory management, and then making conclusions emerging from such results. Sending a copy of the Action Plan that has been sent to the national committee so that it can be made available to other stakeholders and interested organizations and individuals.

Strategy 2.2: Transfer, exchange and share CEPA information and expertise that promotes and results in the wise use of wetlands.

Indicators of results of Strategy 2.2:

- Giving attention to the effectiveness of communication and information sharing systems among relevant government ministries, departments and agencies, such as education, land and water management, and agriculture, and where necessary developing mechanisms to address any shortcomings.

- Updating regularly the website of the national wetland restoration guidelines with appropriate materials, including key easily accessible CEPA pages and other resource materials, ensuring that these remain as information source for the CEPA Program nationally and internationally.

- Developing collaborating agreements with Ramsar International Organization Partners (IOPs), especially IUCN's Commission on Education and Communication (CEC), and other organizations with which collaborative agreements should be made to make suitable resource materials available to assist the global CEPA Program and provide information on effective CEPA approaches.

- Increasing engagements by all forms of communication (electronic or otherwise) with international organizations that are involved in education, particularly UNESCO, and UNESCO's Man and the Biosphere Program and inviting Biosphere Reserve site managers to carry out relevant actions of the CEPA Program, where appropriate;

- Producing, sharing and distributing resource materials to support wetland CEPA actions

- Establishing an on-line searchable listing of expertise in CEPA and maintaining assistance to CEPA at national and international levels, and serving promote CEPA programs and activities

Strategy 2.3: Recognize and support the role of wetland centers and other environment centers as catalysts and key actors for CEPA activities that promote the objectives of this guideline.

Indicators of results of Strategy 2.3:

- Establishing education centers at wetlands of national and international importance to provide basic knowledge to focal points for local and national CEPA activities

- Building the capacity of existing centers at wetlands and developing new centers to deliver high quality CEPA programs to support and enhance the training and capacity building systems.

- Where wetland education centers exist, reviewing their information systems to ensure that it is helping to promote the WRIPs and WMPs and their wise use principle in suitable ways. Helping the centers to foster communication and, where appropriate, promoting participation among local wetland management 'actors' and stakeholders.

- Demonstrating that the national wetlands restoration guideline gains international recognition and support

- Making all efforts to promote and twin resource of wetland education centers to encourage the exchange and transfer of information and expertise among centers in developed countries and those in developing countries and countries in transition

Goal 3: People are motivated and enabled to act for the wise use of wetlands.

This goal is focused on using the CEPA framework and its tools and products to motivate and enable new actors to be actively involved for the wise use of wetlands.

Strategy 3.1: Improve the individual and collective capacity and opportunities of people to participate in and contribute to using wetlands wisely.

Indicators of results of Strategy 3.1:

- Reviewing current national needs and capacities in the areas of wetland CEPA, including in relation to the establishment and operations of wetland education centers, and using this to define training and capacity-building priorities within the national wetland CEPA action plan, including training for the CEPA national focal points (NFPs).

- Identifying sources of experts internationally, including Ramsar experts to solicit sources of experts on wetland information and finding training opportunities to facilitate the sharing of expertise and knowledge at the local, national, regional and global levels.

- Seeking resources through appropriate mechanisms to support the training and capacity building for identified as priorities and ensuring that key groups such as women and indigenous and rural communities have not been overlooked.

Strategy 3.2: Support and develop mechanisms to ensure multi-stakeholder participation in wetland management**.**

Indicators of results of Strategy 3.2:

- Building recognized active participation and skills as an effective process for wetland management nationally

- Creating participatory stakeholder groups with cultural or economic links to wetlands or those communities who depend on the wetlands for their livelihoods and promoting the same at the national level, and strengthening local communities' and indigenous peoples' participation in the management of wetlands

- Developing respect for local wetland knowledge held by indigenous and local communities, and proving that this knowledge is respected and integrated into site management plans.

Goal 4: Developing sustainable wetland protection and restoration road map

Strategy 4.1: This is focused on providing education programs to school children, as they are the owners of tomorrow's Ethiopia and the responsible persons of the future.

Indicators of results of Strategy 4.1:

- Demonstrating the change in behavior and understanding of school children

- Providing school children with the opportunity of field visits to proven degraded wetlands and pristine sites for comparison

- Showing school children the various benefits wetlands provide to people the major road map for sustainability and showing them how difficult human livelihood would be if these benefits could not be sustained.

Log-frame analysis of the Restoration Implementation Plan: As presented, the design here is for the national level restoration implementation plan. Based on the details of the cascading plans of the region, zone, woreda and kebele restoration implementation plans, the respective log-frame analysis can be done by the committee of each level.

	Goals	Strategies	Indicators
NWRIP	I: C: Communication E: Education P: Participation A: Awareness	I. National, regional, zonal, wereda and Kebele campaign programs, awareness, trainings on eco-services, cultural/ religious values, etc.	• Campaign program and completion reports • National, regional, zonal, wereda and Kebele wetlands' day • Identify wetlands of national/ international importance • Gap identification
		II. Demonstrate CEPA effectiveness to implement NWRIP	• Evaluate pilot projects • Review CEPA programs • Release findings/conclusions
		III. Integrate CEPA into policy, planning and development	• Relevant work program • CEPA integrated into business plan, conservation, power generation, etc. • Synergize with international conventions • Collaborate with stakeholders
	2: Provide support and tools for CEPA, above	I. Ensure national, regional, zonal, woreda and kebele leaderships are networked, cohesive and have a general framework of collaboration	• Appoint qualified personnel at all levels • Establish national wetlands' CEPA that extends to the region, zone, woreda and kebele • Collaborate with national focal person • Formulate national, regional, zonal, woreda and kebele CEPA Action Plan
		II. Exchange CEPA information toolkits, etc.	• Effectiveness of communications and information sharing among stakeholders (government/ private) • Developing mechanisms to address shortcomings • Regular updating of website • Updating restoration implementation plans

	Goals	Strategies	Indicators
		II. Exchange CEPA information toolkits, etc.	• Website with easily accessible CEPA pages • Ensuring website remains updated information source nationally and internationally • Developing collaborating agreements with Ramsar International Org. partners (IOPs) • Making available suitable resource materials to assist global CEPA programs • Increasing engagements by all forms of communications (electronic, printed, discussions, conferences, etc.) • Communicating with UNESCO and its biosphere reserve programs • Producing, sharing and distributing resource materials • Establish an online searchable listing of experts in CEPA at national and international levels
		III. Recognize the role of national, regional, zonal, woreda and kebele CEPA Actions and award achievements	• Establishing education centers at wetlands of national and international importance • Building the capacities of existing wetland centers of national and international importance • Reviewing the information systems to promote WRIP and WMP • Helping centers foster all forms of communications • Promoting participation among local wetlands' management actors and stakeholders • Demonstrating national wetlands' restoration guidelines attain international recognition and support • Promoting and twinning resources of wetlands education centers • Transferring of information and experiences among centers in developing and developed countries

	Goals	Strategies	Indicators
	3: People are motivated and enabled to act for the wise use of wetlands	I. Improve the individual and collective capacity and opportunities of people to participate in and contribute to using wetlands wisely	• Reviewing current national needs and capacities in CEPA • Establishing and operating wetlands' education centers • Defining training and capacity building priorities of CEPA • Training national focal persons in CEPA • Identifying sources of international Ramsar, etc. experts • Finding and making available training packages • Seeking resources through appropriate mechanisms to support the capacity building programs • Ensuring key stakeholders, e.g. women, indigenous and local communities are included
		II. Support and develop mechanisms to ensure multi-stakeholder participation in wetlands' management	• Building recognized active participation and skills • Creating participatory stakeholders group by considering their ranks, inclusion on new ones or excluding irrelevant ones • Promoting the same at national and local and indigenous communities levels • Developing respect for local wetlands' knowledge held by indigenous communities • Recognizing the same at meetings and awarding them and include the results in wetlands management and improving wetlands guidelines
	4: Developing sustainable wetlands protection and restoration road map	I. Providing education programs to school children	• Demonstrating the changes in behaviour and understanding of school children • Providing school children with the opportunity of field visits • Showing school children the various benefits wetlands provide to people • Developing road map for sustainability and showing them how difficult human livelihoods could be if these wetland benefits are not there and they could not be sustained

6.2.5. Suggested major roles and responsibilities of the CEPA National Focal Persons (NFPs)

In providing a supportive environment in which wetland CEPA planners and practitioners can develop their work, NFPs should:

- provide leadership for the development and implementation of a wetland CEPA Action Plan at an appropriate level (national, sub-national, local) as described in this guideline;
- Be the main point of contact on CEPA matters between (a) the national committee for wetland restoration and the stakeholders and (b) among stakeholders themselves;
- Be key members of the National Wetland Committees or similar national structures;
- Assist in the practical CEPA implementation at the national level and in national reporting on CEPA activities to the MOEFCC;
- Ensure a high, positive public profile for this restoration guideline and the conservation and wise use goals of wetland resources;
  - Be active spokespersons for wetland CEPA and
- Establish and maintain any contacts, networks, structures and mechanisms necessary to ensure the effective communication of information between relevant actors at all levels and in all sectors.

6.2.6. Sharing experience between nations (International cooperation) (from RCS, 2010b)

Managing shared wetlands and river basins: Under these guidelines for international cooperation, parties or stakeholders are urged to identify all their shared wetland systems (wetlands, rivers, standing waters, groundwater, etc.), and cooperate in the management of the same with the adjoining jurisdiction(s). This cooperation may extend to formal joint management arrangements or collaboration in the development and implementation of a management plan for wetlands in question.

In the same way, parties or stakeholders are urged to identify and then cooperate in the management of shared or international river basins. The establishment of multi-state management commissions is an important concept for those countries, which share river basins to consider and pursue energetically. Experience has shown these to be an effective mechanism to promote international cooperation over water resource management, which includes the wetlands forming part of these river basins.

Managing shared wetland-dependent species: International cooperation in the management of so-called shared species has been considered as priority under numerous international agreements and convention since its inception. In fact, the motivation for countries to develop and put into place a convention like Ramsar was largely provided by a desire to promote international cooperation for migratory water-bird conservation. Today, the Convention continues to promote this aspect of its charter very strongly, and as the level of knowledge regarding migratory species grows, so too does the imperative for the Convention to take a more strategic approach to the management of shared species. For migratory species, it should be realized that it is not always the very large wetland sites that are critical for the conservation. Instead, many small wetlands are also vital elements of migration routes and they are important, collectively, for biodiversity conservation. It also should be understood that not all shared species are migratory. There are non-migratory species, which have a limited range and are found in trans-boundary wetlands or within adjoining countries.

Working in partnership with international/regional environment committees, government and non-governmental organizations and agencies: Essentially this sets priorities for this guideline in the development of cooperation and synergy with these conventions and agencies in order to promote shared objectives and goals. The guideline should also have a unique partnership with a number of international NGOs and it should seek more to allow for expansion the protection of wetlands. Cooperation with international partners will continue to accelerate implementation of the WRIPs and WMPs of this guideline at all levels from international to local. Some of the prominent international organizations with shared missions and visions are BirdLife International, the International Water Management Institute (IWMI), and International Union for Conservation of Nature (IUCN), The World Wide Fund for Nature (WWF) and Wetlands International).

6.2.7. Sharing of expertise and information

(a) Knowledge sharing:

In all countries, there exists knowledge and expertise in wetland management. Sometimes this resides with the indigenous people who may have relied upon the wetland ecosystems for generations and who have applied wise use practices to sustain them for centuries. There is also that unwritten understanding, which people living in association with a wetland have acquired from being a part of the same ecosystem over time, an understanding that has built empathy and a respect for the values of the wetland. Then there is the cutting edge of new understanding born of research and the development of new technologies. This can be practical, hands-on research, equipment that is more sophisticated or low-cost technologies, or it can be about promoting better management practices through the application of new science in the many fields, which wetland managers must now embrace.

The focal points for CEPA should be appointed, and similarly, a National Focal Point in each collaborating institution for the business of the Scientific and Technical Review Panel should be designated. These Focal Points are expected to form global networks of expertise and review their national resources in these two fields (traditional and local knowledge and current/cooperative research findings) with a view to promoting knowledge sharing.

(b) Training:

Training people to implement all aspects of this guideline and to manage wetland sites remains a high priority. Globally, there are ranges of institutions providing training in these various fields. The challenge for the Convention is to deliver the right sort of training to the people that need and desire it. However, this does not provide the resources needed to get wetland practitioners into training programs, or to see training programs delivered on-site in those stakeholder institutions, where it is urgently needed. Another gap is that very few countries have conducted analyses to determine their priority training needs at the national, sub-national and local levels. Without such reviews of training needs, there is a risk that the training provided or offered will lack relevance.

(c) International assistance to support the conservation and wise use of wetlands

The governmental and non-governmental institutions involved in the implementation of the principles of this guideline should recognize the importance of mobilizing international assistance to support the conservation and wise use of wetlands, and that this forms a central element of international cooperation. It should be part of the objectives that developing countries pay more attention to conservation measures in any request for and programming of assistance, and upon developed countries and international organizations to pay due attention to these requests in their development aid policies. The subsequent conferences of the stakeholders should approve a number of additional resolutions and recommendations, calling for enhanced funding for wetland conservation and improved management and control of development assistance funding.

(d) Sustainable harvesting and international trade in wetland-derived plant and animal products

This guideline promotes the conservation and wise (sustainable) use of wetlands, and this includes the harvesting of plant and animal products from these wetlands. At the local scale, such harvesting by the MOWIE should be regulated by a management plan developed in close consultation with the stakeholders and also urges that involved institutions to promote "as far as possible the wise use of wetlands in their territory". In terms of international cooperation under this guideline, trade in plant and animal products derived from wetlands, which extend beyond national boundaries should therefore also be regulated to ensure that harvesting is being done in a sustainable ways. If such harvesting is taking place at a site of national or international importance, then the involved institutions should have clear obligations to ensure that the impact of the harvesting will not threaten or alter the ecological character of such sites. This applies especially for trans-boundary wetland sites, shared by two or more countries or national administrative regions or zones.

(e) Regulation of foreign investment to ensure wetland conservation and wise use:

The regulation of foreign investment is clearly a sovereign right and an issue of self-determination, which must be respected by this wetland restoration guideline. Through this Guideline on International Cooperation, such a guideline should not seek to restrain such investments or inhibit economic development, but rather to provide advice to the involved institutions, which will assist them to avoid activities supported by foreign investments, which are counter to their obligations under the same guideline. It is also important to note the potential, which exists for the involved institutions to regulate foreign investment in ways that ensure that it contributes in a positive way to the long-term sustainability of the wetland resource being utilized.

6.2.8. Establishing a national monitoring program (Modified after RCS, 2010c)

(a) The importance of constructing a national monitoring program

As prescribed in wetland management policy or directives of the government or the WRIPs and WMPs that emanated from the same contribute to:

- Establishing the location and ecological characteristics of wetlands (baseline inventory);
- Assessing the status, trends and threats to wetlands (assessment);
- Monitoring the status and trends, including the identification of reductions in existing threats and the appearance of new threats (monitoring); and
- Taking actions (both *in situ* and *ex situ*) to redress any such changes causing or likely to cause damaging change in ecological character (management).

(b) The relationship between wetland inventory, assessment, monitoring and management

Primarily, it is important to conceptualize meanings and interactions of the above terms and how their interaction influences the restoration function of wetlands.

- **Wetland Inventory** is the collection and/or collation of core information for wetland management, including the provision of an information base for specific assessment and monitoring activities. Wetland Assessment is the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities.
- **Wetland monitoring** is the collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management.
- **Wetland surveillance** is not monitoring but the collection of time-series information or inventory.

Essentially, wetland (baseline) inventory is used to collect information to describe the ecological characteristics of wetlands. Assessment considers the pressures and associated risks of adverse change in ecological character; and monitoring, which can include both survey and surveillance, provides information on the extent of any change. All three are important and interactive data gathering exercises. They should be considered as linked elements of this overall integrated framework which, when implemented, provides for identification of key features of the character of wetlands. Taken together, they provide the information needed for establishing strategies, policies and management interventions to maintain the defined wetland ecosystem character and hence ecosystem benefits/services.

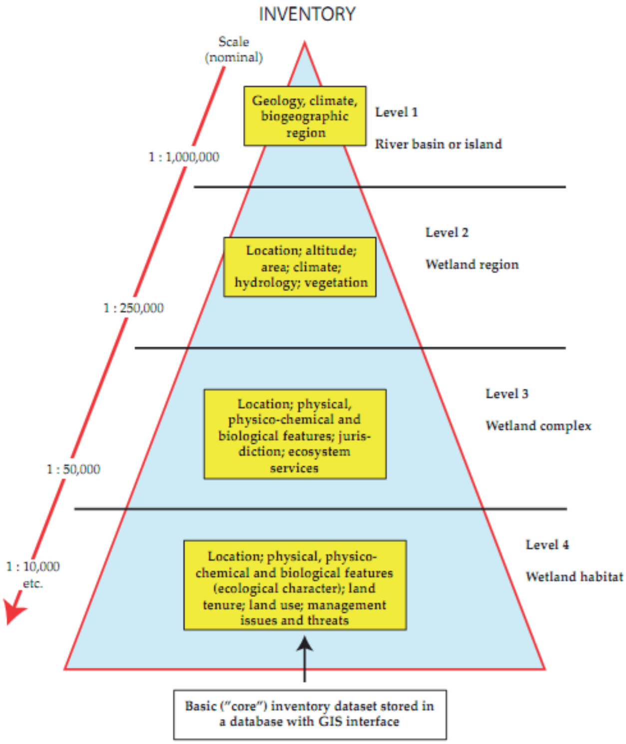


Figure 6.1 : The hierarchical approach to wetland inventory (Data fields most appropriate for each level are shown, with the most data being collected at level 4 (shown at the base of the triangle) (After RCS, 2010c)

(c) Multi-scalar approaches to wetland inventory, assessment and monitoring

Overriding issues in implementing wetland inventory, assessment and monitoring are the choice of the scale at which to undertake the work and the choice of appropriate methods for each scale.

Wetland assessment, as with inventory and monitoring, can be undertaken at discrete spatial scales using (different) appropriate techniques for each. Whenever possible, an integrated inventory, assessment and monitoring program should be developed and conducted at a single appropriate scale. This can be achieved when an integrated analysis encompassing inventory, assessment and monitoring components is planned and implemented.

However, these components are typically planned or undertaken separately. Wetland assessment should be undertaken at a spatial scale compatible with the scale of information contained within the wetland inventory. Subsequent monitoring should also be undertaken at a scale compatible with the assessment.

Wetland inventory, assessment and monitoring will be constrained by the scale and availability of information, the degree of urgency, financial resources allocated for the purpose and even accessibility of the wetlands.

(d) The basic, but highly essential tools, for implementing the integrated wetland inventory, assessment and monitoring framework include:

- **The quality of the inventory**

  State the purpose and objective

  Review existing knowledge and information

  State the purpose and objective

  Review existing inventory methods

  Determine the scale and resolution

  Establish a core or minimum data set

  Establish a habitat classification

  Choose an appropriate method

  Establish a data management system

  Establish a time schedule and the level of resources that are required

  Assess the feasibility and cost effectiveness

  Establish a reporting procedure

  Establish a review and evaluation process

  Plan a pilot study

- **Metadata records for wetland inventory**

The Framework for Wetland Inventory also stresses the importance of establishing a publicly accessible and standardized metadata record for each inventory undertaken, and it includes a standard model for wetland inventory metadata. Metadata has many elements that can include information describing the age, accuracy, content, currency, scale, reliability, lineage, authorship and custodianship of an individual dataset. Recording and describing this information enables data to be easily located, identified, understood and managed. It also enables data to be used more efficiently and effectively.

- **Types of wetland assessment**

There is a wide range of different types and methods of wetland assessment relevant to different aspects of implementation, with each suited to and designed for different purposes and situations. These include:

- Environmental Impact Assessment (EIA)
- Strategic Environmental Assessment (SEA)
- Risk Assessment (RA)
- Vulnerability Assessment (VA)
- Change (status and trends) Assessment
- Species-Specific Assessment
- Indicator Assessment
- Resource (ecosystem benefits/services) Assessment
- Assessment of values of wetland benefits/services
- Environmental water requirement (environmental flows) assessment
- Efficiency in the utilization of resource (e.g. finance)

As long as resources and time allow, in any wetland it is advisable to use more than one method to assess the status of wetlands and suggest the possible mitigation action.

- **Rapid assessment of wetlands**

"Rapid assessment" of wetlands is an approach which, depending on the purpose of the assessment, involves one or more of the different types of wetland assessment tools listed above, but where the methods are adapted to permit the adequate collection, analysis and presentation of the assessment information when this information is urgently needed. It may also involve the rapid collection of 'baseline' wetland inventory information. Rapid assessment methods can be particularly useful in the assessment of the impacts of natural disasters such as storm surges, earth movements, sudden spill of poisonous and undesirable chemical wastes, etc.

The guidance recognizes that the purposes for rapid assessment of wetlands include:

a) Collecting general biodiversity data in order to inventorize and prioritize wetland species, communities and ecosystems; obtaining baseline biodiversity information for a given area;

b) Gathering information on the status of a focus or target species (such as threatened species); collecting data pertaining to the conservation of a specific species;

c) Gaining information on the effects of human or natural disturbance (changes) on a given area or species;

d) Gathering information that is indicative of the general ecosystem health or condition of a specific wetland ecosystem; and

e) Determining the potential for sustainable use of biological resources in a particular wetland ecosystem.

- **Indicator assessment**

The development and use of indicators is designed to assess temporal patterns in the status and trends of ecosystems, habitats and species, the pressures and threats they face and the responses made to address these pressures and threats. Such indicators are not designed to provide a complete and comprehensive assessment of all aspects of wetland ecosystems and their dynamics; rather they are intended to give a series of related pictures of these patterns, in order to guide further design and the focusing of decision-making for addressing unwanted change. Such indicators as listed below are also generally components of hypothesis-driven wetland monitoring program.

a) Trends in extent of selected biomes, ecosystems and habitats;

b) Trends in abundance and distribution of selected species;

c) Change in status of threatened species;

d) Trends in genetic diversity of domesticated animals, cultivated plants, and fish species of major socio-economic importance;

e) Coverage of protected areas;

f) Criteria and indicators for sustainable management of ecosystems;

g) Biodiversity used in food and medicine;

h) Water quality in aquatic ecosystems;

i) Trophic integrity of ecosystem;

j) Nitrogen deposition; and

k) Numbers and cost of alien invasions.

Some specific examples are given in Table 6.1 below.

Table 6.1. Example of indicators used in assessment of wetland ecosystems (RCS, 2010c)

Indicator	Sub-indicator(s)
A. The overall conservation status of wetlands	a. Status and trends in wetland ecosystem extent b. Trends in conservation status – qualitative assessment
B. The status of the ecological character of the wetland	a. Trends in the status of the wetland ecological character – qualitative assessment
C. Trends in water quality	a. Trends in dissolved nitrate (or nitrogen) concentration b. Trends in Biological Oxygen Demand (BOD)
D. The frequency of threats affecting the wetland	a. The frequency of threats affecting the wetland in question – qualitative assessment
E. Wetland sites with successfully implemented conservation or wise use management plans	a. Wetland sites with successfully implemented conservation or wise use management plans
F. Overall population trends of wetland taxa	a. Trends in the status of waterbird biogeographic populations
G. Changes in threat status of wetland taxa	a. Trends in the status of globally-threatened wetland-dependent birds b. Trends in the status of globally-threatened wetland dependent amphibians
H. The proportion of candidate wetlands for international recognition designated so far for wetland types/ features	a. Coverage of the wetland resource by designated reference sites

- **The relationships among the different wetland assessment tools**

It is important to recognize that whilst each assessment tool has a specific application, there can exist considerable overlaps between tools under some circumstances. In some instances, one or more specific tools can be used as part of a broader form of assessment. Practitioners need to consider the choice of tool or tools in relation to the specific purpose of the assessment they need to undertake. The following figure shows the relationships among different assessment tools.

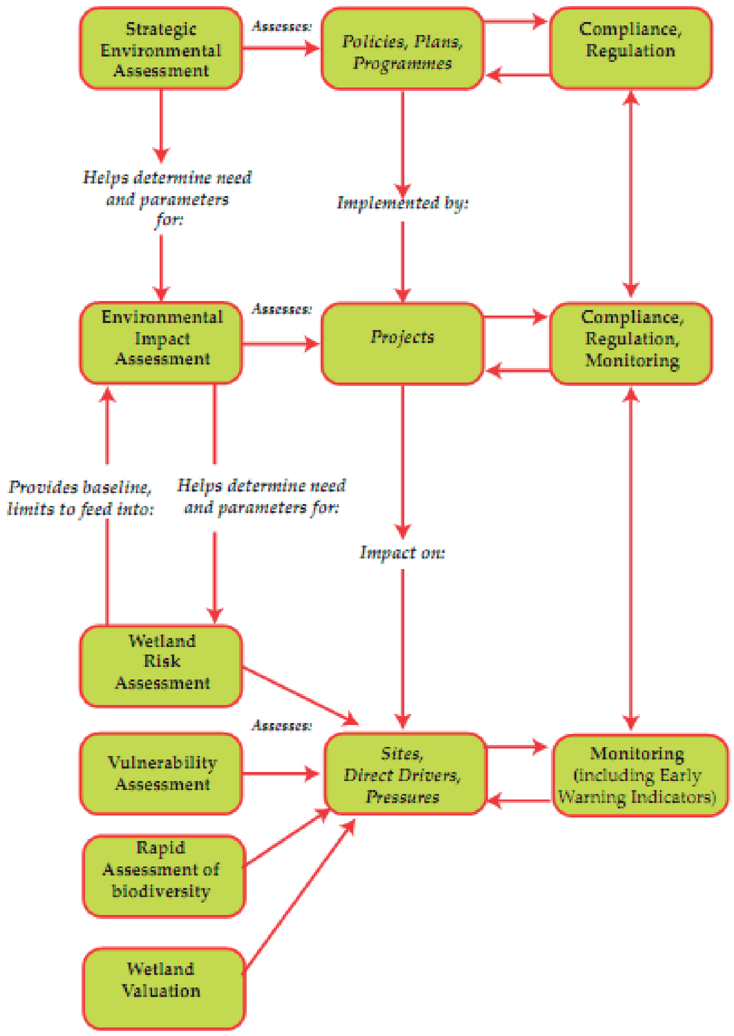


Figure 6.2 : The relationships among the different wetland assessment tools available (After RCS, 2010c)

6.2.9. Wetland monitoring

Wetland monitoring simply provides a series of steps that can be used by wetland managers and planners, working in partnership with local users and managers, to design a monitoring program based on their particular circumstances and needs. See the figure below.

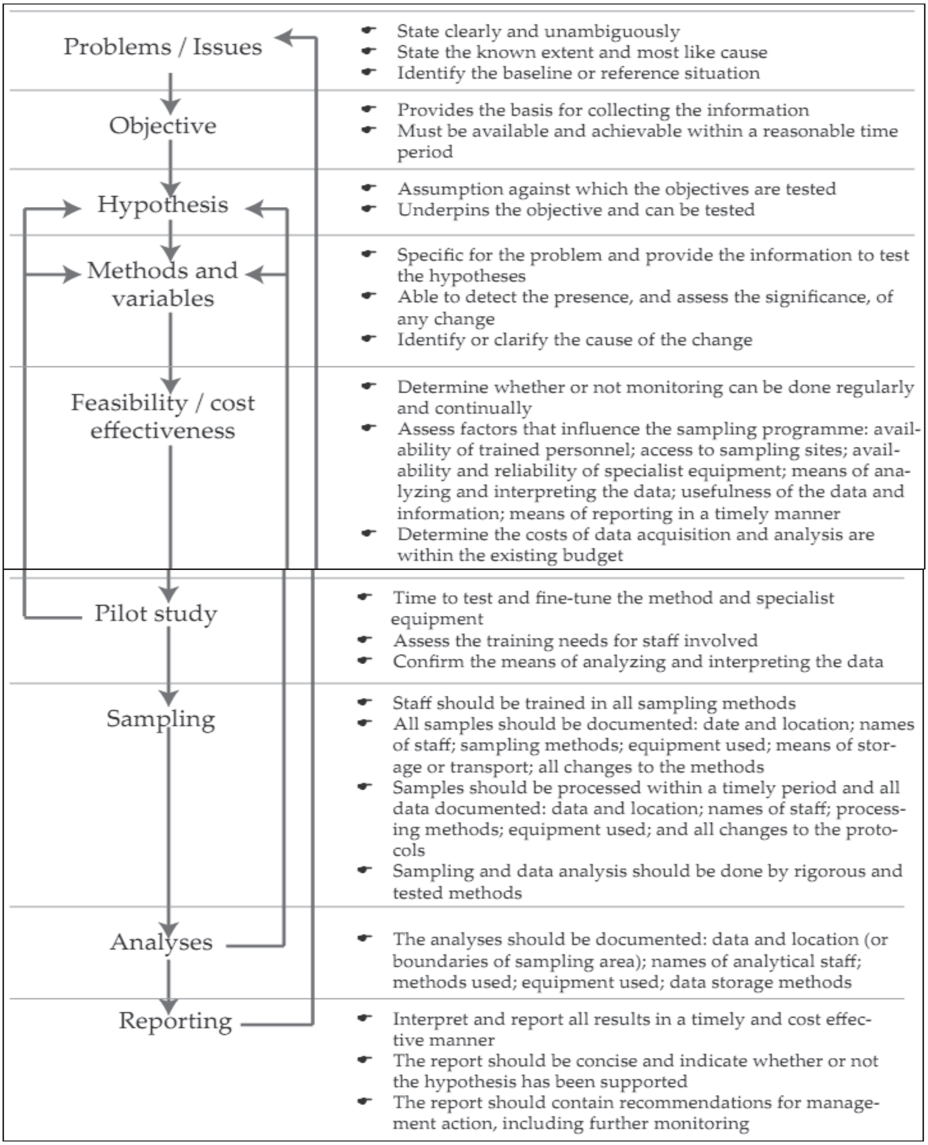


Figure 6.3: Framework for designing a Wetland-monitoring program.

(The arrows illustrate the feedback, which enables assessment of the effectiveness of the monitoring program in achieving its objective(s) and the bullets indicate the specific outcomes of the monitoring program (from RCS, 2010d).

6.2.10. Priorities for improving integrated wetland inventory, assessment and monitoring

The following practical steps for improving integrated wetland inventory, assessment and monitoring are recommended:

i) All countries that have not yet conducted a national wetland inventory should do so, preferably using an approach that is comparable with other large-scale wetland inventories already underway or complete. These should focus on a basic data set that describes the location and size of the wetland and the major biophysical features, including variation in the areas and the water regime.

ii) Once the baseline data have been acquired and adequately stored, more management-oriented information on wetland threats and uses, land tenure and management regimes, benefits and values should be added. When such assessment information is recorded, it should be accompanied by clear records that describe when and how the information was collected and its accuracy and reliability checked.

iii) Each inventory and assessment program should contain a clear statement of its purpose and the range of information that has been collated or collected. This extends to defining the habitats being considered and the date the information was obtained or updated.

iv) Priority should be given to improving the inventory for wetland habitats that are currently poorly covered in most parts of the country. These include those found in arid-zone wetlands, rivers and streams, artificial wetlands, wetlands in close proximity to highly populated settlements, wetlands at risks of excessive dangerous pollution, wetlands exposed to excessive abstraction or even wetlands whose feeder-rivers are diverted upstream.

v) The effectiveness of all aspects of wetland inventory and assessment should be increased through the use of a standardized framework and a generic wetland inventory core dataset, designed to be as flexible as possible for use in all regions of Ethiopia and to accommodate various inventory and assessment objectives. Eventually, such information will be compatible for comparison with internationally collected data.

vi) Models for effective wetland inventory, assessment and monitoring, using appropriate remote sensing and ground techniques, should be compiled and widely disseminated. These should outline useful habitat classifications (e.g., those based initially on landform and not vegetation parameters) and methods and means of collating and storing the information, in particular Geographic Information Systems (GIS) for spatial and temporal data that could be used for monitoring purposes.

vii) Wetland monitoring systems should build upon the information provided in wetland inventory and assessment activities. Specific monitoring should be based on a hypothesis derived from the assessment data and be contained within a suitable management structure.

6.2.11. Water allocation and management (RCS, 2010e)

The concept of **integrated water resources management (IWRM)** has come to the forefront as a strategy to implement the Dublin Principles. IWRM is defined as "a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems".

The principles are:

Sustainability as a goal: Adequate water has to be provided to wetlands to sustain the functioning of these ecosystems, respecting their natural dynamics for the benefit of future generations. Where water requirements are not known, or where the impact of reducing water allocation to wetlands is unclear, the precautionary approach[3] should be applied. The wetland ecosystem is the resource base from which water is derived. It should be managed to protect the resource base in order to provide goods and services in a sustainable manner. This requires sufficient water allocation to maintain wetland ecosystem structure and function. This is directly compatible with the "wise use" concept, which has been defined as "the sustainable utilization of wetlands for the benefit of mankind in a way compatible with the maintenance of the natural properties of the ecosystem".

3 The precautionary approach states that: "In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation" (The Rio Conference or Earth Summit, 1992).

Clarity of process: The process by which decisions are made on the allocation of water should be clear to all stakeholders. Water allocation has often been a contentious issue and this is likely to increase in the future as competing demands rise and available water resources may diminish due to climatic change and other factors. In many cases stakeholders have not understood why a particular allocation decision was made, leading to suspicion and mistrust of decision-makers. Whilst it will not be possible to please all stakeholders in any water allocation decision, by ensuring a transparent process in the decision-making the outcome can often be less contentious and more acceptable.

Equity in participation and decision-making factors: There should be equity for different stakeholders in their participation in water allocation decisions. There should also be equity in the factors that are considered in decision-making, including the functions, products and attributes of wetlands. Decision-making is often a complex process requiring consideration of many factors and competing demands. Some water users may feel that their requirements have been given less weight than others. Whilst weightings may be applied to different demands for legal or policy reasons, no demand should be ignored. In any decision, ecological and social issues should be considered equally with economic considerations.

Credibility of science: Scientific methods used to support water allocation decisions should be credible and supported by review from the scientific community. Science must be based on appropriate hydrological and ecological data, including adequate baseline ecosystem records. The best available knowledge and science should be employed, which should be updated as better knowledge becomes available from research and monitoring. However, lack of perfect knowledge should not be used as an excuse for inaction. In such cases, the precautionary approach should be applied.

Transparency in implementation: Once procedures for water allocation decisions have been defined and agreed, it is important that they be seen to be implemented correctly. This requires a transparent implementation process, so that all interested parties can follow the choices made at each step, have access to information on which they are based, and recognize agreed procedures.

Flexibility of management: Like many ecosystems, wetlands are characterized by complexity, changing conditions, and uncertainty. It is essential that an adaptive management strategy be adopted, which requires plans that can be changed as new information or understanding comes to light.

Accountability for decisions: Decision-makers should be accountable. If agreed procedures are not followed or subjective decisions can be shown to be contrary to the spirit of the above principles, decision-makers should provide a full explanation. Stakeholders should have recourse to an independent body if they feel that procedures have not been followed.

(i) Operationalizing the principles

The guidelines that follow provide specific actions that should be undertaken to put into action the seven guiding principles described above. They are presented in four sections as follows:

(a) The decision-making framework, including policy and legislation;

(**b)** The process for determining water allocations;

(c) Scientific tools and methods; and

(d) Implementation.

(a) The decision-making framework

In order to make decisions on water allocations for wetland ecosystems, an enabling policy environment is required supported by adequate and appropriate legal tools, which clarify the legal status of water and water allocations, and by a framework for assessing the merits of different allocation options. If economic valuation is available on Ethiopian wetlands, it provides a potential decision-support framework. In addition, in order to ensure that water allocation issues are addressed within wetland policy development legislation and economic valuation frameworks; there is a need to build public awareness of the value of ecosystem services and ecosystem health. In this way, policies, legislation and decisions that support the allocation of water to wetlands will be better understood and more readily accepted.

A key element in water allocation is the involvement of stakeholders in the decision-making process. This involvement should include establishing a forum, such as a working group, to enable interaction and conflict resolution. The implementing agency needs to establish a multi-disciplinary team and to open an information centre that holds all reports and data with open access.

Through stakeholder participation, the various water uses and users within the catchment should be defined along with the objectives for water allocation, which should include the desired ecological character of wetlands. Objectives for water allocations to wetlands may be primarily ecological or may be related to wise use practices, such as fishing or livestock grazing. Management problems should be phrased in quantifiable terms.

(b) The process for determining water allocations

Once the frameworks related to policy, legislation and decision-making have been established, a process for determining water allocations should be defined, encompassing the concepts outlined in the guidance above.

Clearly stated and measurable goals and objectives should be defined and explicit outcomes identified. All wetlands that may be affected by allocation decisions should be identified and the goods and services they provide should be determined, as part of the definition of their ecological character. Potential steps in this process can be found in Ramsar Restoration Handbooks and elsewhere.

Tools should be developed to define the water needs of wetlands, the goods and services they provide, and to evaluate their benefits to society. It is essential to establish adequate monitoring of the hydrology and ecology of the wetlands, if this is not already in place to warrant that the selected tools deliver the desired outcomes.

When planning the water requirements of a wetland, historical patterns of flow, groundwater fluxes, and rainfall, and their inter-annual variability, should be examined closely to determine their role in sustaining native biota/habitats. This information is essential if wetlands are to be considered appropriately in water allocation decisions. Planning should also consider 'dry' periods when wetlands should naturally receive low or no water flows. The quality of water required to maintain the ecology of wetlands, including the appropriate temperature of water released from dams, should also be identified.

When the decisions have been made and implemented, wetlands should be monitored to record any declines or losses of goods and services. If such declines or losses are detected, remedial measures should be taken, where feasible.

In catchments with existing dams, or where dams are planned, explicit consideration should be given to changes in the priority of water uses and the provision of environmental flow releases to meet specific downstream ecosystem and livelihood requirements. In some cases "managed flood releases" designed to overtop river banks and supply floodplain wetlands and/or coastal deltas may be necessary.

(c) Tools and methods

Three types of tools are required:

(a) Tools to achieve stakeholder participation in the definition of the desired status of wetlands and their acceptance of the process for water allocation;

(b) Physical-biological scientific tools capable of quantifying the goods and services provided by wetlands, as well as of predicting the impacts of changes in water availability on these goods and services; and

(c) Tools to evaluate the benefits derived by societies from the goods and services provided by wetlands.

Whilst some generic tools may be available, these may need to be developed further or adapted to local requirements. A range of tools is likely to be needed to cope with different resolutions (temporal and spatial) and different levels of expectations.

(d) Implementation of water allocation regime

A long-term strategy or plan should be established to manage water demand so as to achieve water allocations for ecosystems. Water allocations may be achieved in a variety of ways, including flow releases from reservoirs or restrictions to abstraction. In some cases, pumping from groundwater may also be used to augment stream flow. Groundwater extractions to supplement stream flows to wetlands should only be supported where such extraction does not significantly impact on other water-dependent ecosystems and their values.

Flows should normally follow the natural regime as closely as possible to maintain the natural ecology. This may be achieved by relating the magnitude, duration and timing of releases or abstractions to flows in nearby unregulated reference catchments, which will require real-time monitoring. Special abstraction/release rules should be defined for droughts, floods, and emergency situations. In cases where the dominant use of the wetland is farming (e.g., flood recession agriculture), flows may be tailored for specific requirements such as following the planting of rice on the floodplain.

Effective communication mechanisms should be established with all stakeholders for exchange of real-time information about releases and flow patterns.

Management of water quality also needs to follow natural processes and mechanisms as far as possible. Water quality varies naturally according to the source and anthropogenic impacts, such as discharges. Water released from a reservoir may be of different quality to that of the natural river (e.g., colder and lower in oxygen), so outlet structures should be designed to reduce such impacts.

It is important to monitor compliance with water allocations and to ensure appropriate actions and responses. Where necessary, management strategies should be adapted in the light of monitoring and evaluation.

Figure 6.4 below summarizes the elements of the recommended overall process for the allocation and management of water for maintaining wetland ecosystem functions.

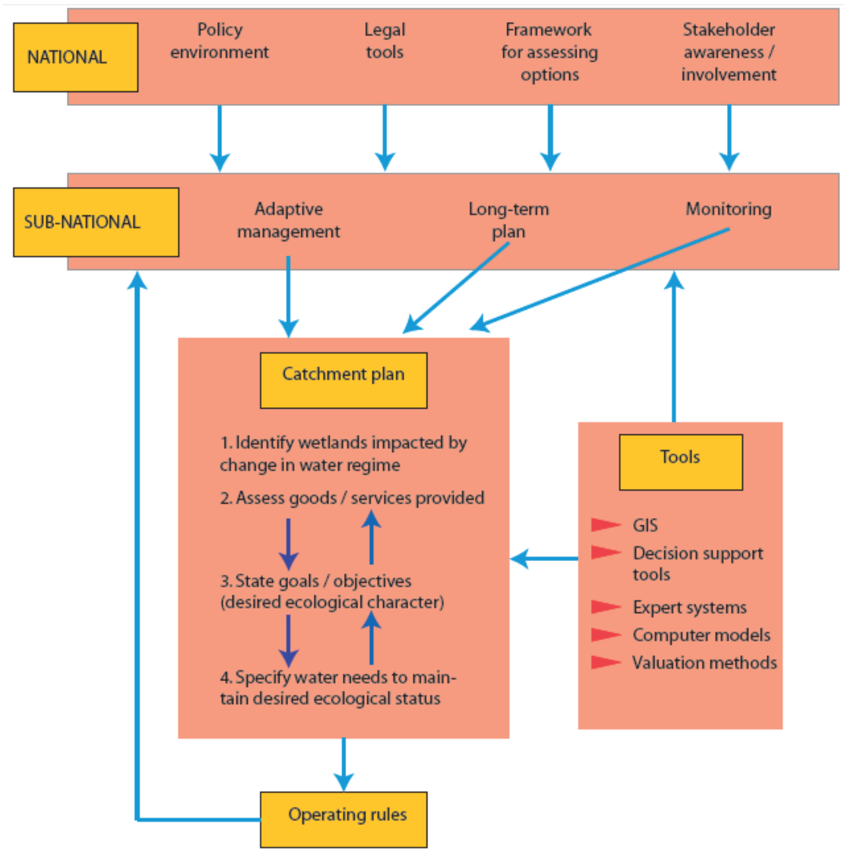


Figure 6.4 : Summary of the elements of recommended overall process for the allocation and management of water for maintaining wetland ecosystem functions (RCS, 2010e)

6.2.12. River basin management (RCS, 2010f)

To start with, common understanding of the definitions of some basic terms of this section of the guideline is important. These terms are:

Integrated Water Resources Management (IWRM) as per the definition of the World Bank is an integrated water resources perspective ensures that social, economic, environmental and technical dimensions are taken into account in the management and development of water resources[4].

4 http://web.worldbank.org/

Integrated River Basin Management (IRBM) is the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems[5].

The term **river basin** encompasses the surface and subsurface water resources, soil and land resources, wetlands and associated ecosystems, including those coastal and nearshore systems that are hydrologically or ecologically linked to the river basin. The catchment areas of groundwater resources in the river basin may not always coincide with the boundaries of surface water catchment areas, and this should be considered in defining the extent of a river basin for management and administrative purposes.

The **water sector** includes those institutions, groups, agencies and organizations, public or private, that are responsible for regulatory, operational and institutional aspects of water policy, planning and regulation; water infrastructure development, operation and maintenance; water allocation and permitting; water treatment and supply; wastewater management, treatment and discharge; water quality management; CEPA and extension services.

The **wetlands sector** generally include those institutions, groups, agencies and organizations, public or private, that are involved in some way in promoting or implementing wise use of wetlands. Their responsibilities and interests may encompass regulatory, operational or institutional aspects of wetland management, such as conservation, restoration, oversight and enforcement of compliance with regulations related to protection and management of wetlands, CEPA, policy and planning.

In addition to the above definition of common terms in wetlands/river basin management, it should be realized that experiences from several countries have shown that poorly integrated or strongly single-sector approaches to water resources management frequently lead to significant degradation of wetland ecosystems within a river basin. This in turn affects the productivity and accessibility of land and water resources in the basin, as well as the associated ecosystem services.

The critical importance of wetlands to all sectors of society through the provision of water-related ecosystem services means that people will need to share the

5 http://www.panda.org/about_wwf/what_we_do/ freshwater/our_solutions/ rivers/irbm/index.cfm.

benefits of wetlands, and so will need to come together over wetlands, whether in conflict or in consensus, and this offers opportunities for integration between different sectors and interest groups.

Integrated River Basin Management in Ethiopia

In order to support the wise use of wetlands, management of wetlands must be undertaken within the context of their larger surrounding "waterscape" (the river basin or catchment, including the hydrological processes and functions within the basin or catchment) as well their larger surrounding landscape.

In the longer term, it is not sufficient to integrate wetland management objectives into land use management plans; they should also be integrated into water resource management plans. In turn, land and water resource management plans need to be integrated to ensure that these plans reflect common and agreed objectives for the wetlands in a river basin. Water-related management objectives for wetlands in a river basin should preferably be "hard-wired" into the business plans and operational plans of the relevant water and land management agencies, to ensure that wetland objectives are fully realized. The aim should be to match water resources strategies with land use strategies, so that these can be implemented jointly to support the maintenance of healthy, functional wetlands that provide a full range of benefits and services for people, including water supply.

In general, stakeholders should apply this guidance that:

- At the national level establish processes for cross-sectoral planning and harmonization of policy objectives and raise awareness about the role and value of wetlands in river basin management;
- At international level promote the integration of wetlands into the management of shared river basins (rivers shared across borders);
- In water sector institutions establish a supportive policy, legislative and institutional environment for implementing result-based management (RBM) that properly integrates wetlands; and
- In wetlands sector institutions ensure that the wetlands sector has the capacity, resources and information to participate meaningfully in river basin management planning, decision-making, and implementation.

Principles for integration of the conservation and wise use of wetlands into river basin management

The NWC and the associated stakeholders should apply these guiding principles in initiating and implementing river basin management approaches into which wetland conservation and wise use are integrated.

- **Sustainability as a goal:** Adequate protection from the impacts of land and water uses within and beyond a river basin should be provided in order to sustain the functioning of wetland ecosystems, respecting their natural dynamics for the benefit of future generations. This protection includes the provision of water allocations for wetland ecosystems.

- **Clarity of process**: The process by which decisions are made on the management of river basins, including the allocation and management of water and wetlands, should be clear to all stakeholders.

- **Equity in participation and decision-making factors**: There should be equity for different stakeholders in their participation in river basin management, including in land use, water allocation, and water management decisions related to wetlands.

- **Credibility of science**: Scientific methods used to support land use and water management decisions related to wetlands, including water allocations to meet environmental water requirements of wetlands, should be credible and supported by review from the scientific community.

- **Transparency in implementation**: Once plans and procedures for river basin management, water allocation and water management decisions related to wetlands have been defined and agreed, it is important that they are seen and made accessible to be implemented correctly.

- **Flexibility of management**: Like many ecosystems, wetlands are characterized by complexity, changing conditions and uncertainty. It is essential that an adaptive management strategy be adopted, which requires plans that can be changed as new information or understanding comes to light.

- **Accountability for decisions**: Decision-makers should be accountable. If agreed procedures are not followed or subjective decisions can be shown to be contrary to the spirit of the above principles, then decision-makers should provide a full explanation. Stakeholders should have recourse to an independent body if they feel that procedures have not been followed.

- **Cross-sectoral cooperation in policy development and implementation**: All of the public sector agencies with responsibilities for activities or policies that influence land, water and wetlands within river basins should commit themselves to cooperative processes of consultation and joint setting of policy objectives, at national level as well as at river basin level.

In summary, to improve the integration of wetlands into river basin management, attention needs to focus on three major areas of activity:

- A supportive policy, legislative and institutional environment that promotes cooperation between sectors and sectoral institutions and amongst stakeholder groups;
- Communication, education, participation and awareness (CEPA) programs to support communication of policy and operational needs and objectives across different sectors, primarily the water and wetlands sectors, and amongst different stakeholder groups;
- Sequencing and synchronization of planning and management activities in different sectors responsible for land use, water resources and wetlands.

Integrating wetlands into river basin management: overview of the scientific and technical guidance

Achievement of wetland management objectives will continue to be difficult until broader land use and water resources management plans at river basin level fully integrate the management and wise use objectives for the wetlands in question. To accomplish that task, The "Critical Path" approach offers a "road map" that can help the NWC and its stakeholders to apply wise use guidelines in a systematic, sequential way to support integration of the conservation and wise use of wetlands into river basin management.

The Critical Path Approach is framed in a cycle that consists of a series of 10 steps (see Figure 6.5 below), arranged in five phases:

Phase 1: Preparation at national level (Step 1 in the figure), providing an enabling and supportive policy, legislative, and institutional environment for river basin management that can be adequately integrated the conservation and wise use of wetlands;

Phase 2: Preparation at river basin level that involves review and possible revision of policy, legislative and institutional aspects related to river basin management (Steps 1 and 2);

Phase 3: Planning involving hydrological, biophysical and socio-economic surveys, assessments and decision-making activities (Steps 3 to 6), leading to the development of a river basin management plan;

Phase 4: Implementation, involving parallel implementation of the river basin management plan and any related wetlands management plans (Steps 7a and 7b);

Phase 5: Review or revisit involving operational review activities (monitoring, data analysis, reporting and response – Step 8) as well as more strategic review of longer-term progress against objectives and plans (Step 9), leading to further development or revision of policies, objectives and plans.

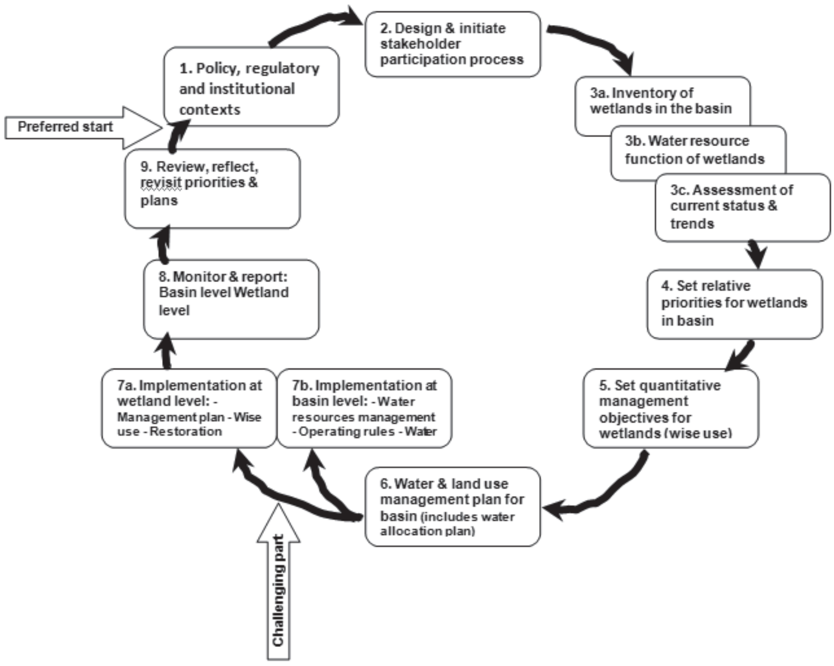


Figure 6.5 : The cyclic Critical Path Approach model for integrating wetlands into river basin management (see details of the operations of this model in RSC, 2010f)

Ideally, the Critical Path cycle should be started at the beginning (Step 1 in Figure 6.5) in a river basin, and completed in full and in sequence, but since the basins and situations within Ethiopia and the respective regional administration in which the wetlands show some differences flexibility should be promoted.

Alternatively, although the model appears to be sequential and thus constraining process, the important thing is "**Start anywhere, but make sure you get started!**".

6.2.13. Managing wetlands (RCS, 2010g)

Operational definitions

Ecological character is the combination of the ecosystem components, processes and benefits (the benefits that people receive from ecosystems) / services that characterize the wetland at a given point in time.

Stakeholder is taken to mean any individual, group or community living within the influence of the site, and any individual, group or community likely to influence the management of the site. This will obviously include all those dependent on the site for their livelihood.

Precautionary Approach as described in Principle 15 of the 1992 Rio Declaration on Environment and Development adopted by the United Nations Conference on Environment and Development (UNCED) states that "In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation".

Inputs are resources.

Outputs are policies, management plans, and management activities to accomplish tasks**.**

Outcomes are condition of the features of the ecological character of the site and other management objectives.

Buffer zone should be that area surrounding the wetland within which land use activities may directly affect the ecological character of the wetland itself, and the objective for land use within the buffer zone should be one of sustainable use through ecosystem management, consistent with the maintenance of the ecological character of the wetland.

Performance indicators:

(a) Are characteristics, qualities or properties of a feature that are inherent and inseparable from that feature?

(b) Should be indicators of the general condition of a feature, and should be informative about something other than them;

(c) Must be quantifiable and measurable; and

(d) Should provide an economical method for obtaining the evidence required to enable the current condition of a feature to be determined.

Description of the ecological character of a wetland

- **Start with available data and information.** In developing a description of the ecological character of a wetland, it is important to start with; whatever data and information are currently available, even if information is not comprehensively available for all fields in the description sheet. Starting with compiling what is currently available also helps to identify gaps and priorities for further data and information collection to enhance the description.

- **Start with qualitative description if quantitative data are not available.** Even if detailed quantitative data are not available, begin by compiling qualitative data and information and do not underestimate the value of expert and local knowledge as a source of such information. Often, bringing together those who know the wetland to share their knowledge can be an important and effective start to compiling the ecological character description.

- **Simple 'conceptual models' can be a powerful tool.** Developing simple two- or three-dimensional 'conceptual models' accompanied by summary descriptions of key features, processes and functioning can be a powerful tool supporting the ecological character description.

- **Separate descriptions for different parts of large or complex wetlands can be a helpful start.** For large wetlands or wetland complexes where different parts of the system function differently or have very different characteristics, it may prove practically helpful to prepare separate descriptions initially for any distinctly different parts, supplemented by an overall summary ecological character description and conceptual models.

Ecological character description sheet

Name of the wetland: ___________________________________

Location (Coordinates): _________________________________

Date: ____________________Place of recording:_____________

Country/Region: _______________________________________

Acronyms used in the table below: "provisioning" (P), "regulating" (R), cultural (C) or "supporting" (S)

Table 6.2: Ecological character description sheet (RCS, 2010f)

Ecological character description sheet		
Site local and official name and coordinates	Natural status (as reported)	Changes and likely changes
1. Summary statement		
Two or three narrative sentences giving a statement of what is ecologically distinctive (not necessarily important) about the site, based on the details below. (With the combination of the components, processes and services that characterize the wetland and supplementing the summary statement with simple conceptual models of the key characteristics of the wetland is encouraged)		
2. Ecological components		
2.1. Geomorphic setting: Setting in the landscape/ catchment/ river basin - including altitude, upper/lower zone of catchment, distance to coast where relevant, etc.		
2.2. Climate: Overview of prevailing climate type, zone and major features (precipitation, temperature, wind)		

Ecological character description sheet		
Site local and official name and coordinates	Natural status (as reported)	Changes and likely changes
2.3. Habitat types: (including comments on particular rarity, etc.) and wetland types		
2.4. Habitat connectivity		
2.5. Area, boundary and dimensions (Morphometry): Site shape (cross-section and plan view), boundaries, area, area of water/wet area (seasonal max/min where relevant), length, width, depth (seasonal max/min where relevant)		
2.6. Plant communities, vegetation zones and structure (including comments on particular rarity, etc.)		
2.7. Animal communities (including comments on particular rarity, etc.)		
2.8. Main species present (including comments on particular rare/endangered species, etc.); population size and proportion where known, seasonality of occurrence, and approximate position in distribution range (e.g., whether near centre or edge of range)		
2.9. Soil: Geology, soils and substrates, and soil biology		
2.10. Water regime: Water source (surface and groundwater), inflow/ outflow, evaporation, flooding frequency, seasonality and duration; magnitude of flow and/or tidal regime, links with groundwater		
2.11. Connectivity of surface waters and of groundwater		
2.12. Stratification and mixing regime		
2.13. Sediment regime (erosion, accretion, transport and deposition of sediments)		
2.14. Water turbidity and color		
2.15. Light - reaching the wetland (openness or shading); and attenuation in water		
2.16. Water temperature		
2.17. Water pH		
2.18. Water salinity		
2.19. Dissolved gases in water		
2.20. Dissolved or suspended nutrients in water		
2.21. Dissolved organic carbon		
2.22. Redox potential of water and sediments		
2.23. Water conductivity		
3. Ecological processes		
3.1. Primary production (S)		
3.2Nutrient cycling (S)		
3.3. Carbon cycling		
3.4. Animal reproductive productivity		

Ecological character description sheet		
Site local and official name and coordinates	Natural status (as reported)	Changes and likely changes
3.5. Vegetation productivity, pollination, regeneration processes, succession, role of fire, etc.		
3.6. Notable species interactions, including grazing, predation, competition, diseases and pathogens		
3.7. Notable aspects concerning animal and plant dispersal		
3.8. Notable aspects concerning migration		
3.9. Pressures, vulnerabilities and trends concerning any of the above, and/or concerning ecosystem integrity		
4. Ecosystem services		
4.1. Drinking water for humans and/or livestock (P)		
4.2. Water for irrigated agriculture (P)		
4.3. Water for industry (P)		
4.4. Groundwater replenishment (R)		
4.5. Water purification/waste treatment or dilution (R)		
4.6. Food for humans (P)		
4.7. Food for livestock (P)		
4.8. Wood, reed, fibre and peat (P)		
4.9. Medicinal products (P)		
4.10. Biological control agents for pests/diseases (R)		
4.11. Other products and resources, including genetic material (P)		
4.12. Flood control, flood storage (R)		
4.13. Soil, sediment and nutrient retention (R)		
4.14. Coastal shoreline and river bank stabilization and stormprotection (R)		
4.15. Other hydrological services (R)		
4.16. Local climate regulation/buffering of change (R)		
4.17. Carbon storage/sequestration (R)		
4.18. Recreational hunting and fishing (C)		
4.19. Water sports (C)		
4.20. Nature study pursuits (C)		
4.21. Other recreation and tourism (C)		
4.22. Educational values (C)		
4.23. Cultural heritage (C)		
4.24. Contemporary cultural significance, including for arts and creative inspiration, and including existence values (C)		
4.25. Aesthetic and "sense of place" values (C)		
4.26. Spiritual and religious values (C)		
4.27. Important knowledge systems, and importance for research (C)		

Guidelines for management planning for wetlands

These guidelines focus on the site-based scale of management planning. Sites include a wide range of different applications since they vary in size, some have boundaries delimiting just a discrete wetland area, and others include surrounding non-wetland buffer zones, habitat mosaics, or catchment areas within their boundaries. It is therefore recognized that the application of these guidelines will need to be flexible, depending upon the particular characteristics and circumstances of each wetland.

The guidelines also recognize that site-based management planning should be one element of a multi-scalar approach to wise use planning and management and should be linked with broad-scale landscape and ecosystem planning, including at the integrated river basin and coastal zone scales, because policy and planning decisions at these scales will affect the conservation and wise use of wetland sites.

General guidelines

Wetlands are dynamic areas, open to influence from natural and human factors. In order to maintain their biological diversity and productivity (i.e., their ecological character), and to permit the wise use of their resources by people, an overall agreement is essential between the various managers, owners, occupiers and other stakeholders. The management planning process provides the mechanism to achieve this agreement.

The management plan itself should be a technical document, though it may be appropriate for it to be supported by legislation and in some circumstances to be adopted as a legal document. The plan should be kept under review and adjusted to take into account the monitoring process, changing priorities, and emerging issues.

The NWC and its respective sub-committees should implement the management planning process, and this authority should be clearly identified to all stakeholders. This is particularly important on a large site where there is a need to take account of all interests, users, and pressures on the wetland, in a complex ownership and management situation.

The guide is arranged in a series of sections designed to facilitate easy look-up when a manager is dealing with a particular aspect of the process, which is organized in the following sections:

1. Introduction

2. The need for management planning

3. Essentials of management planning

4. Successful wetland management planning

5. Knowing the wetland and its values

6. Setting management objectives

7. Achieving management objectives

8. Closing the planning loop

The size of a plan and the resources made available for its production must be in proportion to the size and complexity of the site, and also to the total resources available for the safeguarding and/or management of the site. Thus for small uncomplicated sites, brief, concise plans will suffice. For large or zoned sites, it may be appropriate to develop separate detailed plans for different sections of the site, within an overall statement of objectives for the whole site.

Integrating wetland site management within broad-scale environmental management planning, including river basin and coastal zone management

Wetland ecosystems are adapted to the hydrological regime and are vulnerable to change. For most wetlands, direct rainfall provides only a small proportion of the water regime, with the primary source being rivers or aquifers. Similarly, Ethiopian wetlands in the fringe zones of large bodies of water (e.g. deep lakes) are influenced by the quantity and quality of freshwater flowing into them from rivers and other land-based discharges.

Successful management of wetland sites therefore requires maintenance of these sources of water. The inter-connectedness of the hydrological cycle means that changes some distance from the wetland can have a detrimental impact. Insufficient water reaching wetlands, due to climate change, land use change, abstractions, storage and diversion of water for public supply, agriculture, industry and hydropower, are all major causes of wetland loss and degradation. A key requirement for wetland conservation and wise use is to ensure that adequate water of the right quality is allocated to wetlands at the right time.

The fundamental unit for water issues is normally the river basin (or catchment), as this demarcates a hydrological system in which components and processes are linked by water movement. The river basin will normally include a mixture of different land types, including wetlands, forests, and grasslands, agricultural and urban areas.

The term 'integrated river basin management' (IRBM) must be considered, as discussed above, for the purpose of a holistic approach, which in turn is actually complementary to Integrated Water Resource Management (IWRM) (see above). A key element of IWRM is that river basins are usually the most appropriate physical entity in which to plan the management of water.

As described in the water allocation section of this guideline allocation will be made on the basis of the benefits that water use will bring. Other stakeholders with competing water allocation requirements will include representatives of public water supply, energy, agricultural and industrial communities. All will have powerful arguments to justify their water requirements in terms of public health, food, and economic output, including employment.

Consequently, achieving water allocation for wetlands will often be a long process that needs careful planning and will include training and awareness-building about the benefits of wetlands. These benefits need to be presented in a manner in which the trade-offs with other water users can be evaluated. Some benefits, such as fisheries, can be given a monetary value that fits into a traditional financial analysis, but this is generally not the case for social, cultural and ecological benefits. A framework for decision-making needs to be established, such as multi-criteria analysis, that allows evaluation of all social, cultural and ecological values of wetlands as well as their economic values.

The functions of wetland management planning

The most important functions of a wetland management planning process and a management plan are:

(a) To identify the objectives of site management

This is the single most important function of the planning process. It is essential that management objectives be defined for each important feature of the ecological character of the site and for all other important features related to the functions and values of the site, including socio-economic, cultural and educational values. In other words, those responsible for developing the management plan must be clear about what they are trying to achieve.

(b) To identify the factors that affect, or may affect, the features

The ability to achieve wise use and conservation objectives for wetlands will always be influenced to some extent by a number of factors, including trends, constraints and obligations, in fact anything that has influenced, is influencing, or may influence the features of the site for which objectives are set. It is essential that all the important factors should be identified, and that their impact on the site, particularly on the features of its ecological character, be considered. For the most significant factors, it may be necessary to undertake Environmental Impact Assessments (EIA) as part of the planning process.

(c) To resolve conflicts

On most sites there will be some conflicts of interest and difficulty in identifying priorities. It is essential that the planning process should be recognized as a forum for resolving conflicts and establishing commitments for the future.

(d) To define the monitoring requirements

A function of monitoring, in the context of management planning, is to measure the effectiveness of management. It is essential to know, and to be able to demonstrate to others, that the objectives are being achieved. Thus, monitoring must be recognized as an integral component of management and planning. It should be designed to identify and manage change in ecological character of the site.

(e) To identify and describe the management required to achieve the objectives

In most cases where habitats or species require safeguarding, some action, i.e. management, will be necessary. Having established that a plan identifies the objectives of management, it follows that it must also identify, describe, and estimate the cost of the action required.

(f) To maintain continuity of effective management

Continuity of effective management and monitoring is essential. Management processes must be adapted to meet a wide range of varying factors. Although management will change as circumstances require, the purpose of management should remain more or less constant. This is why continuity of effective management must be maintained, and not simply the continuity of any specified process. Continuity of monitoring is as important as is continuity of management.

(g) To obtain resources

Management planning must identify and quantify the resources required to manage a site, and this should include the preparation of a detailed budget. This information can then be used to support and justify bids for resources. It is often difficult, particularly in developing countries, to allocate funds for the implementation of management plans, but it is essential that the management plan identify mechanisms for financing management. These mechanisms may include generating income on the site, for example, through tourism, harvesting of reeds, fishing, developing water tariffs, etc., and/or the establishment of a Trust Fund for the site or other long-term funding mechanism. In many cases it may be necessary to assess the capacity of the organization responsible for implementing the management plan at an early stage in its preparation. Shortfalls identified in the capacity assessment should be addressed in the Action Plan section.

(h) To enable communication within and between sites, organizations and stakeholders

Communication is essential within and between organizations and individuals. Management plans and the management planning process are a means of presenting information in a structured and accessible format that will inform others about the site, the aims of management, and the management processes. Planning and management for the maintenance of ecological character are largely dependent on the availability of information. It is also important that those responsible for developing the plan should be aware of management techniques and procedures developed or improved elsewhere. The communications, education and public awareness (CEPA) components of the plan from its inception to full implementation should be clearly defined.

(i) To demonstrate that management is effective and efficient

Those responsible for developing the plan must always be in a position to demonstrate that they are making the best use of resources and that management will be effective. In other words, the plan should provide the basis for any cost benefit analysis. It is also important that the need for accountability is recognized.

(j) To ensure compliance with local, national, and international policies

It is essential that the management plan recognizes and is compliant with a wide range of policies, strategies, and legislation. Occasionally policies may be contradictory, and consequently one of the functions of a plan must be to integrate the various policies. A National Wetland Policy and related national biodiversity plans and policies provide the context and framework for the development of a site management plan. In particular, the plan should contribute to the implementation of the National Wetland Policy and/or national biodiversity strategy and other related plans and policies.

Stakeholders, including local communities and indigenous people

Wetland management, and particularly the planning process, should be as inclusive as possible. Legitimate stakeholders, particularly local communities and indigenous people, should be strongly encouraged to take an active role in planning and in the joint management of sites. It is highly desirable that positive steps be taken to ensure that gender issues, including women and their interests, are fully taken into account at all stages in the process. If necessary, appropriate incentives to ensure full stakeholder participation should be identified and applied.

Stakeholder interests can have considerable implications for site management, and will place significant obligations on managers. Public interest, at all levels, must be taken into account. Wetland managers must recognize that other people may have different, and sometimes opposing, interests in the site. It is essential that these interests be safeguarded wherever possible, but this must not be to the detriment of the features of the ecological character of the site. Any use of the site must ultimately meet the test of compatibility with the wise use and conservation purpose and objectives, and this is of added significance where the site has been designated as a Wetland of International Importance.

Consultation with and participation by stakeholders

- It is particularly important that stakeholders be informed at the earliest possible stage about an intention to produce a management plan, but at this stage it should not be confused with formal negotiation. The most important early message is that everyone will be consulted and involved and that all interests will be given proper consideration. Management planners must convey the message that they are open-minded and will deal as objectively as possible with all issues. Relevant stakeholders should include not only local communities but also local government (including all sectors whose decisions can affect the management planning process and its objectives) and the private sector.

- Consultation and negotiation should be about presenting ideas or proposals for discussion and seeking views about specific issues. A structured planning process should generate ideas and proposals – unfocused discussion is rarely conclusive and can be counterproductive.

- Before any consultation, managers must know what they are attempting to achieve, and should define those areas that are open to negotiation. For issues that are open to discussion, a range of well-considered options should be given. Every effort must be made to be inclusive and to achieve consensus, supporting the wise use of resources without compromising the natural integrity of the unit.

- Before embarking upon a plan, it will be necessary to collect or collate all available relevant information about the site in order to describe its ecological character and its functions and values, including all relevant socio-economic, cultural and educational features. Professionals in the natural and social sciences should be involved to ensure effective collection of all relevant data. Local people and other stakeholders are usually an important source of information, and they should be involved through appropriate and proven techniques that are sensitive, among others, to gender and cultural issues, in the data and information collation stage of the process.

- Once data collation and the preparation of the descriptive sections of the plan are complete, the process moves on to preparing management objectives concerning the maintenance of the ecological character and other aspects of interests to stakeholders. The protection of the features of the ecological character is the prime concern and should not be considered negotiable. However, it is important to bear in mind that these features are very often present because they are, and will need to be, maintained by local people. It is very important when introducing the concepts of designation and management planning to stakeholders that they do not gain the impression that the process will curtail legitimate activities, unless such activities could threaten important features or are potentially unsustainable.

- Then move on to identify the management requirement. At this stage, negotiation with stakeholders becomes essential. While the objectives concerning the maintenance of the ecological character should not be negotiable, it is often possible to identify a range of alternative management approaches that would meet them whilst at the same time assisting in achieving other objectives of interest to different stakeholders.

- Finally, management plans should be regarded as public documents, and all stakeholders should be given access to the plan.

The precautionary approach as applied to environmental management

When considering the carrying capacity of a site for any human use, activity or exploitation (i.e., its sustainability), the best available evidence should indicate that the activity will not be a threat to the features of the ecological character of the site.

Stakeholders lead by the NWC are, when implementing their wetland management planning process, invited to take into consideration the precautionary approach, where it shall be applied by countries like Ethiopia according to their capabilities.

Inputs, outputs, and outcomes

Inputs are **t**he resources provided for site management, for example, finance, staff and equipment.

Outputs are **t**he consequential by-products of management or the management planning process. For example, policies are developed for the various management activities, management plans are prepared, interpretation is provided, and a management infrastructure is developed and maintained. Often, outputs are used as a means of assessing whether management is appropriate.

Outcomes are the purposes of management. These are the favourable conditions of the ecological character features, such as habitats and species on the sites, which in turn may depend upon the effective management of particular socio-economic parameters, such as ensuring sustainable fisheries or adequate marketing of rice production and/or equitable distribution of the benefits of tourism.

The only means of judging whether or not inputs and outputs are adequate is by considering the outcomes of management. When this has been done, and only then, it will be possible to determine whether the management is appropriate.

Adaptable management

In order to safeguard sites and their features, managers must adopt a flexible approach that will allow them to respond to the legitimate interests of others, adapt to the ever-changing political climate, accommodate uncertain and variable resources, and survive the vagaries of the natural world.

The adaptable management process is described in five steps and a model showing how these steps operate.

(a) A decision is made about what should be achieved (i.e., quantified management objectives are prepared for the important features).

(b) Appropriate management, based on the best available information, is implemented to achieve the objectives.

(c) The features are monitored in order to determine the extent to which they meet the objectives.

(d) If objectives are not being met, management is modified.

(e) Monitoring is continued to determine if the modified management is meeting the objectives, and **Step (d)**, above, is repeated for any further adjustments, as necessary.

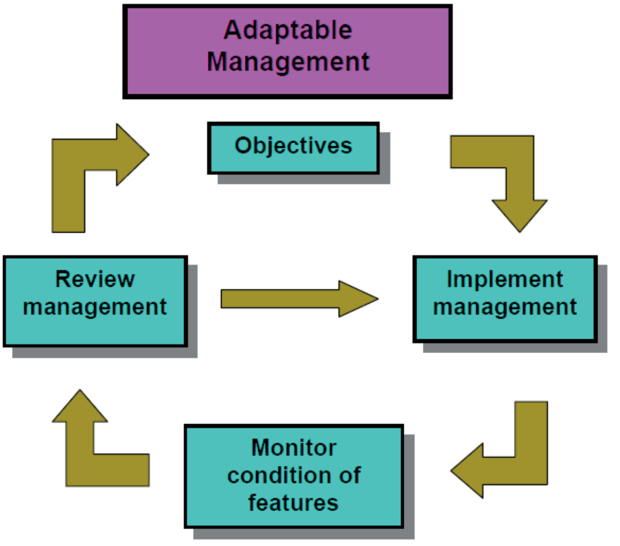


Figure 6.6 : The adaptable management model (RCS, 2010f)

The adaptable management cycle is usually repeated at predetermined intervals. The interval should be established to take into account the nature and in particular the fragility and rate of change or dynamics of the site features or ecological characters.

Management units, zonation and buffer zones

- Where a wetland site is composed of more than one discrete sub-site separated by areas of other land use (for example, discrete wetlands along the floodplain of a major river), separate management plans for each sub-site may be appropriate. However, such individual sub-site plans must fit under the umbrella of an overall plan that should be prepared before those for the sub-sites.

- When the wetland in question does not include a buffer zone, it is generally appropriate for management planning purposes to identify and establish such a buffer zone around the core wetland area.

- The location of a buffer zone in relation to the core wetland area of the wetland in question will vary depending upon what ecosystems are included within the site boundaries.

- Any zonation scheme should recognize the existing multiple uses of the wetlands in question and their surroundings, and ensure that management objectives for the core zone are designed primarily to maintain the ecological character of the wetland, as well as that those for any form of surrounding buffer zone are consistent with this maintenance of the ecological character. Clear, separate but complementary and mutually supportive management objectives should be established for each zone.

- The establishment of a zonation scheme should involve full stakeholder participation from the earliest stage, since it is in 'drawing the lines' between zones that many conflicts can materialize. Establishing zonation and management objectives for each zone (and hence what activities should and should not be permitted within each zone) is an important part of the process of establishing a close involvement of local communities, indigenous peoples, and other stakeholders in the management of the wetland.

- Some general rules should be applied when establishing zones, regardless of their type and purpose:

  (a) Zonation should be established with the full involvement of stakeholders, including local communities and indigenous peoples;

(b) A full and detailed rationale should be made to explain the basis for establishing and delineating zones and this is particularly important when establishing the limits of buffer zones;

(c) A concise description of the functions and/or restrictions applied within each zone must be prepared as part of the management plan;

(d) Zones should be identified with a unique and, if possible, meaningful code or name: but in some cases, a simple numerical code may be adequate;

(e) A map showing the boundaries of all zones must be prepared;

(f) Where possible, zone boundaries should be easily recognizable and clearly identifiable on the ground: physical features (for example, fence lines and roads) provide the best boundaries, and boundaries based on dynamic features, such as rivers, mobile habitats, and soft coastlines, must be identified with some form of permanent marker; and

(g) on large, uniform sites, or in areas of homogeneous habitat crossed by a zone boundary, fixed permanent markers with locations mapped using a Global Positioning System (GPS) should be used.

Format of the management plan

The format of the management plan, as recommended in these guidelines, should comprise five main sections, reflecting the main steps in the management planning process:

(a) Preamble/policy

(b) Description

(c) Evaluation

(d) Objectives

(e) Rationale

(f) Action Plan

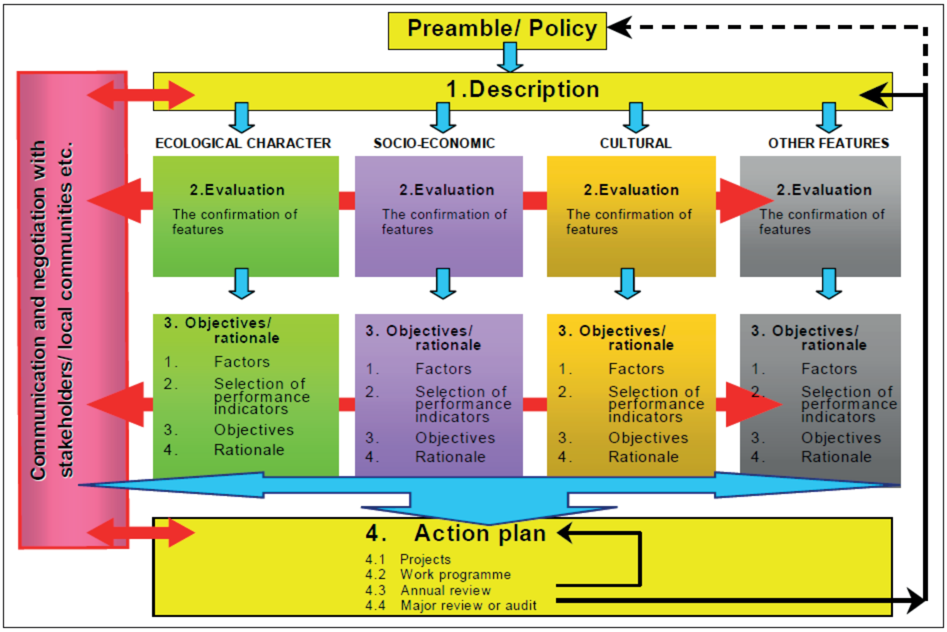


Figure 6.7: Recommended structure and content of a management plan for wetlands (RCS, 2010f)

Some details of the above management plan components

Preamble / policy

The preamble is a concise policy statement that should reflect, in broad terms, the policies and/or practices of supranational, national, or local authorities and other organizations and traditional management systems, including, for example, non-governmental bodies, local communities or private owners' resource management arrangements that are concerned with the production and implementation of the management plan. The preamble should also recall the broad international requirements, if any; namely the maintenance of the ecological character of the Wetland's of International Importance, the wise use of all wetlands, the establishment of nature reserves at wetlands, whether or not they are included in any List, and international cooperation where appropriate to the management of the site, in particular in the case of shared wetlands and water systems.

Description

The description is an important part of the management planning process. It provides the information used to fuel the rest of that process. The description is fundamentally a collation and synthesis of existing data and information. The identification of any shortfall of relevant data and information is also a key function of this part of the process. The description should be regularly reviewed and updated, so as to incorporate new sources of data and information, including updates from time-series monitoring.

Evaluation

Evaluation is the process of identifying or confirming the important features or foci for management planning. The figure above indicates that evaluation of important features should be undertaken for each of four major areas of interest, and the evaluation process must be applied to each in turn. For any wetland, evaluation should be undertaken for ecological character features, as well as for socio-economic features, cultural features, and any other important features identified.

Evaluation criteria must be developed for each feature of interest or major ecological characters the influence the wellbeing of the specific wetland in question. A list of criteria for evaluating ecological character features such as the ones indicated below should be developed.

Criterion 1: Size

Criterion 2: Biological diversity

Criterion 3: Naturalness

Criterion 4: Rarity

Criterion 5: Fragility

Criterion 6: Typicalness

Criterion 7: Potential for improvement and/or restoration

Additional but by no means inferior, features other than ecological characters must be included under the title:

> Evaluation of other features of importance on wetland sites: Most wetlands contain other features of equal importance, for example, cultural, socio-economic, geological and geomorphological features, landscape and palaeo-environmental features. It is important that these features be given appropriate attention and that the full management planning process be followed for each. This is particularly important in relation to ensuring the involvement and input of all stakeholders.

Objectives

An objective is an expression of something that should be achieved through management of the site. Objectives should have the following characteristics:

(a) Objectives must be measurable. Objectives must be quantified and measurable. If they are not measurable, it will be impossible to assess through monitoring whether they are being achieved.

(b) Objectives should be achievable, at least in the long term.

(c) Objectives must not be prescriptive: They define the condition required of a feature and not the actions or processes necessary to obtain or maintain that condition. Objectives are an expression of purpose.

Rationale

The rationale section of the management plan is devoted to identifying and describing, in outline, the management considered necessary to maintain the site features in (or restore them to) favorable status. Decisions in this section are based on a second assessment of the factors. This time, the discussion focuses on seeking management solutions in order to bring the factors under control. Control can mean the removal, maintenance or application of factors. For example, grazing is an obvious factor for wet grassland habitats. Options to be considered here could include removing, reducing, maintaining current levels, increasing, or introducing grazing.

Action plan

This section is a continuation of the rationale. In the rationale, the need for, and the nature of, possible management will have been discussed. The outcome should be an outline of the management processes considered most appropriate to safeguard each ecological character or other feature of a wetland. The function of the management project is then to describe in detail all the management work that will be associated with each feature.

For each management project plan, it is important that the following issues be given attention:

When indicating when the work will be carried out and for how long

Where indicating where on the site activities will take place

Who indicating who will do the work and how much time will be required

Priority indicating what priority is given to the project, and,

Expenditure indicating how much the work will cost

Once the management projects have been developed, for operational purposes it can be appropriate to compile the suite of management projects into an annual Operational Plan which is designed to guide and assist in monitoring implementation. The action plan should therefore include:

Planning for visitors, tourism and recreation

Short-term reviews should be made to confirm that a site is being managed in accordance with the requirements of the plan.

Annual review

Major review or audit: This should be considered as an essential component of any planning process. The functions of audit are to:

(a) Assess whether or not a site is being managed at least to the required standard;

(b) Confirm, as far as possible, that management is effective and efficient; and

(c) Ensure that the status of the site features is being accurately assessed.

After having the management plan completed, designing a monitoring and risk assessment program are requirements to determine the improvements made per time and per resources utilized to effectively report to stakeholders the efforts they put into the wise use of their wetlands.

6.2.14. Managing groundwater (RCS, 2010g)

Background: Guidelines for the management of groundwater to maintain wetland ecological character

In many countries, particularly in arid areas, groundwater is vital to the livelihoods and health of the majority of the people, since it provides almost the entire water resource for domestic, agricultural and industrial use.

Ecosystem processes that help maintain groundwater supplies must be protected and restored where degraded. Groundwater also supports many ecosystems that provide a wide range of benefits/services to people. Integrated management of ecosystems and natural resources is therefore an essential element in maintaining our planet. It is also the case that many wetlands worldwide have close associations with groundwater and that a wetland may depend on the outflow from an aquifer as a water source or the downward seepage of water from the wetland may replenish an aquifer. In such cases, the hydrology of the aquifer and the health of the wetland ecosystem are closely connected. Importantly, this relationship can be disrupted by changes either to the aquifer, such as by groundwater abstraction, or to the wetland, for example by reduced natural inundation of wetlands overlying aquifers.

Water inputs to wetlands often include both surface runoff and groundwater inflow in various combinations. Hence, ensuring the successful delivery of allocated water to a wetland will require integrated management of associated surface and groundwater resources. This in turn will require a sound quantitative understanding of the origins (surface and/or sub-surface), pathways and variability of water flows in and out of the wetland in order to develop water abstraction strategies that minimise or prevent unacceptable levels of change in ecological character of the wetland.

Consequently, the management of groundwater-associated wetlands, like other wetland types, must be closely linked to the management of water resources. The river or catchment basin provides the fundamental unit of management for rivers and other surface water systems. However, in cases where groundwater dominates the hydrological regime, the most appropriate management unit will be the aquifer unit, particularly where the aquifer boundaries do not coincide with surface river basin boundaries. Such cases of wetlands in Ethiopia are common particularly those found in arid zones (greater evapotranspiration than rainfall) that rely on groundwater to maintain their annual water budget, such as the lakes in Afar Region and the case of the outstanding Lake Basaka.

Many wetlands are hydrologically and ecologically linked to adjacent groundwater bodies, but the degree of interaction can vary greatly. Some wetlands may be completely dependent on groundwater discharge under all climatic conditions, whilst others may have very limited dependence, such as only under very dry conditions and some may have no connection with groundwater at all.

It is essential that the NWC and its subordinate sub-committees, government, regional and private stakeholders concerned with protection and maintenance of the ecological character of wetlands should be able to influence and make input to groundwater management plans and strategies. It is also necessary, however, to identify what level of technical input into water resources management is needed from wetland managers. There may be cases where the wetland-groundwater interaction is very limited or absent altogether, and abstraction of groundwater from local aquifers may have very little, if any, impact on wetlands. On the other hand, there are cases when abstraction of groundwater from a deep aquifer at a considerable distance from the wetland can have unforeseen but very significant impacts on the hydrology and hence the ecological character of a wetland, as in the case of Lake Haramaya in Eastern Ethiopia.

A screening study at river basin or regional scale, undertaken by a team of specialists with geological, hydrological and ecological expertise (including GIS tools), should allow wetland and water resources managers to identify areas where there is high potential for wetlands to be dependent to some degree on groundwater, and hence where more detailed studies or field assessments might be necessary in order to ensure that the groundwater needs of wetlands in these areas are accounted for in any groundwater management plan.

The first step in understanding wetland hydrology involves identifying which water transfer mechanisms (see below) are present in a wetland and which of these are the most important. Whether movement of groundwater to or from a wetland is an important mechanism depends not only on the presence of an aquifer, but also on the nature of the soils and rocks between the aquifer and the wetland.

Quantifying water transfer mechanisms

A prerequisite to assessing the implications for a wetland of any external hydrological impacts is to understand the ways in which water enters and leaves the wetland (termed water transfer mechanisms) and to quantify the associated rates of water movement. Basically, groundwater can enter a wetland directly from a spring (spring flow), by lateral movement from an adjacent aquifer (seepage), or by upward movement from an underlying aquifer (discharge). Water usually moves from a wetland to an aquifer by downward movement (recharge).

A scoping study to identify the potential (presence/absence) for significant connectivity between a wetland and related groundwater bodies may only require an initial desktop assessment. However, determining the sustainable yield and permitted abstraction from an aquifer is likely to require intensive specialist field studies and monitoring over time. In general, there are three levels of assessment that can contribute to understanding and quantifying water transfer mechanisms:

- **(a) Desk based information**: Investigations normally start with information available in the office. Spatial data will often include topographical, land use/vegetation, and geological maps and photographs taken from aircraft or satellites. Old photos have proved to be very useful in explaining hydrological links with wetlands, where restoration practices benefit from historical knowledge. Geological maps can reveal the proximity of aquifers to the wetlands.
- **(b) Field visits**: Field visits should be undertaken at an early stage in any investigation. Where possible the field team should be multi-disciplinary,

including a hydrologist, hydro-geologist, and botanist. It is particularly advisable to try and visit the wetland (a) after prolonged rainfall to see if springs or ephemeral water courses can be identified and (b) after a prolonged dry spell when vegetation patterns may indicate areas where the wetland is reliant on groundwater during the dry season or droughts. Photographs should be taken to record specific features, such as weirs or sluices, vegetation distribution, and channel networks. Auger holes should be dug to investigate soil properties of the wetland, particularly to identify areas of permanent water-logging in the dry season that may reflect reliance on groundwater. Where possible, local people such as farmers should be interviewed to gain anecdotal information about potential water transfer mechanisms or changes to the site – for example, are there springs feeding the wetland and are these perennial? This information should provide an on-the-ground check (ground-truthing) of the office-based conceptual model or identify new aspects that have not been covered.

(c) **Field measurement and monitoring programmes**: The quantification of groundwater exchanges with wetlands requires field data. Whilst some data, such as groundwater levels, may be available from hydrometric services, most wetland studies require the collection of field data for the site in question. These data may include dip well or piezometer levels from the wetland soil or the underlying aquifer and soil properties, such as specific yield or hydraulic conductivity. Based on initial understanding, field monitoring programmes will need to be established to collect the necessary data, i.e., over a specific time period rather than a once-off assessment. The data will support the generation of more detailed understanding and construction of associated numerical models.

Testing understanding through water balances

Estimating a water balance, which involves quantifying water transfer rates, provides a means of testing hydrological understanding. The principle of balancing inputs, storage and outputs provides a check that all water transfers have been correctly accounted for and quantified.

Water transfer mechanism inputs to the wetland		Water transfer mechanism outputs from the wetland		Internal change
P: precipitation (rainfall, snow, dew etc) directly on the wetland + R: surface and shallow subsurface inflow to the wetland + L: lateral inflow + OB: over-bank inflow + PU_i: water pumped into the wetland + S: spring flow + GD: groundwater discharge into the wetland + GS: groundwater seepage into the wetland + TI tidal inflow from the sea to the wetland	=	E: evaporation from the wetland + D: drainage + OF: overland outflow + PU_o: water pumped out of the wetlands + GR: groundwater recharge to aquifers + TO tidal outflow from the wetland to the sea	+	**δV:** change in volume of water stored within the wetland which can be positive (increase) or negative (decrease)

Figure 6.8: Balancing potential water transfer mechanism inputs to and outputs from a wetland (RCS, 2010g)

The water balance of a wetland is based on comparing the total quantity of water transferred into a wetland with the total quantity of water transferred out. Therefore, the following relation can be deduced (*ibid*).

$$\underbrace{(P + R + L + OB + PU_i + S + GD + GS + TI)}_{\text{inputs to the wetland}} - \underbrace{(E + D + OF + PU_o + GR + TO)}_{\text{outputs from the wetland}} = \delta V$$

According to the above relationship, if inputs exceed outputs, storage (V) will increase and the water level in the wetland will rise. If inputs are less than outputs, storage (V) will decline and the water level in the wetland will fall.

Uncertainty in understanding use of the water balance equation

It is not possible to measure any rates of water transfer exactly, and thus it is inevitable that quantification of the water balance will not be precise. Although uncertainty is often perceived as a negative issue (often associated in people's minds with user error), it is a fact of life, especially when dealing with natural systems, and should be presented explicitly rather than hidden. Where possible, the uncertainty (or level of confidence) associated with any water transfer mechanism should be estimated. Future effort can then be focused on the better measurement of the most uncertain mechanisms. One approach to the estimation of uncertainty is to quantify the rate of flow in each water transfer mechanism using various different methods. The range in results generated using different methods helps define the certainty with which the water transfer mechanism has been defined. If it is not possible to choose between different estimates of water transfer mechanisms, a mean value can be adopted but the range in values is useful when testing the water balance.

The water balance is tested by comparing the volume of inputs with the volume of outputs. If the volumes match approximately, then the water balance is said to be "closed". However, since all measurements of water transfer mechanisms have some uncertainty, the water balance will never close exactly. In practice, the balance is thought to be satisfactory if the imbalance is within the uncertainty of the measurements.

Defining boundaries for the water balance

Where possible, the water balance should be undertaken for the wetland itself as a single hydrological unit. However, where it is appropriate to subdivide the wetland into hydrologically distinct units, water balances should be calculated separately for the different hydrological units. This would be the case where, for example, a weir controls water levels in different parts of a wetland or when the wetland in question is large in size and warrants subdividing. It may also be prudent to divide the wetland into different hydrological units if different water transfer mechanisms are evident.

Choice of time step in the water balance

The time step (e.g., monthly, seasonal, annual) that is used for the water balance is normally chosen to suit the information needs, the objectives of the study and the availability of resources (time, qualified experts, finance, etc.). If results are needed rapidly, data that are readily available must be used. Rainfall data are widely available as daily values, whereas groundwater data tends to be recorded monthly. Dip wells in wetlands, which monitor water table levels, are normally read at fortnightly or monthly intervals. This is because the relatively low hydraulic conductivity of some wetland soils means that well levels only change significantly over these intervals and hence daily or higher resolution measurements are often not essential.

Period of record

In general, the period analysed should be as long as possible and should include wet, dry, and more 'normal' periods that cover the basic variability of climate at the site. Clearly where long records exist, it may be possible to undertake analysis of the impacts of climate fluctuations or change, but such data sets are rare. Where only short records are available for the wetland site of interest, the period of record should be classified as dry, wet, or normal by reference to other longer term rainfall, river flow, or groundwater level data. Whatever the record length used, it is always advisable to continue or undertake monitoring after the assessment has been undertaken to allow later appraisal of the results when more data have been collected and to refine the water balance at that time.

Predicting hydrological impacts through modeling

The water balance approach described above can assist with testing understanding of which water transfer mechanisms are present and the volume of water movement involved in each. However, the water balance cannot provide definitive determination and prediction of the implications for the wetland of hydrological impacts, such as groundwater abstraction. It also does not contain information about timing and frequency of hydrological events. To define these hydrological properties, a more detailed modeling approach is required. It is not within the scope of this guidance to advice on specific modeling types: specialist modeling experts should be consulted so that the appropriate model or models for a specific wetland can be employed.

It is important to note that merely collecting more data and using a more complex model does not in itself guarantee that understanding will be improved. Even where it is anticipated that a complex model will be required eventually, analysis should always start with a simple conceptual picture of the wetland that becomes more complex as understanding develops. It is essential that there is first a correct conceptual understanding of the water transfer mechanisms. Then modeling can be used:

- To generate quantitative information about the processes that drive the water transfer mechanisms;
- To understand temporal and spatial variability of the processes; and
- To predict what will happen under climatic or water management scenarios beyond the range of data that are available for the wetland.

Framework for the development of groundwater management strategies to maintain wetlands

For the present, a preliminary seven-step framework has been developed as shown in the table below. This contains key issues or areas of concern where wetland managers should communicate and collaborate with water resources managers in order to ensure that the protection and maintenance of wetland ecosystems is taken into account in groundwater and surface water management planning.

Table 6.3: Correspondence, in relation to the maintenance of the ecological character of wetlands, between steps in the groundwater management framework and steps in the River Basin Management (RBM) Critical Path (RCS, 2010g)

Groundwater management framework (Steps A to G)	RBM Critical Path (Steps 1 to 9)
Step 1: Policy, regulatory and institutional contexts	
Step 2: Design stakeholder participation process	
Step A: Screening to identify wetlands potentially associated with groundwater	Step 3(i): Inventory of wetlands in the basin
Step 3(ii): Assessment of current status and trends	
Step B: Conceptual model of groundwater-wetland interactions.	Step 3(iii): Determine water resource function of wetlands
Step C: Situation assessment of combined impacts, status and trends, with focus on groundwater-wetland interface	
Step 4: Set relative priorities for wetlands in the basin	
Step D: Determine groundwater requirements of wetlands	Step 5: Set quantitative management objectives for wetlands
Step E: Agree on and set groundwater allocation for wetlands, and limits on groundwater exploitation.	
Step F: Specify groundwater-related management actions and strategies for wetlands in the basin, and include these in the land and water management plan for the basin.	Step 6: Water and land use management plan for the basin
Step 7a: Implementation at wetland level Step 7b: Implementation at basin level	
Step G: Monitoring and evaluation related to groundwater	Step 8: Monitor and report at basin and wetland level
Step 9: Review, reflect and revisit priorities	

Descriptions of the seven steps in the above table (A - F)

Step A: Screening to identify wetlands potentially associated with groundwater

Wetlands in the landscape should be considered in three dimensions: the more commonly understood lateral shape and size of a wetland, and its morphology, are influenced most strongly by topography and hydrology. However, no understanding of a wetland's water-related functions can be complete without also considering the geological setting of a wetland. Depending on the underlying and surrounding geology, a wetland will be more or less strongly associated with and dependent on groundwater. Screening at river basin level should indicate the likelihood of wetlands in the basin being strongly associated with groundwater, and may indicate the kinds of interactions that can be expected. However, more detailed studies, possibly including field visits, would be needed to confirm these associations in the case of individual wetlands.

Screening will involve overlaying maps of geology, vegetation and land use. In addition, general figures on recharge and abstraction rates should be assembled (these will probably be available from existing water resource management plans) to determine where groundwater resources are exploited. The outcome of the exercise will be to identify wetlands that are linked to groundwater (either as recharge or discharge sites) and that require further detailed study.

Step B: Development of a conceptual model of groundwater-wetland interactions for wetlands in the basin

For each wetland identified in the screening exercise that may be impacted by current or future groundwater exploitation, a conceptual model should be developed. This could be a simple desktop exercise or might involve detailed field surveys and numerical modeling. The conceptual model development should begin by defining water transfer mechanisms through which water moves into and out of each wetland. Calculating a water balance can help to quantify the contributions of water from various sources and any groundwater recharge to aquifers. The water balance should be calculated for different seasons and for wet and drought conditions. Uncertainty in estimating the magnitude of water transfer mechanisms should be made explicit to provide a risk context.

This information is necessary to quantify a wetland's dependence on groundwater, and conversely an aquifer's potential dependence on associated wetlands, so that the groundwater requirements of associated wetlands can be quantified, and conversely so that the water requirements of wetlands for the purpose of groundwater recharge can be quantified as well.

Step C: Situation assessment of combined impacts, status and trends

In most river basins containing exploitable groundwater resources, there may be numerous individuals and/or companies abstracting water from boreholes, and this abstraction may not be adequately controlled, especially when groundwater is considered to be private water in law. Additional surface water abstractions may or may not be known and controlled.

It is vital that any assessment of the current status of groundwater-associated wetlands also include assessment of the separate and combined impacts of both abstraction from and discharge to groundwater and surface water bodies in the basin. It is equally important to consider how changing surface land cover and soil characteristics can affect the recharge of an aquifer and hence the water supply to the wetland. Wider scenarios of climate or land use change for the catchment or aquifer unit should be used to assess how groundwater-wetland interactions may change in the future.

Step D: Determination of groundwater requirements of wetlands

The groundwater requirements of wetlands should be made explicit so that they can be included when determining the sustainable yield of the aquifer and subsequent allocation of available water resources to different uses. In this way the implications for wetland health of different groundwater allocation options can be seen by water managers and society at large and included within basin water allocation plans. In many cases there will not be sufficient water available to satisfy all demands. However, if the implications for ecological character and dependent livelihoods are known to decision-makers, wetland water needs can be considered along with other water uses.

Sufficient water should be allocated for surface or subterranean wetlands which are dependent on the aquifer, in order to maintain desired ecological character, although this may require a trade-off with abstraction being permitted for industrial, domestic or agricultural purposes. Bulk water allocations from groundwater, including allocations for the maintenance of wetlands, should be determined concurrently at the basin or aquifer unit scale and at the individual wetland scale.

Step F: Inclusion of groundwater-related management actions and strategies in the land and water management plan for the basin

Some strategies specifically related to groundwater may be included in the land and water management plan for the basin, in order to minimize the impacts of groundwater exploitation on associated wetlands. For example:

- Groundwater may be the most important water source for a wetland at particular times of the year, such as the dry season or during periods of drought, so higher abstraction may be permitted during wet periods when the wetland is not at risk, in order to offset reduced abstraction when the wetland is in critical need.

- Boreholes should not be located close to the wetland where the cone of depression would reduce water levels in the wetland and cause degradation of ecological character.

- Where wetlands are fed jointly by surface and groundwater, potential exists for meeting water needs in different seasons from different sources (i.e., conjunctive management). For example, a wetland previously fed by groundwater could be sustained or rehabilitated by surface flow releases from an upstream dam. However, it is also vital that the water quality needs of the wetland be considered, as surface water quality may be quite different from the quality of the groundwater.

Step G: Monitoring and evaluation related to groundwater

Especially in the case where wetlands are associated with large regional aquifers, whose boundaries may extend beyond the watershed, it is necessary to monitor the status of the groundwater resource and demands on groundwater, concurrently with monitoring of the status and response of wetlands to changes in groundwater availability. There should also be long-term monitoring of trends in groundwater levels at sites or in regions where intensive exploitation of the resource occurs, or is likely to occur in future, including instances of wide adoption of small-scale groundwater harvesting methods (e.g., multiplicative effects of use of groundwater treadle pumps by small-scale farmers for agriculture).

Wetland vegetation can provide an early warning indicator (e.g., for water stress) of over-abstraction in the short term. Long-term data sets on groundwater characteristics and variability are generally limited, partly because groundwater is difficult to measure, partly because groundwater level and quality tend to vary slowly in response to climatic or other forcing, and hence measuring periods need to be significantly longer in order to establish natural spatial and temporal patterns of groundwater variability. The general lack of data means that an adaptive approach to setting and implementation of objectives is essential. An appropriate monitoring program should be implemented to feed back information in order to refine the conceptual model, and subsequently to refine the determinations of groundwater requirements of wetlands and refine or review the actual groundwater allocations made for wetlands as a form of adaptive management.

References

Abebe, Delelegn and Geheb, K. (2003). Wetlands of Ethiopia. Proceedings of a seminar on the resources and status of Ethiopia's wetlands, vi + 116pp.

Amin, A., Mubeen, M., Hammad, H. M., and Nasim, W. (2015). Climate Smart Agriculture: an approach for sustainable food security. *Agric. Res. Commun.* 2(3): 13-21. ISSN online: 2410-3578

FAO (2013). Climate Smart Agriculture Sourcebook. Food and Agriculture organization, Rome, Italy.570 pp.

Girma Hailu (2000). Environment Law Ethiopia. (Kulwer Law International, Leuven, Belgium, Addis Ababa, Ethiopia.

Guidance for environmental implementation and management plans (Draft 3rd edition) (2013). http://www.energy.gov.za/files/tenders/2013/DOE021201314/EIMP-Guidelines-1October2013.pdf

Kipkoech Anderson K., Tambi Emmanuel and Bangali Solomon FARA (2015). State of Knowledge on CSA in Africa, Case Studies from Ethiopia, Kenya and Uganda Forum for Agricultural Research in Africa, Accra, Ghana

MBWSR (Minnesota Board of Water and Soil Resources) (2009). Wetlands restoration strategy: A framework for prioritizing efforts in Minnesota, USA. www.bwsr.state.mn.us.

Nelson, S. and Huyer, S. (2016). A gender-responsive approach to climate-smart agriculture: Evidence and guidance to practitioners. Spnsored by Global Alliance for Climate-Smart Agriculture (GACSA), FAO, CGIAR and CCAFS.https://ccafs.cgiar.org/climate-smart-villages

Njeru, E., Grey, S. and Kilawe, E. (2016). Eastern Africa Climate-Smart Agriculture Scoping Study: Ethiopia, Kenya and Uganda. Sponsored by FAO (2016), Addis Ababa, Ethiopia

Peters, M. and Clarkson, B. (editors) (2010). Wetland restoration: A handbook for New Zealand freshwater systems. Lincoln, N.Z.: Manaaki Whenua Press (printed ISBN: 978-0-478-34706-7; online ISBN: 978-0-478-34707-4).

RCS (Ramsar Convention Secretariat) (2010a). Wetland CEPA: The Convention's Program on communication, education, participation and awareness (CEPA) 2009-2015. Ramsar handbooks for the wise use of wetlands, 4thedition, Vol. 6. Ramsar Convention Secretariat, Gland, Switzerland.

RCS (Ramsar Convention Secretariat) (2010b). International cooperation: Guidelines and other support for international cooperation under the Ramsar Convention on Wetlands. Ramsar handbooks for the wise use of wetlands, 4thedition, Vol. 20; Ramsar Convention Secretariat, Gland, Switzerland

RCS (Ramsar Convention Secretariat) (2010c). Inventory, assessment, and monitoring: an Integrated Framework for wetland inventory, assessment, and monitoring. Ramsar handbooks for the wise use of wetlands, 4th edition, vol. 13. Ramsar Convention Secretariat, Gland, Switzerland; 58 pp.

RCS (Ramsar Convention Secretariat) (2010d). Wetland inventory: A Ramsar framework for wetland inventory and ecological character description. Ramsar handbooks for the wise use of wetlands, 4th edition, vol. 15. Ramsar Convention Secretariat, Gland, Switzerland; 82 pp.

RCS (Ramsar Convention Secretariat) (2010e). Water allocation and management: Guidelines for the allocation and management of water for maintaining the ecological functions of wetlands. Ramsar handbooks for the wise use of wetlands, 4th edition, vol. 10.Ramsar Convention Secretariat, Gland, Switzerland.

RCS (Ramsar Convention Secretariat) (2010f). *River basin management: Integrating wetland conservation and wise use into river basin management.* Ramsar handbooks for the wise use of wetlands, 4th edition, vol. 9. Ramsar Convention Secretariat, Gland, Switzerland, 90 pp.

RCS (Ramsar Convention Secretariat) (2010f). Managing wetlands: Frameworks for managing Wetlands of International Importance and other wetland sites. Ramsar handbooks for the wise use of wetlands, 4th edition, vol. 18. Ramsar Convention Secretariat, Gland, Switzerland.

RCS (Ramsar Convention Secretariat) (2010g). Managing groundwater: Guidelines for the management of groundwater to maintain wetland ecological character. Ramsar handbooks for the wise use of wetlands, 4thedition, vol. 11, Ramsar Convention Secretariat, Gland, Switzerland

RCS (Ramsar Convention Secretariat (2013a). The Ramsar Convention Manual: a guide to the Convention on Wetlands (Ramsar, Iran, 1971), 6th edition. Ramsar Convention Secretariat, Gland, Switzerland, 109 pp.

RCS (Ramsar Convention Secretariat) (2013). The Ramsar Convention Manual: a guide to the Convention on Wetlands (Ramsar, Iran, 1971), 6th edition. Ramsar Convention Secretariat, Gland, Switzerland, 109 pp.

SNV Netherlands Development Organization & Department of Agriculture, MoAF Bhutan (2015). Climate - Smart Agriculture Sourcebook, Adaptation to Climate Change. SNV Netherlands Development Organization, Thimphu Bhutan, www. Snvworld.org/Bhutan

World Bank Group, FAO and IFAD (2015). Gender in Climate-Smart Agriculture Module 18 for Gender in Agriculture Sourcebook.

APPENDICES

Appendix 1: Wetlands in the Lake Tana sub-basin

(Source: Tana Sub-basin Integrated Land Use Planning and Environmental Impact Study Project, Technical Report: Fisheries and Wetlands Assessment, (LUPESP/TSB: 11/2015) June, 2015, Bahir Dar)

Woredas	Kebele	Wetland Name	Estimated area(ha)
Ebinat	Mechena	FTC	9
	Amstiya	Demit, FTC	11
	E/Gunaguna	Abo Menethua	6.5
	Wariba	Selel	8
	Ziha	BegochKitkitoch	12
N. Achefer	Estumite	Abaydar Wtland	2048.12
	Legidia	Legidia	1444.88
	Kunzilazuria	Demomoki	15
	ShobelaBakusite	Shola	1624.76
	Dawunti	Chemba	1419
	GugeEnsugn	Guge	15
	Woberia Eyesus	Wonberia	1.435
	Ambeshen	Atuga	1
	Ambeshen	ShitaKab	0.5
Dera	Korata	Yijanit	4.5
	Korata	Korata	8.5
	Korata	Gubita	25
	Korata	Bosit	19
	Korata	Dengicha	10
	M/ Mariam	AyineBahir	5
	M/ Mariam	Yidersh	12
	M/ Mariam	Lam Metech	2
	M/ Mariam	Guansame	2
	M/ Mariam	Gegnbila	1.5
	M/ Mariam	Fesash	1

Woredas	Kebele	Wetland Name	Estimated area(ha)
Dera	TanaMitsili	Mosalit	28
	TanaMitsili	Wend Asira	24
	TanaMitsili	Dube	22
	TanaMitsili	Ahun Weta	25
	TanaMitsili	Ahya Sat	4.75
	TanaMitsili	Azima	27
	TanaMitsili	Arade	25
	Tana Mitsili	Dibo Gedel	21
	Gigna	Tankua	35
	Gigna	Atirko	38
	Gigna	Aminda	40
	Gigna	Barhe	28
	Gigna	WalkaMidir	35.5
	Gigna	Feto Midir	43.5
	Zara	TijaEsar	27
	Zara	TireBetin	25
	Zara	Shengo	29
	Zara	Senbete	22.5
	Zara	EjaWenz	24
	Zara	ZereBela	26
	Zara	TikurWuha	27
	Zara	Giribsha	25.5
	Zara	Dibo Gedel	22
Mecha	Zemen Birihan	ByeMeda	200
	Lehulum Selam	Bdrki	10
	Lehulum Selam	Toma	1
	Lehulum Selam	Kechinosh	1.5
	Enashenifalen	Kurit Bahir	2
	Enashenifalen	AsaBila	8
	BertaGebere	Senderes	6
	BertaGebere	Abd Wuhd	
	BertaGebere	Bekilo Mankira	4
	BertaGebere	SayibenBahir	4

Woredas	Kebele	Wetland Name	Estimated area(ha)
	Tagel Wedefit	Mensh Mesik	3
	Tagel Wedefit	GebiruMesk	1
	Tagel Wedefit	Minchras	1
	Rim	Mark Kudi	1
	Rim	Kusquam Mesk	6
	Rim	Qerem Mesk	2
	Rim	Sind Mesik	4
	Rim	Aba Gollu	6
	Kurit Bahir	Kurit Bahir	20
	Kurit Bahir	Minzir	10
	Kurit Bahir	Bojed	1.5
	Kurit Bahir	Dinzibar	5
	MidreGenet	Wosegn Mesik	25
	MidreGenet	Wosegn Bahirshesh	198
	AmritaWenz	Bamind	70
	AmritaWenz	DengiraMender	70
	AmritaWenz	ChebaMender	7.5
	AmritaWenz	Dengel	20
	AdisLidet	AbeyMesk	156
	TatekGebere	Kurit Bahir	30
	TatekGebere	Denbar	7
	TatekGebere	Lol	20
	TatekGebere	Woyiraber	5
	EdigetBehibiret	Birakat	15
Banja	Akena Jefi	GushiraAkena	2.5
	Akena Jefi	KilajetaGushiru	1.75
	Surta	Dantafi	2.5
	Surta	Sitayita	0.0625
	Asem	Gedam	2.5
	Asem	Chagani	1.25
	Asera	Akel	4
Fagita	Ashewa	Mesikela,Marikana	12
	Amesh Shinkuri	Zimbiri	165

Woredas	Kebele	Wetland Name	Estimated area(ha)
Fagita	FurijeGolla	Arerta	62.5
	Waz	Enkuach, Kunta	26.5
	Dimama?	Dimdam	250
	FagitaTuji	Shehanti	80
	SizlaT/Hayimanot	Janagul	150
	GollaAzimach	Anzerek	357.25
BahirDar: Zaria	Debiranta	Tana Dar	150
	Yigodi Tentela	Zimba	60
	Sekelet	Adoki	3
	Sekelet	LumAger	15
	Robit	Engido Dengel	161
	Robit	Hawunet	15
	Robit	Boled	80
	Wegelisa	EnfirazMinch WuhaAnat	1225
	Lata	Kersere	50
	Lata	Lencho	30
	Lata	Amba	20
	DebirMesenta	Mesenta	300
	Wenjeta	?	93
South Achefer	Dilamo	ZolaMariam	1.5
	Ker	Serdo Ber	2
	Kurbiha	Gushet	3
	LihudiDelekes	Fendika	3
	AbchiklyZaria	Chomet	300
North Achefer	Estumite	AbayDar	2048.12
	Legidia	Legidia	1444.88
	KunzilaZaria	Demoaki	15
	ShobelaBakastic	Shobela	1624.76
	Chemba	Dawnti	1419
	GugeEnsugn	Guge	15
	WonberiaEyesus	Wenberia	1.435
	Ambeshem	Atuga	1
	Ambeshem	ShitaKab	0.5

Woredas	Kebele	Wetland Name	Estimated area(ha)
Takusa	Mekonta	Mariam Wuha	25
	Mekonta	Sensaytoka	10
	Mekonta	GibzaToka	5
	Mekonta	GibzaGote	9
	Mekonta	Delgi Giraru	6
	Mekonta	Sbseba	30
	ChantieBargen	Meskeliye/Arko	20
	ChantieBargen	Chegena/ Arko	20
	ChantieBargen	Bargen Anferpiba	23
	Achera	Tinish Toka/Kosan	12
	Achera	Tilk Toka/Achel	15
	Achera	AsratieToka	30
	Achera	Gohil Toka	30
	ChachAliwa	KosanaZeter	12
	ChachAliwa	Shanshinit/BefieToka	15
	ChachAliwa	KechinenaNejoMesik	5.125
	ChachAliwa	Godiguadit	5
	Arima	ArimaGebreale	2.5
	Arima	ArimaAchera	2
	Guayi	Sahirt	2.5
	SebirSerako	Kima	1
Alefa	TaraKazen	Mate	80
	TaraKazen	Kezen	20
	TaraKazen	Kudadie	41
	TaraKazen	Tara	5
	Dengel Ber	Dengel Shewa	10
Alefa	Dengel Ber	GibaGondar	3
	Acha Mangur	ZewudeGrar	6
	Dengel Ber	Beles Mesik	12
	AseyDebir	AzoMewcha	4
Farta	Sahirna	Fegan	0.0625
	AyivaNiva	Ankokoy	0.4
	AyivaNiva	Figfig	0.3

Woredas	Kebele	Wetland Name	Estimated area(ha)
Farta	AyivaNiva	AybaMinch	0.25
	Ayiva Niva	Hawaryat	0.75
	Ayiva Niva	Dashena	0.04
	Ayiva Niva	Fridihoy	0.04
	Buro	Bzushl	0.04
Fogera	Sositu Dilmo	Dilmo Giorgis	2.5
	Wagetera	Taqua	75
	Kidist hana	Dingiz	200
	Shaga	Shesher	125
	Shina	Shesher	400
	Nabega	Shesher	125
	Nabega	Daga	100
	Nabega	Daba	125
	Nabega	Deke Bet	17
	Nabega	Wolela	100
Dembia	Jerjer Amba	Gibara	131
	Tana Weyina	Gira	90
	Tana Weyina	Likilik	127
	Tana Weyina	Ketera	148
	Debir zuria	Abelay	181
	Achera	Ashiwa Bahir	245
	Seraba Dblo	Teter	229
	Aberjha Dhnawawa	Wawa	56
	Aberjha Dhnawawa	Birguada	2
Dembia	Mange	Badima	8
	Mange	Hana	2
	Mange	Wegeda	2
	Gorgora Ketema	Debire sina	17
	Gurandi Wenbha	Tukutuka	52

Woredas	Kebele	Wetland Name	Estimated area(ha)
Dembia	Gurandi Wenbha	Alay	3
	Gurandi Wenbha	Tikur Bahir	2
	Tezeba Genbera	Bichign	116
	Fentaye	Bichign	130
	Jangua Mariam	Abiriha	10
Gondar Zaria	Tsion Seguach	Dilikana Walika	6.5
	D/Chinchaye	Shenkor Mesk	3.75
	D/Chinchaye	Shinkurt Wuha	4
	D/Chinchaye	Chika Wonz	3.5
	D/Chinchaye	Ambo Got	20
	Chira Manchiro	Ferengi Wuha	4.5
	Denkez	Regim Mesik	5
	Denkez	Bahir Mesk	3
	Denkez	Aelo	5
	Denkez	Hamusit	6
	Degola Chinchaye	Selo	15
	Degola Chinchaye	Chiraye	4
	Degola Chinchaye	Shiha	8
	Degola Chinchaye	Senberzgie	20
	Degola Chinchaye	Damotoch	18
	Zengagi	Barena	2
	Zengagi	Dingay Midir	1
	Debire Selam	Debire Kerbe	1
	Debire Selam	Enizeker	1
	Debire Selam	Debire Selam	1
	Debire Selam	Kebila	2
	Debire Selam	Barengua	2
Chilga	Kenweta Amanuael	Amanual Kenweta	3.25
	Mirt Amba	Molla mesk	1.52
Wogera	Ayiva	Shinkuri wenz	4
	Ayiva	Lenchakit	3

Woredas	Kebele	Wetland Name	Estimated area(ha)
	Debir	Mekidie	3
	Derjaji	Delidalit1	0.25
	Derjaji	Delidalit2	0.5
	Derjaji	Regireg	0.5
	Kossoye	Scrdagela	3
	Kossoye	Megech Ras	5
East Estie	G. Atemem	Kassie Gedel	3
	G. Atemem	Kachena	4
	G. Atemem	Lome Wuha	6
	G. Atemem	Werke Midir	7
	G. Atemem	Azegemishign	3
	G. Atemem	Mimita	10
	G. Atemem	Derek Aybet	6
	G. Atemem	Tsid Wuha	4
	G. Atemem	Bere Mesk	4
	G. Atemem	Etsi Esrael	1.25
	G. Atemem	Mebregi	2
	G. Atemem	Amija Godir	1.75
	Shimagle Georgis	Medhanilem	2
	Shimagle Georgis	Tirtiriat	3
	Shimagle Georgis	Giorgis	4
	Shimagle Georgis	Layi Godir	6
	Gib Asra	Kerewa	3.75
Woredas	Kebele	Wetland Name	Estimated area(ha)
	Gib Asra	Selamge	2.5
	Gib Asra	Bad mayat	4.25
	M/Eyesus	Chako	1.25
	Recha	Boled	1.25
	Recha	Getaw Bado	0.5
	Recha	Cheber	0.25
	Recha	Digirineya	0.25

Woredas	Kebele	Wetland Name	Estimated area(ha)
Woredas	Recha	Gira Azimach	0.25
	Recha	Layi Bet	0.55
	Recha	Srsgi	0.25
	Recha	Shola Meda	0.525
	Recha	Bsensa	0.25
	Recha	Deri Bado	0.125
	Recha	Sekela	1.25
	Recha	Wageza	1.25
	Recha	Tilabat	0.5
	Recha	Alela Mesibekia	1.25
	Leway	Asama Meda	5
	Leway	Sar Godir	2.5

Appendix 2: List of major rivers in Amhara Region (Abay Basin Authority, ABA)

No.	Major Rivers in ABA		Location	Easting	Northing
1	Abahim		Debremarkos	10^{0}18'N	37^{0}44'E
2	Abay		Bahir Dar	11^{0}36'N	37^{0}24'E
3	Abay (2)		Bure	10^{0}36'N	37^{0}07'E
4	Amen		Dangila	11^{0}16'N	36^{0}52'E
5	Andassa		Near Bahir Dar	11^{0}30'N	37^{0}29'E
6	Angereb		Near Gondar	12^{0}38'N	37^{0}29'E
7	Ardi				
8	Arno-Garno		Infranz	12^{0}14'N	37^{0}37'E
9	Ashar		Near Dangila		
10	Aveya		Near Mota		
11	Ayma	**Blue Nile**			
12	Ayo		Near Kossober	10^{0}58'N	36^{0}47'E
13	Azuari		Near Mota	10^{0}58'N	38^{0}01'E
14	Beles				
15	Bered		Merawi	11^{0}25'N	37^{0}10'E
16	Beressa		Near Debrebrahan	9^{0}40'N	39^{0}31'E
17	Birr		Near Jiga	10^{0}39'N	37^{0}23'E
18	Bogena		Lumame	10^{0}15'N	37^{0}57'E
19	Boreda		Near Mekanese-lam	10^{0}45'N	38^{0}47'E
20	Buchiksi		Near Kidamaja	11^{0}01'N	36^{0}42'E
21	Buso		Near Borena		

22	Chemoga	Blue Nile	Near Debremarkos	10⁰18'N	37⁰44'E
23	Chena		Near Istay	11⁰37'N	38⁰02'E
24	Chereka		Yechereka	10⁰36'N	37⁰26'E
25	Dirma		Koladba		
26	Donder				
27	Ezana		Near Bahir Dar	11⁰29'N	37⁰24'E
28	Fegoda		Near Arbgebeya	11⁰38'N	37⁰46'E
29	Fettam		Tilile	10⁰51'N	37⁰01'E
30	Gelda		Near Ambessame	11⁰42'N	37⁰38'E
31	Gemero		Near Maksegnit	12⁰23'N	37⁰33'E
32	Gerado		Near Dessie	11⁰06'N	39⁰36'E
33	Geray		Jabi Tehnan		
34	Gilgel Abay		Gishabay	11⁰22'N	37⁰02'E
35	Gorfo		Near Gorfo	9⁰24'N	38⁰50'E
36	Guder		Near Fagita		
37	Gudla		Dembecha	10⁰33'N	37⁰30'E
38	Gulla		Dembecha		
39	Gumara		Near Woreta	11⁰50'N	37⁰38'E
40	Jedeb		Near Amanuel	10⁰24'N	37⁰34'E
41	Jema				
42	Jogola		Werelu	10⁰35'N	39⁰26'E
43	Kechem		Dembecha		
44	Kelkel		Near Gobie		
45	Kilti		Near Durbetie		
46	Kima		Near Delgi		
47	Koga		Merawi	11⁰22'N	37⁰03'E
48	Lah		Near Funotesealm	10⁰41'N	37⁰16'E
49	Lege cora		Near Mekanese-lam	10⁰46'N	38⁰47'E
50	Leza		Near Jiga	10⁰40'N	37⁰20'E
51	Mechela		Near Kabe	10⁰44'N	39⁰21'E
52	Megech		Azezo	12⁰29'N	37⁰27'E
53	Mendel		Near Tiss Abay	11⁰29'N	37⁰34'E
54	Missini		Kossober	10⁰56'N	36⁰52'E

55	Muga	Blue Nile	Near Dejen	$10^{0}10'N$	$38^{0}09'E$
56	Quashini		Near Addis Kid-amie	$11^{0}12'N$	$36^{0}52'E$
57	Ribb		Near Addis Zemen	$12^{0}00'N$	$37^{0}43'E$
58	Sarwuha		Near Delgi		
59	Sedie		Near Mota	$11^{0}02'N$	$37^{0}54'E$
60	Selgi		Near Kabe	$10^{0}45'N$	$39^{0}25'E$
61	Shegez		Near Adiet		
62	Shigez		Yilmana Densa		
63	Shina		Near Adiet	$11^{0}15'N$	$37^{0}30'E$
64	Shy		Near Mehal Meda	$10^{0}15'N$	$39^{0}34'E$
65	Suha		Near Bichena	$10^{0}25'N$	$38^{0}11'E$
66	Talya		Near Jiga	$10^{0}48'N$	$37^{0}25'E$
67	Tekon		Dengel Ber		
68	Teme		Near Mota	$10^{0}25'N$	$37^{0}59'E$
69	Temecha		Near Dembecha	$10^{0}32'N$	$37^{0}30'E$
70	Temim		Jabi Tehnan		
71	Tigdar		Near Gunde Woin	$10^{0}53'N$	$38^{0}01'E$
72	Tiliku Deber		Near Duber	$9^{0}28'N$	$37^{0}53'E$
73	Timbel		Near Fagita		
74	Tinish Deber		Near Duber	$9^{0}27'N$	$37^{0}53'E$
75	Tul		Near Adiet	$11^{0}11'N$	$37^{0}29'E$
76	Wenchit		Near Alem Ketema	$10^{0}05'N$	$38^{0}47'E$
77	Wenka		Near Istay	$11^{0}37'N$	$38^{0}04'E$
78	Wizer		Near Mehal Meda	$10^{0}14'N$	$39^{0}41'E$
79	Yeda		Near Amber	$10^{0}15'N$	$37^{0}49'E$
80	Zingni				
81	Zufil	Awash	Near Debre Tabor	$11^{0}50'N$	$38^{0}05'E$
82	Allawuha		Near Woldiya	$11^{0}54'N$	$39^{0}41'E$
83	Ataye		Near Afeson	$10^{0}20'N$	$39^{0}58'E$
84	Berga		Near Addis Alem	$9^{0}01'N$	$38^{0}21'E$
85	Beshilo				
86	Borkena		Near Combelicha	$11^{0}03'N$	$39^{0}44'E$
87	Desso		Near Dessie	$11^{0}08'N$	$39^{0}38'E$
88	Dirma		Near Dessie		

89	Golina	Awash	Near Kobo	12°04'N	39°37'E
90	Hormat		Near Kobo	12°08'N	39°36'E
91	Jara		Jara	10°31'N	39°57'E
92	Jeweha		Jeweha	10°06'N	39°58'E
93	Kelina		Near Deassie	11°06'N	39°35'E
94	Kete		Near Hayq	11°18'N	39°41'E
95	Kormat		Near Woldiya		
96	Megenagna		Near Mersa	11°36'N	39°39'E
97	Mersa		Near Mersa	11°41'N	39°39'E
98	Mille		Near Passo Mille	11°23'N	39°38'E
99	Robit		Robit	10°00'N	39°53'E
100	Senbete		Senbete	10°18'N	39°58'E
101	Teleyayen		Near Dessie		
102	Tikurwuha		Near Woldiya		
103	Angereb	Tekeze	Near Abdirafi	13°45'N	36°28'E
104	Asera		Near Debarik	13°07'N	37°53'E
105	Genda woha		Near Kokit	12°45'N	36°26'E
106	Guang		Near Metema	13°00'N	36°11'E
107	Mekezo		Near Dansha	13°33'N	36°58'E
108	Sanja		Near Musebab		
109	Shinfa				
110	Tekeze		Near Yechila	13°21'N	38°45'E
111	Zariema		Waldiba		

Appendix 3: Fish species recorded from Wabe Shebelle -Ghenale basins (Source: Abebe Getahun, 2007)

Family	Species	Status
Mormyridae	Mormyrops deliciosus	
Alestiidae	Alestes affinis	
Cyprinidae	Chelaethiops bibie	
	Labeo bottegi	
	Garra dembeensis	Wide spread
	Labeo boulengeri	Endemic
	Labeo neumanni	Endemic
	Labeo stictolepis	
	Labeo barbusbynni	Wide spread
	Labeo barbusgananensis	
	Labeo barbusintermedius	Wide spread
	Varicorhinus jubae	Endemic
	Cyprinus carpio	Exotic
Bagridae	Auchenoglanis occidentalis	
Amphiliidae	Amphilius lampei	Endemic
Clariidae	Clarias gariepinus	Wide spread
Mochokidae	Synodontis frontosus	
	Synodontis geledensis	
	Synodonti spunctulatus	
	Synodontis schall	Wide spread
Aplocheilidae	Notobranchius cyaneus	
	Notobranchius jubbi	
	Notobranchius microlepis	
	Notobranchius patrizii	
Cichlidae	Oreochromis niloticus	Wide spread
	Oreochromis spilurus spilurus	

Appendix 4: List of Identified plants from Omorate river bank (N 04° 48.763 E 036° 02.985 elevation 370 m; source: Brook Lemma, 2015)

Botanical Name	Family	Remark
Acacia polyacantha Willd.	Fabaceae	
Acacia tortilis (Forssk.) Hayne	Fabaceae	
Alternanthera pungens Kunth	Amaranthaceae	
Amaranthus dubius Thell.	Amaranthaceae	
Amaranthus spinosus L.	Amaranthaceae	
Azadirachta indica A. Juss.	Meliaceae	Planted
Basilicum polystachyon (L.) Moench	Lamiaceae	
Boerhavia diffusa L	Nyctaginaceae	
Calotropis procera (Ait.) Airf	Asclepiadaceae	
Cayratia ibuensis (Hook. f.) Suesseng.	Vitaceae	
Cenchrus setigerus Vahl	Poaceae	
Cyperus rotundus L.	Cyperaceae	
Dactyloctenium aegyptium (L.) Willd.	Poaceae	
Echinochloa colona (L.) Link	Poaceae	
Eragrostis cilianensis (AlL.) Vign. Ex Janchen	Poaceae	
Indegofera sp.	Fabaceae	
Indegofera spinosa	Fabaceae	
Moringasten petala	Moringaceae	May be planted
Ocimum sp.	Lamiaceae	
Pennisitum sp.	Poaceae	
Physalis ixocarpa Brot. exHornem.	Solanaceae	
Plecthranthus sp.	Lamiaceae	
Ruellia patula	Acanthaceae	
Salvadora persica	Salvadoraceae	
Solanum sp.	Solanaceae	
Tribulus terristris	Zygophyllaceae	
Xanthium strumarium	Asteraceae	Invasive weed
Withaniasom enifera	Solanaceae	
Zaleyapen tandra (L.) Jeffrey	Aizoaceae	

Appendix 5: List of Identified plants from Gibe 3 river bank margins (N 06° 50.003 E 037° 17.536 at an elevation of 680 m) (Source: Brook Lemma, 2015)

Botanical Name	Family	Remark
Abutilon sp.	Malvaceae	
Aeschynomene sp.	Fabaceae	
Ageratum conyzoides L.	Asteraceae	
Allophylus africanus P. Beauv.	Sapindaceae	
Allophylus sp.	Sapindaceae	
Alternanthera pungens Kunth	Amaranthaceae	
Alternanthera sessilis (L.) DC.	Amaranthaceae	
Alysicarpus rugosus (Willd) DC.	Fabaceae	
Amaranthus caudatus L.	Amaranthaceae	
Amaranthus sp.	Amaranthaceae	
Ammania prieuriana Guill. &Perr.	Lytheraceae	
Aristida adscensionis L.	Poaceae	
Aristida hordeacea Kunth	Poaceae	
Basilicum polystachyon (L.) Moench	Lamiaceae	
Boerhavia diffusa L	Nyctaginaceae	
Cayratia ibuensis (Hook. f.) Suesseng.	Vitaceae	
Centella asiatica (L.) Urban	Apiaceae	
Corchorus fascicularis Lam.	Tiliaceae	
Corchorus olitorius L.	Tiliaceae	
Cyperus alternifolius L.	Cyperaceae	
Cyperus alopecuroides Rottb.	Cyperaceae	
Cyperus digitatus Roxb.	Cyperaceae	
Cyperus distans L.f.	Cyperaceae	
Cyperus rotundus L.	Cyperaceae	
Dinebra retroflexa (Vahl) Panzer	Poaceae	
Eleusine africana Kenn.-O 'Byrne	Poaceae	
Eriochloa fatmensis (Hochst. & Steud.) Clayton	Poaceae	
Ficus capreaefolia Del.	Moraceae	
Ficus exasperataVahl	Moraceae	
Hibiscus sp.	Malvacceae	
Indegofera sp.	Fabaceae	
Ipomea sp.	Convolvulaceae	

Botanical Name	Family	Remark
Ludwigia abyssinica A. Rich.	Onagraceae	
Ludwigia stolonifera (GuilL. & Perl'.) Raven	Onagraceae	
Mimosa pigra L.	Fabaceae	Invasive weed
Panicum maximum Jacq.	Poaceae	
Panicum nervatum (Franch.) Stapf	Poaceae	
Parthenium hysterophorus L.	Asteraceae	Invasive weed
Pennisetum pedicellatum Trin.	Poaceae	
Persicaria senegalensis (Meisn.) Sojak	Polygonaceae	
Phyllanthus sp.	Euphorbiaceae	
Physalis ixocarpa Brot. ex Hornem.	Solanaceae	
Pluchea dioscoridis (L.) DC.	Asteraceae	
Portula cafoliosa Ker.-Gawl.	Portulacaceae	
Rhynchosia sp.	Fabaceae	
Rottboellia cochinchinensis (Lour.) Clayton	Poaceae	
Senna sp.	Fabaceae	
Sorghum arundinaceum (Desv.) Stapf	Poaceae	
Sphaeranthus bullatus Mattf	Asteraceae	
Sporobolus sp.	Poaceae	
Trichodesma physaloides (Fenzl) A.DC. in DC.	Boraginaceae	
Triumfetta rhomboidea Jacq.	Tiliaceae	
Typha latifolia L.	Typhaceae	
Urena lobata L.	Malvaceae	
Urochloa sp.	Poaceae	
Withania somnifera (L.) Dunal	Solanaceae	
Xanthium strumarium L.	Asteraceae	Invasive weed

Appendix 6. Basic considerations in the process of developing cascading Restoration Implementation Plan from the national to the regional, zonal, woreda and kebele levels

Adequate knowledge on land/water-use management, climate imapcts, natural phenomena (Earth movements, floods, landslides, etc.), population of humans and livestock increase in proportion to all sorts of resources, development plans that consider sustainablilty need to be placed in perspective on sustainable basis.

Below are given basic various aspects of resource use that need to be considered to the cascading restoration inplementation plans for wetlands and their associated catchments.

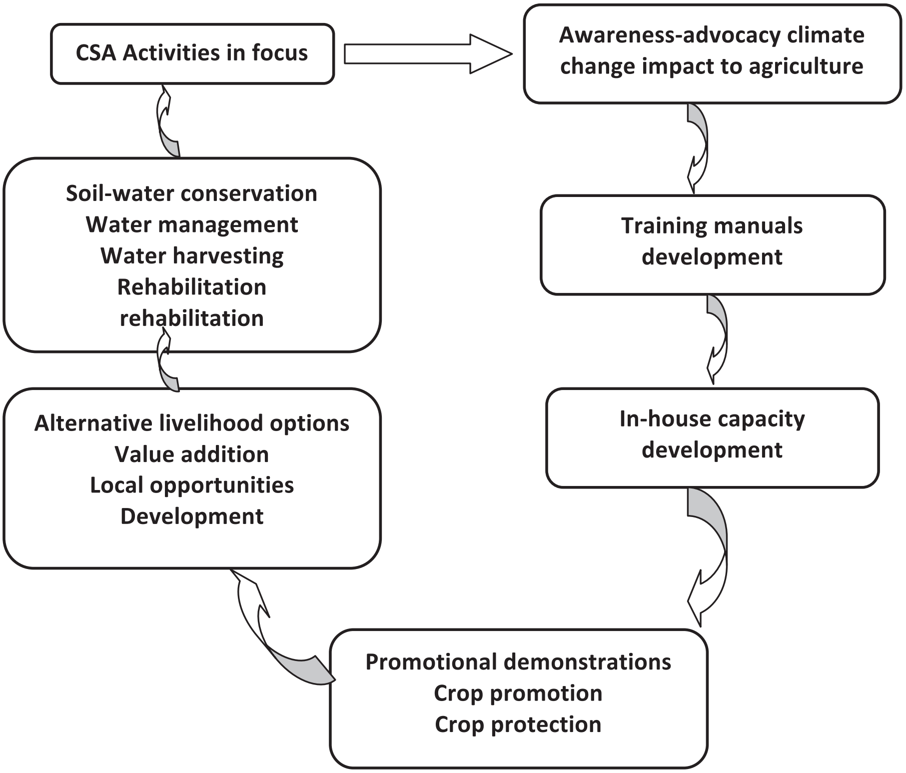
Firstly the following information suggests the importance of agriculture to Ethiopia as this is the most impacting factor on wetland resources based on the following reasons.

Secondly, Njeru *et al.* (2016) wrote explicitly that Ethiopia depends greatly on the agriculture sector, which contributes approximately 42 percent of national GDP, while 80 percent of the country's population depends on this sector for their livelihoods. Chronic food insecurity affects 10 percent of the population and even in average rainfall years these households cannot meet their food needs and must rely partly on food assistance. Overall, the agriculture sector is highly vulnerable to the impacts of climate change. Droughts periodically reverse agricultural sector performance gains, with devastating effects on household food security and poverty levels. Vulnerability to droughts is greatest in the pastoral areas of the lowlands and the densely populated, food-insecure districts of the highlands. Drought-induced famines are further exacerbated by limited coping mechanisms and inadequate contingency planning for drought mitigation and the threat of climate change.

The above statements clearly indicate that agriculture and the natural resources inputs to it as factors imapcting the environment is an impactor to reckon with in any restoration implementation plan of wetlands and their catchments. As a consequence the following points should be used as important inputs in the development of restoration implementation plan of the national committee at the Ministry of Water, Irrigation and Energy with cascading plans at the region, zonal, woredas and kebeles levels.

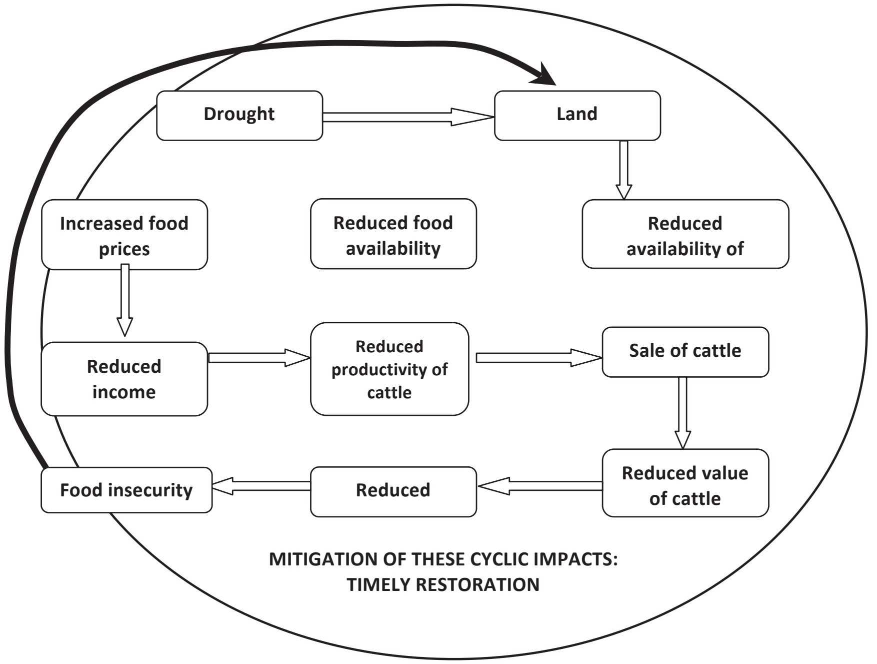
Basic principls described in flow diagrams:

The whole exercise of mapping wetlands, finding out their alteration histories and developing restoration guidelines rests on the sustainable use of wetland resources to ensure continued livelihoods by capitalizing in the conservation of nature. Any action that deals therefore in restoration implementation plan that cascades from nationwide from the ministries to the local communities (*kebeles*) should consider the following in the cascading plan. Further readings on the following points can be accessed in Amin *et al.* (2015) and Njeru *et al.* (2016) among others.

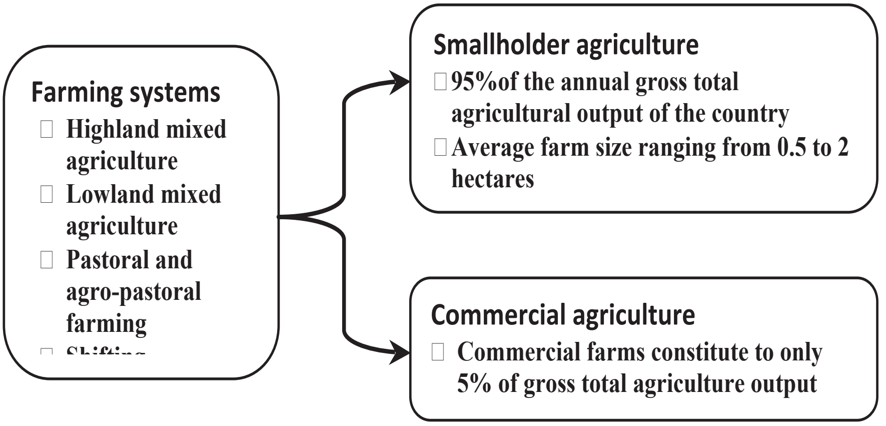


Technologies that can be very important for energy-smart food systems include:

- wind mills
- solar panels
- photovoltaic lights
- biogas extraction units
- environmentally safe power generators
- tools for bio-oil mining and purification
- fermentation and distillation processes for ethanol extraction,
- pyrolysis units
- hydrothermal conversion tool
- solar-wind electricity production
- bio energy-operated water pumps
- renewable energy-powered vehicles
- monitoring systems
- information and communication technologies (ICT)
- cooking stoves
- equipment for water supply, distribution and purification



The overriding agricultural impact comes in Ethiopia from smallholder farming system according to the context described below in a flow diagram (modified from Amin *et al*. (2015) and Njeru *et al.* (2016).

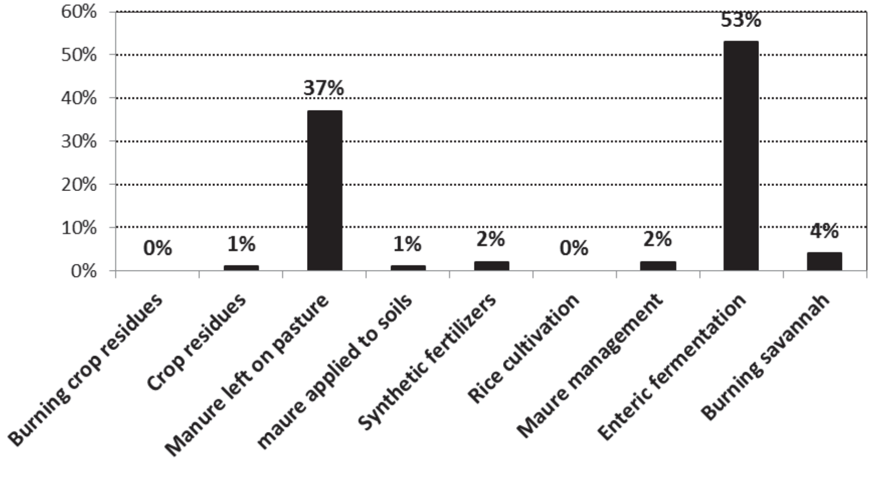


Smallholder agriculture is therefore a major mainstay of more than 80% of the Ethiopian population that impacts wetlands and their watersheds. It should therefore be a major concern and consideration in the planning of wetlands' restoration implementation plans at all levels of sustainable development in the country.

Impact of livestock

Ethiopia has the largest livestock population in Africa and the tenth largest in the world. Livestock is an integral part of the farming systems in the country. It is the source of many social and economic values such as food, draught power, fuel, cash income, security and investment in the highland, lowland and pastoral farming areas.

Ethiopia's annual GHG emissions were estimated at 150 Mt CO2e in 2010, with 50 percent and 37 percent of these emissions coming from the agricultural and forestry sectors respectively. In agriculture, livestock production accounted for more than 40 percent of the emissions, while in forestry the main culprit was deforestation for expansion of agricultural land, which accounted for over 50 percent of forestry-related emissions, followed by fuel wood consumption at 46 percent of the forestry related emissions.



GHG emissions in Ethiopian agriculture in 2012 (modified from FAOSTAT, 2015 and Njeru *et al.*, 2016)

GHG emissions in Ethiopian agriculture in 2012 (FAOSTAT, 2015)

CSA Technologies and Practices in Ethiopia

CSA practices in Ethiopia include sustainable landmanagement (SLM), conservation agriculture (CA), integrated soil fertility management (ISFM, agroforestry, crop residue management, composting,integrated watershed management (IWM, crop rotation and intercropping, use of effective micro-organisms, promotion of improved livestock feed and rangeland management. These are summarized below based on the references given herein. However, interested readers can use the subtitles to read extensively on the efforts done in Ethiopia.

Integrated watershed management: include the SLM Program (SLMP1 and SLMP2), Managing Environmental Resources to Enable Transitions Project (MERET), Productive Safety Nets Program – Public Works (PSNP-PW) and numerous NGOs. Dam siltation problems (e.g. Gilgel Gibe I Dam), river bank erosion during flash floods and events of landslides upstream of Gilgel Gibe River gully reclamation at Yeku Watershed in Amhara region and scaling up an integrated watershed management approach through social protection programs in Ethiopia as well as the MERET (Managing Environmental Resources to Enable Transitions to More Sustainable Livelihoods Coordination Unit) and PSNP (Productive Safety Net Program) schemes. A local-level participatory planning approach has ensured success for social protection schemes that provide payment in exchange for work to build public assets. The successful MERET program, which concentrated on integrated watershed management, has informed the broader

Productive Safety Net Program, heralded as a leading example in the fight for food security and inclusive development.

Integrated soil fertility management: Some soil fertility-related programs currently under way by the Ministry of Agriculture include national soil fertility mapping, management of vertisols and acidic soils, collection of information on soils from various stakeholders and implementation of research on recommended soil fertility management practices. A number of NGOs and development partners are also undertaking agricultural development activities related to soil fertility improvement.

Conservation agriculture: While soil conservation practices such as reduced tillage have long been practiced by farmers in Ethiopia, the promotion of conservation agriculture technology began in earnest in 1998 through joint promotion and demonstration of the technology on 77 farmers' plots by Sasakawa Global (SG, 2000), Makobu Enterprises and regional agricultural development bureaus.

Biogas and biomass fuel production: Biogas has been promoted as a means of managing manure from which a large amount of GHG emissions emanate, as well as for domestic energy production. The National Biogas Program of 2007 that was spearheaded by SNV had the goal of constructing 14 000 biogas plants in the four selected regions over a period of five years. Most biogas systems are small scale and utilized for domestic lighting and cooking by households connected to the biogas digester. At present, the Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES) Project being implemented by the International Livestock Research Institute (ILRI) seeks to use dairy waste management interventions to contribute to rural electrification by introducing alternative energy sources such as biogas.

Agroforestry: Agroforestry, an old agricultural activity traditionally practiced in many parts of Ethiopia, involves the integration of trees and shrubs into farmland either through planting or natural regeneration. While traditional practices such as the intercropping of Moringa trees in farmer fields do exist, the government of Ethiopia in 2011 also announced a national program to plant over 100 million *Faidherbia albida* trees in farmers' fields as part of the activities outlined in the Climate Resilient Green Economy (CRGE) Strategy. Organizations such as ICRAF are also conducting research into agroforestry including field trials of different tree species as well as planting densities and tree-crop combinations and their impact on agricultural yields and the physical environment. In addition, research is ongoing into the use of conservation agriculture with trees (CAWT), a technology which combines agroforestry and conservation agriculture. Other tree species that have been used in agroforestry in Ethiopia include *Calliandra* and *Cajanus* species.

Small-scale irrigation: Ethiopia has embarked on the promotion and implementation of small-scale irrigation across the country. Consequently, the area under small-scale irrigation infrastructure increased from 853 000 hectares in 2009 to 2 084 760 hectares in 2013, while the area under irrigated crop production stood at 1 231 660 hectares in 2013 (MoA, 2014). There is a need to ensure that appropriate training in agronomy and water management is given along with support to develop irrigation infrastructure.

Crop diversification and improved variety popularization: As part of ensuring food security, the Government of Ethiopia (GoE) as well as international organizations and NGOs are involved in the development and popularization of new crops and crop varieties, both at community and household level. Initiatives like the Eastern Africa Agricultural Productivity Project (EAAPP), SLM Program and Agricultural Growth Program (AGP) are conducting crop variety popularization activities.

Traditional CSA practices: Various types of traditional CSA practices have been implemented and adopted in Ethiopia. Such practices include **Derashe** Traditional Conservation Agriculture, **Konso** Cultural Landscape, **Hararghe** Highland Tradition Soil and Water Conservation, Hararghe Cattle Fattening, Hararghe Small-Scale Traditional Irrigation, **Ankober** Manure Management, and Traditional Agroforestry in **Gedeo**, East Shewa, East Wollega and West Gojam zones.

CSA Stakeholders, Programs and Projects in Ethiopia

Government programs

- The Ministry of Agriculture and its projects

  Sustainable Land Management Program (SLMP)

  Drought Resilient and Sustainable Livelihoods Program (DRSLP)

  Food Security Program (FSP)

  Agricultural Growth Project

  MERET Project: The Managing Environmental Resources to Enable Transitions (MERET) to More Sustainable Livelihoods Coordination Unit is a World Food Program (WFP) supported project initiated in the 1980s. This marked the beginning of large-scale soil and water conservation in Ethiopia.

- The Ministry of Environment and Forests and Climate Change and its various projects (mostly new or under initiation as the ministry is recently established

- Agricultural Transformation Agency (ATA) and its various projects

Development Agencies and Non-Governmental Organizations

- World Vision Ethiopia (WVE)
- Sasakawa Global (SG2000)
- Food for the Hungry Ethiopia (FHE)
- The Canadian Foodgrains Bank (CFGB)
- CARE Ethiopia
- Alliance for a Green Revolution in Africa (AGRA)
- International Centre for Insect Physiology and Ecology (icipe)
- Farm Africa
- Climate Change Forum – Ethiopia (CCF-E)
- Food and Agriculture Organization of the United Nations (FAO)
- Africa Climate-Smart Agriculture Alliance (ACSAA)

Research and Academic Institutions

- International Maize and Wheat Improvement Centre (CIMMYT)
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
- World Agroforestry Centre (ICRAF)
- International Livestock Research Institute (ILRI)
- Ethiopian Institute of Agricultural Research (EIAR)

Private Sector

- Makobu Enterprises

Key Policies Relevant to CSA in Ethiopia

Ethiopia has a consistent set of policies and strategies for agriculture and rural development that reflect the importance of the sector to the economy and livelihoods of its people (Njeru *et al.* 2016). The major policies that require serious attention in the design of cascading restoration implementation plans are as follows.

- **Climate Resilient Green Economy Strategy (CRGE)** (2011): Aims for carbon-neutral middle-income status by 2025.
- **Ethiopian Program of Adaptation to Climate Change (EPACC)** (EPACC) (2011): More programmatic approach to adaptation planning.
- **National Adaptation Program of Action (NAPA)** (2007): The NAPA represented the first step in coordinating adaptation activities across government sectors.
- **Growth and Transformation Plan (GTP)** (2010): The GTP recognizes that the environment is a vital pillar of sustainable development.
- **Ethiopia's Agricultural Sector Policy and Investment Framework (PIF) 2010-2020** (2010): The goal of the PIF is to "contribute to Ethiopia's achievement of middle-income status by 2020. The development objective is to "sustainably increase rural incomes and national food security". This objective embodies the concepts of producing more, selling more, nurturing the environment, eliminating hunger and protecting the vulnerable against shocks.
- **Comprehensive Africa Agricultural Development Program Compact (CAADP)** (2009): One of the pillars of CAADP is extending the area under sustainable land management and reliable water control systems.
- **Environmental Impact Assessment Proclamation** (2002): Ensure that the environmental implications are taken into account before decisions are made.
- **Environmental Policy of Ethiopia** (1997): Overall guidance in the conservation and sustainable utilization of the country's environmental resources.
- **Agriculture Sector Program on Adaptation to Climate Change (APACC)** (2011): The Agriculture Sector Adaptation Plan to Climate Change.
- **Ethiopia Nationally Appropriate Mitigation Actions (NAMA)**
- **International climate change policy regime**

Constraints to CSA Promotion and Adoption in Ethiopia

- Food insecure farmers find it costly to invest in better land and agricultural management systems which often have slow returns on investments.
- There are practices that are difficult to integrate into existing farming systems because they impact on other elements of the farming system.
- There is a general lack of quality agricultural inputs, particularly in rural communities where quality agrochemicals, farm implements and equipment, seeds, tree seedlings and other inputs necessary for practicing climate-smart agriculture are either not readily available or unaffordable. In many cases low quality inputs and implements are used, resulting in suboptimal results which can ultimately have a negative impact on the promotion of climate-smart practices.
- There is a general lack of knowledge on climate-smart practices and misconceptions about what climate-smart agriculture is.
- There is often competition between crops and livestock for mulch, which is usually required as animal fodder.
- Increased population, land fragmentation and inadequate land tenure systems that do not encourage investment in the land mean that farmers are unwilling to make significant investments in sustainable agricultural practices that may or may not produce immediate or short-term results.
- While extensive CSA-related research is being done in the country, many of the technologies are still not reaching the broader farming population.
- A large number of short-term to medium-term programs and projects are conducted in a fragmented manner by a wide number of stakeholders that are unsustainable in the long run.
- The current extension system is not geared towards climate-smart agriculture and while efforts are ongoing to address this issue, it will take considerable effort and time to change the mindset of farmers so that they move from unsustainable practices to more sustainable climate-smart agricultural practices.
- The livestock subsector, where a considerable proportion of the agricultural GHG emissions emanate and where the potential for the reduction of agricultural GHG emissions is greatest, has unfortunately not received the focus and attention the sector warrants, especially from a GHG mitigation perspective.

Opportunities for CSA Promotion in Ethiopia

- For smallholder farmers in Ethiopia, the possibility for greater food security and increased income – together with greater resilience to weather variability and climate shocks rather than mitigation benefits – will be significant drivers for adopting climate-smart agriculture practices.

- There is great willingness and commitment on the part of government to reduce poverty; improve agricultural production and productivity (as one of the mainstays of the economy); and ensure food security while addressing climate change. Ethiopia is one of the countries that have consistently invested more than 10 percent of their national budget in agriculture.

- Ethiopia has appropriate national policies and strategies such as the Climate Resilient Green Economy (CRGE) Strategy, with some structures already in place to support their implementation.

- The current emphasis on the promotion of integrated watershed management to improve agricultural productivity and promote sustainable land management provides a good opportunity for large-scale implementation and promotion of climate-smart practices.

- The presence of private sector companies, international development organizations and numerous NGOs involved in CSA-related activities presents an opportunity for up-scaling CSA across the country.

- The existence of a large national research network through the Ethiopian Institute of Agricultural Research as well as the presence of a number of CGIAR institutes, many of whom have either country offices or regional offices in Ethiopia, presents a great opportunity to enhance, increase coverage of and disseminate research technologies and findings related to climate-smart agriculture.

- Ethiopia's large agricultural extension system, with an estimated 8 500 farmer training centers and over 45 000 development agents stationed at *kebele* level throughout the country, provides an opportunity for large-scale awareness raising, training and support for farmers on climate-smart agriculture.

Appendix 7: Final results of the prioritization matrix for restoration of wetlands

No	Wetland	Reviewer 1	Reviewer 2	Reviewer 3	Total	Rank
1	Haramaya	49	52.03	41	142.03	1
2	Zwai	47	46	48.95	141.95	2
3	Aba Samuel/Akaki	42.5	46	46.97	135.41	3
4	Abijata	48.5	41	44.99	134.49	4
5	Afdera	35	56.01	42.02	133.03	5
6	Hawassa	41	44	46.97	131.97	6
7	Koka	42.5	45	44	131.5	7
8	Hayq	45	36	50.05	131.05	8
9	Basaka	43	39	46.97	128.92	9
10	Cheffa	45	42.52	40.04	127.56	10
11	Chamo	43	41	43.01	127.01	11
12	Boye & Kito	38.5	41.745	44.99	125.234	12
13	Shesher & Welella	35	39.99	44.99	119.98	13
14	Hashenge	38	39.02	40.04	117.02	14
15	Hora Kilole	36	40	38.57	114.57	15
16	Chelekleka	22	39	37.95	98.95	16

Appendix 8: Prioritization matrix for wetland restoration

The following prioritization matrix and the respective criteria were used to make priorities in the restoration of wetlands. largely modified from Wheeler *et al.*, (1995). Descriptions and rating parameters are provided for each of the criteria below the table.

Wetland	Present condition H/M/L	Cost effective H/M/L	Feasibility H/M/L	Flood control H/M/L	Ground water H/M/L	Surface water H/M/L	Habitat quality H/M/L	Water quality H/M/L	Social values H/M/L	Suitability to restore H/M/L	Sustainability H/M/L	Score
Lake Haramaya												
Chelekleka pan												
Lake Zwai												
Lake Basaka												
Lake Abijata												
Lake Chamo												
Lake Hayq												
Lake Hawassa												
Koka Lake												
Akaki-Aba Samuel wetlands												
Shesher-Welella wetlands												
Cheffa wetland												
Boye/Kitto wetlands												
Lake Afdera												
Lake Hashange												
Lake Hora Kilole												

Abbreviations H – High (score 4-5); M = Medium (score 3-2), and L – Low (score of1)

Note: As this is an exercise in ranking, there is no need for stat analysis. The average of 3 independent expert scorers were taken. The final score should be validated with rapid bio-assessment of a few wetlands and/or verification of ecological condition from literature and secondary sources (which was not done in this study).

Scoring guide – ***previous condition***

5= very bad, needs restoration; 4= bad, some restoration; 3= medium, needs rehabilitation; 2= good, needs protection rather than restoration; 1= no need, near pristine

Scoring guide – ***cost effective***

5= reasonable and manageable cost; 4= acceptable cost; 3= medium cost, can be managed; 2= costly and not highly justifiable; 1= very costly not justifiable and manageable, abort restoration project.

Scoring guide – ***feasibility***

5= highly feasible, site access, funding, community participation, etc; 4= feasible , funding and participation Ok even if site requires additional cost; 3= moderate feasibility, site and funding costly but high community participation; 2= low feasibility – poor site, and funding , low community participation; 1= not feasible – wetland already lost and not salvageable, no need to attempt restoration.

Scoring guide – **ecosystem functions - flood control, groundwater supply**

5=very high flood control/groundwater supply functions; 4= high flood control/ groundwater supply functions; 3= medium flood control/groundwater supply functions; 2= some flood control/groundwater supply functions; 1= no flood control/groundwater supply functions.

Scoring guide – ***habitat, water quality***

5= Poor HQ and WQ, needs restoration urgently; 4= fair HQ and WQ, needs restoration; 3= medium HQ and WQ, restoration later; 2= good HQ and WQ, protection rather than restoration; 1= Very good HQ and WQ, no need for restoration.

Scoring guide – ***social values***

5= high social value; 4= good social value; 3= moderate social value; 2= little social value; 1= no social value, no need for restoration.

Scoring guide – ***Suitability to restore***

5= highly suitable landscape; 4= fairly suitable; 3= moderately suitable, 2= Not suitable, landscape needs modification, etc; 1= Not suitable at all – deep gorge, mountainous, etc.

Scoring guide – ***sustainability*** 5= highly sustainable; 4= fairly sustainable ; 3= moderately sustainable; 2= doubtful whether sustainable; 1= Not sustainable and no need for restoration.

Ethiopian Wildlife and Natural History Society (EWNHS)

Date of Establishment

It was established in September 1966 as a Social Club under patronage of the then Emperor Haile Selassie. Through lapse of time, it was evolved into a not-for-profit conservation institution in Ethiopia.

Identity

EWNHS is a membership-based not-for-profit, secular and non-partisan grassroots conservation institution. As BirdLife International Partner in Ethiopia, it is bird conservation focused and operates at national level. EWNHS is one of the most prominent NGOs in Ethiopia that advocate for wise use and conservation of biodiversity, natural resources and environment at large.

Legal Status

EWNHS has been re-registered and licensed (Reg. No. 0720) as an Ethiopian Residents Charity in December 2009, in accordance with the Charities and Societies Proclamation No. 621/2009.

Governance

While the highest organ of the society is the General Assembly of all members, a Board of Management, seven in number, governs the Society under guidance from the General Assembly. Board members serve on a voluntary basis at policy levels, whilst a Secretariat headed by an Executive Director (who is a non-voting member and secretary of the Board), runs the day-to-day activities of the Society, assisted by other salaried employees.

Vision

The Ethiopian Wildlife and Natural History Society would like to see an Ethiopia and Horn of Africa where nature is conserved with involvement of everyone, and is sustainably serving the livelihoods of present and future generations.

Mission

The Ethiopian Wildlife and Natural History Society strives to conserve nature and promote the sustainable use of natural resources.

It does this through

- Conservation Action on the ground,
- Environmental education & awareness raising,
- Applied conservation research,
- Promoting best practices and
- Working in collaboration with and active participation of communities, and in partnership with national & international stakeholders.

Program Areas

EWNHS has three broad program areas, focused towards achieving its mission, which include:

1. Environmental Protection and Biodiversity Conservation
2. Education, Awareness and Community Outreach
3. Environmental Monitoring and Research

Strategic Objectives

To address each of the program areas and enhance its organizational capacity, EWNHS has identified 13 strategic objectives, which will guide the work of the organization.

Environmental Protection and Biodiversity Conservation Program

1. To contribute to the conservation of Key Biodiversity Areas (KBAs) and Threatened and Endemic Species.

2. To rehabilitate and improve the condition & productivity of degraded ecosystems, including those affected by Climate Change

3. To enhance the conservation of flyways for Migratory Birds and other biodiversity.

4. To contribute to the conservation & management of Protected Area (PA) Networks & Biosphere Reserves (BRs) in Ethiopia and Transboundary.

5. To mitigate the threats of key productive sectors (e.g. agriculture and energy) to biodiversity & ecosystem services, through awareness-raising and mainstreaming.

Education, Awareness and Community Outreach Program

6. Raise awareness, strengthen capacity and empower local communities around priority sites to manage biodiversity and improve livelihoods so that conservation interventions are sustained and community resilience to climate change increased.

7. To sensitize the public and decision makers on the need for environmental protection, sustainable utilization & management of natural resources and conservation of biodiversity.

8. To contribute to the improvement of community livelihoods in and around priority KBAs, PAs and BRs

Environmental Monitoring and Research Program

9. To monitor, document and disseminate information on status and conservation trends of endemic & threatened species, and priority habitats or sites.

10. To conduct and support demand-driven research on conservation of threatened species and community livelihoods in and around priority KBAs, PAs and BRs.

Organizational Development Objectives

11. To increase the financial sustainability of EWNHS by addressing key resource mobilization limitations and associated external threats.

12. To strengthen and diversify the EWNHS human resource base and develop a concrete plan for leadership succession.

13. To strengthen capacity and enhance effectiveness in internal & external communications and market EWNHS widely to enhance partnership with all concerned stakeholders.

Core Competencies

The core competencies of the Society include the following, among others:

1. Reputable image within the public domain both at domestic and international levels

2. Trustworthy track records in financial management, transparency and accountability

3. A wealth of experience in fund management & administration for other institutions. Thus far, EWNHS has managed funds for the Royal Netherlands Embassy, Horn of Africa Regional Environmental Center, Ethiopian Sustainable Tourism Alliance, Counterpart International and Critical Ecosystem Partnership Fund

4. Pioneer in promotion of Environmental Education in Ethiopia and production of thematic promotional materials (published and disseminated over 20 assorted thematic promotional publications)

5. An authority in the avifauna (bird community) of the country - a hub for avifauna of Ethiopia

6. Rich experience in project development, appraisal, management and monitoring

7. Well experienced in managing and implementing national, regional and international projects that are complex and involve multi-stakeholders

8. Rich experience in tourism and ecotourism promotion and infrastructural development

9. A wealth of experience in engaging local communities and facilitation of revolving micro-credits

10. Possesses up to the standard stand-alone procedural manuals and policy documents to guide and control the day-to-day activities of the Society

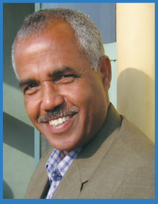
11. Highly resilient institution to have survived impacts of a series of government changes, competitions for resources amongst booming civil societies and donor-driven motives and changes in funding trends

Contact person & address of Institution:

Mengistu Wondafrash (Mr) - Chief Executive Officer
Mobile Phone: + 251(0)911 242369;
E-mail: wondafrash.mj61@gmail.com
Ethiopian Wildlife and Natural History Society
P. O. Box 13303, Addis Ababa
Phone: + 251 (0)11 6636792 /+ 251 (0)116 632774
Website: www.ewnhs.org

Abebe Getahun is a Professor of Aquatic Biology at the Department of Zoological Sciences, Addis Ababa University, Ethiopia. He obtained his BSc in Biology and MSc in Zoology from the Addis Ababa University, Ethiopia and MPhil and PhD from the City University of New York, USA, in Ecology, Evolution and Behavior. He has conducted extensive research on the diversity, distribution and utilization of fishes of Ethiopia including on aquaculture/aquaponics. He has authored or co-authored over 60 articles and two books ("A Guide Book on Fishes of Lake Tana" and "Freshwater fishes of Ethiopia: Diversity and utilization"). He is teaching undergraduate and post graduate (MSc and PhD) courses; advising PhD, MSc and undergraduate students and also involved in research projects.

He can be reached at:
abebe12002@yahoo.com, cell phone 0911-119656



Brook Lemma, Professor of Freshwater Ecology and Wetlands Management at Addis Ababa University, obtained his PhD from the Technical University of Dresden, Germany. He has published over 70 scientific papers and four books and modules with the fifth and latest entitled: "Freshwater Ecology and Management of Ethiopian Wetlands". He has provided consultancy services to FAO, IGAD, national ministries and private enterprises that deal with the wise-use and conservation of wetlands.

Contact addresses: brook.lemma@aau.edu.et; Tel. No. + 251 (0)910 880822

Seyoum Mengistou is Professor of Aquatic Ecology at AAU. He obtained his BSc and MSc in Biology from AAU and his PhD in Limnology from Waterloo University, Canada, in 1990. He has served as Director of the Zoological Natural History Museum, Head of the Biology Department and Editor-in-Chief of the Ethiopian Journal of Biological Sciences. He has mentored and supervised several MSc and PhD students in the Aquatic Sciences, Fisheries and Aquaculture Stream of the Department of Zoological Sciences, AAU. He is the recipient of several research grants and has conducted many studies on lakes, rivers, wetlands and reservoirs of the country. He is a member of several societies and the Ethiopian Academy of Science. He has published about 45 articles on aquatic ecology issues in both local and international journals and written three book chapters.
Together with graduate students, he has continued research on macrophyte ecology, zooplankton secondary production, sediment ecology, bio- assessment using macro-invertebrates and water hyacinth control.

He can be reached at:
seyoumeng@gmail.com, cell phone 0911-370946, Arat Kilo CNS campus, Room No, 24.

ISBN 978-99944-73-47-2
9 789994 473472 >

Design + Print @ Eclipse +251-115-572222/23