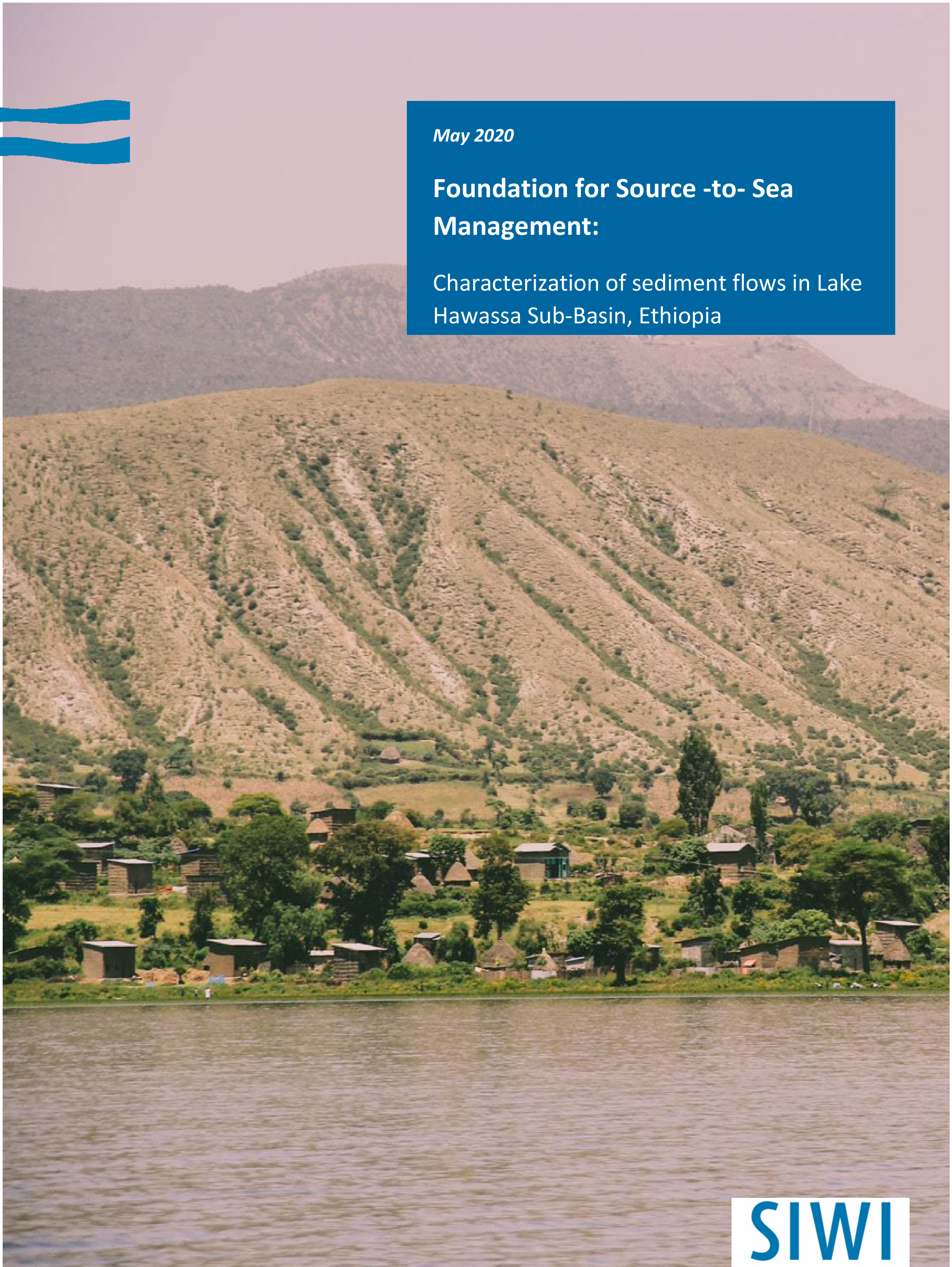
May 2020

Foundation for Source -to- Sea Management:

Characterization of sediment flows in Lake Hawassa Sub-Basin, Ethiopia



This document has been authored by Mulugeta Dadi BELETE (PhD) [Associate Professor of Hydrology and Water Resources Engineering]. It has been produced as an outcome from the “Foundations for Source-to-Sea Management” project carried out by SIWI from September 2019– May 2020 and funded by the German Federal Ministry of Economic Cooperation and Development (BMZ).

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This project followed the guidance provided in “Implementing the Source-to-Sea Approach: A Guide for Practitioners” and “Source-to-Sea Framework for Marine Litter Prevention: Preventing Plastic Leakage from River Basins”. Both of these resources as well as many others can be found at www.siwi.org/source-to-sea.

About SIWI

SIWI's vision is a water wise world, where we recognize the value of water, and ensure that it is shared and allocated sustainably, equitably and efficiently, to meet everyone's basic needs.

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Founded in 1991, the Stockholm International Water Institute (SIWI) provides and promotes water wise solutions for sustainable development in the areas of water governance, transboundary water management, and through international policy processes.

Foundations for Source-to-Sea Management

The Stockholm International Water Institute (SIWI), funded by the Federal Ministry of Economic Cooperation and Development (BMZ) conducted a project "Foundations for Source-to-Sea Management" to pilot the source-to-sea approach in the Vu Gia Thu (VG-TB) River Basin, Viet Nam and the Lake Hawassa sub-basin, Ethiopia. By focusing on the first three steps of the source-to-sea approach, the two pilots:

- Increased knowledge of priority local challenges constraining sustainable development;
- strengthened awareness of the linkages between upstream and downstream activities and their impacts;
- built local capacity for taking a holistic approach to natural resource management and economic development;
- highlighted the opportunities and challenges associated with implementing the source-to-sea approach to management.

Background and Acknowledgments

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Contents

Acronyms and abbreviations

AFLaH	Alliance of Friends of Lake Hawassa
AgNPS	Agricultural non-point sources
CBNRM	Community based natural resources management
CERVaS	Center for Ethiopian Rift Valley Studies
CoP	Community of practice
EPA	Environmental protection authority
GEF	Global Environment Facility
GIZ	German Agency for International Cooperation
IDRC	Internation Development Research Centre
IUCN	International Union for Conservation of Nature
JICA	Japanese International Cooperation Agency
IFAD	International Fund for Agricultural Development
IWRM	Integrated water resources management
LC	Land cover
MERET	WFP food-for-work project
MoWR	Ministry of water resources
PSIAC	Pacific Southwest Interagency Committee
REDD+	Reducing Emissions from Deforestation and Forest Degradation
RVLBO	Rift valley lakes basin office
RVLB	Rift valley lakes basin
SIDA	Swedish International Development Cooperation Agency
SIWI	Stockholm International Water Institute
SLM	Sustainable land management
SNNPRS	Southern nations, nationalities, peoples regional state
USAID	United States Agency for International Development

USLE	Universal soil loss equation
WWDSE	Water works design and supervision enterprise
WWF	World Wide Fund for nature

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Executive Summary

Introduction

This study examines governance and technical challenges in the management of sediment inflow into Lake Hawassa, one of the Rift Valley Basin Lakes of Ethiopia. It applies a customized 'source –to- sea' systemic approach, which has been successfully applied to marine litter prevention, into a 'source –to- lake' approach for sediment erosion and solid waste inflow prevention. It provides an opportunity to highlight potential measures and steps to improve governance of water resources through its recognition of water system as a continuum. This can be integrated to support existing approaches such as Integrated Water Resources Management (IWRM). It is built on the recent experiences of proactive sustainability action around the world and with the adoption of growing understanding of how the earth behaves as a system in which water, atmosphere and land, and the living and non-living parts therein, are all connected.

Results of system characterization along the source-to-lake continuum

To respect and grasp heterogeinty of the system components, three distinction continuums were identified in the sub-basin: the first continuum contains an extremely gullied landscape along the way from the ridge of hydrological region of the sub-basin to the lake; the second continuum recognized solid waste as one of the sources of sediment flowing into Lake Hawassa from the adjacent City; and the third continuum includes Cheleleka wetland (the natural sediment trap for Lake Hawassa) along its continuum from the Northern ridge to the lake. The first continuum contains 750 segments of gullies with a total linear length of about 668 km, which are concentrated on the Western side of the lake with a sediment contributon of about 68,575 m3/yr. This magnitude is about 5 times greater than the sediments generated by the estimated sheet and rill erosion processes in the Sub-Basin together (=14,039 m3/yr) and about 3.4 times greater than the solid waste that enters the basin from Hawassa City (e.g. waste generated and leaked in the environment leaking during the collection and transportation processes of the solid waste management system of the city (=20,166 m3/yr). As a result of these sediment influxes, Lake Hawassa has lost about 4% of its storage capacity in a decade (1999-2011). Assuming an average width of gullies to be 8 m (field observation) and 2 m of unusable agriculture lands in both sides due to gully formation, it is estimated that about 800 ha of cultivable lands have been out of production which is a significant hit to the agricultural economy; as well as livelihood of the local community who own an average land holdings of 0.5 ha per family.

Similarly, Lake Cheleleka (which serves as a natural trap) has been progressively silted up over the last 35 years (1972-2007) at a rate of ≈0.27 km2/yr or ≈2.25% per annum). This is comparable in scale with the nationally recognized tragic problem of Lake Haromaya's disappearance in the Eastern part of Ethiopia.

What are the underlying pressures and drivers responsible for sediment erosion?

The key pressures and drivers for sediment erosion in the catchment include:

- significant land-use changes (expansion of agriculture contributes over 80% of the forest area loss)

- failure of the land holders to apply appropriate soil and water conservation measures
- high erodibility of the soil due to its pumice nature
- the use of "wood" as an energy source for 84% of total energy demand (About 50% of which is taken from shrub-lands and wood-lands, and exceed their mean annual increment of woody biomass. Only 5-10% is from woodlots with the remainder from crop residues)
- the limited technical capacity of the local development agents as well as the community to solve the problem of extreme gully erosion. (The nature of gullies make the conventional techniques of soil and water conservation provided by technical guidelines not suitable or sufficient).

Results of stakeholder identification and the corresponding engagement plan

Numerous relevant stakeholders were identified. Primary stakeholders (e.g. the actors affected by the erosion and sedimentation and benefit from the interventions) include: farmers (mostly in the downstream), fishermen, hotel owners, boat renters and other business runners, fish sellers and consumers, urban community, rural community.

Targeted stakeholders (e.g. the actors or sectors whose practices are contributing to the problem and whose behaviour intervention strategies are aimed at changing) include: farmers (mostly in the upstream), sand miners, fire wood traders, contractors in the construction industry.

Enabling stakeholders (e.g. actors that provide the enabling conditions for behaviour changes to occur and benefits to be sustained over time) are: Basin development authority; Agriculture, land, and natural resources offices, Environmental authority, Municipality, Tourism sector, Investment bureas, Hawassa University (CERVaS), and AFLaH.

Supporting stakeholders (*e.g. actors such as development partners or financiers whose strategies are aligned with and can support the project objectives*) are: Hawassa industry park (investors association), Hotel and resort owners; GIZ-NaTUReS (The Natural Resources Stewardship Programme (NatuReS), and SOS Sahel.

Community-based natural resource management (CBNRM) can be part of an effective engagement plan. This promotes the notion that communities should, and could, satisfactorily manage their own resources according to their local custom, knowledge and technologies and is recommended to serve as a vehicle for effective participation of the community. Accordingly, tentative project structure to guarantee stakeholders' involvement in managing the source-to- lake system is also suggested to include: Steering Committee, Project Coordination Office, Wereda Development Teams, and Community Development Teams.

Results of governance system diagnosis along the Source-to-lake continuum

Status of the sediment erosion problem in the various continuums is direct evidence demonstrating that the current governance system falls short of preventing sediment transport into the lake. A recently established institution, Rift Valley Lakes Basin Development Office (RVLBDO), which operates under Basin Development Authority (BDA) within the Ministry of Water, Irrigation, and Energy (MoWIE), is in charge of executing Integrated Water Resources Management (IWRM) in the sub-basin. With this mandate, this institution is expected to work in collaboration with the two regional states (SNNPRS and Oromiyaa) since 71% of the sub-basin lies in SNNPRS and 22% lies within the Oromiya Regional State administrative boundary.

A number of enabling governance instruments are identified including:

- *Conservation Strategy of Ethiopia* that provides a framework for integrating environmental planning into new and existing policies, programmes and projects;
- *Ethiopian Water Resources Management Policy (1999*) that covers certain elements of water resources management including soil and water conservation measures to reduce sediment soil erosion and lakes siltation; local community participation in sub-basin management and water conservation measures and practices; a recognition of wetlands as a key feature in sub-basin management;
- *Food Security Strategy (2002) and New Coalition for Food Security Programme (2003)* which addresses the main causes of land degradation;
- *Federal Rural Development Policy*, which pays attention to the land tenure issue and the proper use of land;
- *Productive Safety Net Programme* that enables many natural resource management activities in the sub-basin;
- *Rural Land Administration and Land Use Proclamations* which defined the rights and obligations of users of rural land, including traditional subsistence farmers. Thus, protection of land becomes an obligation and failure to protect can lead to loss of title;
- *Sustainable Land Management Investment Framework (2008)* aimed at the restoration, maintenance, and enhancement of the productive function of land.
- *Environmental Impact Assessment Proclamation (No. 299/2002)* notified the mandatory requirements of some specified projects (public or private) to undertake timely EIA, identifying the likely adverse impacts, incorporate the means of their prevention with the support of qualified experts.
- Governance baseline: Summary of priority challenges
- If properly put in place, the governance instruments outlined above would have made a big difference in managing the source-to-lake system. For instance,
- The forest degradation at the source of sediment erosion could have been well managed if stakeholders can execute the forest development, conservation, and utilization proclamation (Proclamation No. 1065/2018) that advocates participatory forest management planning. The major constraints in forestry development in the sub-basin are land and tree tenure, population pressure, land shortage and high demand for agriculture, deforestation, lack of collaboration among the concerned institutions, lack of capacity to design and implement forest management plans, and high royalty fees on forest products, which discourages the private sector involvement.
- Down along the continuum, the farmers are not practicing the appropriate soil and water conservation measures in their farm against their obligations set by the rural land users, and land use restrictions [Federal rural land administration and land use proclamation 456/2005].
- The large width of the gully networks has been a roadway and source of sand mines that provides access to sand miners whom, in turn, carry out activities that exacerbate the problem with limited chance of recovery. This situation can be enforced by the combination of conservation strategy of Ethiopia (CSE, 1997); environmental policy of Ethiopia (EPE, 1997) and Environmental impact assessment Proclamation (EIA, 2002) that recognize the importance of incorporating environmental factors into development activities from the outset.
- ‘One-fits-all’ mentality of technical specification of soil conservation measures is also creating a gap against new innovations to reduce erosion and sedimentation, which can of course be solved by capacity building programme.

- The buffer zone is not serving to filter the storm runoff that carries sediment due to its bareness (no vegetation). To support this, the Basin Development Authority (BDA) drafted and submitted a buffer zone procalamation that will address all water bodies, both in the rural and urban set-ups, to the House of Representatives for their approval in the near future.

The study outlines the basic theory of change on the ecohydrological solution to the problems at hand. It promotes a specific key message and suggested approach. Instead of targetting sediment reduction, a wider strategy to support the functional restoration of the landscape and enhance its retention capacity for vital resources (e.g. sediment, water, nutrients) should be adopted. Such a strategy can be bolstered through the adoption of holistic and systemic approaches such as Source to Sea Management.

Chapter 1

INTRODUCTION

1.1 Water systems as a continuum: A paradigm shift for improved governance

Despite its challenge, complexity, and multi-faceted nature, water resources need to be considered from a holistic perspective (Nepal, 2012). In order to develop appropriate solutions to water related problems, planners must understand the prevailing physical, socio-economic, and governance systems along the upstream-downstream or land-to-water continuum.

There are different management approaches and development principles that recognized the source-to-water linkage: such as integrated land and water resources management (ILWRM) (Flügel et al., 2018); Land-water linkage (FAO, 2002); "Ridge to reef"(FAO, accessed in 2019); watershed resources management (Easter et al., 1986); sustainable land management (World Bank, 2006); integrated environmental management (Born and Sonzogn, 1995); the popular concepts of IWRM (UN, 1992; GWP, 2009; 2014) and IWSM (Wolfgramm, 2015). These have a common objective of 'integration': meaning moving away from compartmentalised planning to a coordinated, cross-sectoral planning and implementation approach where major stakeholders are engaged and different knowledge systems and practices are used (Granit et al., 2014). In order to complement the above situation, Granit et al., (2017) proposed the source-to-sea system approach, which is a holistic management approach that uses knowledge and practices from different disciplines (interfacing social sciences, humanities, arts, and engineering) and can be integrated with existing approaches such as Integrated Water Resources Management (IWRM) (Mathews and Stretz, 2019), by combining important analytical methods. This approach is built on the recent experiences of proactive sustainability action around the world and with the adoption of growing understandings such as: *the earth behaves as a system* in which water, atmosphere and land, and the living and non-living parts therein, are all connected (Steffen et al., 2004); the orders of outcomes framework (Olsen et al., 1999; Olsen, 2003) that provides the analytical underpinning of a proposed theory of change to achieve sustainable outcomes; and identification of six flows: water, sediment, pollutants, materials, biota and ecosystem services that connect geographical segments along the source-to-sea continuum.

The source-to-sea approach (Granit et al., 2017) has been successfully applied to marine litter prevention (Mathews & Stretz, 2019). This study attempts to make a case for adopting S2S for use in one of Ethiopian Rift Valley Lakes, Lake Hawassa, to address an alarming challenge of excessive sediment inflows. Sediment flux into the lake has a direct linkage with the land it drains. It is a function of upstream erosion process and transport, and deposition and remobilization processes in the catchment. Resource management practices in upstream areas can have both beneficial and adverse effects on downstream communities. Recognizing these linkages in a river basin means realizing that events that occur in the upper part of the basin have a direct influence downstream and that issues arising downstream can sometimes be addressed through interventions upstream (Nepal et al., 2014).

As a semi-urban lake, Lake Hawassa provides diverse ecosystem services (Tesfaye, 2019). This includes provisioning of fresh water supply; fishing; habitat services for birds, hippopotamus, and crocodiles; and cultural services such as recreation, tourism, spiritual, religious, aesthetic, science and education. Despite being a freshwater source, Lake Hawassa is a closed-lake (in terms of surface hydrology) and resembles the 'sink' or ‘pollutant retaining’ nature of a sea, where surrounding areas are part of the hydrological boundary of the lake. For this reason, the bigger “Source-to-sea” notion is applied into a “Source –to – Lake” [S2L] context as an applicable approach to the local situation and the topic at hand.

1.2 Sediment as a physical as well as a chemical pollutant

Sediment is a natural component of all water bodies (Megahan, 1999) and both erosion and sedimentation are natural geomorphic processes (Megahan et al. 2004). However, excess sediment can be damaging to the ecological health of waterways and reduce their environmental, social and cultural values. Excessive sediment flows into water bodies such as lakes, can alter and disrupt the health of aquatic ecosystems. As a physical pollutant, sediment principally limits penetration of sunlight into the water column by increasing turbidity, thereby limiting or prohibiting growth of algae and rooted aquatic plants; and reduces storage capacities (Abebe et al. 2010; Eroglu et al., 2010). As a chemical pollutant, many of the persistent, bioaccumulating and toxic organic contaminants are strongly associated with sediment (FAO, 1996); including fertilizers (McIsaac et al., 1989).

1.3 Study area description

1.3.1 Geographic location

Lake Hawassa sub-basin is located in the central North-East of the Ethiopian Rift Valley Basin (*figure 1*) and covers an area of 143,651 ha. It contains five sub-watersheds: Dorebafena-Shamena, Wedesa-Kerama, TikurWuha, Lalima-Wendo Kosha and Shashemene-Toga. The geographical coordinates of the sub-basinis $6^{0}45^{1}$ to $7^{0}15^{1}$ North and $38^{0}15^{1}$ to $38^{0}45^{1}$ East latitude and longitude respectively. The sub-basinis are covered by two Regions, two Zones and 12 weredas. Overall, 71% of the sub-basin lies in SNNPRS and 22% lies within the Oromiya Regional State administrative boundary areas. The balance, 7% is Lake Awasa, which falls in both regions.

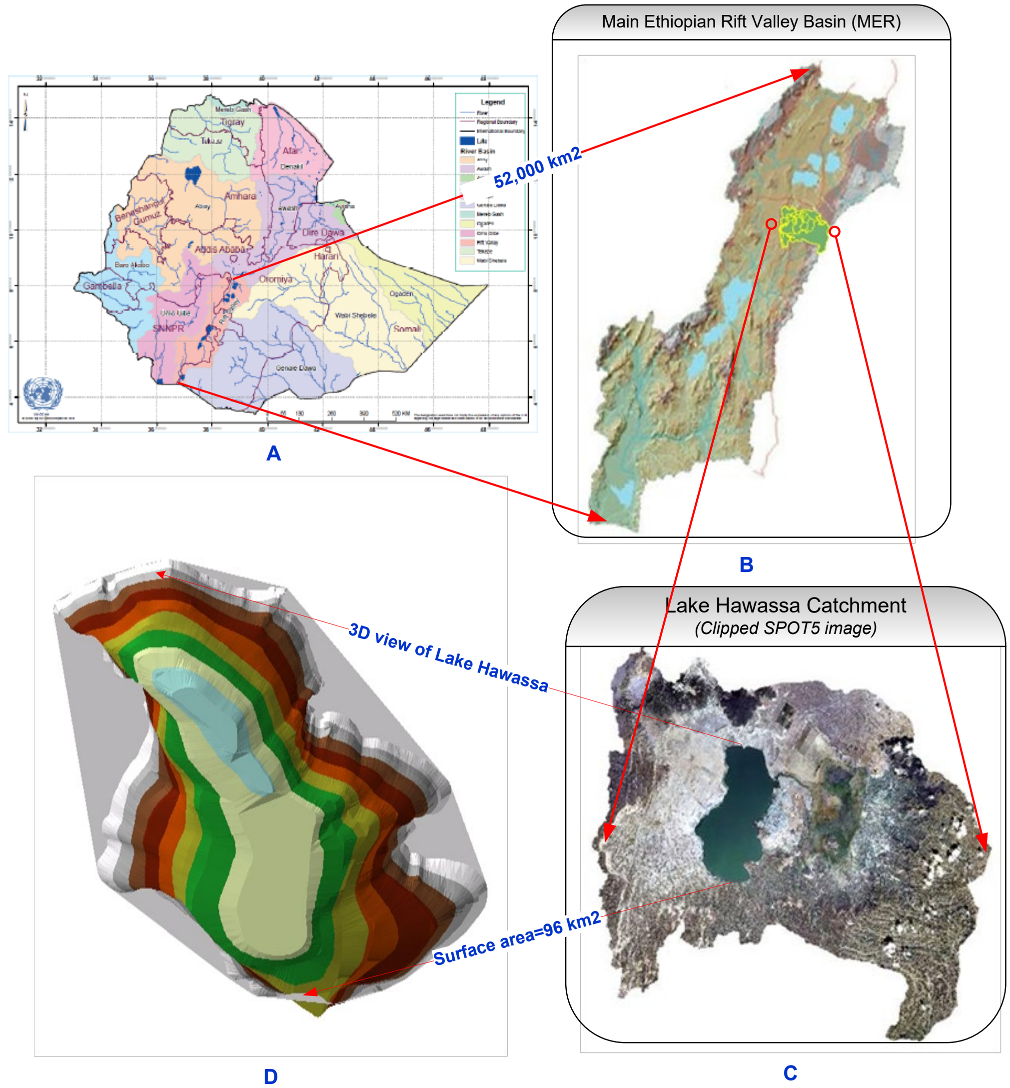


Figure 1. Maps of the study area at different scales

A: The 12 river basins of Ethiopia; B: The Main Ethiopian Rift Valley Basin ; C: Lake Hawassa sub-basin ; D: 3D view of Lake Hawassa

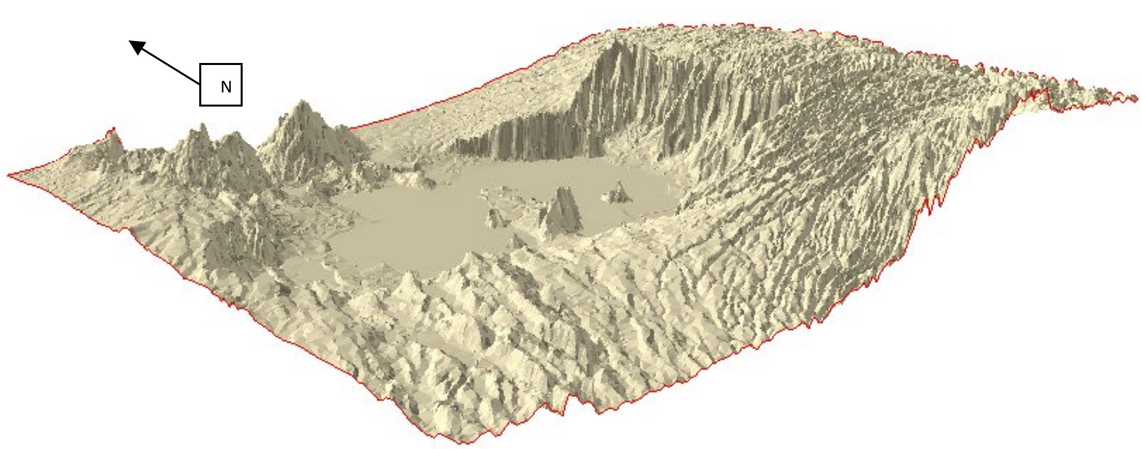


Figure 2. Three dimensional view of topographic diversity of the sub-basin

1.3.2 Water quality of Lake Hawassa

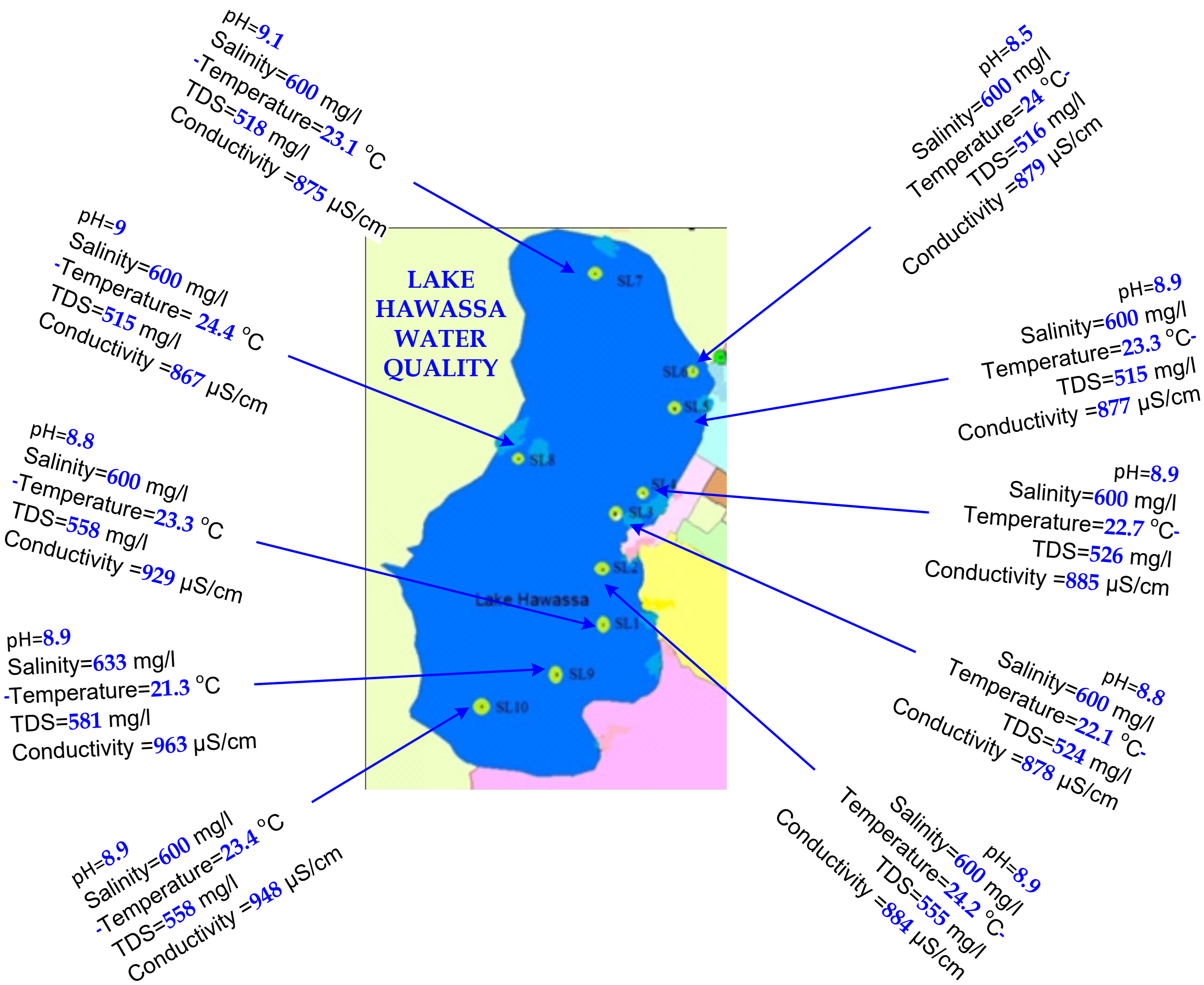


Figure 3. Physical water quality parametres of Lake Hawassa (Belete, 2014)

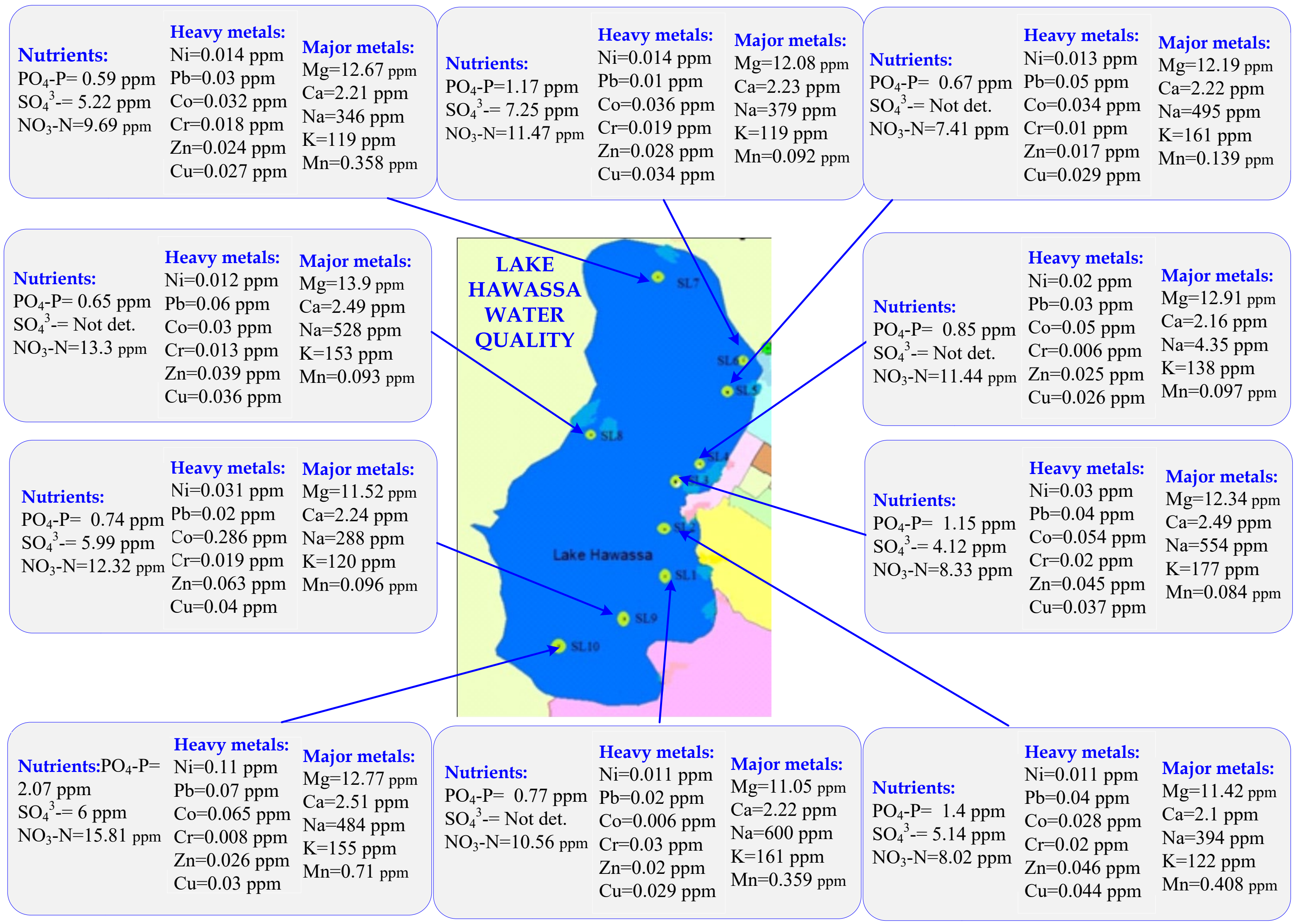


Figure 4. Chemical water quality parameters of Lake Hawassa (Belete, 2014)

1.3.3 Species divesity of Lake Hawassa

Fish fauna:
1. *Oreochromis niloticus*
2. *Labeobarbus intermidius*
3. *Barbus paludinosus*
4. *Aplochelichthys antinorii*
5. *Clarias gariepinus*
6. *Garra sp.*

Vegetation around the lake:
1. *Nymphaea caerulea,*
2. *Potamogeton schweinfurthii,*
3. *Typha angustifolia,*
4. *Paspalidium germinatum*
5. *Ludwigia stolonifera.*

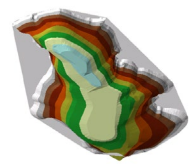
Zooplanktons: Rotifera
1. *Asplanchana seiboldii*
2. *Asplanchna sp.*
3. *Brachionus calyciflorus*
4. *B. caudatus*
5. *B. fulcatus*
6. *B.bidentata*
7. *Cephalodella gibba*
8. *Filinia longiseta*
9. *Fillinia sp.*
10. *Keratella cochlearis*
11. *K. tropica*
12. *K. valga*
13. *Lecane luna*
14. *Polyarthra sp.*
15. Testudinella sp.
16. Trichocera elongate
17. *Brachionus quadridentata*

Zooplanktons: Copepoda
1. Thermocyclops consimili
2. *Mesocyclops aequatorialis*
3. *Mesocyclops sp.*
4. *Phyllodiaptomous*

Zooplanktons: Cladocera
1. Diaphanosoma excisum
2. Moina micrura
3. Ceriodaphnia sp

Zooplanktons:Dipetra
1. Chironomous larva

LAKE HAWASSA



SPECIES DIVERSITY

Phytoplanktons: Cyanophyceae (Cyanobacteria)
1. *Anabaena circinalis*
2. *Anabaena sp.*
3. *Anabaenopsis sp.*
4. *Aphanizomenon sp.*
5. *Cylindrospermopsis Africana*
6. *C. Curvispora*
7. *Microcystis aeuroginesa*
8. *Nostoc sp*
9. *Planktolyngbya sp.*
10. *Psuedoanabaena sp.*
11. *Raphidiopsis sp*

Phytoplanktons: Dinophyceae (Dinoflagellates)
1. *Peridinium sp.*

Phytoplanktons: Cryptophyceae (Cryptophyta)
2. *Cryptomonas obvata*

Phytoplanktons: Euglenophyceae (Euglinophyta)
3. *Phacus longicaudar*
4. *Lepocincilis sp.*

Phytoplanktons: Bacillariophyceae (Diatoms)
1. *Cymbella*
2. *Fragillaria*
3. *Mellosira sp.*
4. *N. rostellate*
5. *Navicula cryptocephale*
6. *Navicula sp.*
7. *Nitzschia sp.*
8. *Nitzschia vernicularis*
9. *Surirella*
10. *Synedra*
11. *Thalassiosira sp*

Avian fauna (endemic):
1. *Yellow-fronted Parrot Poicephalus flavifrons,*
2. *Black-winged Lovebird Agapornis taranta,*
3. *Banded Barbet Lybius undatus and*
4. *Forest Oriole, Oriolus monacha.*

Avian fauna (wetland migrant birds):
1. Egyptian Goose, *Alopochen aegyptiacus*
2. Cotton Pygmy Goose, *Nettapus coromandelianus*
3. White-faced Wistling Duck, *Dendrocygna viduata*
4. Spur-winged Goose, *Dendrocygna viduata*
5. Knob-billed Duck
6. Red-knobbed Coot, *Sarkidiornis melanotos*
7. African Fish Eagle, *Haliaeetus vocifer*

Figure 5. Species diversity of Lake Hawassa (Extracted from Patnaik (2014)*)*

1.3.4 Topography and soils

The majority of the sub-basin is flat to gently undulating but bounded by steep escarpments. The altitude ranges from 1,680m at Lake Hawassa to 2,700m on the Eastern escarpment: an altitude range of 1,020m. Most slopes (56%) are flat to gentle (0-8%) with a further 33% moderately sloping (8-30%) and only 5% steep to very steep (>30%). In terms of traditional eco-climatic zones (Hurni, 1998), most of the area is classed as Weyna Dega with Dega in the eastern highlands with growing periods of 120-180 days in the west and 180-300 days in the eastern highlands (MoWR, 2010). *Figure 2 (above)* demonstrates the topographical variations in the sub-basin. Four major soil types have been identified: Andosols (10% of the basin), Cambisols (54%), Luvisols (27%) and Leptosols (2%) with Nitisols and Regosols occurring in association with these soils.

1.3.5 Farming and cropping system

Rainfed agriculture is the predominant type of agriculture in the basin, and most of the famers practice double-cropping production benefiting from the bi-modal rainfall regime of the basin. The period from March to May is locally named as “Belg” season; and from June to November named as “belg” season.

The distribution of the farming systems within the sub basin is shown in *table 1*. There are three major farming systems, enset based mixed farming, lowland cereals mixed farming and commercial farming. Mixed farming implies that cattle are, to varying extent, integrated into the crop production system. Out of total area of the sub-basin, 87% has been categorised into farming systems, the remainder is lake, seasonal and permanent marshland and urban areas.

Table 2. Farming system distribution (ha)

Major farming system	Farming sub-system	Area (ha)	Area out of farming system area (%)	Area out of sub-basin area (%)
Enset Based Mixed		47,218	38%	33%
	Enset Based Mixed Perennials	15,094	12%	11%
	Enset Based Mixed Cereals	32,124	26%	22%
Lowland Cereals Mixed		57,825	46%	40%
Commercial		19,324	16%	13%
	Smallholder Commercial	8,315	7%	6%
	Large-scale commercial	11,009	9%	8%
Total coverage		124,368	100%	87%

Source: MoWR (2009)

1.3.6 Population

An older estimate of (MoWR, 2010) shows that the sub-basin is relatively urbanised with 9 urban areas occurring within the sub-basin although only two centres have populations greater than 10,000; Hawassa at 158,275 and Chuko in Wendo Genet Wereda at 14,600. According to the (2009/2010) socio–economic profile, the total population of the sub-basin is estimated to be 3,374,341 (Male 2,027,239 and female 1,397,760) from these, urban population 519,390 (male 286,263 and female 233,127) and rural population 2,798,998 (male 1,687,063 and female 1,111,935). Population density (urban and rural) for the whole sub-basin is very high at 624 people per km^2 (total RVLB average = 167 people/km^2). The rural population density is 3.65 per ha in the west and 5.17 ha in the east.

1.4 Methodology

The very nature of source-to-lake approach is defined by its diverse requirements of physical, socio-economic, and governance information along the continuum. To satisfy this need and conduct an integrated scientific study, a combination of diverse scientific methods is needed. For this, the following methods were employed for this study:

1. Document analysis,
2. Systematic literature review,
3. Interviews,
4. Focus group discussion,
5. Field visit,
6. Early result validation was done through field visit, and
7. Frequent consultation of the stakeholders.

This study mainly focuses on the first three steps of source-to-sea approach as shown in *figure 6* below:

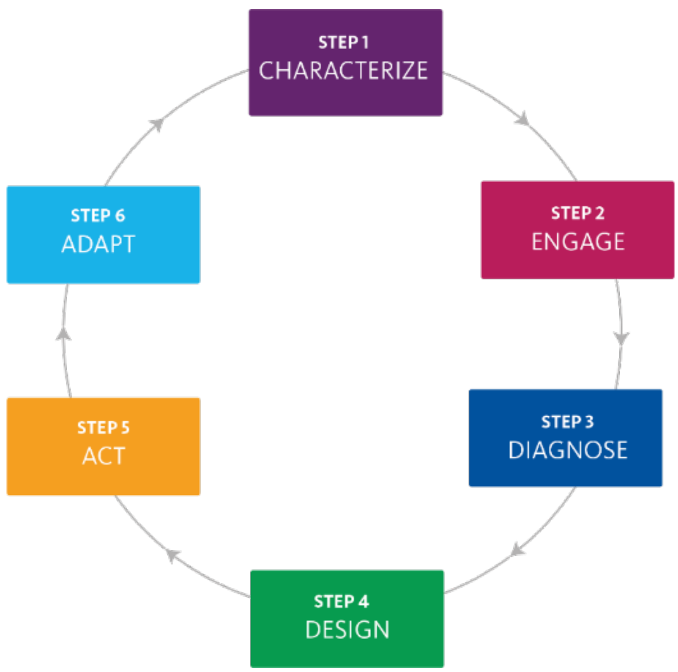


Figure 6. The six steps of the source-to-lake approach

Chapter 2

Characterization of sediment flow along the Source - to - Lake (S2L) continuum in Lake Hawassa Sub-Basin

2.1 Introduction

In the source-to-sea approach, characterization of the key flows is the first step. It defines the attributes of segments in the continuum and the system in general. As specified in chapter one of this document, we are attempting to downscale the concept of “source-to-sea [S2S]” approach to suit the local condition and coined the concept as “source-to-lake [S2L]”. In our case, this S2L approach takes sediment as the key flow which calls for urgent intervention on one hand, and hydrologically delineated catchment area as system boundary on the other hand.

In order to serve as a technical platform for the subsequent steps in the source-to-lake procedures, this step shall address the following guiding questions:

1. What is known about the sediment flow and how it has been altered from its natural range of variation?
2. What caused this alteration in the sediment flow and where does it occur?
3. What is the impact from this alteration?
4. Given the sediment flow that has been altered, the origin of the alteration and its impact, what is the system boundary?

2.2. The sub-basin hydrological region as the Source –to- Lake System boundary

Freshwater ecosystem structures and functions are tightly linked to the sub-basin or catchment of which they are a part (Baron et al., 2002). Lake Hawassa is literally the "sink" into which the landscape drains. It is greatly influenced by terrestrial processes, including many human uses or modifications of land and water. From the perspective of sediment flow in the source-to-lake continuum, management in a piecemeal approach cannot solve the problem confronting freshwater ecosystems (Baron et al., 2002). Such argument is in favor of the basic philosophy of source-to-lake approach which recognized the interlinkage among the segments in the continuum. In addition, the major agent of soil erosion and sediment transport in the sub-basin is water. Due to poor vegetation cover on intensively cultivated land, when a raindrop strikes the soil surface it may break soil aggregates or individual soil particles, making them more susceptible to transportation. Transportation of the material detached is affected mainly by running water. Generally, given that the nature of sediment production and transport follows the hydrology, fixing the unit of analysis and the system boundary to be the sub-basin catchment is scientifically justified.

2.3. Identification of representative continuums and system components

In order to address heterogeneity of the lake system, three distinct continuums are considered as shown in *figure 7*. All of these continuums contribute sediment of different nature to the lake. This study pays more attention to the first continuum and marginally touches the others due to the fact that they are to be addressed by other studies.

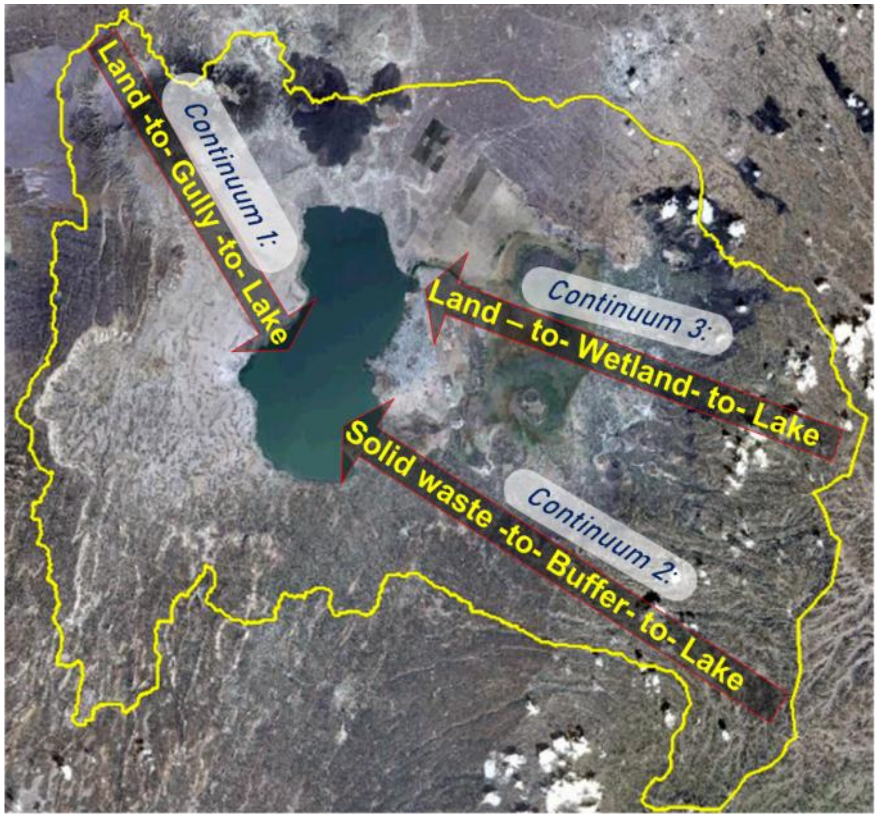


Figure 7. Typical source-to-lake continuum characterizing the sediment flow in Lake Hawassa sub-basin

- *Continuum # 1*: represents the sediment flow path that drains the forest lands -agricultural lands - extremely gullied landscape – deltas - & – the lake. Shortly termed as ***'Land-gully-lake continuum'***.
- *Continuum # 2:* This sediment flow path carries the municipal solid wastes from Hawassa City into the lake system through the buffer zone. Shortly termed as ***'Solid waste-buffer-lake continuum'***.
- *Continuum # 3*: This continuum contains wetlands as a major component in impacting the sediment flows. This continuum provides a chance for sediment trap in the wetlands. It is shortly termed as ***'Land-wetland-lake continuum'***.

2.4. How much sediment is silted-up in Lake Hawassa and what are its impacts?

2.4.1. Amount of sediment accumulated in Lake Hawassa and associated impacts

Sequential bathymetry surveys (*figure 8*) conducted in 1999 by WWDSE (2001) and by Belete (2013) revealed that Lake Hawassa has lost 4% of its storage capacity in a decade due to sedimentation (Abebe et al., 2018).

> Lake Hawassa has lost 4% of its storage capacity in a decade due to sedimentation. If left unmanaged, the sediment will ultimately fill up the lake and destroy the ecosystem.

In 1999

In 2011

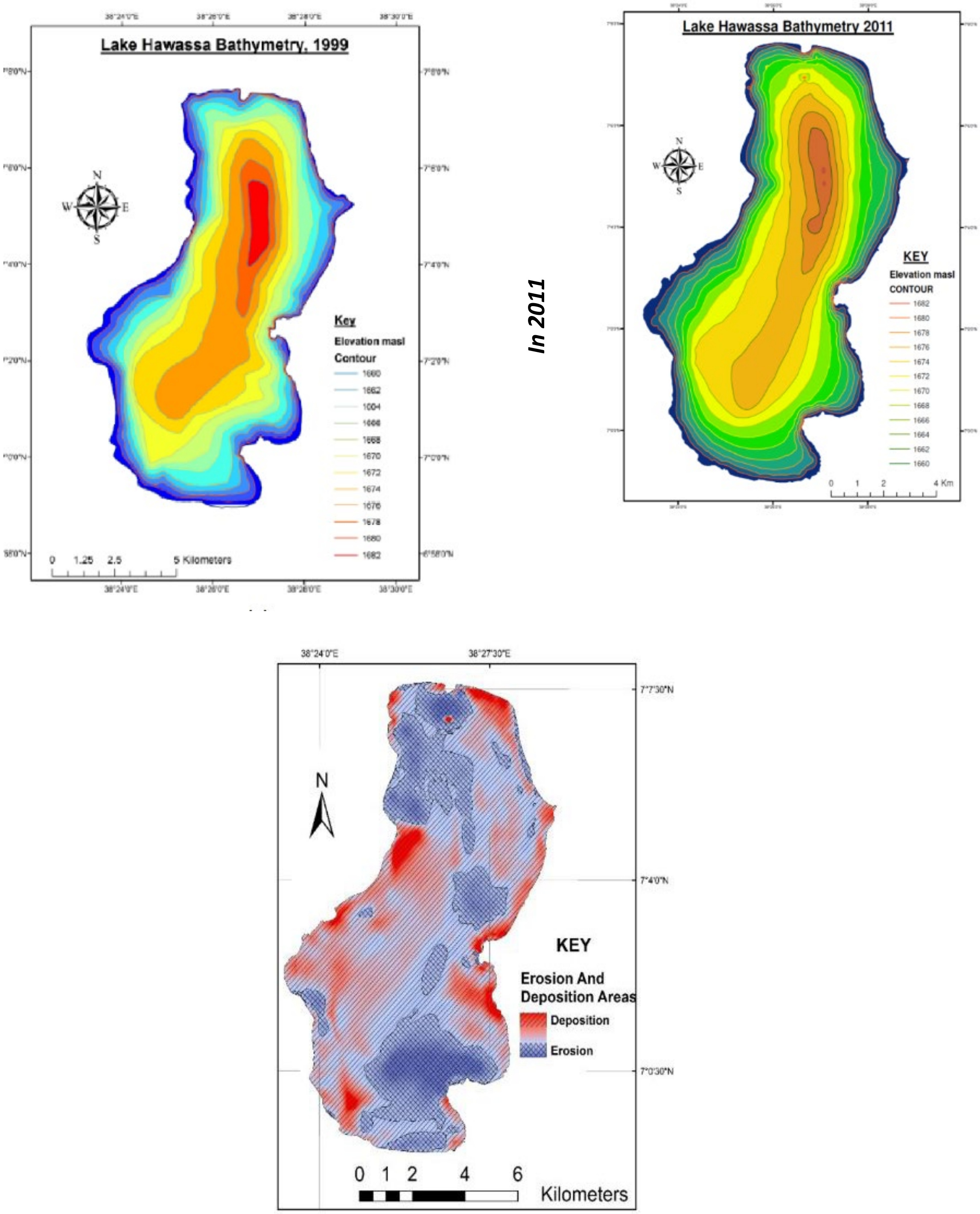


Figure 8. Bathymetric maps of Lake Hawassa in 1999 and 2011 and spatial variations of sediment deposition

In addition to the morphometric changes, sedimentation also has impact on the aquatic system. Despite the absence of specific empirical evidences on such effects, it is well understood that sediment load potentially has the following environmental impacts on freshwater bodies like Lake Hawassa:

- Burial of bottom-dwelling organisms
- Loss of important or sensitive aquatic habitat,
- Decrease in fishery resources,

- Loss of recreation attributes,
- Nutrient balance changes,
- Circulation changes,
- Increases in turbidity,
- Loss of submerged vegetation, and

2.5. Characterization of the Land-gully-lake continuum' [#1]

2.5.1. Pictorial representation of the continuum with its linking components and system

Figure 9. Pictorial representation of Land-gully-lake continuum' [#1] and the system boundaries

2.5.2. Where in the system does active sediment erosion occur? Identification of hot-spots

Basically, sediment is the result of erosion; and there are three types of erosion in the land-to-lake continuum: sheet; rill; and gully erosions. Techniques of assessing the first two are usually the same whereas gully erosion is rarely assessed. In this study, the well known Wischmeier and Smith's (1978) empirical Soil Loss Model (*USLE*) and the customized Pacific Southwest Interagency Committee (PSIAC, 1968) model were employed (*figures 10 and 11*) to assess the sheet and rill erosion sediment erosion hot-spot. The former model was adapted for Ethiopian condition (Hurni, 1985) and the latter used as a support. For sediment erosion from gullies, we used direct methods based on mapping the gully networks and computing its density (= $total\ length\ of\ the\ gully\ along\ the\ continuum/The\ corresponding\ land\ area\ containing\ the\ gully.$

2.5.2.1 Identified hot-spots using universal soil loss equation (USLE)

This method uses six catchment characteristics (Wischmeier and Smith, 1978) to identify erosion hot-spots in the sub-basin. It estimates annual soil erosion rate based on the following equation:

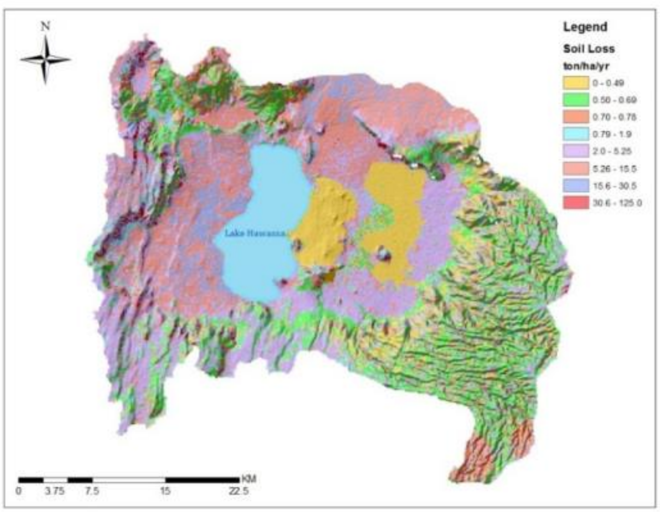


Figure 10. Result of USLE model

A = R * K * L * S * C * P

Where:

A*= average annual soil loss in tons/ha/year;*

R*= Rainfall erosive index factor (MJ mm/ha.hr.yr);*

K*= Soil erodibility factor (ton hr/ MJ mm);*

L*= Slope length factor (dimensionless);*

S*= Slope steepness factor (dimensionless);*

C*= Crop-Management factor (dimensionless);*

P*= Conservation practice factor (dimensionless)*

2.5.2.2 Identification of hot-spot using PSIAC (Pacific-Southwest Inter-Agency Committee) model

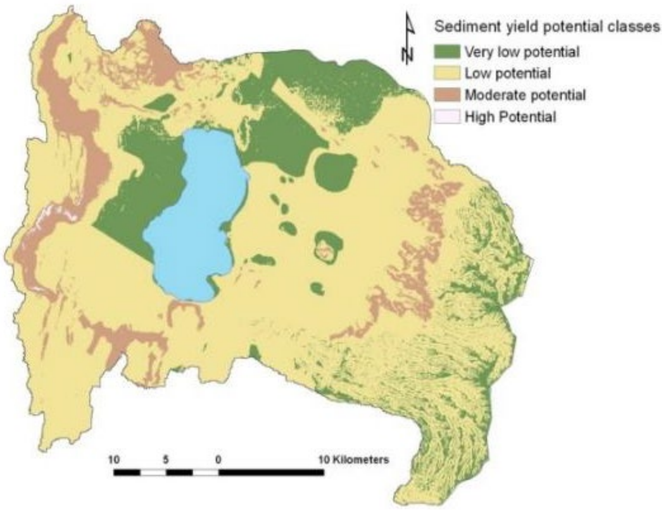


Figure 11. Result of PSIAC model

The model requires nine factors to characterize the sub-basin with a score to each factor. The first division includes sub-basin parameters related to geographic features, namely: ***X1****= geology,* ***X2****= soils,* ***X5****= topography,* ***X6****= ground cover, and* ***X7****= land use. These parameters respond to other parameters, such as* ***X3****= climate (rainfall), which causes erosion and the development of gullies and rivers. The response of the geographic parameters to the rainfall is represented by the following parameters:* ***X4****= run off.* ***X8****= upland erosion, and* ***X9****= sediment transport in the stream channel.*

2.5.2.3 Gullies: the main sources as well as main pathways of sediment flow in the sub-basin

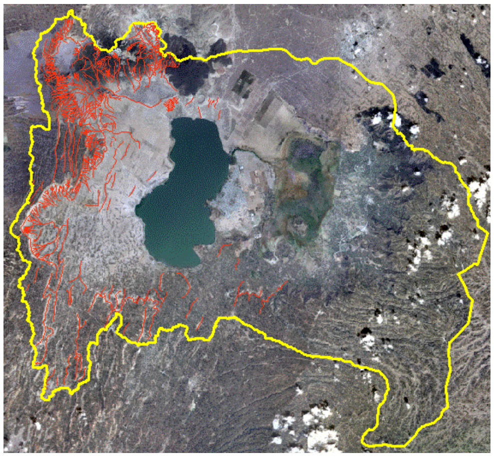


Figure 12. Maps of individual gully segments

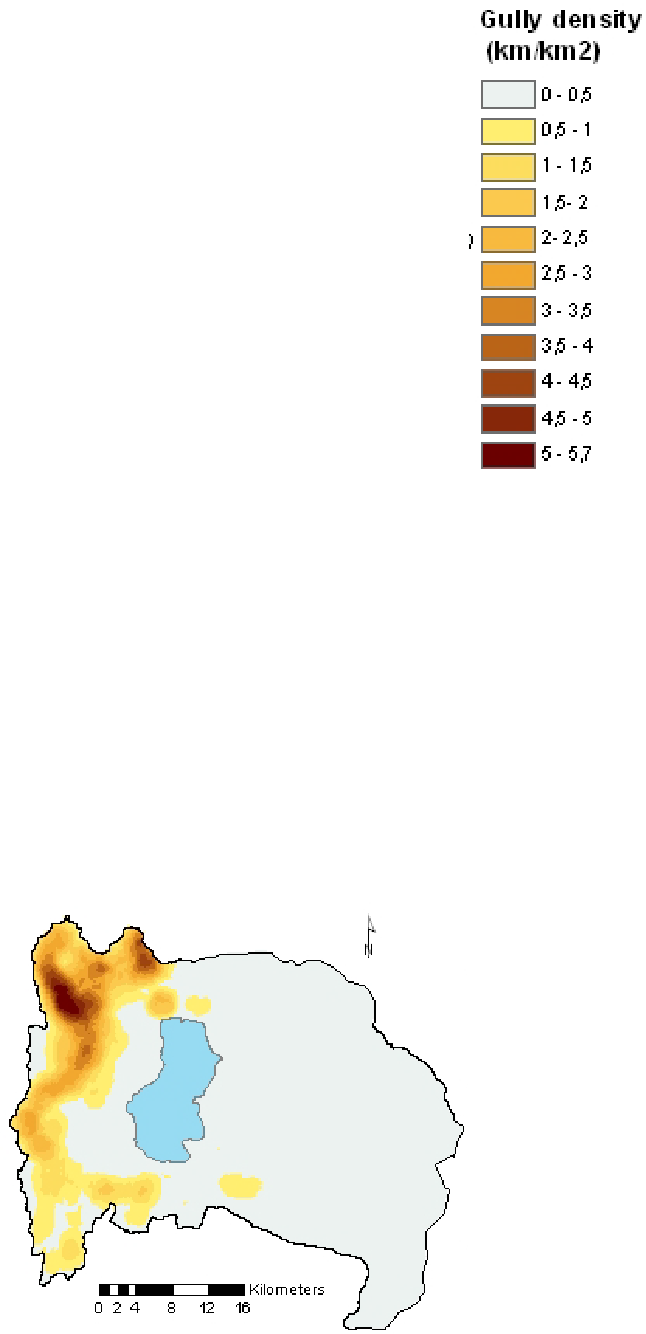


Figure 13. Distribution of gully density in the sub-basin

Gully erosion is the dominant type of erosion in the sub-basin and it is considered as a significant process for delivering sediment to the lake. The spatial distribution of gully density is assessed based on the data provided by MoWR (2010). Accordingly, the sub-basin contains 750 segments of gullies with a total linear length of about 668 km which are concentrated on the Western side of the lake (*figure 12*).

Assuming an average width of gullies to be 8 m (field observation) and 2 m of unusable agriculture lands in both sides due to gully formation, it is estimated that about 800 ha of cultivable lands have been out of production which is a significant hit to the agricultural economy as well as livelihood of the local community who owns an average land holding of 0.5 ha per family (MoWR, 2010).

2.5.2.4 Analyzing the relative contribution of gully vs sheet + rill erosion vs. solid waste for the sediment flow in the sub-basin

Box 1. Relative contribution of gully vs. sheet & rill vs. solid waste on sediment sources

[1] Comparison in terms of erosion rate:

= Average rate of gully erosion in the sub-basin ≈ <u>22</u> ton/ha/yr (*Hoogenboom, 2013*)

= Average rate of sheet + rill erosion in the sub-basin = <u>7.5</u> ton/ha/yr

= Ratio = $\frac{Gully=22}{Sheet+Rill=7.5} \approx \mathbf{3\ fold}$

[2] Comparison in terms of volume:

= Volume of sediment erosion due to gully = <u>68,575</u> m^3/yr. (Derived from *Hoogenboom, 2013*)

= Volume of sediment erosion due to sheet + rill =

= 7.5 ton/ha/yr x 1337 ha of land = 10,028 ton/yr

= 10,028 ton/yr x 1.4 t/m^3= <u>14,039</u> m^3/yr (Assuming bulk density of sediment (*Ghimire et al. 2013*)

= Ratio = $\frac{Gully=68{,}575\ \mathrm{m3/yr}}{Sheet+Rill=14{,}039\ \mathrm{m3/yr}} \approx \mathbf{5\ fold}$

[3] Solid waster as a contributor to lake sedimentation as compared to gully erosion:

Amount of solid waste lost in the environment in Hawassa City= 55.25 ton/day = <u>20,166</u> m^3/yr (*RiPPLE, 2014*)

= Ratio = $\frac{Gully=68{,}575\ \mathrm{m3/yr}}{Solid\ waste=20{,}166\ \mathrm{m3/yr}} \approx \mathbf{3.4\ fold}$

2.5.3. What activities and factors in the catchment alter the natural regime of sediment flow?

2.5.3.1 The land use dynamics gord beyond the natural range of variations

Wondrade et al. (2014) studied the dynamics of land use changes in Lake Hawassa sub-basin for the duration between 1973 and 2011 as shown in *table 1* below.

Table 3.Spatial coverage and proportion of land cover classes resulted from classified images

Land cover (LC) classes	1973 Area of LC (km^2)	1973 (%)	1985 Area of LC (km^2)	1985 (%)	1995 Area of LC (km^2)	1995 (%)	2011 Area of LC (km^2)	2011 (%)
Water	103.3	7.2	101.5	7.1	100.3	7.0	95.8	6.7
Built-up	4.2	0.3	5.8	0.4	8.6	0.6	24.6	1.7
Cropland	625.3	43.6	699.7	48.7	766.7	53.4	809.1	56.4
Woody veget.	301.1	21.0	275.8	19.2	218.7	15.2	194.9	13.6
Forest	148.0	10.3	102.5	7.1	93.2	6.5	81.0	5.6
Grassland	71.8	5.0	78.2	5.5	73.8	5.1	65.8	4.6
Swamp	67.8	4.7	77.3	5.4	70.7	4.9	64.2	4.5
Bare land	18.1	1.3	28.4	2.0	42.1	2.9	39.9	2.8
Scrub	95.2	6.6	66.5	4.6	61.7	4.3	60.5	4.2
Total	1434.9	100.0	1435.7	100.0	1435.8	100.0	1435.9	100.0

Description: *Water = All areas of open water, including lakes, rivers, and ponds; Built-up= all residential, commercial, and industrial buildings, transportation infrastructures, and play grounds; Cropland= Mechanized and smallholder's farms, tilled and planted, bare crop fields, and limited areas temporarily left as fallow; Woody Vegetation= Land covered by bushes and shrubs, in some cases mixed with grasses. Forest= Natural and plantation forest with trees forming open to closed canopies, 30 -70% and more than 70% respectively; Swamp= Area with topographic low where water table is near, or above the land surface.; Bare land = Land surface devoid of vegetation, sand along lake side, exposed rocks, and quarries.; Scrub= Specific area characterized by scattered bushes to closed canopy vegetation dominated by shrubs, grasses, and small trees usually less than 5m tall, and occasionally with few scattered trees.*

Another study by *Dessie (2004)* and *Esayas (2010)* revealed that expansion of agriculture in particular smallholder farming, contributes to over 80% of the forest area loss. This expansion is characterized by two major modes of change: 1) *internal:* clearings created by the intrusion of small farm plots, grazing lands, and villages 2) *external:* expansion of agriculture from the exterior into the forests. Generally, the changes from natural vegetation to cultivation as depicted by *figure 14*.

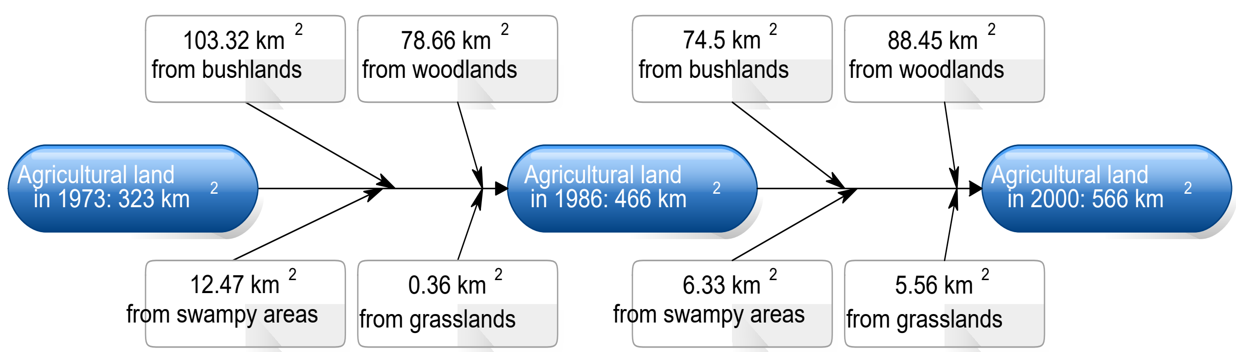


Figure 14. Trends of agricultural land expansion in the sub-basin[Raw data: Abrha (2007)]

2.5.3.2 The pumice/erodible nature of the soil worsens its susceptibility to sediment erosion

Figure 15. Pumice nature of the soil that further complicates the gully erosion problem

The weaker and softer rocks are more easily eroded and generally yield more sediment than do the harder more resistant types. The relative susceptibility of the sub-basin parts with distinct geologic types were appraised by *Ayenew (2019)* (*personal communication*) from Addis Ababa University, department of Earth Sciences, who has substantial involvement on researches on the Lake Hawassa sub-basin. The rate is shown on *table 2*.

Table 4. Rating of geological formations (from least to most susceptible to erosion)

	Coding in map	Geological property	PSIAC Rating
1	Qwo	Obsidian and pitch stone	2
2	NQs	Nazreth group and dino formation, undifferentiated	3
3	Qwa	Rhyolitic and trachytic lava flows	4
4	Qdi	Ignimbrites, tuffs, water lain byroclatics, occasional lacustrine beds	5
5	N1_2n	Stratoidsilicics: ignimbrites, unwelded tuffs, ash flows, rhyolites and trachytes	6
6	Qvs	Volcanic sedimentary rocks: lacustrine dominantly volcanoclastics sediments, tuffs	7
7	Qwpu	Pumice and unwelded tuffs	8
8	Ql	Lacustrine sediments: sand, silt, pyroclastic sediments, diatomites	9
9	Qdp	Coarse unwelded pumiciouspyroclastics	10

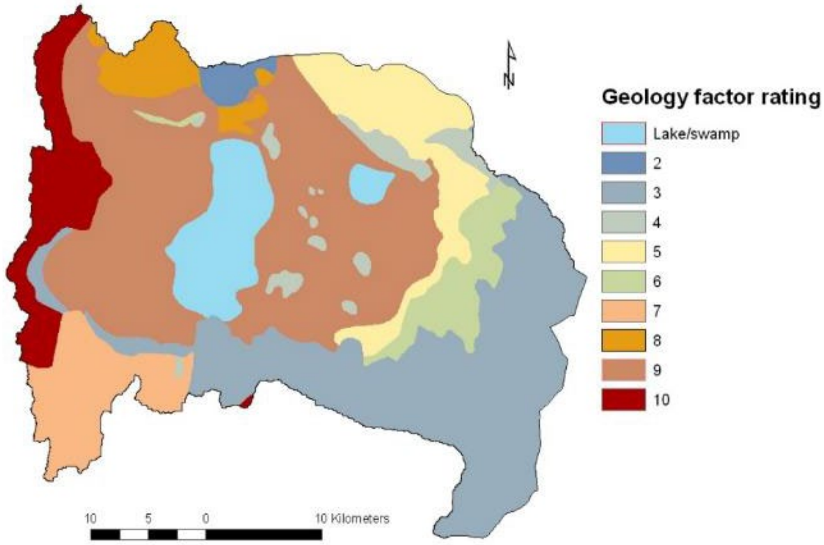


Figure 16. Spatial distribution of geology factor values

2.5.3.3 The use of "wood" as energy source and absence of alternative energy

Fuel wood supplies 84% of total energy demands of which about 50% is from shrub-lands and wood-lands (exceeding their mean annual increment of woody biomass) and only 5-10% is from woodlots with the remainder from crop residues and dung (*MoWR, 2010*). Household energy requirements are supplied largely by fuel wood collected from existing woodland and shrub land, maize straw, and charcoal with cow dung also used in the western part of the sub-basin. The use of biomass accelerates the rate of deforestation and erosion while the use of crop residues and dung as fuel, rather than returning this organic matter to the soil, causes a decline in soil fertility and deterioration in soil structure.

Table 5. Fuelwood demand per capita, stock and planting requirement (MoWR, 2010).

Wereda	Total Stock (m^3)	Total yield (m^3/ha/yr)	Per capita demand (m^3/per/yr)	Total Demand (m^3)	Difference (Yield-Demand) (m^3)	Status
Awasa Zuria	509,478	247,274	1.2	605,009	-357,735	Deficit
Shebedino	5,509	141,549	1.2	374,444	-232,895	Deficit
Shalla	748,594	40,996	0.6	84,986	-43,991	Deficit
Shashemene	324,217	67,580	1.3	411,752	-344,172	Deficit
Siraro	91,199	10,617	0.8	47,207	-36,590	Deficit

2.5.3.4 Socio-political changes

Ethiopia has witnessed several dramatic political changes during the course of the last century. These changes have been accompanied by transitional periods characterized by uncertainty and insecurity. In the absence of firm political control, control of resources has also been lacking. Many among the rural population have then taken the opportunity to usurp what has been available in terms of, for instance, forest land and forest products, adding to the process of forest decline (*Dessie, 2004; Dessie and Christiansson, 2008*).

2.5.3.5 Land tenure system

All lands in Ethiopia are nationalized and were redistributed in 1975. This policy has continued with the present government and the 1994 constitution specifies that land cannot be subject to sale or exchange (*FAO, 2004*). Issues of land tenure could include insecurity of tenure, ability to use land as collateral and the transferability of property rights and the impacts these have on land investment or factor (land, labor or capital) allocation. A major source of tenure insecurity emanates from the periodic land redistribution to land-poor households (*Mahmud Joseph and Pender, 2005*). This indirect driver is also identified by *MoWR (2010).* This issue is very critical as the less secure the tenure, the greater the encouragement to exploit the land, and become the major obstacles to conservation.

Currently, the government is implementing a land certification programme that is expected to reduce the effect of land insecurity among the land users but its effectiveness is not yet evaluated.

2.5.3.6 Limited technical capacity of the local development agents as well as the community to solve the problem of extreme gully erosion

The local development agents as wellas the community perceived that the sediment erosion is beyond their technical as well as financial reach; and tend to blame others and wait until external support is realized *(Personal communication, 2019).*

2.5.3.7 The gullies are not amenable to the conventional techniques of soil and water conservation

Conventionally, gullies are classified as: small, medium, and large; and there are technical specifications for each of these categories. However, the gullies prevailing in the sub-basin are not amenable to these categories. This is due not only to their depth, but also their widths as they are unusually wide which means they tend to be more ‘river’ than gully.

Figure 17. The gullies are unusually deep to treat conventionally

2.6. Characterization of the ‘Solid waste-buffer-lake’ [continuum #2]

2.6.1. Quantification of Municipal solid waste generated in Hawassa City that is lost in the environment and eventually joins the lake as sediment flow

In terms of sediment flow, the residential areas are the significant suppliers of solid waste to the source-to-sea/lake continuum. As shown in figure 8, about 55.25 tons of solid waste leaks into the environment without proper collection, transportation, and disposal.

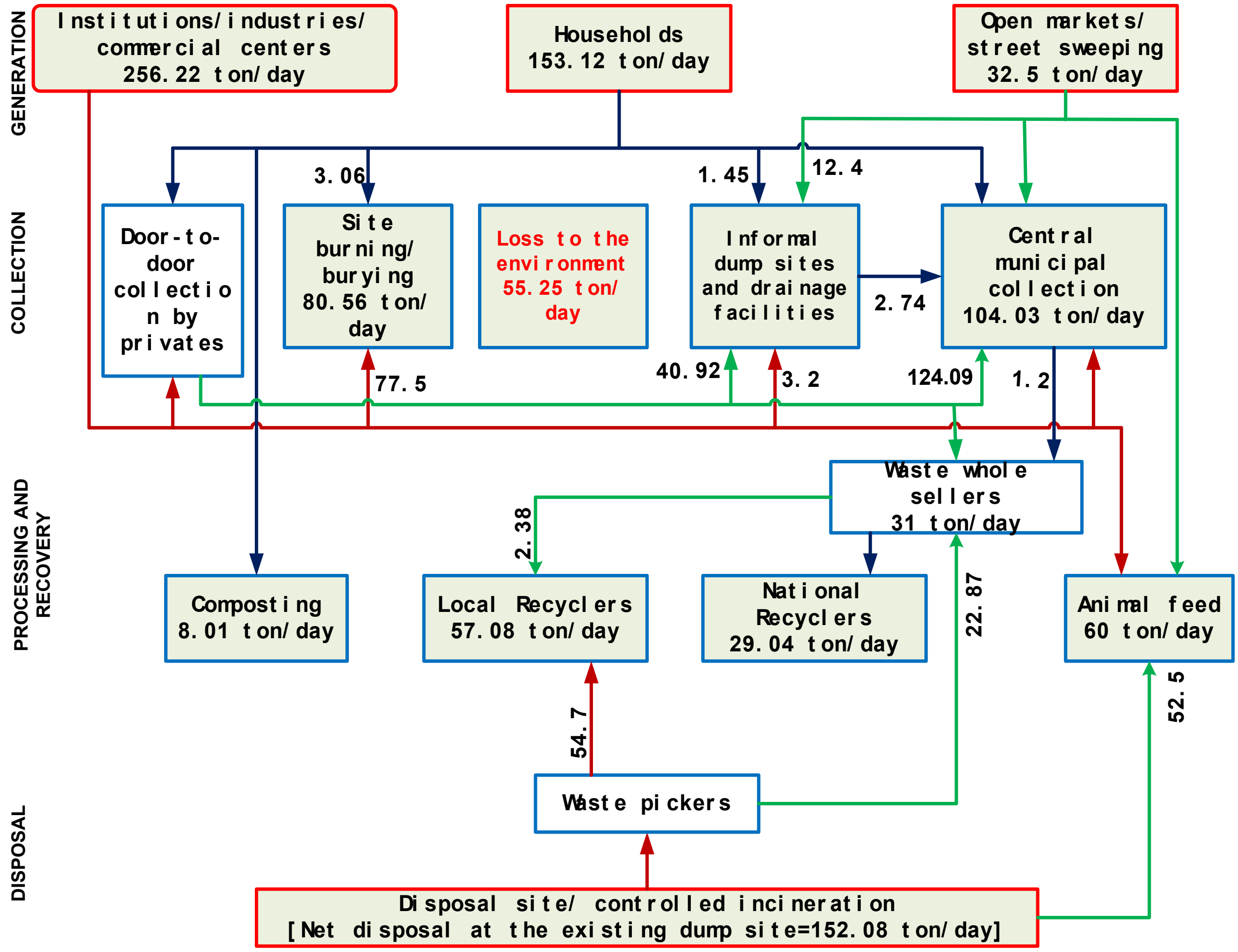


Figure 18. Material balance of municipal solid waste in Hawassa City (RiPPLE, 2014)

2.6.2. How does the solid waste management look like in Hawassa City?

The major governance documents that were used to evaluate the status of solid waste in Hawassa City include:

1. Solid waste management citizens' charter standards
2. Solid waste management standards implementation manual

In order to assess the current governance and management issue of municipal solid waste in Hawassa City that in turn links to sediment flow in Lake Hawassa, we used 27 indicators extracted from the local citizen charter. *Figure 19* revealed that solid waste management in Hawassa City is not up to standard and need to be improved.

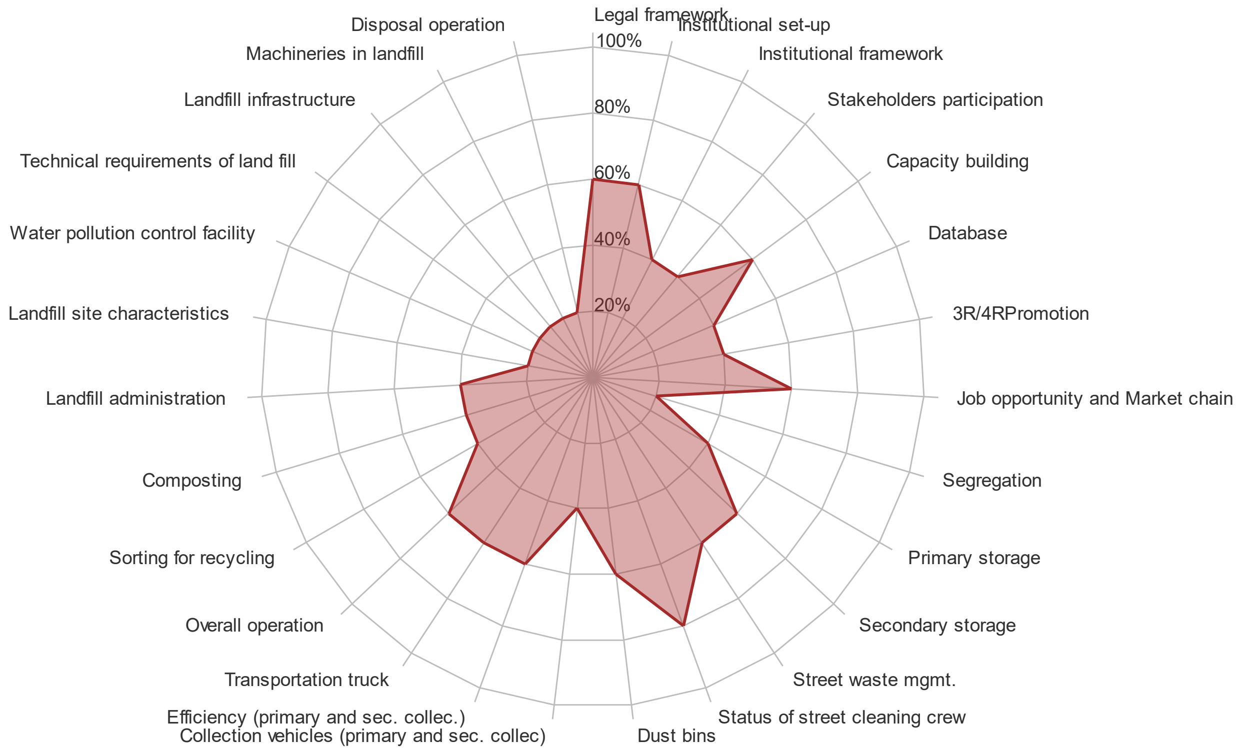


Figure 19. Current status of solid waste management in Hawassa City from the perspective of degree of compliance to the national standard[Source: Belete (2018)]

Key: ***1****=1 pt. =0-20% [very poor];* ***2****=2 pts. = 20-40% [poor];* ***3****=3 pts. =40-60% [Satisfactory];* ***4****=4 pts. =60-80% [Very good];* ***5****=5 pts. =90-100% [Excellent]*

2.7. Characterization of the land-to-wetland-to-lake [continuum #3]

2.7.1. What happened to Cheleleka Wetland, which has been serving as natural sediment-trap?

Wetlands have been described as a *living machine* (MacDonald, 1994) and the *kidneys of the planet* (Wallance, 1998). They can also be thought of as "*biological supermarkets*" and the third most important ecological system on this planet (WCU, 1987).

In the nineteenth century, Lake Hawassa and Cheleleka had been a single lake (Grove et al. 1975) and Lake Cheleleka was serving as a natural regulator of flow, sedimentation, and biogeochemistry for Lake Hawassa. The progressive silting up of Lake Cheleleka over the last 35 years (1972-2007) (*figures 20 and 22*) is an example that indicates the severity of the sedimentation problem in the sub-basin (Belete, 2017). This 12 km^2 loss in 45 years (≈0.27 km^2/yr or ≈2.25% per annum) is comparable with the nationally recognized tragedy of the disappearance Lake Haromaya, in Eastern Ethiopia, which experienced a loss of 8.3 km^2 in 30 yrs (≈0.28 km^2/yr or ≈3.37% per annum) (Alemayehu et al., 2007). The trends tend to confirm the report by Ramsar (2018) that noticed the rate of wetland disappearance to be three times faster than forests (globally).

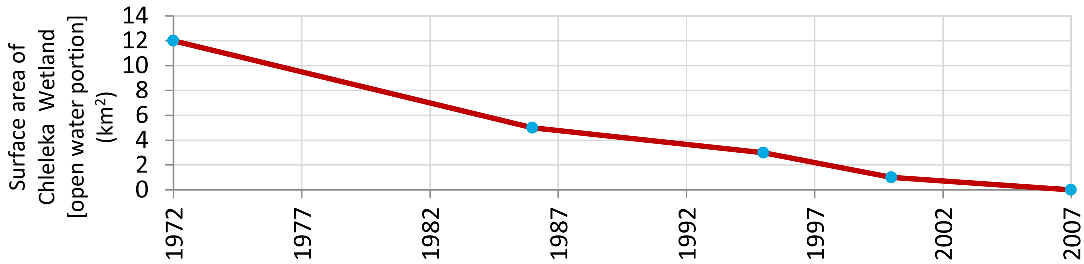


Figure 20. Time series of changes in the surface area of Lake Cheleleka

2.7.2. An overview of the anthropogenic factors affecting Cheleleka wetland

There are about 3000 illegal households (*figure 21)* with agro-pastoral ways of life living close to or on the Cheleleka wetland. The 'pull factors' that attract those households include: availability of fertile soil suitable for vegetable production; ample water, salty minerals (locally called "Bole") as supplementary food to cattle; and grasses suitable for livestock production; high economic return from fattening, dairy farming, horticulture activities and grass sales; and communal land with open access to all actors. There are also 'push factors' moving people there, such as: population growth and the resulting shortage of land for farming and grazing in the surrounding area; intimacy of livestock for the people socio-economic and cultural life; recurrent drought or shortage of grass and water during dry period; absence of communal grazing lands in the highland areas; social value associated with the size of herd; and economic motive to own many cattle.

Figure 21. Partial view of residential houses in the wetland

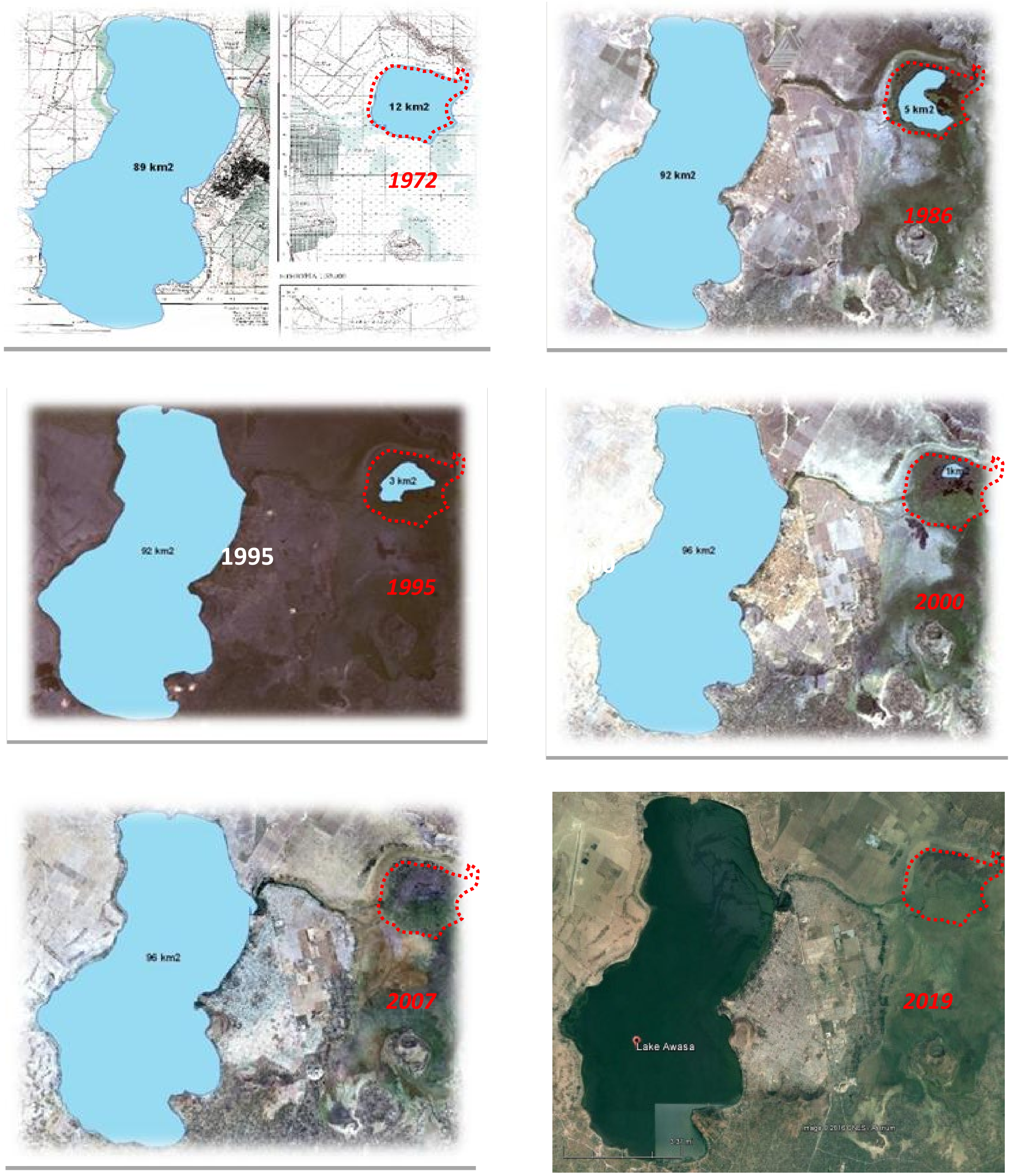


Figure 22. Temporal variation in open water portion of Cheleleka wetland

Chapter 3

Stakeholder identification and engagement plan to control erosion and sedimentation along the S2L continuum

3.1. Introduction

Step 2 is identifying and assessing the various stakeholders (*figure 23*) against the source-to-lake continuum in order to know what (and whom) to look for in the subsequent steps.

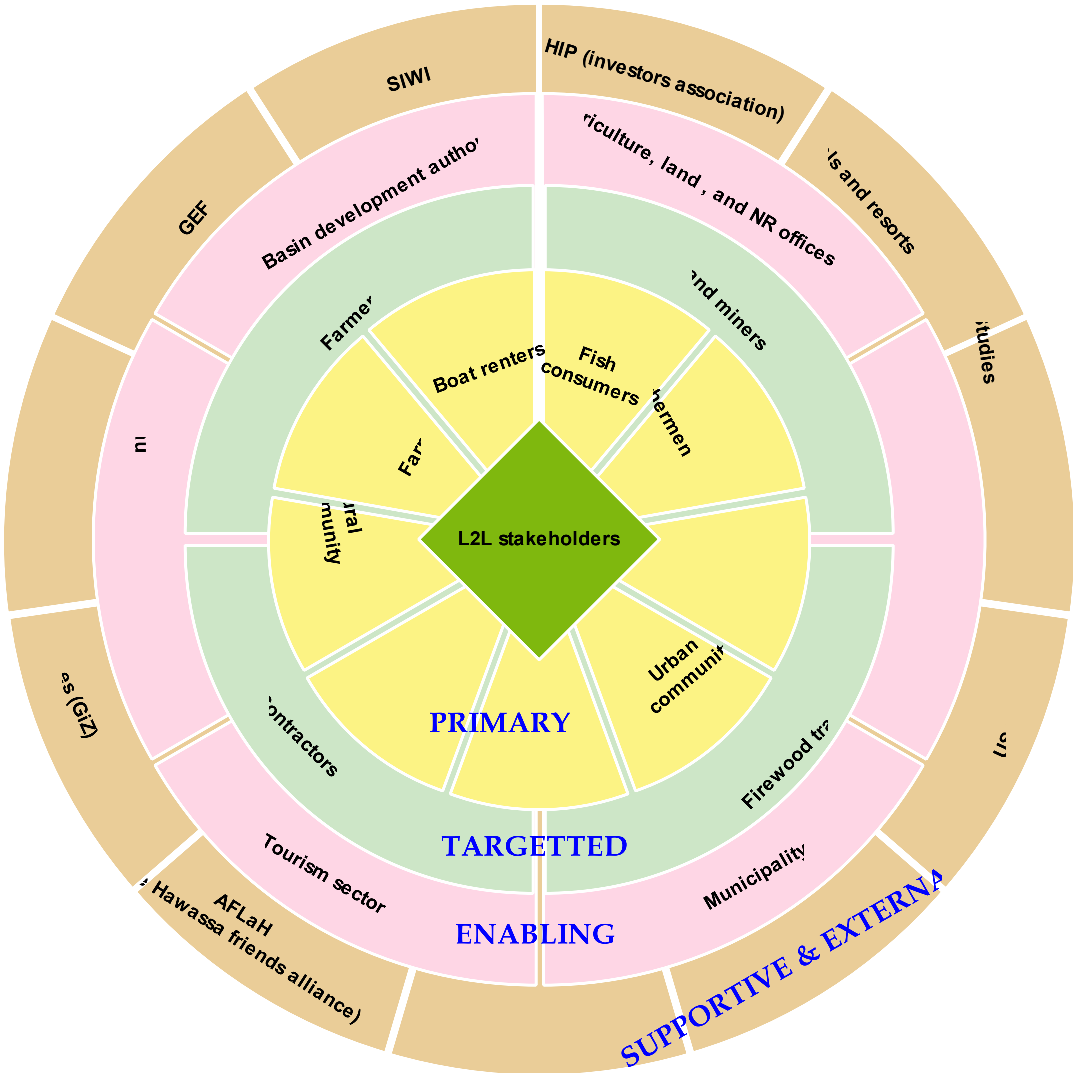


Figure 23. Stakeholders to manage the source-to-land system of Lake Hawassa sub-basin

Table 6. Stakeholders categories and role

	Categories	***Role/position/interest/concern***
Primary stakeholders		
1	Farmers	*Those farmers who are at the downstream and lost their land due to gully erosion and their productivity due to sheet and rill erosion. This group mainly includes farmers in the western, north-western., and south of the lake.*
2	Fishermen	*The lake is a fish depot for this groups of stakeholders and any ecosystem alteration due to sedimentation affectes their livelihood. They are mailnlylocated@AmoraGedel (in SNNPRS region) and TikurWuha (in Oromiyaa region) fish markets*
3	Hotel owners	*This group includes those hotels who are resorting around the lake (Lewi resort; Haile resort; Wabishebele hotel; Oasis etc. For the sake accessibility, thes hotels have an association called "hotel owners association" and it is feasible to approach them through this association.*
4	Boat renters and other business runners	*In addition to the hotels who are renting boats, thisgroups include those boat business runners at 'FikirHayq' (around the lake)*

5	Fish sellers and consumers	*This includes those small businesses of fish selling as well as the consumers.*
6	Urban community	*The lake serves as source of fish and recreation for this group*
7	Rural community	*The meant source of fish; water supply ; cloth washing*
Targeted stakeholder		
8	Farmers	*This group comprises those farmers who are at the upstream and failed to properly manage their land. Mainly includes farmers in the western, north-western., and south of the lake*
9	Sand miners	*These illegal sand miners are further activating the gully erosion by digging the gully bed for the purpose of sand extraction.*
10	Fire wood traders	*These retailers and also whole sellers in the cities/towns are indirectly encouraging deforestation and need to be aware of it.*
11	Contractors in the construction industry	*In order to transport construction materials from upstream of the lake, these contractors shall cross the gully network with heavy trucks that in turn triggers further erosion. The local sand miners follow their footprint to extract sands.*
Enabling stakeholder		
12	Basin development authority	*Mandated institution to implement IWRM in the basin*
13	Agriculture, land, and natural resources offices	*Mandated institution to manage the natural resources in the basin.*
14	Environmental authority	*Mandated institution to protect the lake from pollution.* This enabler, just like the above one, has wereda level governance structure to actually collaborate at the grass root level. Further more, these weredas have kebele level development agents to involve in the day-to-day implementation and follow-up of the project.
15	Municipality	*Mandated for solid waste management and lake protection*
16	Tourism sector	*The lake is also an attraction for tourists*
17	Investment bureau	*Governing the investments around the lake*
18	Hawassa University (CERVaS)	*Centre for facilitation generation and application of knowledge*
19	AFLaH	*Volunteer group*
Supporting stakeholder		
20	Hawassa industry park (investors association)	*Through their social responsibility*
21	Hotels and resorts	*Through their social responsibility*
22	SIWI	*Supporter*
23	GIZ	*Supporter*
24	Hawassa University (CERVaS)	*Research, technology transfer, university-industry linkage, and community service*
External stakeholder		
24	SIDA	*Potential donor*
25	GEF	*Potential donor*
26	USAID	*Potential donor*
27	EU	*Potential donor*

3.2 Stakeholder engagement through community-based natural resource management

While managing the land-to-lake system, there are diverse stakeholders to consider (as shown above). Most of the stakeholders have been in the system for a long period of time and also experienced different engagement approaches over time. There are a number of reasons for people to come together and have dialogue on shared issues. The expectation is that through dialogue, perceptions and problem definitions will change and converge (Poncelet, 1998). However, the multi-stakeholder dialogue is not just a conversation (Röling and Woodhill, 2001), nor the same as consultation (Burns et al., 2004). It is an interactive and mutually benefiting approach to getting things done- 'a contrived situation in which a set of more or less interdependent stakeholders in a resource are identified and invited to meet and interact in a forum for conflict resolution, negotiation, social learning and collective decision-making towards concerted and collective action' (Röling and Woodhill, 2001). It is both a process and an outcome (Burns et al., 2004).

In the current policy discourse, the philosophy of involving multiple stakeholder groups in development projects appears to be gaining popularity (Warner, 2005). Most of the issues we face today are neither owned nor solved by individual stakeholders anymore. Sustainable solutions for sustainability problems require sustainable processes of stakeholder involvement and engagement (Huijstee, 2012). With growing interdependence comes a growing need to search for collaborative approaches (Huijstee, 2012). Too often we talk about 'the community' as if we are all the same (Burns et al., 2004). Practically, stakeholders are diverse and need to properly participate in development projects for its success.

Community-based natural resource management (CBNRM) is, in various forms (Blaikie, 2006) and numerous definitions and interpretations (Anderson and Mehta, 2013), an established policy goal of development with the notion that communities should, and could, satisfactorily manage their own resources according to their local custom, knowledge and technologies (Blaikie, 2006) and it empowers the communities with the knowledge, skills, and authority to sustainably manage natural resources, such as water resources (Anderson and Mehta, 2013). It has been recognized as an alternative to conventional conservation approaches in the 1970s and 1980s (Roe et al., 2000) and promoted by most major international funding institutions since the early 1990s (Blaikie, 2006). The term 'community' may be understood in three ways-community as a *spatial unit*, as a distinct *social structure* and as a set of shared norms (Agrawal & Gibson, 2001).

Many organizations and projects has been creating space for local people to participate and benefit through the application of CBNRM approach in Ethiopia including JICA, GIZ, USIAD, IDRC, IUCN, IFAD, SLM and MERET projects. The study team also recommends SIWI to tailor the CBNRM approach to the upcoming project.

3.3 Suggested structure for effective stakeholder participation

The study team decided to tentatively indicate the likely structure of the project once the fund is raised and the project site is selected. We suggest four layers of stakeholders' involvement as shown below.

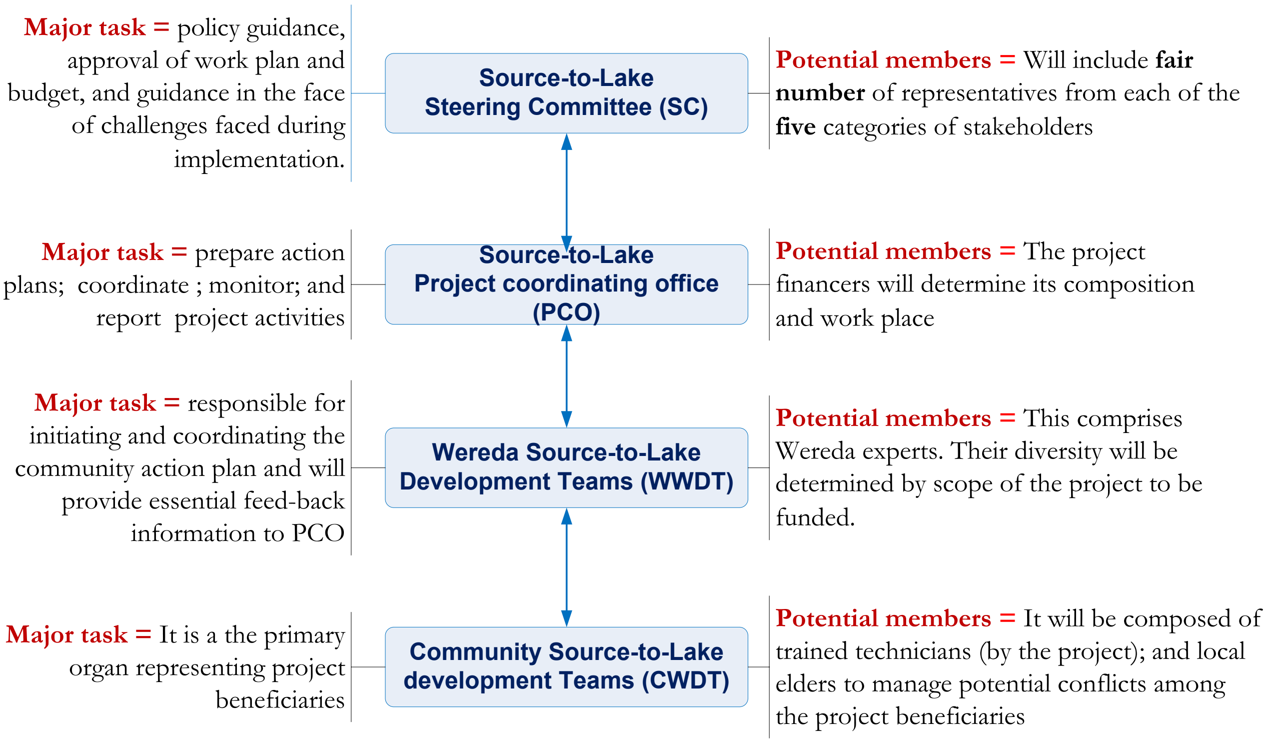


Figure 24. Recommended project structure

Chapter 4

Diagnosing the governance system in the source-to-lake continuum for sediment flow in the sub-basin

Current levels of sediment erosion in the continuum is direct evidence that the current governance system has fallen short of preventing sediment transport into the lake.

To understand the specifics of this situation more clearly, this section investigates the policies, laws, regulations, plans, procedures and the institutions that deliver them. Here, the governance baseline is considered in the context of the historical trends.

4.1 Which institutions are mandated to protect Lake Hawassa and other water bodies against sedimentation problems?

According to the current political delineation, the system boundary of the land-to-lake system falls into two regional governments, two Zones and 12 weredas. Overall, 71% of the sub-basin lies in SNNPRS (shortly, South Region) and 22% lies within the Oromiya Regional State administrative boundary (North-western part). The balance, 7% is Lake Hawassa, which falls in both regions. This complicates the implementation and management of projects, which will have to be implemented jointly between SNNPR and Oromiya Region. Furthermore, because the project area includes more than one regional state, the MoWR, MoARD and any other concerned ministries at Federal level must be included in project design.

The sub-basin also does not neatly encapsulate its constituent weredas, which further complicates implementation. In both regions, there is no public, private, or civil society institution that is mandated to address the whole land-to-lake continuum but Rift Valley Lakes Basin Office (RVLBO) which is operating under BDA (Basin Development Authority) within the Ministry of Water, Irrigation, and Electricity is closest. Such situation strongly justifies the strategic partnership of SIWI with RVLBO. *Box 2* presents some mandates of various institutions.

Box 2: Federal vs. regional governance in Ethiopia

Since 1994, the Federal Government embarked on a decentralisation process in a four-tier system of government. Below the federal government, the country is divided into nine regional states and two city administrations. The regional administrations are divided into administrative zones which are then separated into weredas (or districts). The weredasare considered to be the key element of local government and, in recent years, the Federal Government has taken further measures to devolve decision making and power to the wereda level. Below weredas, communities are further subdivided into smaller electoral units, known as kebeles, to further enhance community participation in the planning and implementation of development programmes.

The regional state governments formulate and enact region-specific legislation, and approve regional budgets and development plans. All regions have various sector bureaux to implement the regional development plans. The sectors covered by the various bureaux, which broadly replicate the federal ministries, comprise agriculture, health, water resources, planning and economic development. Other bureaux include mines and energy, transport and communications, works and urban development, trade and industry, and tourism.

Other mandated institutions which will play a significant role in addressing some components of the source-to-lake continuum are:

[1] Bureau of Environmental Protection *[of both regions]:*

= Responsible to develop, conserve, and utilize forests which is one of the key components of source-to-lake continuum.

= Wetlands identification, delineation, and implementation of community-based management are done by this bureau.

[2] Bureau of agriculture and natural resources *[of both regions]*:

= Preventing soil erosion from the landscape

[3] Bureau of water resources development *[of both regions]*:

= mainly focuses on the development, operation and maintenance of rural (and urban) water supply systems in their regions; and also irrigation developments

Box 3: Some of the mandates of RVLBO in relation to the management of land-to-lake system

1. To undertake policy studies, surveys and research needed to create a conducive environment for the implementation an integrated water resource management within basins; and follow up implementation;
2. To facilitate and undertake activities necessary for implementation of integrated water resources management in the basin;
3. To ensure that projects, activities and interventions related to water in the basins are, in line with the integrated water resources management process;
4. To develop plans for protection and sustainable uses of basins; follow-up implementation once it is approved by the relevant organ;
5. To develop and implement basin models in order to guide and support strategic planning of water resources and water administration functions;
6. To identify measures that should be taken against pollution and damage to basins; implement same in collaboration with relevant organs;
7. To measure, collect, compile, analyze and disseminate information for proper planning, administration and steering of water resources in the basin;
8. To ensure continuous collaboration with Regional Governments organs and other relevant bodies by setting up a forum for effective networking;
9. To develop and manage basin information system
10. To prepare and update basin master plans; implement and support the implementation of the same upon approval;
11. To prepare basin development and management plans, submit the plan to the Ministry, follows up the implementation of the plans;
12. To conserve, protect and manage water bodies and related ecosystem.

4.2 Trends and overview of governance system

Figure 24 and the corresponding explanations present a substantial body of governance instruments and their chronology since 1965 up to now. These instruments are already in place with a direct or potential bearing on the land –to- lake system management.

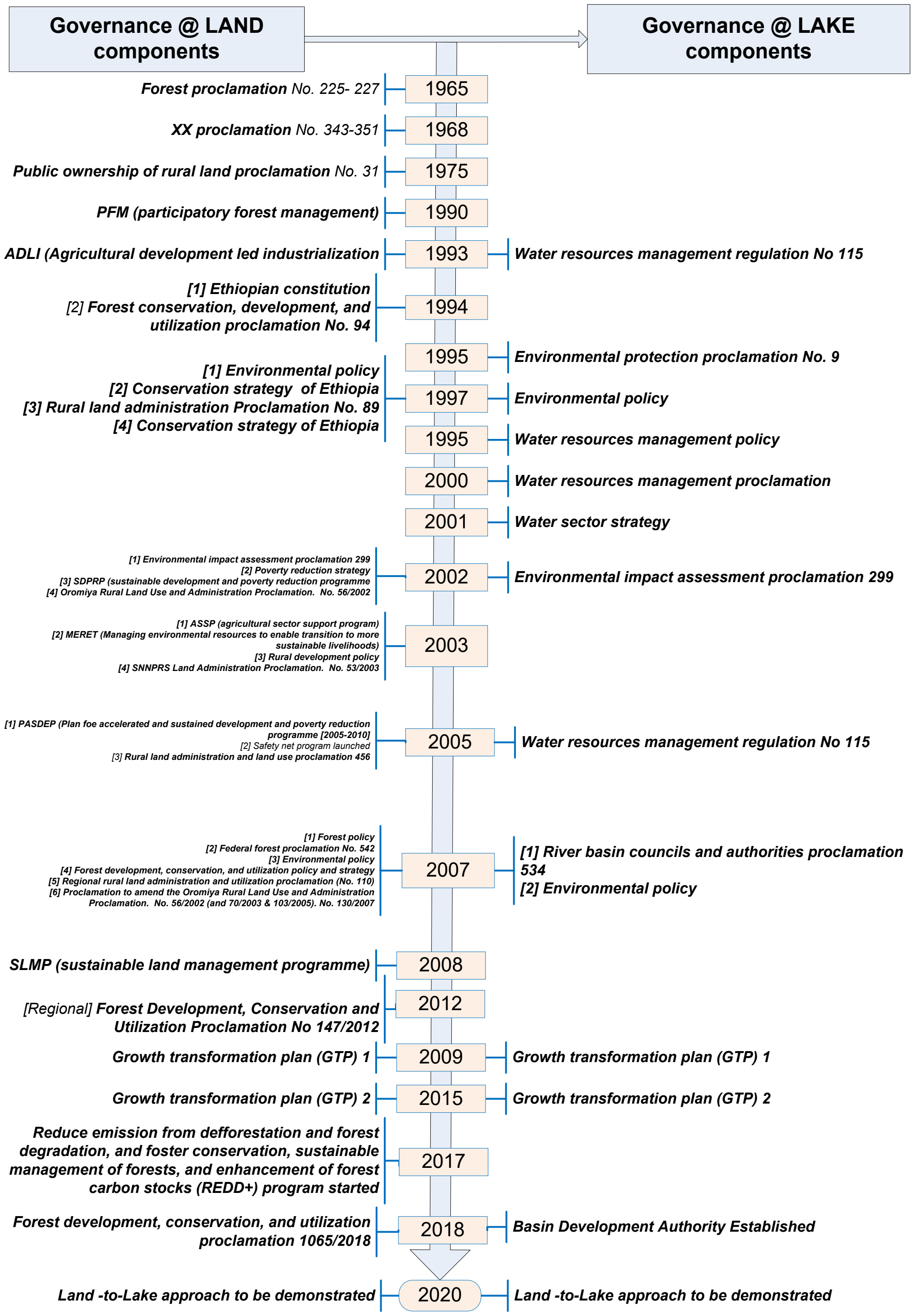


Figure 25. Trends of governance system since 1965

Some of the key governance instruments in relation to the land –to- lake system management are:

1. **Conservation Strategy of Ethiopia:** The Conservation Strategy of Ethiopia and the environmental policy of Ethiopia (EPE 1997) developed from the CSE provides a framework for integrating environmental planning into new and existing policies, programmes and projects. It recognises the importance of incorporating environmental factors into

development activities from the outset, so that planners may take into account environmental protection as an essential component of economic and social development.

2. **Agricultural Development Led Industrialisation** (ADLI) (1993): It envisages using agricultural development as the engine for economic diversification and industrialization. It is still the government's core policy for rural development as well as overall economic development

3. **Ethiopian Water Resources Management Policy** (1999): It covers certain elements of water resources management including soil and water conservation measures to reduce sediment soil erosion and lakes siltation; local community participation in sub-basin management and water conservation measures and practices; a recognition of wetlands as a key feature in watershed management.

4. **Food Security Strategy (2002) and New Coalition for Food Security Programme** (2003): This document outlines what it considers to be the main causes of land degradation, (actually symptoms of improper management of natural resources):

- cultivation of steep slopes, without conservation practices, poor, nutrient mining farming practices
- using crop residues and dung for household energy instead of for ameliorating soil fertility
- biodiversity losses due to land degradation and deforestation.

5. **Federal Rural Development Policy:** In the context of land-to-lake continuum, this governance instrument pays attention to the land tenure issue and the proper use of land. Important changes such as the moratorium on land re-distribution and the distribution of land certificates are given a legal basis in a number of federal and regional proclamations (see below).

7. **Rural Land Administration and Land Use Proclamations:** In connection with tis proclamation, several federal and regional proclamations have been issued regarding the rural land governances, including:

- Federal Rural Land Administration Proclamation (No 89/1997)
- Oromiya Rural Land Use and Administration Proclamation. No. 56/2002. 7 October 2002.
- State of Southern Nations, Nationalities and Peoples Land Administration Proclamation. No. 53/2003. 1 March 2003
- Federal Democratic Republic of Ethiopia Rural land Administration and Use

Proclamation. No. 456/2005. 15July 2005.

- Proclamation to amend the Oromiya Rural Land Use and Administration Proclamation. No. 56/2002 (and 70/2003 & 103/2005). No. 130/2007.

The proclamation of 1997 defines in broad terms individual land use and disposal rights. It delegates responsibility for land administration to the Regions. Oromiya and SNNPRS have also enacted Proclamations for the Administration and Use of Rural land. All proclamations (federal and regional) describe the rights and obligations of users of rural land, including traditional subsistence farmers, and in the more recent proclamations, also of private commercial farmers.

The 2005 federal proclamation demonstrates the government's concern about land degradation and its commitment to combating the problem. Most importantly it defines obligations of rural land users, and land use restrictions. Thus, protection of land becomes an obligation and failure to protect can lead to loss of title.

8. **Productive Safety Net Programme:** with the support of World Bank, the local government has been using this programme to undertake many natural resource management activities.

9. **Sustainable Land Management Investment Framework** (2008): This framework aimed at the restoration, maintenance, and enhancement of the productive function of land in the country leading to improved economic and social well-being of those who depend on these resources while preserving the ecological functions of these lands. It recognizes that land degradation is a serious economic, social, and environmental problem in Ethiopia directly affecting the livelihoods of 85% of the country's population by reducing the productivity of land resources and adversely affecting the stability, functions of, and services derived from natural ecosystems. It also emphasized at the community planning, land monitoring mechanisms, experience-sharing and best practice, and strengthen the institutional environment and land tenure security.

10. **Environmental Impact Assessment Proclamation** (No. 299/2002): This proclamation states that an EIA is mandatory for categories of projects specified under the directive issued by the Environmental Protection Authority, whether such projects belong to public or private bodies. The Proclamation requires certain projects to be subjected to EIA prior to implementation of the project. Procedures that need to be followed in the process of EIA are:

- *To undertake a timely EIA, identifying the likely adverse impacts, incorporate the means of their prevention,*

- *To ensure that an EIA is conducted and an environmental impact study report prepared by an expert who meets the requirements set forth by the directive issued by the Authority*
- *To submit an environmental impact study report to the Authority or the relevant Regional environmental agency for review.*

The relevance of the above governance instruments will be demonstrated in the upcoming governance baseline sub-section.

4.3Governance baseline analysis

Characterizing a source-to-sea system should start with identifying the issues that need to be addressed segment by segment, as well as for the system as a whole (Granit et al., 2017). The governance baseline is intended to set the stage for how the stakeholders behave in controlling sediment flow into Lake Hawassa. Here five priority problems in the system governance are identified.

4.3.1.1 Forest degradation in the state-owned protected forests

At the utmost end of the land-to-lake continuum, forest, woodlands, and shrub land degradations are observed. The main species include *Acacia tortilis, Acacia seyal, Zizipusspinachristius, Balanitesaegyptica and Croton macrostachyus* in the woodlands and *Dodoniaangusitifolia, Dombeya torridae and Carissa edulis* in the shrub lands (MoWE, 2010). Some community plantations are also found in Hawasa, Zuria, Wendo Genet and Shashemene Zuriaweredas with species of *Grevillea robusta, Acacia albida, Schinusmolle, Cupressus lusitanica, Podocarpusgracilor and various Eucalyptus species*.

Despite the enforcement of *Forest development, conservation, and utilization proclamation (Proclamation No. 1065/2018*), the contemporary governance system could not fulfill the following important activities:

- Prepare and implement participatory forest management plan;
- Establish fast-growing tree species plantation along the periphery of the forests to indicate demarcation of the forest and to be used by the local community for firewood and construction;
- Cause issuance of a certificate of title deed which is supported with maps.

Generally, the major constraints in forestry development in the sub-basin are: land and tree tenure, population pressure, land shortage and high demand for agriculture, deforestation, lack of collaboration among the concerned institutions, lack of capacity to design and implement forest management plans, and high royalty fees on forest products, which discourages the private sector involvement (MoWR, 2010).

4.3.1.2 The farmers are not encouraged enough to take necessary conservation measures in their farm

In this governance context, two key issues are important. First, is the lack of ownership feeling of the farmers (insecurity of tenure) on the land they are cultivating. Second, is the need to encourage the farmers to take necessary conservation measures through government arrangements. To balance these contradicting issues, both Oromiya and SNNPRS (and the federal government) have issued proclamations clarifying land use rights and promoting the issue of land user certificates intended to increase tenure security. In parallel, land use planning and management issues are set out (see Box 4):

Box 4: Obligations of rural land users, and land use restrictions [Federal rural land administration and land use proclamation 456/2005]

- ⇒ prohibition of free grazing on any lands where soil and water conservation works have been carried out with cut-and-carry to be introduced gradually
- ⇒ soil conservation and water harvesting on lands with slopes of <30%
- ⇒ annual cropping of lands with slopes of 31-60% only to be allowed with bench terracing
- ⇒ prohibition of farming or free grazing on lands with slopes of >60%, reserved for forestry, agro-forestry, perennial cropping and forage production
- ⇒ area closure to be implemented on degraded areas with compensation paid to previous land users
- ⇒ gullied areas to be rehabilitated by individuals and communities
- ⇒ a sustainable land use strategy for the conservation of wetland areas to be produced

Table 6 shows the actual situation of the sub-basin in terms of land governance by integrating the slope (*figure 25*) and land use map (*figure 26*). As evidenced from the table, those intensively cultivated lands with slope above 15% are practically not managed as per the expected governance against the rural land administration and land use proclamations.

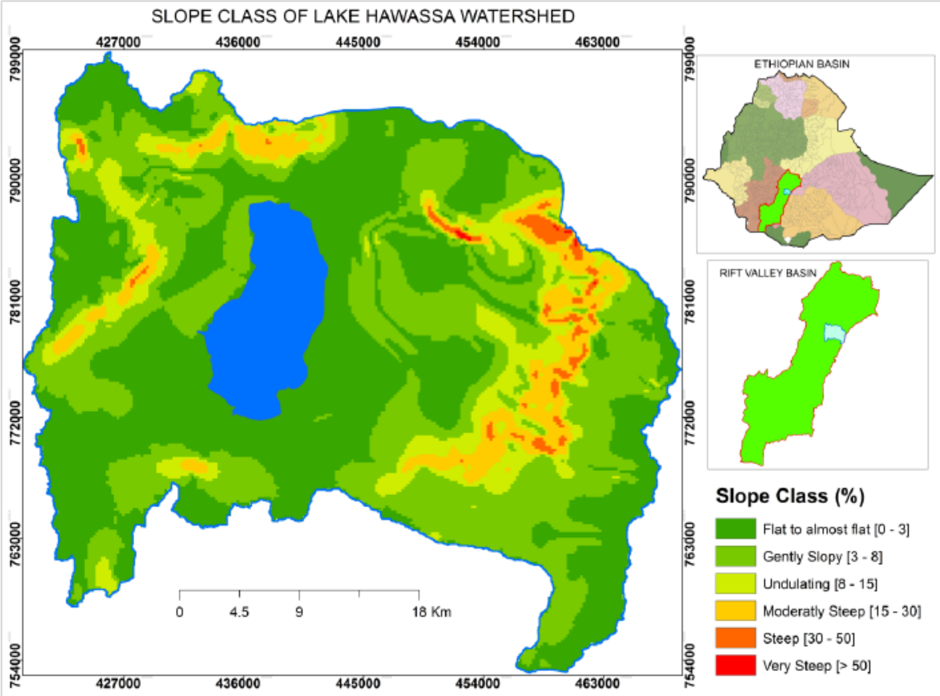


Figure 26. Slope class of Lake Hawassa Sub-basin

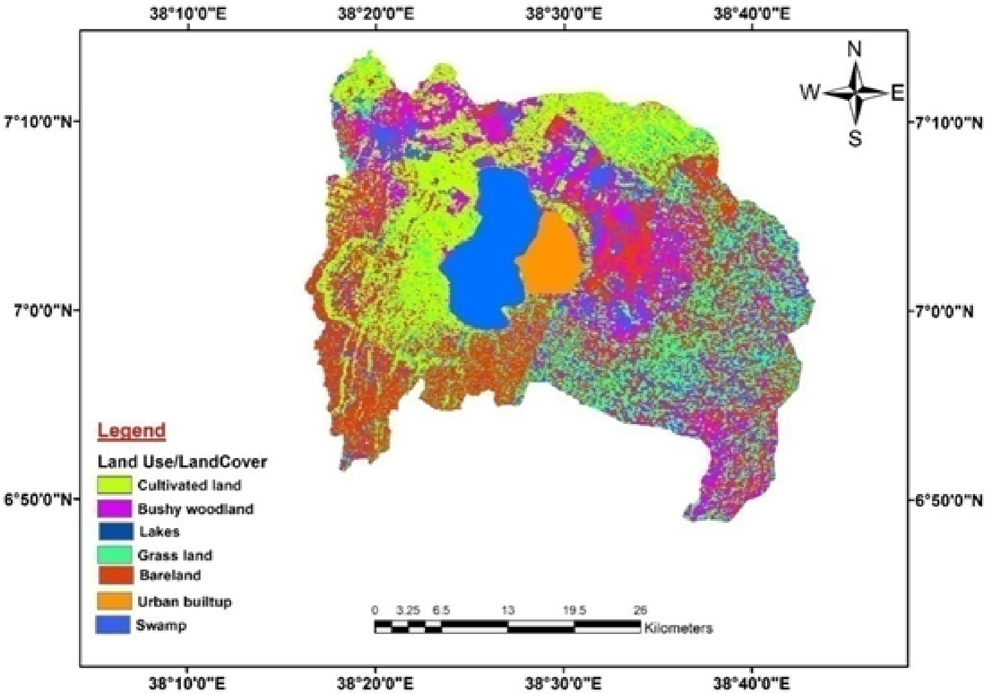


Figure 27. Major Land use land cover in the Hawassa catchment

Table 7. Land uses vs. slope-classes in the sub-basin

Land use type	***Slope category according to the rural land use policy ranges for comparison***											
	0-3 slope		**3-8** slope		**8-15** slope		**15-30**slope		**30-60**slope		**>60** slope	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%

Intensively Cultivated	28,313	*51*	26,909	*79*	15,299	*72*	15,156*	*69*	6,720**	*71*	**840*****	***61***
Moderately Cultivated	1,404	*3*	1511	*4*	412	*2*	103	*0*	2	*0*	-	-
Shrubland	3,937	*7*	2,332	*7*	2,530	*12*	2,662	*12*	554	*6*	40	*3*
Riparian Vegetation	822	*1*	-	-	-	-	-	-	-	-	-	-
Grassland	757	*1*	1,759	*5*	2,208	*10*	3,034	*14*	1,014	*11*	55	*4*
Urban Area	2,987	*5*	1,086	*3*	200	*1*	83	*0*	30	*0*	0	*0*
Forest	17	*0*	135	*0*	375	*2*	811	*4*	1138	*12*	430	*31*
Marshland	7,038	*13*	-	-	-	-	-	-	-	-	-	-
Water Body	9,719	*18*	-	-	-	-	-	-	-	-	-	-
Total=	54,994	**38**	34,079	**24**	21,178	**15**	22,019	**15**	9,521	**7**	1,374	**1**

*N.B: * These areas are expected to be treated by stabilized terraces, but not yet fulfilled; ** These areas are more critical than the above; *** Very critical area*

4.3.1.3 The gully network has been a road-way and source of sand mines with no chance of recovery

Box 5: Key issues along the source-to-lake continuum

> The gully networks which are the major source of sediment flow into Lake Hawassa has been left to stay active; untreated; and further triggered by the tractive forces of car tyres due to the fact that the lorries which transport selected materials from the hillsides of the sub-basin have been using it as the main road (instead of providing access roads) and did not allow any intervention until the project was over. In the aftermath, following the foot print of these contractors, the local youngsters continue to produce sand mines as part of their livelihood (*figure 27*).

The issue indicated in *box 5* above indicates a failure to enforce the *conservation strategy of Ethiopia (CSE, 1997)*; *environmental policy of Ethiopia (EPE 1997)* and the *environmental impact assessment Proclamation (EIA, 2002).* These recognize the importance of incorporating environmental factors into development activities from the outset, so that planners may take into account environmental protection as an essential component of economic and social development.

Figure 28. Extensive sand mining along the gully network

4.3.1.4 'One-fits-all' technical specifications for soil conservation do not work

The available technical specifications on the soil conservation are limited to well known features of the landscape in which the land use; slopes; and soil nature are known. General specifications are then made to guide implementation of the measures. The limitations of those general specifications hinders the local experts and prevents them to act in line with the actual erosion and sedimentation problems prevailing in Lake Hawassa catchment. *Figure 28* (below) shows the unnecessary placement of gabion wire mesh in extremely gullied landscape with the assumption that 'gully is gully'and treatments are all similar.

Figure 29. Incompatible attempts to rehabilitate the extreme gullied landscape

4.3.1.5 The buffer zone is not serving to filter the storm runoff that carries sediment

The deltas are just open fields where no attempt is made for their protection (*figure 29*). Hawassa City EPA prepared a buffer zone regulation in 2016 to implement in its mandated areas around Lake Hawassa. Following this governance instrument, some attempts to protect and beautify the buffer zone has been observed. Recently, the Basin Development Authority engaged itself to prepare the national regulation and it is now under revision at federal level. Finalizing and enforcing this regulation is hoped to solve the problem.

Figure 30. The biodiversity and its anthropogenic pressure at the delta/lake shore/buffer

Chapter 5

Recommendation: Instead of 'targetting sediment reduction', go for 'functional restoration/resource retention of the landscape

5.1. Ecohydrological solutions to the sediment problem

Functional landscapes are able to conserve efficiently and effectively utilize the soil, water and nutrients (resources) within their extent in order to attract and support life. By contrast, landscapes that are dysfunctional tend to lose these material resources and tend to less likely attract life.

The previous sections of this report have detailed how the landscape has been degraded and failed to provide its services as an ecosystem. At this stage of time, the ecosystem is not resilient to the drastic pressure placed upon it. It is dysfunctional, as evidenced by problems with floods and sediment transport from the landscape. In recognition of the severity of the problem, several efforts by various organizations have been attempted to manage runoff, conserve soil and water and reclaim gullies. In the classical approach to control gully erosion, the solution mainly focuses on hydrotechnical design and construction of permanent and temporal erosion control measures that reduce soil erosion threats. As an approach, the physical soil erosion control measures are said to be integrated with the biological ones for more efficiency. While elements of this approach remain valid and viable, a hydrotechnical solution alone is clearly insufficient for the sustainable use of the water resources.

The ecosystem services provided by the landscape can be enhanced by through measures to influence the hydrology and ecology in several relatively simple ways. The hydrologic parameters/processes to be regulated include:

- Reduction of fetch length of unobstructed slope surfaces. This reduces the ability of water to detach and transport soil particles and minimises opportunities for overland flows to coalesce
- Reduction of flow velocity;
- Avoidance of flow concentration;
- Flow energy dissipation;
- Enhancing water impoundment;
- Provision of constructed patch and interpatch system; and
- Increasing water infiltration

Whereas, the ecological parameters to be stimulated include:

- Proper selection of economically important and ecologically friendly grasses and/or trees;
- Supporting vegetation growth (through e.g. natural compost application, etc).

Such concepts feed into to the fields of emerging and problem-solving science called *ecohydrology* and the corresponding *eco-engineering*. Ecohydrology can work to augment ecosystems resilience to anthropogenic changes through the manipulation of biota and hydrology interactions in a landscape (Zalewski et al., 2004; 1997). Applied techniques can serve to not only 'eliminate threats' of the sedimentation problem, but also 'amplify opportunities' to conserve and utilize scare water, sediment, and nutrients that would otherwise be lost from the system.

5.2. Strategic interventions for transformative change

An intervention strategy underpinned by knowledge developed under framework of ecohydrogy is recommended to rehabilitate the landscape and control excessive sedimentation of Lake Hawassa. This considers three key hypothesis made within the field ecohydrology. First, the abiotic (e.g., hydrological) processes are dominant in regulating ecosystem functioning (Zalewski et al., 2004). Biotic interactions may manifest themselves when abiotic factors are stable and predictable. Second, "the shaping of the biological structure of an ecosystem(s) in a catchment can be applied to regulating hydrological processes", which is achieved by stimulating the growth of vegetation through composting and plant selection. Third, "Both types of regulation (H2 and H3) integrated in a synergistic way can be applied to the sustainable development of freshwater resources, measured as the improvement of water quality and quantity (providing of ecosystem services)" (Zalewski, 2000).

Figure 25 drafts out how the unique characteristics of flows (water, sediment, and nutrients); stakeholders; governance system and practices within the system boundary could operate functionally. This would result in a situation where the sediment is trapped/conserved; the water infiltrates; and the nutrients and organic matter recycle within the system without significant leakage of vital resources.

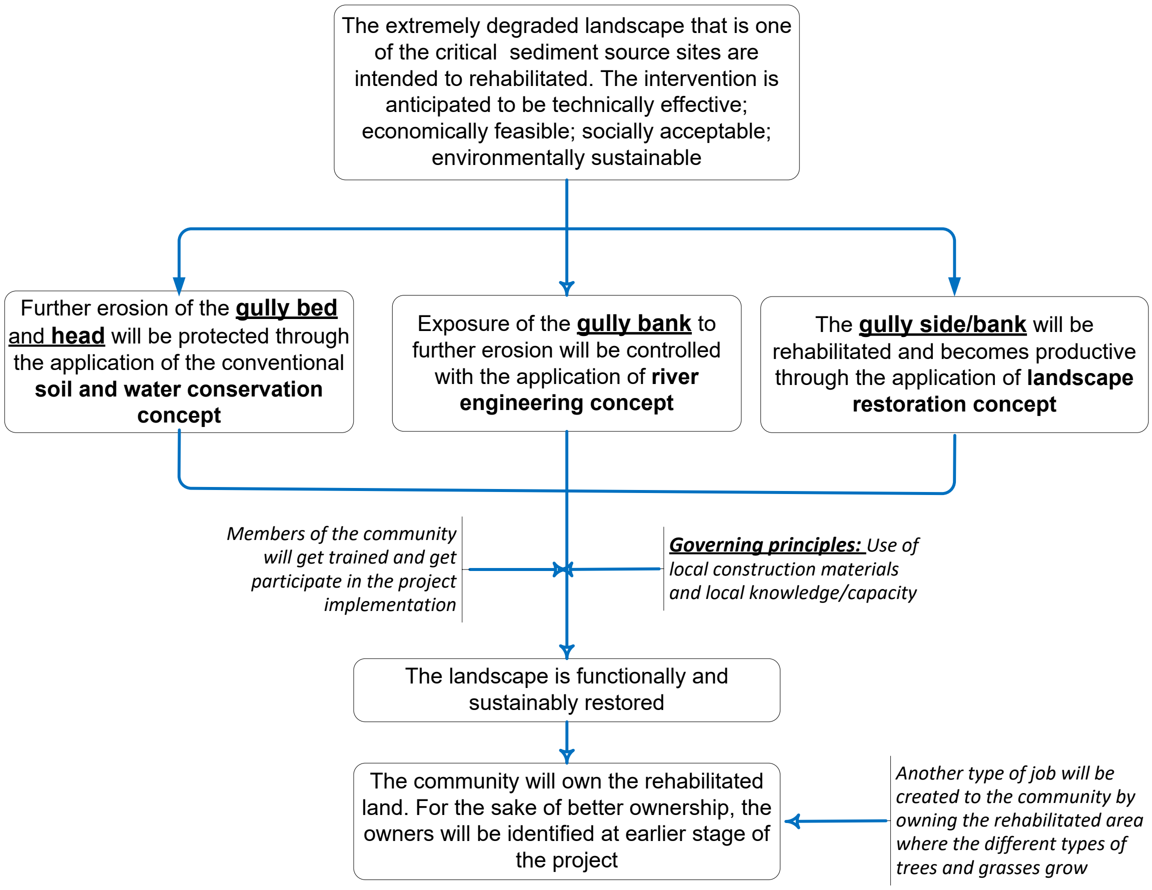


Figure 31. Pathway of changes of the proposed management system

5.3. Building upon existing best practices in the sub-basin

The demonstration project, implemented by Hawassa University in collaboration with Borichawereda agriculture & natural resources; and Rift Valley Lake Basin Office, included several principles and processes that could be considered for additional interventions. This includes, for example, the following planning, design, implementation, and monitoring principles:

1. *Minimum earth work*
2. *Low-cost options*
3. *Avoidance of mechanistic approach as much as possible*
4. *Avoidance of over-engineering of the environment*
5. *Maximizing the use of local materials*
6. *Integrative science*
7. *Respecting and considering local knowledge*
8. *Rely on local technical capacity or building the know-how locally*
9. *Multiple goal*
10. *Based on community consensus*
11. *Maximizing community ownership*
12. *Maximizing women participation*
13. *Empowering the community*

14. *Incremental innovation*
15. *Impact monitoring*

Such approaches and learning developed across a number of projects in Lake Hawassa sub-basin, as those shown above, should be integrated and effectively applied in future efforts to promote source-to-lake management interventions in the region.

APPENDIX: Pictorial display of landscape restoration best practices in Lake Hawassa Sub-Basin

Pictorial trends of the project "Restoration of gullied landscape of Boricha Wereda, in Lake Hawassa Sub-Basin" is displayed in here.

1st.

Before the intervention

2nd

During on-job training to the local community

3rd

After 4 months

4th

After 8 months (after one rainy season)

5th

After 9 months

6th.*Current Status of our best practice in Lake Hawassa sub-basin*

***Current status:** After one year and three months*

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