

# Assessment of Ecosystem Services for Sustainable Management of Lake Hawassa and Its Biodiversity, Southern Ethiopia

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## Abstract

The study was conducted to assess Lake Hawassa ecosystem services to suggest management strategies for sustainable use of the lake. The Economics of Ecosystems and Biodiversity ecosystem service analysis method was used to accomplish the aims. Interviews were conducted with local people to identify the lake's ecosystem services. Ecosystem services importance was rated by the perceptions of the interviewed local people. Secondary data were used for additional information. The major ecosystem services were categorized into provisioning such as food and fresh water; regulating services such as hydrological, water purification and bio-disease control processes; habitat services for birds, fishes, hippopotamus, and crocodiles; and cultural services such as recreation, tourism, spiritual, religious, aesthetic, science and education. The use of local reeds for the coffee ceremony and annual epiphany celebration are unique to the lake. However, the ecosystem services are not equally important for all stakeholders. Lake fresh water supply is the most important and most dependent ecosystem service for all local people. Fishing is the second most important ecosystem services where 79% of the interviewed local people depend on it. The regulating services, which are not appreciated by local people, are equally important for all stakeholders. Habitat services are important to fishers, private and governmental tourism sectors, and conservationist. The cultural services are mainly important to local people. The study's results could be used to increase awareness of the public and policy makers on the socio-economic and ecological importance of the lake.

**Key words/phrases:**-Ecosystem services, Sustainable use, Management strategies

## Introduction

Fresh water ecosystems represent 0.01% of all water on the planet, covering a total of 0.8% of the Earth's surface [1]. The fresh water ecosystems provide many function and services, for example, cycling of nutrient and maintaining the hydrological cycle. They are important for livelihoods of many people in developing countries by providing ecosystem services [2]. In spite of all these importance, globally, fresh water ecosystems have been severely damaged by human disturbances. Agriculture, urban development and introduction of exotic species and their subsequent invasion are some of the anthropogenic factors that affect aquatic ecosystems [3]. All of these human activities have led to severe degradation and loss of aquatic biodiversity [4], and also cause strong impacts on the livelihood of humans themselves [5]. These anthropogenic activities are making fresh water ecosystems as the most endangered ecosystems on the planet [6] and their ecosystem services are in stress [7].

In Ethiopia, there are many economically important fresh water lakes. But most of these lakes are under increasing pressure from human beings that can lead to their ecosystem disturbance and loss of their biodiversity [8]. Lake Hawassa is one of the seven, but the smallest Ethiopian Rift Valley lakes. A number of studies conducted on the lake Hawassa showed that its biodiversity is under stress and the future use of the lake is in danger [9]. Farming the lake's shores, discharging untreated industrial and municipal waste waters, and overfishing are the main anthropogenic drivers that challenge the lake's sustainability. Additionally, vegetation clearing in the catchment and shore areas cause soil erosion and in

crease sedimentation [8]. Rapid population growth, Hawassa city development, unemployment and changes in land use are the indirect drivers of these anthropogenic changes. All these problems have their own negative impacts on the supply of Lake Ecosystem services and can affect the sustainable use of the lake [9].

Lack of sustainable management plan could leads to unsustainable use of the lake resources. Immediate attention is necessary to mitigate and/or reverse all the existing environmental problems of the lake. There was no any study on the scientific assessment and documentation of the lake ecosystem services. Integrated assessment of ecosystem services provides information to policy makers for planning a sustainable management plan of natural resources [2]. Local communities should also be engaged in the assessment, planning and management of the resources. This study was conducted to collect relevant information for the policy makers about the ecosystem services of Lake Hawassa to help them in planning a sustainable lake management and use plan.

## Research methodology

### Description of the study area

The study was conducted in Lake Hawassa, one of the smallest but the most attractive Ethiopian Rift Valley lakes found at altitude of 1680 m.a.s.l. The geographic coordinate of Lake Hawassa are 6°33' to 7°33' N and 38°22' to 39°29' E latitudes and longitudes, respectively. The lake is found west of Hawassa city, the capital city of the Southern Nations Nationality and People Regional State (Fig. 1) and it has an open area of 96 km<sup>2</sup>. Hawassa city is

located at about 275 km south of Addis Ababa (capital city of Ethiopia) and on the main Ethio-Kenya international road. Lake Hawassa has a higher population density (498 persons per km<sup>2</sup>) than other Rift Valley Lakes of Ethiopia [10].

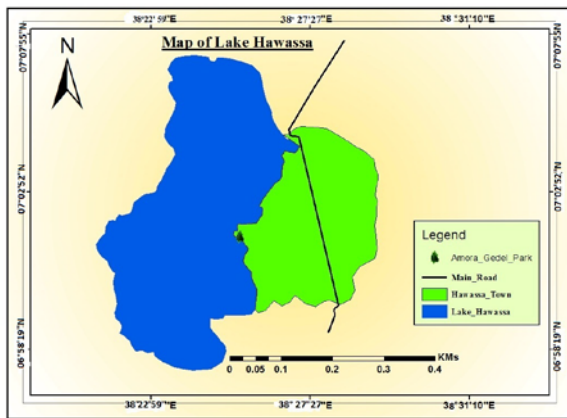


Fig 1. Map of Lake Hawassa

**Ecosystem service analysis**

Ecosystems functions are defined in relation to their components, structure and processes. According to TEEB [11], ecosystem function is the capacity of ecosystem components, structures and processes to supply ecosystem goods or services. Ecosystem services analysis is an important tool to sustainable management of natural ecosystems by making people more aware of the economic benefits of ecosystems as well as the effects of ecosystem degradation [12]. Ecosystem service analysis aims for a systematic and quantitative identification, quantification and prioritization of the ecological and economic importance of ecosystems for human beings [13], [14]. The lake ecosystem services were identified and categorized based on TEEB [11] classification scheme.

In order to achieve the stated objectives of the study, participatory approach was used to gather the relevant data. Interviews and focus group discussions (FGDs) were used as a source of primary data. The interview was conducted based on the guidelines on qualitative research proposed by Guest *et al.* [15]. FGD is stakeholder participatory method suitable for purposeful discussion of a problem [16]. In addition, secondary data from reviews of relevant documents and related literature were also used. The collected primary and secondary data were compiled and analysed qualitatively, and some descriptive statistics were also employed.

**Results**

Lake Hawassa provides various ecosystem services that directly or indirectly contribute to the livelihood of local people living in the catchment areas. The ecosystem services obtained from the lake and its shores are summarized in Table 1.

Table 1: The identified ecosystem services from Lake Hawassa & its shores

Provisioning services	Regulating services	Habitat services	Cultural services
Food (fish, crops, & livestock)	Carbon sequestration		Aesthetic information
Fresh water supply (for drinking, agriculture, cloth washing and bathing)	Climate regulation	Lifecycle maintenance (nursery services)	Opportunities for recreation & tourism
Raw materials (wood, reeds & grasses)	Water purification	Gene pool protection	Inspiration for art
Genetic resources	Regulation of water flows		Education & science
Natural & traditional medicinal resources	Moderation of extreme events		Spiritual experiences
Ornamental resources	Biological control		

1) **Provisioning services** are the products provided by the lake and its shores ecosystems for direct benefits of humans. The provisioning services were categorized into six groups: *food* (fish, crops and livestock), *fresh water supply*, *raw materials* (fuel wood, wood for local house construction, agricultural tools, etc.), *traditional medicines*, *genetic resources* and *ornamental resource* (e.g. Bird feathers for decoration). The percentage distribution of the interviewees who have been using provisioning services from the lake and shore is also presented in fig 2.

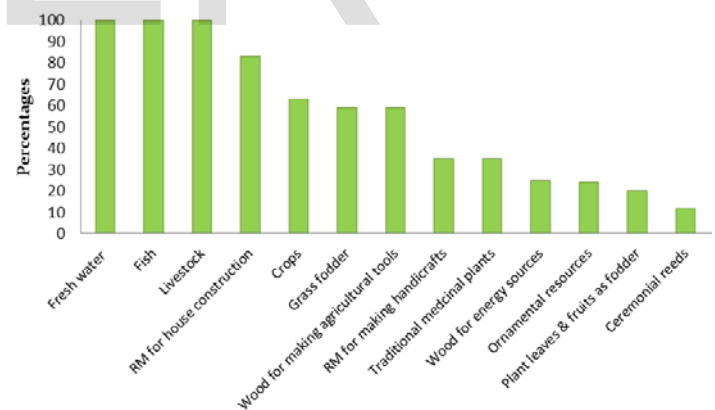


Fig 2. The distribution of interviews using provisioning services for their livelihoods

**Food:** the lake serves as a source of food for many local communities, mainly in the form of fish and it also used for cultivation of crops, livestock and wild fruits. Food is one of the most important products of the lake for their livelihood. The lake has provided a reliable source of food for residents and fishermen. It has great potential for the production of different commercial fish species such as *Barbus* spp., *Tilapia* and North African catfish where the local people are dependent for their livelihood to a large extent. All of the interviewees had replied as they use fish from the lake.

Farming is the other major economic activity that takes place in the lake shore. Based on field observation, there are commercial farms adjacent to the lake. The larger part of the lake shore is already converted to agricultural land. In these areas, most of the poor local people (about 63% of the interviewee) depend on the mixed crop cultivation where directly or indirectly related to the lake water resources. The major cultivated crops by irrigation in the shore area are vegetables (tomato, carrot, green/red pepper, onion, beet-root, cabbage, etc.), cereals (maize and sorghum), pulses (haricot bean, *Phaseolus vulgaris*), fruits (such as banana, avocado, papaya, mango, etc.), narcotic plants (Tobacco, *Nicotiana tabacum*), sugarcane, etc. Maize, sorghum, banana and tomato are the main food crops grown in the area. The lake plays an important role in food security in the area by providing both ecological and economic benefits of local communities.

Livestock production is among important agricultural activities in the lake shore and catchment areas. It is practiced by almost all inhabitants for generating their own income. Livestock also provides meat, milk, manure, wealth and social status of local peasants. It plays important roles as sources of income and food for the farmers and foreign exchange to the country. They rear different livestock such as cattle, sheep, goat, horse, donkey, etc. The lake shore and lake water are considered by the poor local farmers as a gift from 'God' for their survival.

**Fresh water supply** is the also most valuable products of the lake ecosystem. The lake fresh water is an immediate resource for many poor people who have no pip water sources at home. All of the interviewed inhabitants have been used the lake water for washing clothes and different household materials, bathing, swimming, and livestock watering. Adults, young men and children living along the shores have free access to lake water for different activities.

**Raw materials:** the lake and its shores have different raw materials used by nearly all households living in the shore area. They are used for production, construction, consumption and sale purposes. The lake and its shore areas are the main sources of ceremonial reeds, and thatching grass used for construction of house wall and roof, animal fodder, crop guarding huts, and traditional handicrafts, wood for shelter, agricultural tools, fuel, local boats and fishnets. About 59% and 20% of the interviewed farmers are collecting grass fodder, and leaf and fruits, respectively from vegetation found on the lake shore to feed their livestock. The south and southeast parts of the lake shore are also used as a grazing land (Fig. 3).



Fig 3. Pictures showing the local community use the shore as grazing land (left) & collecting grass fodder (right).

The coffee ceremony in Ethiopia is a daily activity. It is an integral part of social life. For this special coffee ceremony, the local community commonly uses the reeds and *Juncus sp.* ('qetema' in Amharic). When they make coffee,

they usually arrange the cups on the 'Rekebots' that they put on a mat or beds of ceremonial reeds and grasses (Fig. 4). For some local people and for about 12% of interviewees, daily, they collect ceremonial reeds from the lake shore and sell to hotels, restaurants and coffee houses and it is the only income sources for some poor people.



Fig 4. Pictures showing the local man cut & collect 'qetema' for sell (left), & how the local community use it for the local coffee ceremony (right)

**Ornamental resources:** the lake also provides local people with various plant and animal resources to make different ornamental products that are kept in restaurants, hotels, households and schools. Out of the interviewed local community members, 24% use many animals and plant products, like bird feathers, wild animal horns and hides as well as flowers for ornamental purposes. Additionally, the community elders use various colourful bird feathers and plant products from the lake for their 'Fichee Chambalala' (Sidama's people new year) and other traditional celebration.

**Natural and traditional medicinal plants:** The shrubs and other plants around the lake are used for medicinal purposes. During the interview, seven species of medicinal shrubs and trees were mentioned by the local people. The most commonly used medicinal plants in the shore area are listed in the Table 2 below. The community used for the treatment of different parasitic fungi infections and gastrointestinal parasites both in humans and domestic animals. About 35% of interviewees had been using wild plant leaves, fruits, roots and their barks separately or in combination form for the treatment of their domestic animals. They also used these products for the treatments of human dermal, respiratory and intestinal infections as well.

Table 2: Medicinal plants found around the lake

Common name	Scientific Name
Grawa	<i>Vernonia amygdalina</i>
Rate	<i>Aloe spp.</i>
Koso	<i>Hagenia abyssinica</i>
Bissana	<i>Croton macrostachyus</i>
Kitikta	<i>Dodonaea angustifolia</i>
Kesekes	Unkown
Damakesse	<i>Ocimum lamifolium</i>

**2) Regulating services** are benefits obtained from the regulation of ecological and hydrological processes. They are derived from the lake ecosystem processes, such as the capacity of the lake to regulate climate, hydrological cycles and other biogeochemical processes; fundamental to provide all other ecosystem services. The lake provides different regulating services, such as climate regulation through sequestration of carbon, water purification, water regulation, and biological control.

The lake as any inland water provides water during dry seasons and it serves a water storage site during the wet seasons. Since in Ethiopia the population in the past few years increases from time to time, if the lake and its watershed are managed very well can provide water continuously for irrigation, production of drinking water and generating hydroelectric power.

The lake vegetation such as papyrus, reeds and other grasses through their photosynthetic activity will raise the dissolved oxygen levels in the lake water by pumping air down into their root zones through their hollow stems. The oxygen enhances aerobic decomposition of organic matter. The macrophytes and phytoplanktons are also important in providing attachment surfaces and growth of aerobic microbes. Therefore, the lake vegetation has huge roles in storage, dilution, filter, removal and recycling of organic compounds and other nutrients enters the lake from point and non-point sources.

Various zooplanktons in the lake are serving as biological control agent of disease vectors and crop pests. For example, Copepoda (*Mesocyclops*) is predators of malaria causing mosquitoes. Additionally, some lake water beetles are also important to remove exotic water weeds such as water hyacinth (*Eichhorina crassipes*).

**3) Habitat services:** Lake Hawassa provides a suitable habitat for reproduction and shelter for different birds, fishes, wild animals, plants and microbial species. Formerly, the lake water was healthy and still now it serves as a living and breeding sites for six common fish species listed. Papyrus, reeds and other vegetation in the lake shore are a spawning and breeding site for fish.

Lake Hawassa is also serving as a feeding site for different migratory and resident birds. The east and southeast parts of the lake is a well known home for the flock of Marabous' Stork, Hammerkop, Kingfisher and other prey bird searching fish remains over the grounds of the lake shore. Flamingos, White Pelicans and Egyptian Goose are also among the water birds that get their niches from the lake (Fig. 5). Based on the survey and document obtained from regional cultural and tourism office, about 80 bird species exist in the woody plants and swamp vegetation of the lake.



Fig 5. Common birds taken from the lake swampy vegetation

The lake also provides a home for mammals such as Hippopotamus (*Hippopotamus amphibius*) and reptiles like crocodile (*Crocodyla niloticus*). The forest and woodland vegetation which are found in the vicinities of the lake also used

as a living, feeding and breeding places for other mammals like black and white Colobus Monkey, Vervet Monkey, Anubis Baboon, and Squirrels.

**4) Cultural services** are the immaterial benefits where people obtain from the ecosystem and /or landscape [2]. In this regard, due to its attractive landscape and biodiversity, Lake Hawassa provides different cultural services.

The lake is one of tourist attraction sites in the region and even in the country. Tourism is an important income source of the city. Every day, a number of local people and foreign visitors visit the lake. The lake has great tourism and recreation potential that can bring economic growth of the city. The number of visitors of the lake and the amount of annual tourism income generated for the year 2006 to 2012 is shown in the fig.6. The number of visitors of Hawassa city and the lake was approximately 22 thousands in the year 2006 and increased to about 197 thousands people in the year 2012. The annual income generated from tourism activities was 1.5 million Ethiopian Birr (ETB) in 2006 and it increased to 83 million ETB in the year 2012 (Source: Hawassa City Culture and Tourism Bureau).

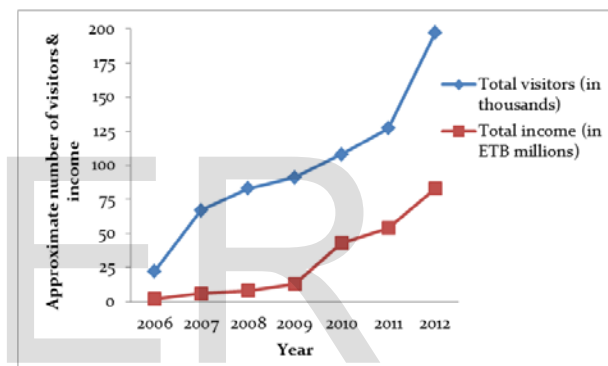


Fig 6. Total visitors and income generated from year 2006 to 2012 (The revenue is given in ETB where one ETB is approximately equal to 0.051 US\$ at the time of field work, March 28, 2014)

Over the last few years, the number of visitors and tourism revenue has been continuously increasing. This is due to increased accessibility of infrastructures, accommodations, local tourist guides and other related services. The local government and office of cultural and tourism also receive additional concession income from lodges, resorts and hotels. The local people are also making their own business as tourist guides, and by selling cultural cloths and other handicrafts. The tourism activities are also important sources of income for the investors and earners of salaries.

The lake ecosystem functions, processes and its biodiversity are the other valuable components of scientific research and education for the academics of higher educational institutes and research centers found in Hawassa city as well as in the neighbouring regions. A number of research projects have been conducted on the lake at national level. Graduate students, experts and researchers from different universities as well as research institutes of the country have been conducting various studies on various issues concerning Lake Hawassa. Additionally, the lake and its biodiversity used as 'open air



classroom' for the primary and secondary school students and also outdoor environmental education for college and university students.

On the lake shore, there is a special and spiritual place called 'Gudumale', a place where (local) Sidama people annually celebrate their spiritual and New Year known as 'Fiche Cambalaalla'. There is also other religious area named 'Timikete Bahir' that serves as an open space to celebrate religious rituals and epiphany using the lake water once a year by the local followers of the Ethiopian Orthodox Tewahido Church as well as occasional baptism for followers of Protestant religion.

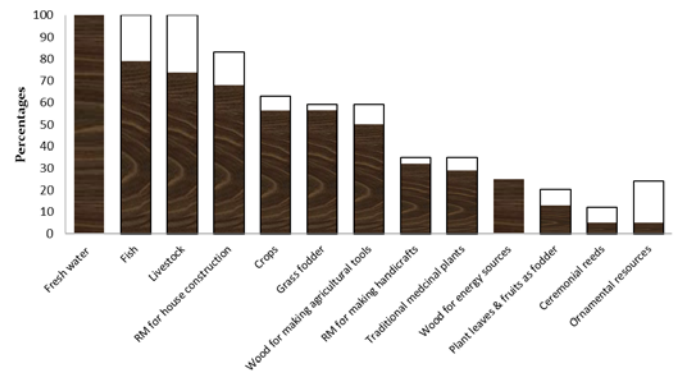
**The relative importance of Lake Ecosystem Services**

All the interviewed local people were asked to rate and categorized the ecosystem services obtained from the lake under important and dependent ecosystem services for their livelihood. Among all the identified ecosystem services, fresh water supply, fish, production of livestock, and raw materials for house construction were found to be the most important and dependent ecosystem services for most of the primary stakeholders. On the other hand other provisioning services such as crops, wood for making agricultural tools, raw materials for making handicrafts, grass fodder, fuel wood, plant fruits and leaves as fodder, ceremonial reeds, medicinal plants, and ornamental resources were grouped under the second important and dependent ecosystem services for some groups of stakeholders.

The percentage of primary stakeholders participating in the identification and ranking of ecosystem services is given in the fig. 7. The percentage of important ecosystem services to the livelihood of primary stakeholders is shown at the top of the bar, and dependent ecosystem services at the middle of the bar. Here, dependency means proportions of the community are fully dependent on ES.

The local interviewed people were also asked to rank provisioning ecosystem services from the first to the least important and dependent. Accordingly, the result showed that all participants were rated as the lake fresh water is the most important one and their livelihood is dependent on it. They used fresh lake water for their livestock watering, washing clothes, bathing, irrigations, drinking at rural side, and different domestic purposes.

Fishing is also the second most important ecosystem services for all. However, 79% (264 out of 336) of interviews are dependent on fishing. At least one family member of these local people catches fish from the lake. Fish is their important sources of food and proteins, as well as income for fishers and inhabitants around the lake.



**Fig 7. Percentages of interviewees who rates the ES as important (white bar) & dependent (black bar) categories**

For the villagers at the lake shore, obtaining of water for their livestock and grazing land at the shore is also a question of survival. Livestock agriculture and economic benefits obtained from meat and dairy products is other sources of income for the local people living on the lake shore. The result showed that all of the interviewed local people are practicing livestock agriculture. They have been used the shore for grazing and water for their livestock. However, only 74% of them selected the service as dependent on it, but not for the local people who have other grazing land than the lake shore.

Extraction of raw materials (mainly wood and thatching grasses) from the lake shore for construction of their houses rated at the fourth place among the most important and dependent ones. It was important for 83% of the primary stakeholders, but it is a dependent service for 68% of local people. The lake shore is the only source of raw materials to build their shelter.

Getting farmland (irrigation area and water) for productions of crops and vegetables is the other most important services for the local farmers living on the shore. It was rated as the fifth important and dependent services. Crop production is important sources of income for 63% of primary stakeholders, but only 57% of them are dependent on it. For local farmers who cultivate crops during the rainy seasons, irrigation water from the lake is not a primarily important one.

Use of the lake shore as a source of animal feeds (mainly grasses) is important to 59% of the local people, but only 57% of them are dependent on the lake shore for getting grass fodder. The local people have free access to collect grass fodder from the lake shore. The use of wood such as acacia and other trees from the lake shore for making agricultural tools is important to 59% of the primary stakeholders. However, 50% of interviews are dependent on the lake shore for getting raw materials for making agricultural tools.

About 35% of the participants were mentioned as they use plants and herbs found on the shore as sources of traditional medicines and important for these groups. But, only 29% of them are dependent on this service. Local people on rural sides of the lake have no any opportunity for electric supply so far and use fuel wood for cooking their food and other domestic activities. Collecting wood for energy sources was rated by 25% of the participants as both important and

dependent ecosystem services. Uses of plant fruits and leaves as fodder, ceremonial reeds and ornamental resources were the other raw materials used and dependent for 13, 7 and 5% of the local people, respectively.

The result showed that the value of the lake is mainly depends on the needs and motivations of the local people. Thus, ecologically and indirectly most important (regulating, habitat and cultural) services were not appreciated and mentioned by the local people. What is important for some groups might not be important for others.

### Discussion

Several ecosystem services were identified from the lake through interviews based on understandings of the local people and using relevant literatures. The identified ecosystem services were categorized into provisioning, regulating, cultural and habitat services. These ecosystem services are consistency with the ecosystem services reported by various researchers [17], [12], [11]. However, only 16 main ecosystem services were identified from Lake Hawassa and its shores. All the 22 ecosystem services that are identified by TEEB might not be generated from a single natural ecosystem. Additionally, ecosystem services identification might vary in different parts of the world. It usually depends on the understanding level and cultural setting of the society where the services are delivered. For instance, in this study, some provisioning services (e.g. local coffee ceremonial reeds) do not exist in other parts of the world. The annual cultural and religious ceremonies (e.g. 'Fiche Cambalaalla' and epiphany celebrations) using the lake water are also unique cultural services of Lake Hawassa.

The ecosystem services obtained from the lake and from the shores were identified together, since the lake ecosystem could not be seen as the different ecosystem from the shore areas. Both the lake and the shores are communal resources that used by all the community members. In this study, crop cultivation and livestock productions in the lake shores were also categorized under the provisioning services (e.g. food sub-services), since the energy inputs and capital invest in their production is insignificant rather the farmers cultivate different crops and vegetables mainly using the natural lake resources. Additionally, the crop production is also providing a mix of different services (e.g. regulating, habitat and aesthetic services). Therefore, it was appropriate to categorize crop cultivation and livestock production under the lake ecosystem services [14].

The anthropogenic pressures (e.g. discharges of industrial and hospital waste waters, overfishing and deforestation) reduces the quality and quantity of the lake ecosystem services which are manifested in declining quantities of food (fish), poor quality of water for domestic purposes and recreational value which affects the tourism industry. This has impacts on incomes, employment and the economy of the country as a whole.

The lake water pollution, habitat fragmentation and vegetation clearing in the lake shores affect the stability of the Lake's ecosystem and this in turn has implications for the climate regulation function of the lake. The local climate, including rainfall and temperature, which are critical for crop and livestock productions to ensure food security, is also altered.

In conclusion, the direct ecosystem services were rated as the most important and the most dependent ones for the livelihood of local people whereas, the indirect

lake ecosystem services are not well perceived by the local people. However, environmental economists do not have yet realized the economic values of Lake Hawassa and the surrounding landscapes.

Overexploitation, loss of water quality and destructions of the nursery habitat results reduction in the quality of fish catches (both in size and number). Due to the rapid developments of Hawassa city, the urban area spreads further into the lake shore and wetland areas. The birds and other wildlife habitats become fragmented. This habitat fragmentation together with lake water pollution leads to threatening and loss of biodiversity. All these environmental problems can cause considerable ecological, social and economic impacts on local people who are dependent on the lake ecosystem services.

Therefore, the local government should plan and implement 'Lake Hawassa ecosystem services and biodiversity protection, use and management plan'. The management plan is potentially important to mitigate the lake environmental problems, maintain the healthy functioning of the lake and to prevent the potential conflicts among users and polluters of the lake. The management plan should have the following activities:

The local government in collaboration with ENGOs and private sectors should work on organizing the local community in small-scale enterprises to generate an alternative income sources. These could be important to reducing pressure on the lake from illegal fisheries, common reed cutters and farming the shore areas.

Planting indigenous trees on the degraded lake shore, and preventing further clearing of trees and shrubs could be an important strategy in sustainable management of the lake in terms of halting the sediment flow to the lake and improving lake water quality. The plantation could also be important to reduce an increased water level and prevent possible flooding the city.

The lake sustainable management plan should have different pollution prevention strategies such as constructing ponds at the shores, imposing industries to construct efficient effluent treatment plants, etc.

Rehabilitation and conservation of the threatened *Oreochromis niloticus* (Tilapia) fish is also needed to revive the fish biodiversity using standard fish nets. The management plan should include restrictions on seasonal fishing as well as fishing using nets other than the standard 80 mm mesh size fishnets. Finally, further analysis of the Lake Ecosystem services economic valuation; identification and analysis of stakeholders and the determination of the lake potential to provide ecosystem services would be important to generate more valuable.

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