



Research article

Potential impact and mitigation measures of pump irrigation projects on Lake Tana and its environs, Ethiopia

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ABSTRACT

Environmental Impact of pump irrigation projects from Lake Tana (Megech - Seraba, Tana Asrate, Tana Mekonta, Tana Wenjeta, and Tana Zegie) was studied from July 2018 to February 2019. Interactions between project activities and environmental parameters were also done by a matrix, and quantitative and qualitative analysis. As a result, identified positive impacts are new job creation, the opportunity to promote traditional agriculture and income increase, whereas land, fisheries and wetland degradation, pollution, deforestation and wildlife, inefficient water use, the decline in soil fertility, erosion, sedimentation, small aquatic animal death, and cumulative impacts are negative ones. Mitigation measures for these impacts to reduce their effects to the minimum level and recommendations have been proposed so that the execution of the projects becomes a success without harming or with the least negative effect on the environment.

1. Introduction

Lake Tana is the largest lake in Ethiopia, constitutes almost half of the freshwater body of the country (Reyntjes et al., 1998; De Graaf et al., 2004). Currently, intensive development intervention is underway in the Lake Tana growth corridor. Among them, pump irrigation projects which take water from Lake Tana are the main once.

Irrigation has contributed much to poverty alleviation, food security, and improving the quality of life for populations (Hussain and Hanjra, 2004; Smith, 2004; Gebremedhin and Asfaw, 2015). However, irrigation has notable negative impacts on the environment. Globally, 2710 km³ per year or 70% of the total water withdrawn, is used by agriculture, compared with 19% by industry and 11% by the municipal sector (FAO, 2011). Potential negative impacts of large capital-intensive irrigation schemes are extensively documented (Adams, 1992; Dougherty and Hall, 1995; Petermann, 1996). So, the sustainability of irrigation is being questioned (FAO, 1997). To avoid this, Environmental Impact Assessment (EIA) is a planning tool for predicting the potential environmental consequences of proposed developments and decide right mitigation measures (Environment, Labor and Justice, 2010; Canter, 1983; IAIA and IEA, 1999). It also protects the environment and the quality of life in that vicinity and beyond (Terrin, 2018). It was started many years ago from the basic and specific aspects by concentrating its attention on personal

essential projects aiming to prevent environmental collapse. Although today environmental impact assessment is formally adopted as a process in many countries and organizations (World Bank, 1991), the intrinsic complexity of the subject leaves plenty of room for improvement in terms of clarity and effectiveness (Jiggins, 1995).

Ethiopia is highly vulnerable to severe environmental degradation mainly due to the unwise use of natural resources and poorly planned development projects of which irrigation is the one, prompted by rapid population growth (Yonas, 2006). Sustainable development is essential to integrate environmental concerns into development activities, programs and policies. Therefore, the aim of this study was to investigate the most unforeseen environmental impacts of proposed pump irrigation projects Megech - Seraba, Tana Asrate, Tana Mekonta, Tana Wenjeta, and Tana Zegie, all are from Lake Tana, and to recommend mitigation for sustainable development.

2. Materials and methods

2.1. Descriptions of the study area

Lake Tana is Ethiopia's largest lake possessing half of the nation's freshwater and the source of the Blue Nile is supporting the lives of over 123 million people in the Nile Basin by its 60% approximate contribution

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to the basin (Goshu and Aynalem, 2017) and found in Tana Sub-Basin which is northeast part of the Blue Nile Basin. The drainage area of this sub-basin is 15320 km² and endowed with eight different agro-climatic zones, moist tepid, sub-humid tepid, moist, cool, moist, warm, moist cold, moist very cold, sub-humid cool and sub-humid cold. Most of the project area (79.4%) is found in the moist tepid agro-climatic zone followed by sub-humid tepid, moist, cool and sub-humid, cool which account for 12%, 5%, and 3%, respectively. The rainy season of the area is from June to September. The lake is fed by eight perennial rivers, namely Gilgel Abay, Rib, Gumara and Megech which are the major ones (93% contribution) and Gelda, Arno Garo, Enfiranz and Dirma and other several seasonal streams (ADSWE, Amhara Design and Supervision Works Enterprise: LUPESP, 2015: unpublished data). The Blue Nile is the natural out-flowing river and Tana Beles is the man-made second outlet.

Pump irrigation projects, Megech-Seraba is located in the North, Tana-Asrate and Tana- Mekonta in Northwest, Tana-Zegie and Tana Wenjeta in South of the lake (Figure 1), each has a command area of 4995

ha, 1333 ha, 1140 ha, 1265 ha, and 4849 ha, respectively (ADSWE, 2017; ADSWE, 2018: unpublished data).

2.2. Morphometric characteristic of Lake Tana

According to SMES (2008: unpublished data), Lake Tana morphological characteristics summarized in Table 1. At present those figures might be different due to various reasons such as sediment, climate change, and other factors.

2.3. Methodology and approach to the study

EIA is an iterative process, which continues and develops in conjunction with the design of the Scheme and assessment methods range from simple to complex, requiring different kinds of data (Contant and Wiggins, 1993). This study was conducted in line with the methodology or guidelines of national, international and FAO, and also has

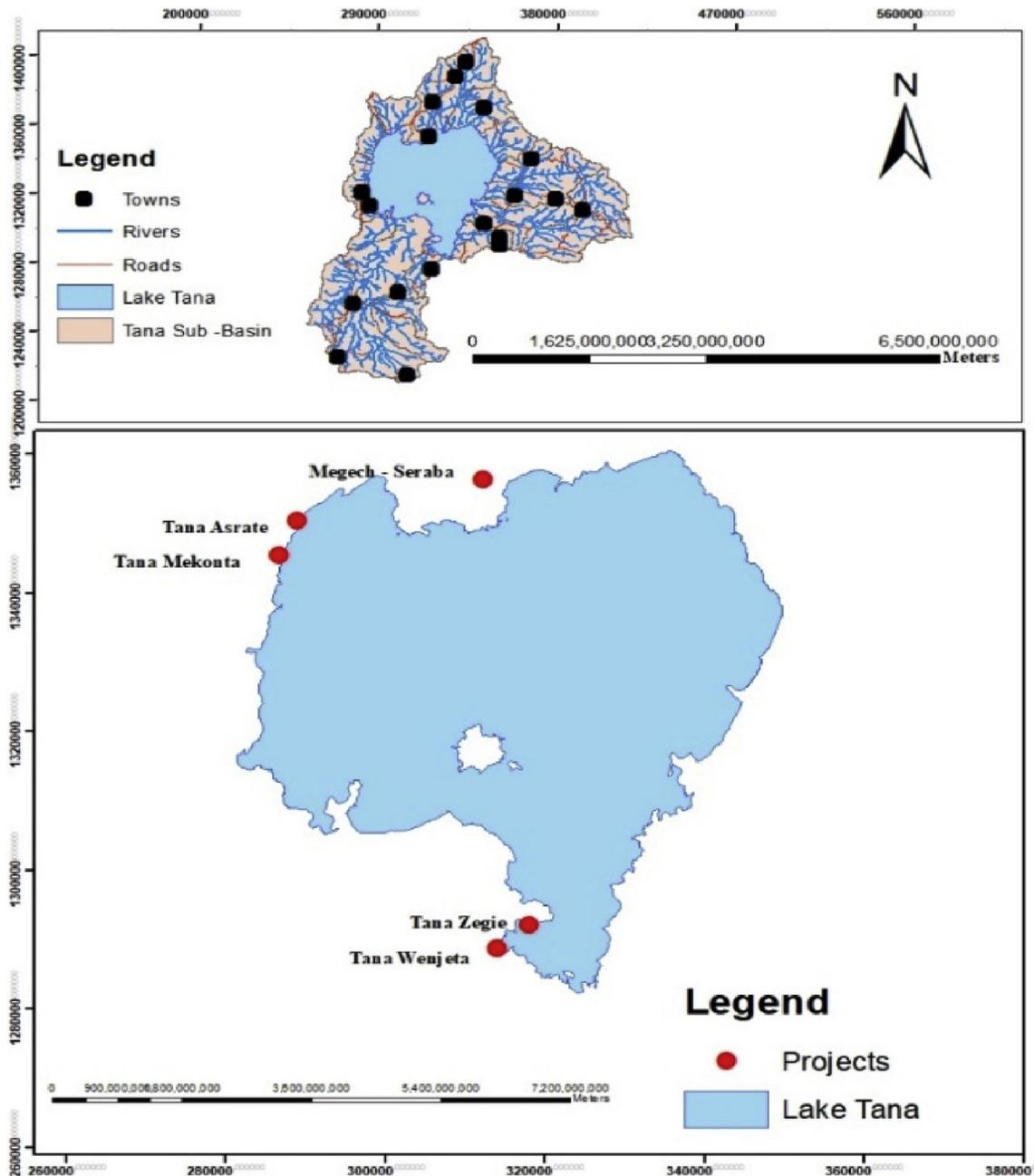


Figure 1. Map of the study area.

Table 1. Morphometric characteristics of Lake Tana.

Parameter	Value
Catchment area (km ²)	15320
Maximum and average depth (m)	14 and 9
Lake surface area	3061 km ² (at 2008) but 3000 km ² (at 2017)
Gross lake volume in a million-meter cube	26000 mm ³ (at 2008) and 28.00 km ³ (at 2017)
Live Storage (mm ³)	6000 to 9100 at 1785 and 1784 sill level
Lake regulation elevation ranges	1784 to 1787
Chere Chera Weir Sill level (m)	1784
Natural out flow Sill level (m)	1785
Lake operational Sill level (Navigable)	1784.75

(Source: SMEC, 2008, unpublished data; Yihun and Wondwossen, 2017)

been adapted from Hegmann et al. (1999), Beanlands and Duinker (1983). In general terms, the main stages in the assessment are document review and secondary data collection, screening and scoping, consultation (expert and key informant interview) and baseline surveys by field observation (transect walk).

Document review and secondary data collection: Any relevant published and locally approved unpublished studies and literatures on the same related issues were reviewed. Secondary data were also collected at their corresponding Woreda Agriculture, and Environmental Protection and Land Administration offices.

Screening and scoping: These were carried out to assess whether impacts were likely, and what the character of such impacts might be (Wathern, 1988). Distinct stages of screening, scoping, assessment, and identification of mitigation measures were done. So, the effects of the development during construction and operational phases were assessed based on the existence of the development; the use of natural resources; the emission of pollutants, elimination of waste; and the description of the area.

Expert interview: A discussion with actively working EIA and natural resource experts (three and two experts at Woreda and zonal levels, respectively) in projects' corresponding Woreda and the zone was randomly selected among their members and conducted. The issues raised were about physical and biological aspects of the environment, watershed management practice and current situation of Lake Tana. So, that obtained information was validated and cross-checked with other sources.

Key Informant Interview: This interview was conducted with community representatives, experts and scheme representatives. Totally 61 key informants were discussed at their own projects (at Megech-Serbia 12, Tana Zegie 15, Tana Wonjeta 14, Tana Asrate 9 and Tana Mekonta 11). A scaling checklist was used to capture the relative rating of each impact and to guide the evaluation of different criteria. The Battelle Environment Evaluation Index (EIV) is used to aggregate the data collected by scaling checklists.

$$EIV = \sum_{i=1}^n (Vi)Wi$$

Where:

EIV = Battelle environmental index value;

VI = relative change of the environmental quality by parameters;

WI = relative importance or weight or parameter and

N = total number of environmental parameters.

Magnitude of environmental parameters was given numerical values according to their impact, extent as: high (+3 or -3), medium (+2 or -2)

and Low (+1 or -1) which are seen as qualitative (ranked) variable form (Tables 2 and 3).

The relative importance of Environmental Parameters (WI) were not equally considered in terms of its importance or weight. It varies from country to country. In Ethiopian, parameters which contribute Growth and Transformation Plan (GTP) of the country, as food security, employment, agriculture, natural resource management are more important. So, as seen in Tables 2 and 3 their values were presented as low, Medium and High.

Field observation: It was done at, pump site, command area, and the surrounding of the project area. Current environmental situations of the area like the lake, soil, and wetlands, the weed, agricultural practices, sediment along the lake shore, current chemical use and land use type were considered in the field observation.

2.4. Data analysis

Predicting the magnitude of a development likely impacts and evaluating their significance is the core of the environmental assessment process (Morris and Therivel, 1995). A method used by EHSC (2016), matrix method was used to identify interactions between various project activities and environmental parameters and components. The prediction was based on the available environmental baseline of the projects' area, projects resource utilization and waste. Such predictions were described in quantitative or qualitative terms using SAS software according to their normality test.

3. Results and discussions

3.1. Positive impacts

It is possible to have an enormous list of positive impacts (direct and indirect) that can be realized due to the implementation of the envisaged irrigation project in the area. Some of them are mentioned as follows: 1) Increase in agricultural yields and production, generating additional revenues; 2) Increased and diversified food supply all year; 3) Increase in local development and employment; 4) Improve forage varieties which increase animal productivity and production; and 5) Increase in land values and price due to irrigation water.

3.2. May these projects aggravate threats of Lake Tana?

According to literature, secondary data and expert interview source, Lake Tana is exposed to several treating factors. Based on the same source and locals' thought, these factors are getting an increase from time to time. For this reason, threats might be aggravated by the projects, or the project themselves may suffer from the threats. So, as listed in the following subtitles, it has been identified and corresponding mitigation has been discussed.

Tana-Beles hydropower: It is the second outlet of the lake (Goor et al., 2010), according to local fishers thought, in the inlet, there is a filter or track rush which was designed to prevent the entrance of fish to water canal but the filters allow much fish to enter to the turbine. More are

Table 2. Impact significance matrix/rating of impacts during the construction phase.

Topic	Potential Impacts	Significance			Is mitigation Needed?
		Low	Medium	High	
Construction materials	Land and fisheries degradation		✓		Yes
Spoil disposal	Pollution		✓		Yes
Deforestation and wildlife	Deforestation and wildlife		✓		Yes

Table 3. Impact significance matrix/rating of impacts during the operation phase.

Topic	Potential Impacts	Significance			Is mitigation Needed?
		Low	Medium	High	
Lake water	Lake and wetlands degradation		✓		Yes
	Lake water imbalance/reduction		✓		Yes
Soil and water use	Inefficient water use		✓		Yes
	A decline in soil fertility		✓		Yes
Earthwork	Erosion		✓		Yes
Sediment	Sedimentation			✓	Yes
Chemicals	Pollution		✓		Yes
Wildlife	Impact on flora and fauna			✓	Yes
Animal death	Small aquatic animal death			✓	Yes
Land use Core and buffer zone	Land use change			✓	Yes
	Disturbance of Lake Tana core and buffer zone			✓	Yes
Cumulative effects	Cumulative impact			✓	Yes

killed by the turbine and some pass it and are found at the outlet, at which there is high fish mortality. Similar findings were also done by Mequanent and Sisay (2015). It is also possible to see that the loss of water, 2.99 bm^3/year (ADSWE, Engineering Design, 2018).

Regulating water taking by this project should be done and it also must be based on its purpose, for example, if there is no shortage of power no need of releasing more water. Setting of effective filters (track rush) in the inlet and having better management of the sub-basin can be considered as a solution.

Wetland degradation: The total area of wetlands in the sub-basin is 340928.8 ha including Lake Tana and the rivers, but these are used in inappropriate way (Mequanent and Sisay, 2015). Because of this reason, such as Fogera plain in 21 years (from 1987 to 2008) from the three wetlands (Shesher, Welela, and Daga-Takua) a total of 1733 ha has been lost. Changes between 1986 and 2013 indicated a total of over 52% of wetlands is converted to other land use forms. Of this, about 43% of the wetland conversion are for cultivation and settlement (BNWI, 2014). Based on the local source, change of wetlands have been changed from time to time. Existing wetlands land use types are drained for agriculture, overgrazing, upper catchment land degradation, Eucalyptus encroachment or plantation, invasion of alien species or weeds, over-harvesting of their resources, settlement and urban expansion, pollution and water diversion which threats of wetlands and are serious problems which need solutions similar to Mequanent and Sisay (2015) and Goshu and Aynalem (2017) studies. From this, it is possible to extrapolate the probability of land use change of wetlands by these projects. So, these are serious problems of Lake Tana and its environments.

Proposed solutions for this problem are (i) existing land use type of wetlands must be conserved and water hyacinth also should be removed (ii) avoid and minimize wetlands impacts and finally, encourage wetland restoration (iii) Ethiopia should be a signatory to Ramsar Convention on wetlands to bring its sustainable development (iv) the role of wetlands in climate regulation, adaptation, and mitigation have to be recognized (v) the government should not accept the promise of compensatory mitigation as justification for the destruction of wetlands. These mitigations are also suggested by Mequanent and Sisay (2015), and ADSWE, LUPESP (2015: unpublished data).

Improper solid and liquid waste management: Irrigation projects have been planned in the sub basin; some tributaries have been dammed, for example, Ribb Dam, and Megech Dam which is under construction.

Due to urbanization, population increase, agricultural intensification and industrial development around the lake are leading to increasing the release of solid and liquid wastes into the lake. Moreover, existing solid and liquid waste management in this sub-basin is very poor, for example, it is possible to see that the drainage system of cities (such as Bahir Dar and particularly Gondar) and other towns. Wastes from these projects are also a challenge. Unless otherwise good waste management is done, these and other point sources are also very risking to the lake.

Invasive Weeds: Infestation of the weed in Lake Tana was observed and recognized by Ayalew et al. (2012). As mentioned by Erkie (2017), in addition to, human factors and climate change the weed becomes a threat for the lake. Furthermore, he said, because of this weed a numbers of water bodies or water resources have been failed for problems. The most impacts were on aquatic ecosystems, agriculture, fisheries, transportation, living conditions and social structures.

Currently, except Megech-Seraba pump project area, there is no water hyacinth thought it has the power to invade it, evading at an alarming rate. Therefore, the weed is threatening to the lake. According to experts' interview, these projects with the combination of water hyacinth have a synergistic effect on the lake.

Based on the local source, there was controlling of this weed for the last four years, but it was not effective. As a result, its infestation was increasing from year to year Nowadays, the issue of this weed is becoming nationwide. If this is not controlled, the lake will be in problem. These irrigation projects will also aggravate the impact on the lake and the projects' sustainability will be also in question. Therefore, as soon as possible, controlling the weed is an urgent issue and should be made by the government as it has got attention, the scientific method can lessen difficulties. The locals should also continue triggering the government.

Decline in fisheries: In filed observation, expert interview, key informant discussion, and literature, it was understood that illegal fishing activities are very common in this sub basin and resulted that the decline in fisheries. This depletion was earlier reported by de Graaf et al. (2006). Due to their spawning aggregation (de Graaf et al., 2005) and ecologically highly specialized endemics (de Graaf et al., 2008), Lake Tana *Labeobarbus* species are highly vulnerable. This decline is aggravated by these projects and distraction can be followed from water loss due to projects, In addition, the most illegal fishing activities which also are a factor for declining fisheries are (i) fishing season (at spawning time) particularly for *Labeobarbus* species from July up to the end of November as breeding time has been studied by Nagelkerke and Sibbing (1996), Palstra et al. (2004), de Graaf et al. (2005), Getahun et al. (2008), and Dagnew et al. (2014), (ii) illegal fishing tools (monofilaments, fences, poisoning chemicals, and small mesh size). Overall, fishing is taking place in spawning season and spawning ground of each species. So, with the combination of these projects (which are taking water from the lake) can be a bottleneck for the ecosystem of the lake. Unless otherwise controlling and managing is done. These projects also aggravate pressures on the system.

The abstraction of fish passage: At Ribb Dam, there is no fish ladder which blocks migration of fish; creating immense pressures on the survival of the lake fish, particularly on the migratory endemic species, *Labeobarbus* species. Similar studies at one of the tributaries of Lake Tana, Gelda River (Gebremedhin et al., 2017) showed that this spp. is failing to problems because of the absence of this fish ladder, a similar impact may be observed on Megech Dam. These projects may also have a direct and indirect impact on fisheries, aggravates impacts on fisheries and the lake.

Providing restoration of upstream and downstream longitudinal connectivity, as studied by Michel (2018) like pool-type fish, passes (Philippe, 1897), Denil fish passes (Larinier, 2002a; Rajaratnam and Katopodis, 1984), nature-like bypass channels (Gebler, 1998), fish lifts or locks (Travade et al., 1998; Clay, 1995), production of fish in the reservoir and aquaculture (Hortle and So, 2017), rehabilitation of rivers for fish (Cowx and Welcomme, 1998; Dudgeon, 2005; and Nunn and Cowx, 2012), providing fish hatchery and spillways or off takes could be taken as a solution.

Settlement and urban expansion: Settlements in this sub basin are mostly scattered and settled in relation to natural resources bases, among these resource water bodies, and agricultural lands are the most required, particularly urbanization near to the lake. From experience, urbanization is expected to be more on each project due to the access to the irrigation water supply. The government should control this illegal settlement, particularly near to the lake and this project; planning and controlling of settlement can be a solution to this problem.

3.3. Construction phase potential negative impacts

Construction phase major negative impacts and proposed mitigations are predicted, discussed and analyzed as follows (Table 2).

3.3.1. Land and fisheries degradation

Projects require bulk materials for construction (sand, gravel, crushed rock and others) for infrastructure construction and concrete; which is sourced locally. According to Kay (1996) and FAO (1997), obtaining the above construction materials has impacts on the environment such as wastes or eroded materials, changes in topography if pits are deep, they present a risk to animals and human and vector breeding sites. Sands are taken from tributaries of the lake at which *Labeobarbus* spp. spawn.

Sand mining in the watershed, a relatively recent phenomenon, is rapidly growing and expanding to all tributaries of the lake (Asfaw, 2013) and also according to the local and the expert information source, sand mining is taking place mainly in the inflowing rivers, especially at fish spawning season because at that time rivers getting more flood from the rain and has a chance of bringing sand from the catchment. Currently, at the site where fish spawn, there is high fish mortality due to sand mining. These projects may aggravate the existing situation as such, it is becoming an important pressure on the migratory *Labeobarbus* species, a similar study has been reported by Asfaw (2013).

To minimize its effect, the following mitigation are proposed: 1) maximize the re-use of excavated materials in the works, as to fill, cloth all borrows pits and quarries; 2) ensure materials only sourced from approved sites and time, for example, spawning time of *Labeobarbus* spp. In the river is from July up to the end of November (Nagelkerke and Sibbing, 1996; Palstra et al., 2004; de Graaf et al., 2005; Getahun et al., 2008; Anteneh, 2005; Gebremedhin, 2011; Dagnew et al., 2014); 3) Site borrow pits and quarries carefully so as to minimize impacts on existing land users; 4) Strip all the available topsoil from borrow pits and quarries, and store it safely for use in site restoration; 5) finally, when the construction is finished, restoration and afforestation should be done.

Pollution: During construction there is a creation of various solid wastes, principally surplus earth and rock, metal scraps, plastics, cardboard, paper, wood, office wastes, used oil and solvents, washing water and sewage, concrete washings, runoff from camp and workshop areas and various liquid waste. So, these and others unforeseen pollutants can pollute the lake and the surrounding.

Mitigation that can minimize or remove the problems are: 1) identify all waste streams for effective management; 2) manage the wastes based on the 3 s (reduce, re-use, recycle); 3) minimize the production of waste that must be treated or eliminated; 4) dispose of in authorized and approved areas all the garbage and >500 m from rivers, streams, lakes, or wetlands; 5) identify and demarcate equipment maintenance areas (at least greater than 500 m from rivers, streams, lakes or wetlands); 6) recycling systems are highly recommended.

3.3.2. Deforestation and wildlife

It is known that the project area is important for biodiversity conservation at all levels, including genetic diversity, species and ecosystem diversity since it is covered by dense forest and forest area and wetland with various flora and fauna species as mentioned on the baseline environmental condition of the project area.

There is some clearance of different shrub and tree species due to the construction of artificial ponds, pumping station and alignment

distribution channels. This will have significant adverse impacts on biodiversity of flora of the project. During construction, apart from clearance of different shrub and tree species the operation of various construction equipment's, vehicular and human movements is likely to generate noise and vibration on wildlife. Particularly at Tana Zegie project the operation of various construction equipment's, vehicular and human movements is likely to generate noise and vibration, and these lead to some disturbance of wildlife.

Proposed mitigation measures are: 1) minimize site clearing; 2) afforest cleared sites with indigenous trees; 3) minimizing site clearance to protect the natural habitat of wildlife; 4) as much care as possible should be given by considering animal behavior and their time.

3.4. Operation phase potential negative impacts

Operational phase major negative impacts and proposed mitigations are predicted, discussed and analyzed as follows (Table 3).

3.4.1. Lake Tana and wetlands degradation

There may be negative impacts associated with irrigation water resources on the lake now and in the future, if it is not well managed and not done based on design. A similar assessment was done by Githaiga et al. (2003). According to Falkenmark and Rockstrom (2004), the estimated amount of water required to maintain ecosystem goods and services is 75% of the total water use while humans should use a maximum of 25%. This balance, if not maintained, the environment could suffer from multiple pressures.

Therefore, proposed mitigation measures are as follows: 1) carry out NABU principles: recommended activities in each zone (core zone, the buffer zone, and development); 2) wetlands conservation and restoration which is arguing Zalewski (2000, 2015) apply land use policy and planning tools to improve wetlands and restoration policies, and setting sound management of these natural resources for sustainable development; 3) Controlling of the water hyacinth: Though there was controlling of this weed by locals and regional government every year, this weed re-invading it the left time. To control this weed totally, continuous assessment and follow-up from governmental and non-governmental organizations and all nations should alert, could be done strong extension work (awareness creation); 4) outflow of Lake Tana is regulated by the Chere Chera weir. This weir regulates water storage in Lake Tana over a 3 m range of water levels from 1784ma. s. l. to 1787ma.s.l. The amount of water that is lost for different irrigation and hydro power projects balanced by rising higher of the Chere Chera weir and careful lake water use; 5) environmental implications of water developments and the impact of lake water levels must be evaluated every year.

3.4.2. Lake Tana water balance

Generally, the following main issues would be a solution to the threats of the lake. These have been discussed as follows:

- a. Chere Chera weir: outflow from Lake Tana is regulated by the Chere Chera weir. According to SMEC (2008), Chere Chera weir regulates water storage in Lake Tana over a 3 m range of water levels from 1784ma. s. l. to 1787ma. s. l. Regulating outflow from the Blue Nile River could be fixed to 10 m³/s from March to June (SMEC, 2008: unpublished data).
- b. There are also the most relevant plans and strategies as an example of the necessity of harmonizing national and regional policies with the biosphere reserve management plan, the Fisheries Development, and Utilization Proclamation (Proclamation No.,315/2003, 2003), and the Master Plan for Lake Tana Watershed.
- c. The Amhara National, Regional State Lake Tana and its environs biosphere reserve delineation and administration's determination, the council of the regional government (Regulation No., 125/2014, 2014) issued with the main goal of protecting, conserving and

Table 4. Water balance of Lake Tana.

Type	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Ungagged river inflow (bm ³)/year	1.70	1.70	1.70	1.70
Gauged river inflow (bm ³)/year	5.61	5.61	5.61	5.61
Runoff (bm ³)	0.40	0.40	0.40	0.40
Precipitation on the lake (bm ³)/year	4.56	4.56	4.56	4.56
Total inflow (bm ³)	12.27	12.27	12.27	12.27
Water abstraction by irrigation (bm ³)/year	-	0.03	0.39	0.90
Evaporation from the lake (bm ³)/year	4.01	4.01	4.01	4.01
Outflow of the lake by the Blue Nile (bm ³)/year	3.73	3.73	3.73	3.73
Outflow of the lake by the Tana Beles (bm ³)/year	-	2.99	2.99	2.99
Total outflow/year	7.75	10.76	11.12	11.65
Change in Lake storage (bm ³)/year	4.52	1.50	1.15	0.62
Change in lake level (m)/year	1.43	0.48	0.36	0.20

Source: ADSWE, Engineering Design 2018, unpublished data, bm³-billion-meter cube

developing the natural and artificial resources available in the Lake Tana and its environs.

- d. The Government and people have been aware of the problem of Lake Tana particularly weeds, water hyacinth. So, this awareness may be put into practice.

3.4.3. Projects in the sub basin and scenarios

The demand for water for Tana Beles Hydropower and irrigation projects, Lake Tana water balance has been calculated by ADSWE, Engineering Design (2018: unpublished data), with scenarios summarized (Table 4 and Figure 2) as follows:

- i. Scenario 1: considering there are no projects

The scenario without the Tana Beles Hydropower project and with no development of the irrigation projects. Chere Chera weir is assumed to be unregulated.

- ii. Scenario 2: by considering completed projects

The scenario with the Tana Beles Hydropower project and with the development of the completed (Koga) irrigation projects under minimum lake level operation of 1784 ma.s.l. Chere Chera weir is assumed to be regulated.

- iii. Scenario 3: by considering (completed and ongoing) projects

The scenario with the Tana Beles Hydropower and other ongoing irrigation projects under minimum lake level operation of 1784ma. s. l. Chere Chera weir is assumed to be regulated.

- iv. Scenario 4: by considering (completed, ongoing and proposed) projects

The scenario with the Tana Beles Hydropower, completed, ongoing and proposed irrigation projects under minimum lake level operation of 1784ma. s. l. The Chere Chera weir is assumed to be regulated.

As seen in Figure 2, change in lake level and storage and total outflow is high in scenario 4, but total inflow is constant.

Although the height of the water level in the lake is balanced by the weir, because of sediment and siltation, the volume of water may be reduced, as weir height rises the sediment and silt may reduce the depth of the lake. From this, it is possible to see that, water balance can be regulated by the weir, but avoid or reduce siltation and sedimentation of the lake (Table 4).

An irrigation requirement for all projects from the lake is 3916.29 mm³/year. It is possible to see water requirements for each project in each scenario, for example of these projects which are included in scenario 3 total water abstraction is 0.39 bm³ (Tables 4 and 5). The storage capacity of the lake between 1785ma. s. l. and 1787ma. s. l. is about 6

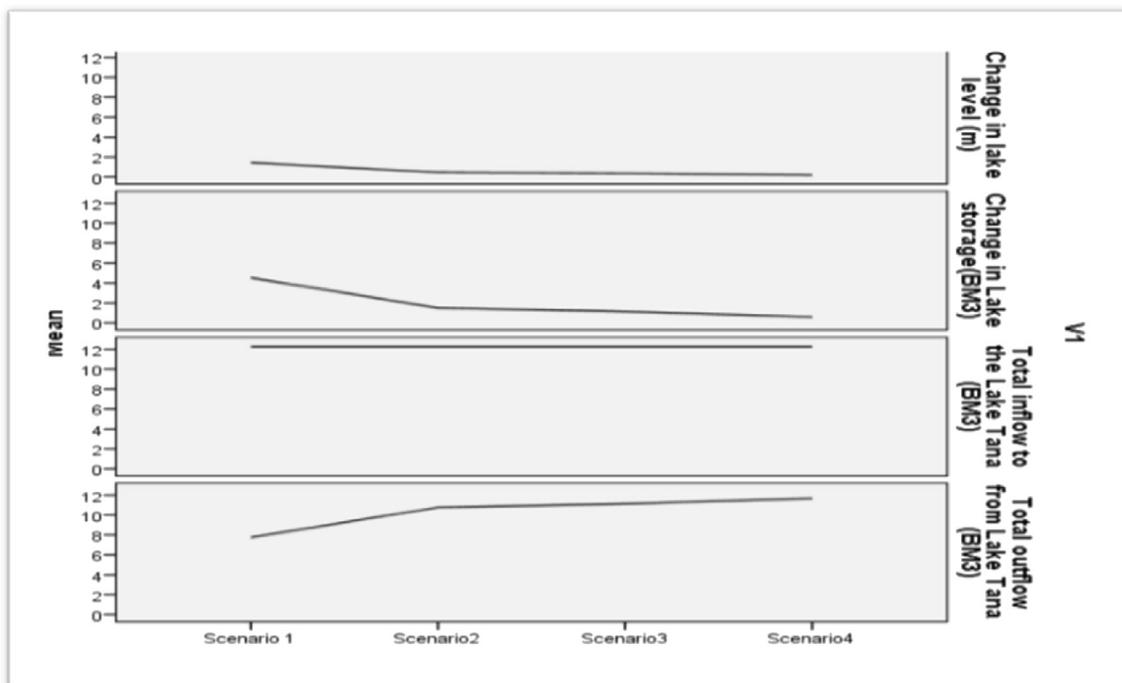


Figure 2. Scenarios and its variabilities (Variables, V 1).

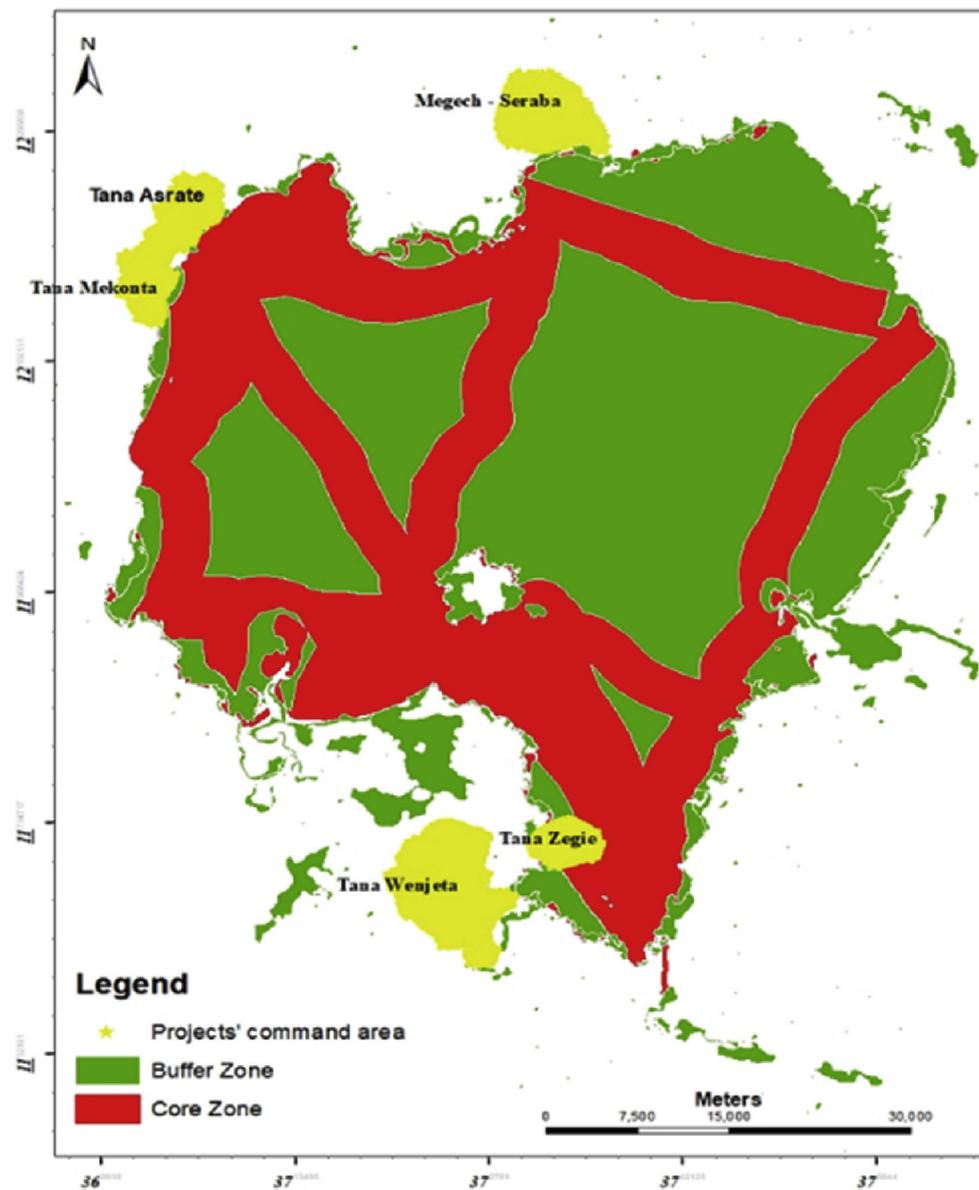


Figure 3. Location of each project in relation to Lake Tana Biosphere Reserve area.

bm^3 . Active storage ranging from 6 bm^3 to 9.1 bm^3 (ADSWE, Engineering Design, 2018, unpublished data).

This storage capacity is very much greater than the intended irrigation demand. So, based on this data, pumping water from the lake may not have any significant effect on the overall water balance of the lake but there may be for down users. This is because the amount of water drawn from the lake is very small compared to the active storage of the lake which is regulated by the Chere Chera weir. This figure can be true if and only if things are constant. i.e. there is an assumption of constant total inflow and regulated outflow from the lake. If there is good resource management in all aspects, the volume of inflow increase. In this case, any other developments may also be allowed.

Inefficient water use: As studied by Kay (1996), furrow irrigation efficiencies as high as 90%, but are more typically 40–70%, with losses of 20–40% due to over-irrigation and furrow-end to a pond. Therefore, as mitigation, improving design, construction and timely maintenance and repair system components is a must.

The decline in soil fertility: The dominant soils in the command areas are clay poor in N and organic carbon (ADSWE, LUPESP, 2015;

unpublished data). Intensified cropping results in a decline in soil fertility unless managed. Irrigation gives farmers the option for second or even third season production, thereby enhancing the productive capacity of the limited human environment. Unfortunately, these opportunities for intensifying the agricultural production can have a deleterious effect on the quality and fertility of soils of the irrigated plots. Irrigation also increases cropping intensity in turn results in a controlled removal of nutrient from the soil. If there is nutrients removal more rapidly than replaced, the system will not be stable, the resource base of the soils will be degraded and crop yields will be reduced. Intensive cropping can also lead to the deficiencies of nitrogen, phosphorus and potassium and other minor or trace elements.

Application of chemical fertilizers is the most common means of restoring nutrient however, chemical fertilizers alone could not be a solution to keep soil productivity in the long-term (Gastal and Lemaire, 2002). According to the Food and Agricultural Organization report, FAO(1997) and our investigation, to maintain soil fertility in command area, the government and the users should 1) proved inorganic fertilizers based on the deficiency and organic ones; 2) electrification the area for

Table 5. Comparison of projects which are taking water from Lake Tana and its tributaries.

Project name	Command area (ha)	Water consumption (mm ³)	Lake Tana water depth (m)
Megech Dam	7300	89.9	0.0285
Megech- Serava	4995	40	0.0127
Ribb Dam	19925	198	0.0627
Gumara	13980	113.2	0.0359
Gilgel Abay	10310	79.4	0.0252
North East Tana	5750	48.3	0.0153
North West Tana	6720	53.8	0.017
South West Tana including Tana Zegie	5130	42.1	0.0133
Megech (Robit)	6532	37	0.0117
Gilgel Abay diversion	3264	30	0.0095
Irrigation from ungagged rivers	-	133	0.0421
Tana Beles	-	2985	0.9458
Tana Wonjeta	4848	39.28	0.0124
Tana Asrate	1333	15.87	0.0049
Tana Mekonta	1139	11.44	0.0035
Total	91226	3916.29	1.2405

Source: ADSWE, Engineering Design 2018, unpublished data

power supply, so that manure can be used for organic fertilizer; 3) as reported by Reganold (1995), and Conacher and Conacher (1998), good land husbandry practices in the area can be a solution.

Erosion: Construction of canals drains; head work structures, pump and farm access roads as well as quarrying and borrowings are source of soil erosion, removing of vegetation cover and disturbing of the topsoil and sub-soil. Some part of the command area is steeper slopes, greater than 5%, as reported by Harper et al. (1993), areas greater than five percent are exposed for potential for erosion. Therefore, large amount of soil excavated from near the demand quarry sites leaves borrow pits and areas that are easily eroded. Then these washed down into the reservoir basin accelerating the filling-in of the canals and lessening the effective life of the scheme as well as the lake sedimentation problem.

Farmers straining from the last 17 years have a better background about erosion effect. So that, they are dealing with erosion control. To make them more effective, it is better to have specific erosion control and avoidance practices suggested as part of the farmer training package; including: 1) avoiding steep slopes of cropping (replace with perennial crops) within the command area; 2) managing flow velocities within the canal system. Protected drop structures at suitable intervals can a good solution within the primary and secondary canal systems; 3) consolidating quarry sites and re-vegetating borrow areas; direct seeding with grass or herbaceous plants would be ideal; 4) Providing cut off drains that dispose the run off to the natural waterway and energy dissipating structures and outlets that cut the flow of storm water.

Sedimentation: Lake Tana is highly exposed to sediment load. The magnitude of annual soil loss of the sub basin ranged from 0 to 3228.04 tons/ha/year with an average annual soil loss rate of 37.65 tons/ha. Up to 43.83 % of the area resulted in a tolerable soil loss rate, 11 tons/ha/year (Mersha and Mamaru, 2018: unpublished data). According to ADSWE: LUPESP (2015: unpublished data), the mean annual sediment load of major inflowing rivers (Gilgel Abay, Gumara, Ribband Megech) is 16705498.97 tons (97%) but mean annual sediment outflow by Blue Nile River is 1848104.19 tons, 11.1% of the inflow sediment. These irrigation projects can also aggravate sedimentation in one or the other way. As a result of this, the lake is at risk, too, by proposing projects unless otherwise are measure is taken to minimize sediment entry. Therefore, to minimize this risk, the following mitigations are proposed: 1) dispose of spoil on the appropriate site, mainly refill of quarry sites; 2) provide drainage systems along the canals; 3) soil and water conservation

activities in the catchment are needed (Hailelassie et al., 2008) and apply effective upstream slope stabilization during the dry season; 4) implementation of the NABU's principles and strategies.

Pollution: In the sub basin, used fertilizers are NPSZ and NPSB + Urea and for weeds and pest control are Diazinol, 2-4D, and Maltin. Based on the experience of others, the presence of these projects could aggravate the utilization of these and other chemicals. These chemicals are likely to have significant adverse effects on the environment. Similarly, according to EHSC (2016), intensification of agriculture result in a significant increase in the use of fertilizers due to (i) the use of improved seeds and crop varieties which require and respond to high nutrient levels (ii) increased ability of farmers to purchase inputs (iii) a possible reduction in soil fertility. A significant proportion of the nutrients in the fertilizers are removed from the fields in soluble form in drainage waters. Elements of P and N (as soluble nitrate NO₃) accelerate on aquatic weeds which could choke drainage channels. The following mitigation can be a solution: 1) provide buffers between the command area and the lake; 2) built artificial wetlands to collect all untreated effluents released from operations before entering the lake (Kivaisi, 2001); 3) develop and promote integrated pest management, IPM 4) promote organic agriculture; 5) fertilize based on fertility; 6) establish appropriate waste management systems.

Impact on flora and fauna: There might be land use change because of the access to water, the risk of deforestation mostly at Tana Zegie. Even though culture and religious restrict some agricultural activities such as animal rearing and plowing for cropping at Zegie, with the availability of irrigation facilities, farmers may encourage the changing of forestland. Probability of land use change with the argument of Zalewski's study (2000 and 2015) may occur. This can have an adverse impact on the biodiversity of fauna, flora and the lake. Therefore, to overcome the problem, the following solutions are proposed: 1) irrigation practice must support existing land use type; 2) encouragement of private forestry including fruit tree plantation; 3) respect NABUs principle and rules.

Small aquatic animal death: Aquatic animals like a fish, frog and other small ones may enter to pump site and lines and die because of pressure created by pump turbines. As mentioned earlier Tana Beles pump site can be considered as an example. To avoid these problems, preparing mesh, track rush which will prevent the entrance of animals to the pump site at 200 m radius.

3.4.4. Land use change

The existing land use, land cover of the Tana Sub - Basin is dominated by cultivated land (52.66%) followed by water bodies (19.66%) (ADSWE, LUPESP, 2015: unpublished data). There is a high agricultural practice in the area, because of this reason the natural vegetation has been cleared almost completely except around the settlements and very few areas. So, existing land use type almost all except Tana Zegie, which is forest and forest coffee production is cultivated land. Therefore, there will not be land-use change. However, the land has been used for canal work, powerhouse accesses road and water storage which are not significant. Whatever it is, the locals should keep existing land use type and consider the effect of climate change in the long term.

3.4.5. Does projects obey Lake Tana Biosphere Reserve (Regulation No. 125/2014, 2014)?

Regulation No. 125/2014, 2014, defined as 'Lake Tana biosphere reserve shall mean the place comprising, core, buffer, and development zones in the Lake Tana and its environs recognized with definite boundaries (Figure 3). Lake Tana Biosphere Reserve, registered on June 19, 2015, is among the fourth UNESCO world biosphere reserve sites of Ethiopia (Worku, 2017). Any development that is taking place in this area should respect Lake Tana Biosphere Reserve rules and regulation. If there is disobeyed of the law, any development may not have accepted.

Projects in their plan of development reports as seen in Figure 3, they respect the law, except for motor pump seat, but based on experience or current resource utilization trained and expert interviews' saying this may not be put into practice. Regular inspection and implementation of

the regulation is necessary to have sustainable development. Modern technology and careful operation of their pump seats since for all projects it is at the core and buffer zones. Therefore, the government should keep the promise of UNESCO world biosphere reserve sites.

Cumulative impacts: It is the bare fact, water demand for hydro-power, irrigation, domestic, municipal, transportation, industrial and ecological services are increasing and controversy. Therefore, like the study of Contant and Wiggins (1993), cumulative impacts result in. Since the impact on the water resources of the lake both now and in the future is significant. Proposed solutions that could lessen the impact are: 1) Very careful considerations of lake water utilization; 2) Detail analysis of environmental and social consequences; 3) Water resource development activities should be assessed; 4) Environmental implications of water developments and the impact of lake water levels should be evaluated and; 5) The evaluation is crucial because the lake water is important to the livelihood of many people including domestic water supply, fisheries, grazing and water for livestock, papyrus reeds for boat construction, water transport and tourism destination.

4. Conclusion

Based on the result: it is concluded that projects have a positive, and a negative impact, but if proposed mitigation measures for identifying negative impacts are not put into practices, the negative impact may weight greater than positive once. Identified negative impacts are pollution, deforestation, and wildlife, inefficient water use, the decline in soil fertility, erosion, sedimentation, small aquatic animal death, disturbance of Lake Tana core and buffer zone, lake water reduction and cumulative impacts. Different threatening factors like sediment, water loss of hydro power, wetland degradation, improper solid and liquid waste management, invasive weeds, illegal fishing, the abstraction of fish passage, settlement, and urban expansion can aggravate impacts unless otherwise controlled. So, to make projects environmentally friendly, economically, socially, and sometimes governmental accepted, solutions and recommendations have been made.

5. Recommendations

From result, it is strongly recommended that: 1) proper implementation of the proposed mitigation for negative impacts, can reduce the impact; 2) projects should encourage replacing and use of environmentally friendly technologies and for this, the government should provide an incentive measure; 3) effective monitoring of environmental and social management plans must be put in place so as to reduce the impacts of projects; 4) since threatening factors have direct and the indirect relationship between the project and its environment, it should be alleviated. Additionally, researches and or other development projects should not be on a separate basis.

Declarations

Author contribution statement

Dagnaw Mequanent Tesema, Minwelet Mingist: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Additional information

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