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Article

Trends of forest cover and prospects of Great Ethiopian Renaissance Dam (GERD) to Ethiopia and the downstream countries

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Abstract: The need for forest products, agricultural expansion, and dependency on biomass for the household energy source has largely influenced Ethiopia's forest resources. Consequently, the country lost its forest resources to less than 6% until the millennium. In this study, quantitative and qualitative historical data analysis was employed to understand the socioeconomic benefits of large dam construction to Ethiopia and downstream countries. Moreover, remotely sensed data was also used to analyze the trends of vegetation cover change in the Nile catchment since the commencement of the dam; focusing on areas where there are high settlement and urban areas. It was identified that Ethiopia has one of the lowest electricity consumption per capita in Africa; about 91% of the source of household energy supply depends on fuelwood today and more than 55.7% of the population does not have access to electricity. The normalized difference vegetation index result shows an increment of vegetation area in the Nile catchment and a reduction of no vegetation area from 2011–2021 by 37.1%; which is directly related to the protection of the dam catchment for its sustainability in the last decade. The hydroelectric dam construction has prospects of multi-benefit to Ethiopia and downstream countries either through the direct benefit of hydropower energy production, related socioeconomic values, and reducing risks of destructive flood from Ethiopian highlands. Generally, it explains the reason why to not say 'No' to the reservoir as it is an ever more vital tool for fulfilling growing energy demand and supporting ecological stability.

Keywords: large dams; restoration; political controversy; food security; household energy

1. Introduction

Ethiopia is largely an agrarian country with over 90 % of its population living in rural areas where the local community is dependent on the forests fuel, income generation, fodder, and construction materials. Of the current total estimated population of 114 million, about 85% are engaged in agriculture for the subsistence of the workforce for existence. Agriculture is the cornerstone of the economy contributing about 53 % of the GDP and accounts for more than 90% of all exports (Alemu et al., 2003; Wendimu, 2021). It also covers 85% of the labor force and produces over 90% of the foreign exchange (Alemu et al., 2010).

According to the (World Bank, 2016), the country has registered remarkably rapid and stable growth in the past decade, 2000; though Ethiopia had one of the highest poverty rates in the world, with 55.3 percent of the population living below the international poverty line. As poverty is the oldest and the most resistant virus that brings about a devastating disease in the third world or developing countries (Tazoacha, 2001), its impact is continuous due to the limited basic resources and

increasing population growth which results from the limit on the benefits gained from natural resources.

Forest resources are among the front-line natural resources known for supporting the livelihood of local poor people in Ethiopia (Fekadu et al., 2021; Hyunshik and Solomon, 2019; Tolosa, 2019). However, the rapid population growth which leads to an increase in the demand for crop and grazing land, and wood for fuel and construction caused the Ethiopian forest the most vulnerable to deforestation (FAO, 2017). Besides these, the lack of alternative energy and shortage of electricity caused the rate of deforestation critical. In Ethiopia, the pressure on forests is particularly high, due to fuel wood and charcoal production alongside to expansion of agriculture on a large scale. As fuelwood remains the main energy source for the majority of the people in Ethiopia (Feyisa et al., 2017), the country lost its forest resources by about 18.6% which is 2,818,000 ha between 1990 and 2010 (FAO, 2010). Ethiopian cities and towns burn over three million tons of charcoal each year (Bekele and Zenebe, 2013) and dependency on charcoal is rather increasing as a result of rapid growth in urban population, and a rise in the price of modern sources of energy like electricity, LPG and kerosene. Thus, the most important source of fuel, which is a necessity for humankind are forest based which is charcoal and fuel wood (Bahru et al., 2014). The current study focused on the fact-based figures about the importance of hydropower source and facility construction and its multi necessities for the environmental restoration and the development of the country Ethiopia and the prospect of assistance for the downstream countries of the river Abay.

2. Research methodology

Quantitative and qualitative historical analysis was employed to understand and interpret the facts behind the GERD and its future environmental and socioeconomic prospects for the country and benefits for the Nile basin downstream countries. The historical research methods and approaches were used as it can improve understanding of the most appropriate techniques to confront data and test theories (Buckley, 2016). Also, a critical review of facts was conducted to analyze the GERD's benefit to Ethiopia and the possible advantages for the Abay basin countries. Additionally, remotely sensed data of vegetation cover change and bare land restored from the year 2005 to 2021 was used to analyze the forest cover change in the Abay catchment in Ethiopia.

2.1. Analytical framework

The aim of this paper was to analyze the trends of population growth; natural resources mainly forest cover change and the prospects of the ongoing GERD on the conservation and management of forest resources and the future hope in reducing the pressure of power sources, and supporting the ongoing national forest restoration (Green Legacy) program in the country. The study was supposed to show the facts behind; the need and importance of GERD for the sake of fulfilling the basic needs of the growing demand for sources of energy, and reduction of extent of forest degradation in Ethiopia and the stabilization of deforestation induced impacts on the

downstream countries. Also, it is supposed to contribute some fact based information in reducing the controversy over the GERD between Ethiopia, Egypt and Sudan. Analysis of figurative data of secondary sources, evaluation of written documents regarding GERD in Ethiopia, and/or abroad including other concerning countries and worldwide was conducted. In the study, access to information was one of the major limitations that led to conduct a systematic review of online data.

2.2. Systematic review

In order to get a clear data, the systematic review was conducted based on defined analytical criteria, and meta-analysis as identified in **Figure 1** with clear inclusion and exclusion criteria applied to ensure that the emphasis remains on facts and figures regarding population growth, rate of deforestation and change of forest cover, amount of electricity coverage versus demand, socioeconomic, environmental benefits of large dams and its contribution in ecosystem restoration. These criteria were used to minimize biasness that might be found in narrative reviews and make the study based on scientific methods without siding to one partner.

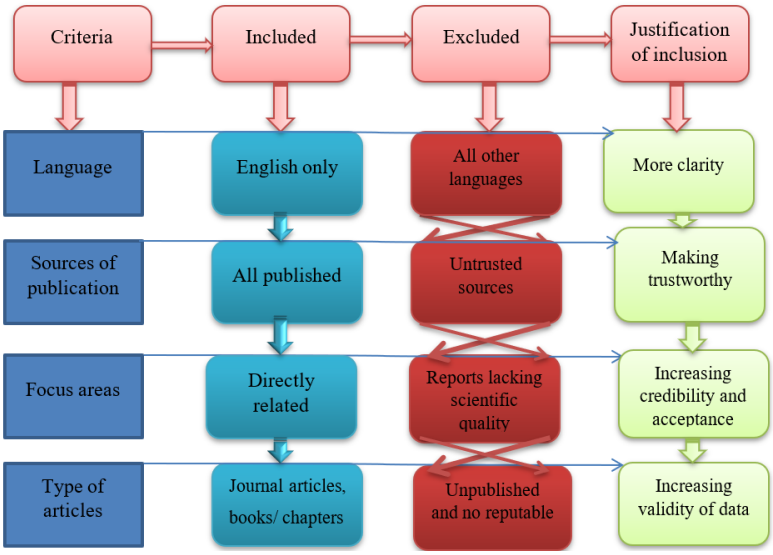

Figure 1. Inclusion and exclusion criteria for the articles included in the study.

As a systematic review presents results by combining and analyzing data from different studies conducted on similar research or subjects, the above figure was developed to show clear steps and procedure used in the data gathering methods.

3. Results and discussions

3.1. Is the construction of GERD is an opportunity or a threat to the downstream countries?

Grand Ethiopian Renaissance Dam (GERD) is believed to lay base for a new era of cooperation in the eastern Abay basin beyond the national benefits in Ethiopia. It has the potential to foster cooperation by offering regional socio-economic benefits through the coordination and management of hydraulic infrastructure in the basin for an improved water regulatory regime (Yihdego et al., 2016). As Ethiopia is

one of the fastest growing economies in Africa (Degefu et al., 2015), it's possible to classify the benefits as a cross bordering in solving the problems of the environmental degradation and pollution that could result due to such rapid economic and population growth.

On the other hand, the dam is expected to be the sources of electrical power to some of the neighboring countries beyond the national demand which may have a potential of reducing impacts of deforestation in the countries. It is expected to contribute for the socioeconomic benefits in the countries. Also it creates the opportunity of reducing undesired land use change that may increase erosion and reservoir sedimentation. For instance, reservoir sedimentation is not the problem of the Ethiopia where more than 85 % of the Abay is sourced only rather, it's the problem for the dam of Sudan (Merowe high Dam, or Merowe Multi-Purpose Hydro Project) and the (the great Aswan High Dam) of the Egypt. Dams have one of the most important roles in utilizing water resources (Tahmiscioğlu et al., 2007). For a country such as Egypt which depends on the Nile River to secure 95% of the water needed for different purposes as drinking, household uses, agriculture, fishing source, water transportation, tourism, electricity generation from the High Dam and industry (El-Nashar and Elyamany, 2018), management and working together on the sustainability of the water source should be top most priority rather than political disputes. As Ethiopia and Sudan are facing a frequent drought, poverty and desertification, alleviating the problems in these countries, especially through improved food security is intricately linked to ensuring sustainable access to the waters of the Abay (Yihdego, 2016). Furthermore, natural resources management mainly watershed management and rehabilitation of the degraded highlands of Ethiopia will have a high solution for the long run sustainability of the water Abay.

Majority of reports and written documents out from Ethiopia are stating the short comings of the GERD (Abdelhaleem and Helal, 2015; Aziz et al., 2019; El-Nashar and Elyamany, 2018; Hammond, 2013; Negm et al., 2018; Ramadan, 2013; Ramzi Ibrahim, 2017; Wheeler et al., 2016) mainly predicting about the future water loss of Egypt and Sudan when the GEDR starts is function. However, controlling of over disastrous flood is the most downstream benefit of constructing dams and reservoirs (Cernea, 1997). For instance, Sudan is the most affected country by the flood during the Ethiopian summer season. Sudan suffers annually from torrential rains coming through Ethiopian plateau which is the Blue Nile River (El Siddig Ahmed El Tohami, 2019). This is not only the problem of Sudan but it has been reducing the productivity of agricultural land and affecting the food security in Ethiopia. Recent political controversy between Ethiopia, Sudan and Egypt is more focused on negative impacts of GERD only; however, the collaborative work between the concerning basin countries would change or reduce the negative impacts on the respective countries. Because, Sudan's flood problem gets decline when there is reduction in flood over Ethiopia (Walsh, 1994); and when there is sustainable natural resources management is implemented. Natural resources degradation, a major form of which is deforestation and de-vegetation, has become a serious problem in Ethiopia (Ango and Bewket, 2007); and trends show forest generally decline in east Africa (Mwangi et al., 2018). Therefore, a key issue relating to forests in Africa is decline of forest cover as well as the degradation of what remains as a

consequence of several factors; and developing alternative energy sources is one of the key strategies in responding to forest decline, fostering sustainable forest management and climate change adaptation.

3.2. Trends of population size, household energy source and forest loss in Ethiopia: Facts and figures

Even though the absence of accurate time series population data limits the estimation of past size and growth rates of the Ethiopian population (Bekele and Hailemariam, 2010), the first national census was conducted in 1984 and estimated the total population to be 42.6 million. Subsequent censuses estimated 53.5 million (1994) and 73.5 million (2007), while the 2012 Inter-Censual Population Survey estimated 83.7 million (Bekele and Lakew, 2019). According to the United Nations Revision of World Population Prospects, the world population prospects 2019 presented that if Ethiopia follows its current rate of growth (3.02%), its population will double in the next 20 years and cross 188 million by 2050 (UN, 2019).

The relationship between population growth and environment is complex (Ghanem, 2018), as growing population ultimately needs some form of land use changes (Hunter, 2017) and affect the environment and biodiversity. Forests are among the main natural resources which are influenced by the complexity in between the relationships. For instance, the massive declined in forest cover change are often associated with deforestation and agricultural expansion in the periphery of the forest. As a result, Ethiopia lost an average of 140,900 ha or 0.93% of its forest covers annually from the year 1990–2020 (Feyisa et al., 2017). This resulted loss of fertile top soil and nutrients which transported to the neighboring countries mainly to Sudan and Egypt (Oljirra, 2019). On the other hand, due to the shortage of electrical energy sources in Ethiopia, 80% source of household energy supply depends on fuel wood today (MWE, 2013). Forest clearing in the form of fuel wood exploitation and charcoal production are the main challenges that contribute to the decline of forest coverage (Negassa et al. 2020). Furthermore, besides charcoal production and fuel wood collection, land for agriculture and forest products as sources of subsistence income are basic for the livelihoods of rural societies mainly. Thus, the intricacy increases with the current estimates show a population growing by about 2.44 percent per year, or an increase of about 2 million persons annually (Amare, 2015).

It was reported that more than half of the total population 55.7% of households without or insufficient access to electricity and the majority of unelectrified households are located within 10 kilometers of the national grid on average (Padam et al., 2018). The average person living in Ethiopia consumes the least electricity per capita (85 kw/capita) in sub-Saharan African countries compared with North African countries (1442 kw/capita) (Hafner et al., 2018). This implies that while energy capacity and quality are crucial for development, in many African countries, electricity supply is notoriously unreliable (Ahlborg et al., 2015). In this case, the main source of household energy is forest based which is biomass. This energy crisis resulting from complete dependency on biomass fuel is becoming a major challenge for the conservation of forest resources in Ethiopia (Tadesse and Teketay, 2018), and the cause of failure in climate change adaptation (Locatelli et al., 2008).

The impacts of high population growth and human activities on forests have been significant, with average annual deforestation rates estimated at 85,000 ha per year (GoV, 2016). From the year 1984 to 1990 Ethiopian population increased from 42.6 million to 47.9 million (UNDP, 2018), and the forest coverage loss increased from 3.96% to 18.6% (Reusing, 2000; Rainforest, 2020). As a result, the country's forest cover reduced to less than 6% having a closed forest cover (Yirdaw, 1996), however, percentage share of fuel use for cooking by rural household by using firewood increased from 84.5% in 2004 to 90.9% in 2012 (Mondal et al., 2018). More than 97.5% of the energy consumed by rural and urban households in Ethiopia during the 1990s and early 2000s is derived from biomass fuel and 78.9% of biomass fuels are in the form of firewood and charcoal (UNDP, 2018). In Ethiopia, deforestation rates remain high and the gap between demand and domestic supply of forest products is expanding, even though government-initiated re-greening efforts began over a century ago (Lemenih and Kassa, 2014); with the recent "Green Legacy" initiative is in action.

The Nile unites the highland mountains of Ethiopia and the lowland deserts of Egypt. Nevertheless, it heedlessly destroying the terrain and deserting the country by carrying fertile soils of Ethiopia while millions perish from thirst and famine (Arsano, 2007; Mondal et al., 2018). In the following figure (**Figure 2**) water contribution percentage, its sharing, access to electricity and the impacts of lack of energy sources in the forest sector including the percentage of biomass household energy dependency is presented as reviewed from different sources (Arsano, 2007; Ashebir, 2009; FAO, 2020, 2001, 2003, 2005, 2007, 2009; Mondal et al., 2018; Omer, 2018; Suleiman et al., 2017; World Bank, 2013).

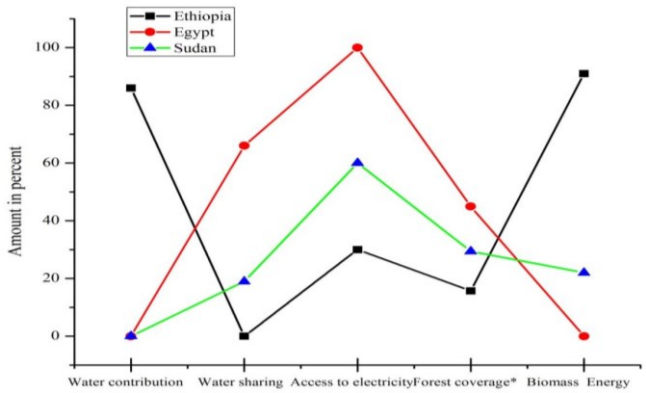

Figure 2. Abay water contribution, forest cover change and sources of household energy in Ethiopia, Egypt and Sudan.

* In Egypt the desert area covers 96% of the total land area of the country. However, from the rest 4% of land area about 44.98% is covered by forest.

3.3. Expected contribution of GERD in Ethiopia and the stream countries: Distinguishing fact from fiction

Our Planet Earth needs more and more water and more and more energy due to growth in population and consumption, especially in developing countries (Alawamy et al., 2017). Large-scale dam development provokes strong emotions because of costs and benefits, whether potential or actual, to political, socio-cultural, economic,

and environmental systems (Zahran et al., 2016). However, there is a relationship between hydroelectricity production and ecosystem/biodiversity conservation (Boyé and de Vivo, 2016). Dams are an ever more vital tool for addressing our growing water and power needs and the emergence of new challenges such as sustainable development and climate change. Also, the hydropower dams play an important role in avoiding global warming resulting from fossil fuels consumption (Veilleux, 2013). Globally more than 45,000 large dams have been built generating 19% of the World's electricity, and supporting 30-40% of its irrigated lands (Guo, 2007). With current population and economic growth trends, global demands for water, food and electricity will continue to increase in the coming decades and with the predicted consequences of climate change, the threats of floods and droughts should increase as well (Arias, 2011).

Studies shows that the vegetation around the GERD decreases and the water area increases during dam construction (Chen eta al., 2022; Solomon and Lukas, 2022), however, it was identified that the vegetation cover of Abay catchment showed increment in vegetation cover from the year 2005 to 2021 (**Figure 3**). In the last 20 plus years, vegetation covers of Ethiopia showed increments and from the year 2011 to 2021 the non-vegetation area reduced in 37.11% in the catchment of Abay.

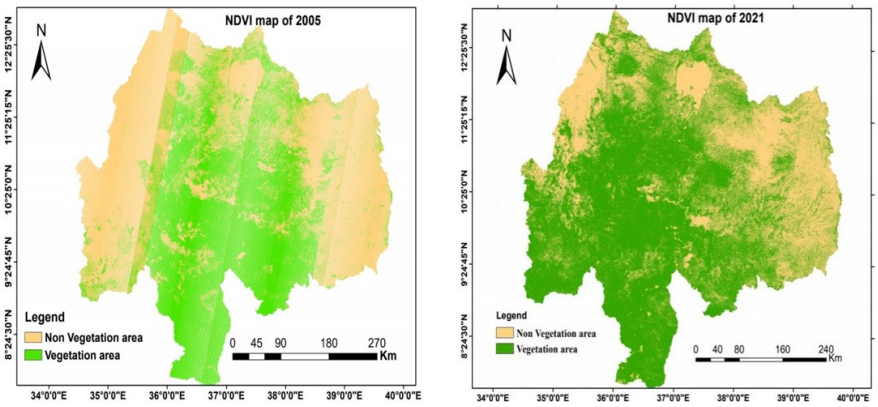

Figure 3. The 2005 normalized difference vegetation index (NDVI) vegetation map of Abay catchment (left) and 2021 NDVI vegetation map of Abay catchment (Right).

Given the importance of forests in reducing flood peak flow and delaying the flood peak time (James et al., 2010; Tamura, 2022; Viezzer et al., 2022), understanding the indirect positive impacts of dams on the land cover change gained through degraded land restoration is essential. This could adversely reduce the impacts of flood on the downstream countries mainly Sudan. Thus, conserving and restoring, forest system in Ethiopia particularly in the Abay catchment are practices of Ecosystem-based Disaster Risk Reduction (Eco-DRR) and Nature-based Solutions (NbS) to Ethiopia and the downstream countries. The restoration of forest resources in the Abay catchment in last ten years increased in 62.89% taking the GERD and its sustainability into account (**Figures 3** and **4**).

Various methods of ecological restoration can contribute to mitigating flood hazards, but so far, this has rarely been the major aim of restoration (Jähnig et al., 2022; Kiedrzyńska et al., 2015; Nilsson et al., 2018; Ward et al., 2020) and attention

given to this has been weak in most cases.

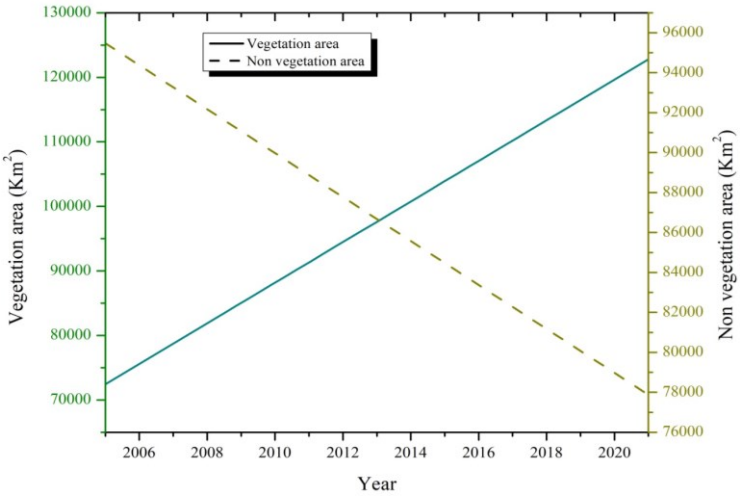

Figure 4. Vegetation cover changes and restoration of Abay catchments (2005–2021).

On the other hand, GERD is designed to trap 100 years of sediment inflow which has the benefit of large dams in Sudan and Egypt. Thus, is more recommendable to work on watershed management so as to reduce the sediment inflow and attain the long-term sustainability of water resources and large dams. Additionally, collaborative work is necessary as every drop of water wasted by actual generations becomes priceless for our future generations. The UN projects that the population in the 11 basin states will reach 860 million people by 2050. This implies that the sustainable management and utilization of the water is not advantageous only for Ethiopia but also for the entire upstream (Ethiopia, Eritrea, Uganda, Congo, Burundi, Tanzania, Southern Sudan, Rwanda and Kenya) and downstream (Egypt and Sudan) countries.

3.4. Hydroelectric dam development: The contribution to socioeconomic and environment

Having access to modern energy sources is essential for environment protection, economic development and livelihood improvement (WCD, 2000); as large dams are not the only available options to solve such major challenges, but are likely to be part of the solutions chosen, especially in developing countries (Garandeau, 2014) For instance, in an effort to ensure energy independence and exploit natural resources, Amazonian countries are embarking on a major dam building (Reddy, 2015).

Our planet Earth needs more and more water and more and more energy, due to growth in population and consumption, especially in developing countries (Garandeau et al., 2014). Globally, particularly in developing countries, hydroelectric production and economic growth occur together with ecosystem/biodiversity conservation in watersheds (Lees et al., 2016). Looking back on 5000 years of history, dams are a decisive technology to balance the uneven distribution of water in space and time, raise the water head for hydropower generation, and reduce or increase downstream runoff, consequently, delivering

flood protection or low flow augmentation (Petersson and Ostrowski, 2003; Thu Ha et al., 2020). Large dams have often been seen as an effective way of meeting water and energy need (Cakmak, 2001); however, due to climate change and forest degradation, sources of water, dams and reservoirs are affected either in their capacity of water flow or storage (Wei et al., 2020).

Thus, sustainable forest management and introduction of a regulated flow regime for upstream dams would possibly protect the groundwater recharge function of the downstream floodplain and reduce substantially the losses (Barbier, 2003). Consequently, ways to sustainably develop and manage large dams and more equitably distribute their benefits and costs within society have recently come to the forefront of international thinking (Haas, 2009). Because, natural ecosystems (forests, grasslands and wetlands) tend to do better jobs of regulating water flows and, importantly, sediment and nutrient fluxes than agricultural and urban systems (McCartney et al., 2017).

A study revealed that impacts of large dams upon GDP of countries are crucial in the socioeconomic development (Shi et al., 2019); which generally support large dams as the vital factor to promote economic development. As a result, developing countries and international agencies, such as the World Bank undertake major investments in dam construction in order to increase development reduce poverty through increased irrigation, water storing and electricity production (Egre and Milewski, 2002).

The Upper Blue Nile Basin is one of the most important river basins in Ethiopia (Teklu et al., 2009). Ethiopia's largest hydropower dam being built on this river which is close to the border of Sudan has been a source of concern for downstream countries mainly Sudan and

Egypt. There has been negotiation on the process of operation of the dam mainly with Ethiopia, Egypt and Sudan with fear of the negative impact of the dam on the mentioned countries. Study shows that during the impounding phase, the GERD benefits mainly Ethiopia and to some extent Sudan and negative effects of the GERD on Egypt's economy are reversed when the GERD becomes operational (Kahsay et al., 2015). The Economic benefits from alternative water use would be sufficient to make riparian countries better off compared with the status quo in the three countries (Nigatu and Dinar, 2016). Therefore, we cannot, on environmental grounds, say 'No' to large dams and reservoirs; nor can we, having regard to projections of demand and availability, accept the view that there is no need for such projects (Iyer, 1989).

4. Conclusion

Different studies indicated that there is a relationship between hydroelectricity production and forest conservation. As the main cause of deforestation and forest degradation in developing countries is the use of biomass for household energy source and lack of electric power, thus, the contribution of construction of hydropower dam is important and we cannot, say 'No' to dams, and reservoirs. The World Bank confirmed that the Abay Basin is one of the least developed river basins in the world. Therefore, as far as water is a critical resource in terms of national

development, it's ideal to work on the sustainability of the water and create more development opportunity from the water resources. Moreover, the nature based solution to the land degradation should get focus to reduce the risks of ecosystem based disasters causing the challenges on the downstream countries.

Author contributions: Conceptualization, title development, methodology, software formal analysis and manuscript writing TS; writing draft manuscript, review and editing, MH. Both authors have read and agreed to the published version of the manuscript.

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