Impacts of Ethiopia Dam on Vegetation and Water and Ecological Countermeasures

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Abstract—Ethiopia is one of the highest lying countries in Africa, known as the "Roof of Africa". The Grand Ethiopian Renaissance Dam is established to solve the problem of electricity shortage, storing and supplying water. This study analyzes the impacts of the Renaissance Dam in Ethiopia on vegetation and water through random forest model and index map via semi-automatic classification module of QGIS’s plugin. Results show that area of vegetation around the dam decreases and the water area increases during dam construction. Based on previous studies, the dam has variable impacts on surrounding vegetation, water quality and level. Renaissance dam has had a negative impact on the surrounding vegetation and water level for decades of construction, but a positive impact on the water quality. Considering the ecological system and sustainable development as the ultimate goal, it needs to make full use of environmental assessment and establish the ecological operation mode of dam for achieving better results.

1. Introduction

In the last half-century, more and more dams have been constructed, and most of them have two main functions: one is to hold water to compensate for changes in river flow; The other is to raise the upstream water level so that water can flow into the channel, or to increase the height difference between the reservoir surface and the downstream river surface. Dams have many advantages such as controlling floods, increasing irrigation, storing and supplying water, generating hydropower, and improving navigation.

Ethiopia is one of the highest lying countries in Africa, known as the "Roof of Africa", which gives the upper Blue Nile a favorable water level for hydropower development [1]. Ethiopia's infrastructure has struggled to keep pace with economic development and population growth, leaving a huge gap in hydropower resources. In 2016, Ethiopia's generating capacity was 2,300 megawatts, up from 370 megawatts in 1983, but electricity coverage is still only about 55% of the country.

The Grand Ethiopian Renaissance Dam (GERD) is very important because 1) it can properly solve the problem of electricity shortage for the majority of the Ethiopian population, 2) it makes Ethiopia
better use of Nile water, 3) it may make the country the largest energy exporter in Africa, which is beneficial to economic development. However, it may bring some disadvantages. For example, it may induce earthquakes, change water quality in the reservoir area, block river fish channels, threaten fishery resources, and interrupt downstream flow. Therefore, this study takes the GERD in Ethiopia as the research object, chooses QGIS, to analyze its positive and negative impacts.

2. Background of Ethiopia dam

As one of the fastest developed countries in economy, however, Ethiopia with the second largest population in Africa (80 million people), is one of the poorest countries in Africa and has suffered from unstable rainfall with big significant influence of climate change.

According to Derbew[2], only 52% population could use the energy in this country, which may face a big challenge—the government predicted that there would be an increase by 32% in the demand for electricity. For satisfying the rising demand and improve the economy, the government decided to build The GERD.

According to the plan, this project which would cost about $ 5 billion[3], would produce a reservoir with a volume of more than 63 billion cubic meters. Since the project will cause a great influence on countries along the Nile River, it took a long time from the plan to the official start before reaching an agreement with other countries[4].

As a dam in north-western Ethiopia, GERD is approximate 14km away from Sudan (Fig. 1). In this place, the rainfall is seasonal—it achieves at the peak from May to October. The annual rainfall is about 860mm, while that of the nearly mountainous area is about 2250mm. It is clear that under the rain washing, a large amount of sediment and animal and plant debris will be carried into the river, which becomes a major factor affecting water quality[5].

![Fig. 1 Geographical location map of Ethiopia](image)

3. Conventional methods and the ones in this study

Many scholars have studied impacts on vegetation and water in terms of environment, landforms, engineering construction, and remote sensing. In the field of remote sensing, the Different types of coverings in a specific area can be expressed by estimation of its Specific spectrum. According to the classification of data sources, there are two main methods to extract specific spectrums: field measurement and remote sensing images. The latter includes satellite images and aerial photography. This paper mainly discusses the extraction method based on remote sensing images. Commonly used remote sensing data are NOAA，MODIS，Spot，ALTSER，AVIRIS，IEO—SAR，landsat8.
3.1 Previous research measures

3.1.1 Special reflection band index
The objects around the dam are mainly water, vegetation and bare land. Among them, vegetation and water have special reflection characteristics in remote sensing images, such as NDVI and NDWI. The research in this aspect is mainly to establish buffers in satellite images and vegetation and water data sets according to the river position, and extract the data in the buffers to characterize the band of the region through image classification or extraction of special bands of vegetation. Traditionally, indices such as NDVI are often used for direct analysis. NDVI was used to detect the ecological impact of a new dam on vegetation in the Amazon Basin [6]. NDVI index was used to evaluate the impact of the Three Gorges Dam on the vegetation of Dongting Lake [7].

3.1.2 Machine learning
Many methods of traditional machine learning, such as K-means, SVM, random forest, have long been used in the classification of remote sensing images. Both this paper and [8] used a random forest model to assess the impact of dams on different vegetation types. At the same time, a large number of scholars have used a neural network to classify remote sensing images. And because the training of neural networks requires a lot of data, the classification results are more accurate. After adding a large number of training samples to the neural network in [9], the neural network was used to classify the wetlands under the influence of the Three Gorges Dam, and the overall classification accuracy of the image classification map reached 93.45%.

3.2 Data and methods in this study
In the progress of processing data, this study used Qgis’s plugin, semi-automatic classification. The remote sensing data is Landsat-8 images from the USGS website. The data are between April 2021 and April 2013, during the progress of construction of GERD. The algorithm for the classification of this application is random forest. This algorithm could get better classification results through building multiple different decision trees.

4. Results

4.1 The evolution of vegetation
In the progress of processing data, this study used Qgis’s plugin, semi-automatic classification to analyze the evolution of vegetation. The algorithm for classification is random forest. Between April 2021 and April 2013, during the progress of construction of GERD. Result shows that the area of vegetation around the dam overall decrease (Fig. 2).
4.2. The evolution of water
After processing by the QGIS, the water level changes, the square of it is enhanced (Fig. 3). According to Figure 3, the water square had changed most significantly between 2018 and 2021 with the building of the dam and the water storage in the reservoir.

As for the water quality, it becomes clearer and clearer with time, according to the images from google earth (Fig. 4). These four images indicate that the water quality had changed most obviously from 2018 to 2020 after the building of the main body of the dam. From the satellite maps, the colour of water had changed dynamically during this period.
5. Discussion

5.1. The impacts of dam construction on vegetation

As an artificial large-scale project for river reconstruction, the dam can provide a more stable water supply for people, and high-quality electricity emitted with little carbon dioxide and reduce flood disasters. However, due to the change of the natural process of the original river, it inevitably has a positive or negative impact on the local river and the vegetation around the river. Therefore, the environmental assessment of the river has become a very important part of dam construction and maintenance work. Out of the environmental protection and restoration of river ecology, since the century, a large number of dams have been demolished. Among them, vegetation is also an important part of the assessment of the impact of dams on the environment. Vegetation around rivers can protect ecological diversity, conserve water, protect soil, filter pollution, provide wood and absorb carbon dioxide.

The impact of dam construction on vegetation is different in different times and spaces, such as Sanxia dam. The Three Gorges Dam and Fuxing Dam are also super large dams on important rivers. They also took decades to build, besides that, they are also the super large dams of a developing country.

Dam impoundment in the high-water period may prevent the downstream forest from being damaged by flood, enlarge the upstream water area and increase the vegetation coverage in the upstream. The release of water during a low flow period will not reduce the vegetation in downstream due to drought. On the contrary, the construction of the dam may also increase the human activities around the dam and reduce the downstream water, which may reduce the vegetation around the dam. The vegetation around different lakes downstream of the same dam may also be different. It is believed that Landsat images were used for artificial neural network classification of Poyang Lake area [9], and it was found that after the completion of the Three Gorges Dam, the wetland of Poyang Lake degenerated, and its area decreased. It is suggested that [7], the completion of the Three Gorges Dam accelerated the vegetation expansion around Dongting Lake. Both Dongting Lake and Poyang Lake are located in downstream of the Three Gorges Dam. They are far away from each other, but their vegetation has been affected by the Three Gorges Dam.

At the same time, the vegetation in the reservoir area of the Three Gorges Dam has increased during its construction. In the 30 years after the completion of the Three Gorges Dam, the vegetation coverage

Fig. 4 The water quality in a) 2014; b) 2018; c) 2020; d) 2021
rate decreased significantly from 1978 to 1999, but increased in the 8 years after the completion of the Three Gorges Dam [10, 11].

In general, in the period of construction of Three Gorges Dam, the ecosystem near the dam was destroyed. But after the repair and protection work, dams have a positive ecological role with the ecology around the dam gradually restored. Like Three Gorges Dam, GERD will continue to have a negative impact on the surrounding vegetation for decades of construction, but it is likely to have a positive impact on the surrounding areas and even the ascending environment downstream of the dam if it is fully operational without the political or economic impacts.

5.2. The impacts of dam construction on water

According to the result above, it is clear that dam makes a significant influence on the water, including to the water quality and the water level of the river.

The satellite maps from Google earth indicate that the water quality has been improved (Fig. 4). For more details about the water quality, the physical and chemical conditions which are affected by the physical, chemical and biological elements should be researched.

5.2.1. Impacts on water quality

To evaluate the influence of the dam on water quality, the chemical and physical index could be used.

First, the dam could make a positive influence on the chemical index of water quality. Organic matter is the common content in the water, the amount of it is one of the important standards to the pollution degree. The organic pollution index indicates the organic content in the water, including BODi, CODi, NH3–Ni, Doi. According to the research about Lancang River, China [12], the pollution index (As=0.05) of water is much lower than the requirement (As<2) after building the dam. And the pollutants in the water may be diluted and absorbed by much water, the index decreased after building.

Second, suspended solids are an important physical index of water quality [13]. Due to the dam which slows down the flow of water (from 5% to 42%), the suspended particles in the water are settled down, which could improve the water quality of the reservoir and upstream reach. However, the reduction of suspended solids in the water also makes the land along the downstream coast no longer as fertile as before, such as the land on the Nile River in Egypt, which has a great impact on its agriculture. What is wrong, upstream river bed and banks will be eroded by the river, for which bridges, dams and other structures would be broken.

5.2.2. Impacts on the water level

The change of the water level of groundwater especially that of downstream indicates a negative effect of the dam on water level [5]. Due to dam closure, the water level of downstream of the river will decrease gradually, causing the depletion of the groundwater in downstream coastal countries, such as Egypt. Therefore, this will affect the water use along the downstream coast, and may even reduce the confined water, which in turn will cause ground collapse. The coastal city may suffer from seawater intrusion due to the too low water level, which will also lead to soil salinization.

5.2.3. Impacts of dam construction on animals

The reservoir discharge mode that simulates the natural hydrological regime is to create suitable hydrology and hydraulics conditions for the reproduction, spawning and growth of important river organisms, and to change the tendency of homogenization of hydrological process in current reservoir operation [14]. The basic work is to select landmark species, clarify the relationship between hydrological process and ecological process, and establish the corresponding mathematical model [15]. To investigate and master the adverse environmental effects caused by the hydrological regime changes after the completion of the reservoir. In the process of simulation, it is necessary to make a sensitivity analysis on the influence of different reservoir ecological operation modes on the ecological process. Based on comprehensive consideration, formulate a reasonable ecological dispatching plan.
6. Countermeasures and future work

In order to prevent the "blister disease" for adult fish, the flood discharge time can be extended and the maximum amount of flood discharge can be appropriately reduced under the premise of ensuring flood control safety. Study and optimize the opening of discharge facilities under different elevations, so that water with different air volumes can be mixed, to achieve a balance between energy dissipation and gas oversaturation, and to minimize the occurrence of gas oversaturation. Combined regulation of main and tributaries can reduce the proportion of gas supersaturation flow and reduce the influence of gas supersaturation on downstream aquatic life.

6.1. Conventional countermeasures to reduce the impact of dam construction

In order to reduce the above effects and restore or shape the bio-like original ecological environment, a series of solutions are put forward based on the experience of human damming for thousands of years, especially in recent decades. For the change of biological habitat characteristics, it is mainly solved by river ecological restoration projects (fishway construction, river regime regulation, etc.). For the change of hydrological regime and energy and material transport, at present, it is possible to improve the current reservoir operation method and carry out multi-objective ecological operation taking into account the needs of river ecosystem without affecting the economic and social benefits of reservoirs [16].

Dam construction had over a century’s history. Dams constructed throughout the world caused far-reaching effects on the river basin [17]. It has an important function in melding the regional water resource, reducing watering disasters and obtaining clean energy sources. It also controls the rivers, in adjusting the seasonal flux change, changing water temperature and chemical components, blocking the sediments, disarranging the river erosion and the process of geological aggradations, blocking the contact of water life networks, altering the landform of the river system.

With traditional hydroelectric [9] engineering causing a series of problems, plenty of experts and scholars developed a new subject called “eco-hydraulic engineering”, which combined ecology, environmental hydraulics and hydraulic engineering. This subject is based on traditional hydraulic engineering, absorbing and fusing ecological theories, then becoming a new engineering subject. Based on the principles of eco hydraulic engineering, we can take relevant countermeasures and some other measures to alleviate the disadvantages caused by dam construction. Therefore, this thesis brings forward some measures.

6.2. The control of Reservoir sediment and Eutrophication

In order to slow down reservoir siltation, the effective reservoir operation technology of "storing clean water and discharging muddy water" [19] has been summarized through decades of research and practice at home and abroad. The reservoir adopts the operation mode of "storing clear water and draining muddy water", combined with the measures of adjusting the running water level and draining sand through the bottom hole to reduce sediment deposition and effectively prolong the service life of the reservoir. In addition, by changing the operation mode of the reservoir, the water level [20] in front of the dam can be decreased in a certain period, the pressure of the water level can be relieved fork and bay, so the water speed slow flow area can be increased, the eutrophication condition of the water body can be destroyed, and can effectively prevent the eutrophication of the reservoir water body. Secondly, small and medium-sized reservoirs can promote the flow of water in the reservoir area and prevent eutrophication of the water body by increasing the flow of the reservoir over a period of time. and prevent the eutrophication of water.

6.3. Future work

Dam construction, like a coin, has two sides. It is the job of dam builders, dam builders and dam managers to make use of the advantages and avoid the disadvantages. Only by taking the improvement of the ecological system and sustainable development as the ultimate goal, making full use of
environmental assessment and establishing the ecological leading dam operation mode, can the dam construction achieve better results. Study the disadvantages caused by the dam project and demonstrate the feasibility of the dam construction scheme, from the human factors, social factors, ecological factors, natural resources factors, climate change factors, river sediment factors. We should distinguish between the advantages and disadvantages of dam construction. In addition, we should promote the positive aspects and mitigate the negative effects of dam construction. Thus promote the sustainable development of society, promote the harmonious coexistence of man and nature.

7. Conclusion
This study analyzes the impacts of GERD in Ethiopia on vegetation and water through QGIS.

In the construction of the GERD, vegetation coverage rate has decreased significantly. This is understandable, in such a large project implementation process, the collection of building materials, construction personnel living, road construction may cause vegetation damage. Up to now, the dam has not been fully operated. It is foreseeable that vegetation around the dam will continue to be negatively affected by dam construction over the next period of time. According to the precedents of other dams, when the dam is completed and seriously promoted by ecological restoration, it will have a positive impact on the surrounding vegetation.

GERD has both the positive and negative influence on the water in the reservoir and downstream as well as the water level. First, the images have been processed by QGIS to analyze the change of the water level and the water square, in which the largest changes from 2018 to 2021 are indicated. The satellite maps have been compared to illustrate that the building of GERD positively affects the water quality, especially the decrease of suspended solids. In addition, the physical index is also analyzed via referencing other examples about the dam. Finally, some examples have been shown to analyze the negative influence of dams on the groundwater of the downstream country.

Only by taking the improvement of the ecological system and sustainable development as the ultimate goal, making full use of environmental assessment and establishing the ecological leading dam operation mode, can the dam construction achieve better results.

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