"The Spacio-Temporal Changes of Kiri Dam and Its Implications" In Adamawa State, Nigeria.

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ABSTRACT

This study focuses on the assessment of the spatial and temporal changes of Kiri lake between 1984 and 2016. The study used both geo-information techniques and field survey to carry out analysis on the spatial as well as the changes in the depth of the lake. Landsat TM and OLI of 1984 and 2016 respectively were digitized in order to determine the extent of surface area changes that has occurred. Field method was used in determining changes in the depth of the lake. The results revealed that the lake has reduced in both surface area and depth. The surface area of the lake in 1984 was 100.3 m^2 which reduced to 57.0 m^2 in 2016. This means that the surface area of the lake has reduced by 43% within the period of 32 years whereas the depth has reduced by more than half of its original depth. The original depth of which was 20 m has reduced to an average depth of 8.48 m. This revealed that an average siltation of 11.52 m has occurred within the period under study. The implication of this shrinkage will be devastating on the savannah sugar cane plantation that depends on the lake for its irrigation water thereby affecting the company and the economy of people that earn a living from it. The study therefore recommends that the lake should be dredged to remove silted materials that have accumulated over the years and for a long lasting solution, the catchment should be protected from erosion by planting and protecting vegetation cover in the area.

Keywords: Lake, siltation, Landsat, water, irrigation, dam

Introduction

Water is an important abiotic component of the ecosystem which is widely regarded as the most essential of natural resources that makes life possible on the Earth's surface. However, freshwater systems are directly threatened by human activities and stand to be further affected by anthropogenic climate change (Vorosmarty *et al*., 2010). The global average lake surface water warming rate due to climate change shows a 20% increase in algal blooms and a 5%increase in toxic blooms over the next century as well as a 4% increase in methane emissions from lakes during the next decade (O'Reilly, *et al*. 2015). Increased evaporation associated with warming can lead to declines in Lake water level, with implications for water security.

Rivers are part of the hydrological cycle that connects the webs of life, bringing together freshwater, marine and terrestrial environments. They are critical natural processes that have shaped the diversity of life on earth, as well as human patterns of civilization. The world's rivers are facing numerous crises due to degradation mainly due to human use of the environment. Human dependence on freshwaters has contributed to habitat degradation in many places. Water pollution and biodiversity loss as a result of changes in land use has altered water courses and led to invasion of new species (Malmqvist & Rundle, 2002; Dudgeon *et al*., 2006; Martinuzzi *et al*, 2014).

The planetary life cycle processes of rivers are affected by pollution in many ways thereby affecting the quality and functionality of the world's freshwater. Approximately two-thirds of the world's rivers have suffered impairment from the over 50,000 large dams that have been built over the past century (McCully, 1996). Many of the world's great rivers such as the Indus, the Colorado, and the Yellow river no longer reach the ocean, turning once-productive deltas into biological deserts. Marine environments and wetland ecosystems are experiencing the greatest loss of biodiversity, in large measure due to dam construction more than the losses experienced in tropical rainforests. Over the past 40 years, freshwater ecosystems have lost 50% of their populations and over a third of remaining freshwater fish species are threatened with extinction.

At the moment, the great river basins of the world are experiencing a new wave of damming and each of these rivers is outstanding in its contributions to planetary cycles, biodiversity and human livelihood dependence. However, these basins are threatened by impudent and narrow-sighted schemes that irreversibly disconnect rivers from their major functions thereby costing the planet billions in lost ecosystem services.

All rivers contain sediments which in effect, can be considered a body of flowing sediments as much as of flowing water (McCully, 1996). When a river is stilled behind a dam, the sediments it carries sink to the bottom of the reservoir. The proportion of river's total sediment load captured by a dam is known as its "trap efficiency" approaches 100 per cent for many projects, especially those with large reservoirs. As the sediments accumulate in the reservoir, so the dam gradually loses its ability to store water for the purposes for which it was built. Every reservoir loses storage to sedimentation although the rate at which this happens varies widely. Worldwide around 40,000 large reservoirs suffer from sedimentation and it is estimated that between 0.5% and 1% of the total storage capacity is lost per year (White, 2001). Despite more than six decades of research in reservoir construction and management, sedimentation has probably remains the most serious technical problem faced by the dam industry.

Water flowing in streams or rivers has the ability of scouring channel bed, carrying particles that are later deposited elsewhere. This phenomenon of sediment transport can affect substantially the design of reservoirs. Many cases have been recorded where reservoir siltation rendered water storage structures useless in less than 25 years. Sedimentation problems were observed predominantly with small to medium size reservoirs (with catchment area of less than $100km^2$). Even when dams are equipped with advanced structural features, the hydrology of the catchments and sediment transport processes most be properly taken into account in order to ensure it viability. Therefore, the study reservoirs must be holistic as a complete system, taking into account structural features, hydraulics, hydrology, sediment transport, catchments erosion and catchments management.

Reservoirs created by dams on rivers, get silted through river water. A significant proportion of the sediments settles down in the reservoir, thus reducing the space available for water storage and also produces structural damages to the dam in question and causing appreciable damage to any power generating turbine located within the area. Studies reveal that silts get deposited in all part of the reservoir. Siltation reduces the benefits from dams constructed with a huge amount of money by any nation. This could also have a number of impacts, including increased evaporation losses and could damage the power turbines in event where it is used in power generation (Mama and Okafor, 2011).

The economic importance of dams such as for use in irrigation, power generation, water supply recreation and fishing are determine by the size and volume of water in them. The importance increases with the increase in volume of water it is able to hold. However, anthropogenic sedimentation as a result of watershed disturbances has reduced the capacity of dams to accommodate sufficient water thereby resulting to threats on aquatic ecosystem (McIntyre *et. al*., 2005).

Throughout history, the negative impact of siltation on the efficiency and effectiveness of Dams have been increasing. Siltation reduces the amount of water a reservoir can hold thereby reducing the dam's capacity in meeting up with its objectives of providing continuous flow of water for either Irrigation, Flood Control or Hydro-electric Power Generation. Sediment movement is part of the natural function of freshwater ecosystems, when human activity significantly increases the amount of sediment through their activities, these changes the stream flow which can have significant effects on aquatic flora and fauna. Without significant changes to the current unsustainable use of water resources, future degradation of river, lake, and wetlands will jeopardize both biodiversity and critical ecosystem services relied upon by humanity. Indeed, in many parts of the world, increasing human population and development pressures, create a double squeeze on freshwater ecosystems from both cropland and urban expansion. The expansion of croplands increases the amount of sediments, nutrients, and pesticides entering freshwaters (Martinuzzi *et al*, 2014). Studies have shown that Nigeria is among the nations facing serious threats of water security and biodiversity (Vorosmarty *et al*., 2010). Hence, this study intends to assess the spatial changes of Kiri Dam and the effects of these changes on the efficiency of the dam to meet its objectives.

Study area and methodology

Study Area

kiri Dam is situated in Shelleng Local Government Area (LGA) of Adamawa State. It is located on latitude 9^0 53' 5"N and longitude 12^0 0'32"E on an elevation of 170m above sea level (Figure 1). It is located in Kiri village, Shelleng L.G.A in Adamawa State is approximately 35km upstream from the confluence of Gongola/Benue River at Numan L.G.A. Adamawa State. The dam was constructed between 1976 and 1981 and was commissioned in 1982. The catchments area is about 57, 200km^2 from Shere hills on the Plateau to Numan. However, the construction of Dadin Kowa Dam in Gombe State in 1987 has greatly reduced the size of the catchment.

The initial concept of the project is to impound sufficient water during the months of high river flow to meet the water requirements for the irrigation of 12,000 hectare of sugar cane plantation for the Savannah Sugar Company.

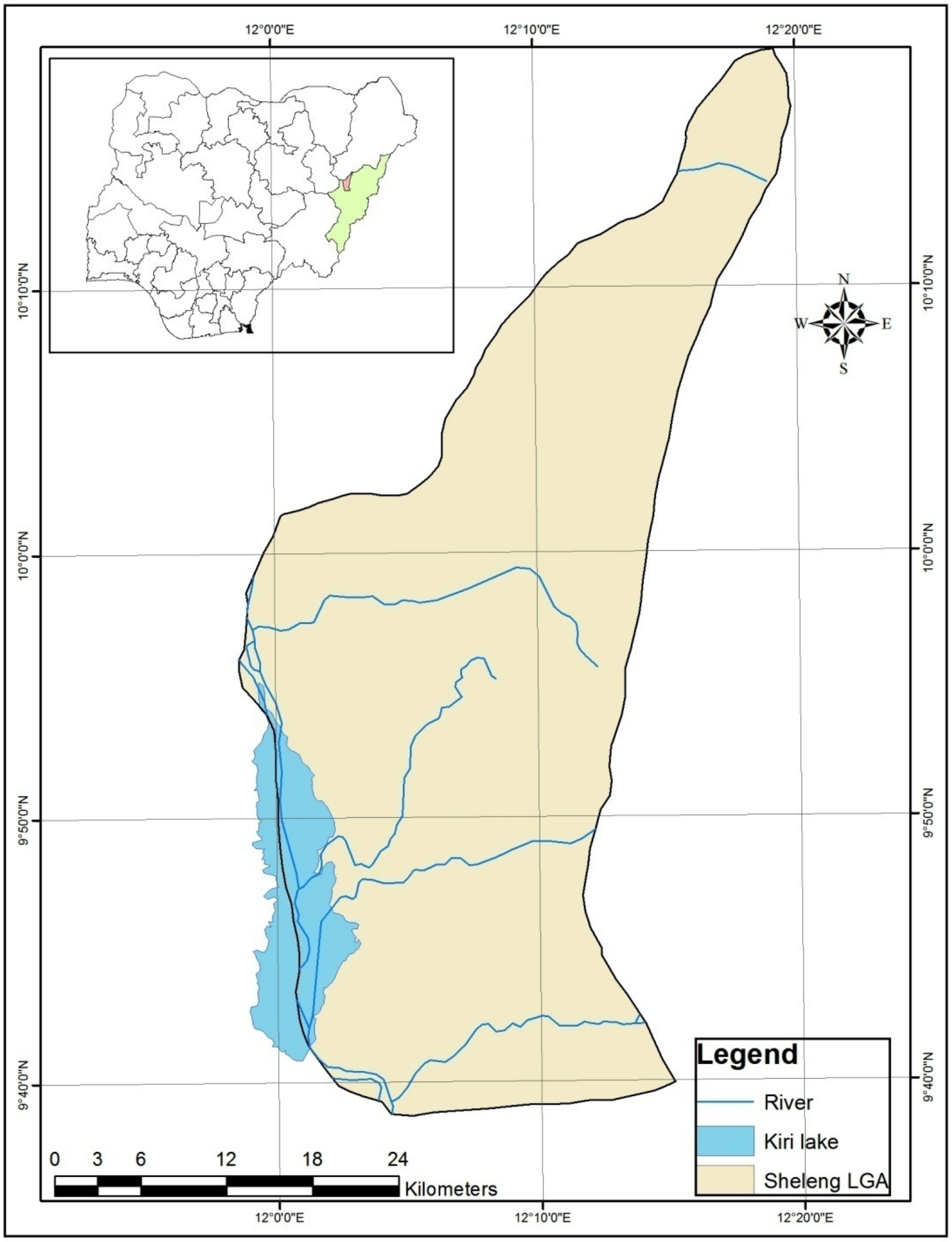

Figure 1: The Study Area

Methods

Satellite images of 1984 and 2016 were acquired from USGS website (i.e., Landsat TM and Landsat OLI). ArcGIS 10.3 was used in carrying out the analysis. The materials used in measuring the reservoir depth include: suspension Derrick, fish weight (sinker weight), Gauging reel (winch) 35m, suspension cables and fish tail.

Information regarding the Dam was obtained from the Upper Benue River Basin Development Authority Yola (UBRBDA Yola).

The area of the lake was digitized from the satellite images collected in order to determine its spatial extent while sample points were systematically located for measurement and recording of the depth of lake within 20 meters apart. The instrument used for carrying out the measurement is called the suspension derrick.

Results and Discussions

Spatial Extent of Kiri Lake

Results from the digitized satellite images show that the lake has decreased from 100.8 km^2 to 57.03km^2 (see figure 2, 3 and 4). This revealed that the lake has reduced by 43.77km^2 (43%) of its original size after 32 years. This shows an annual reduction of 1.4 km2. Therefore, if the trend responsible for this shrinkage is not checked the reservoir may likely dry up in the next 41. Hence, there is the need to conserve the lake for the socio-economic benefits of the communities around the lake.

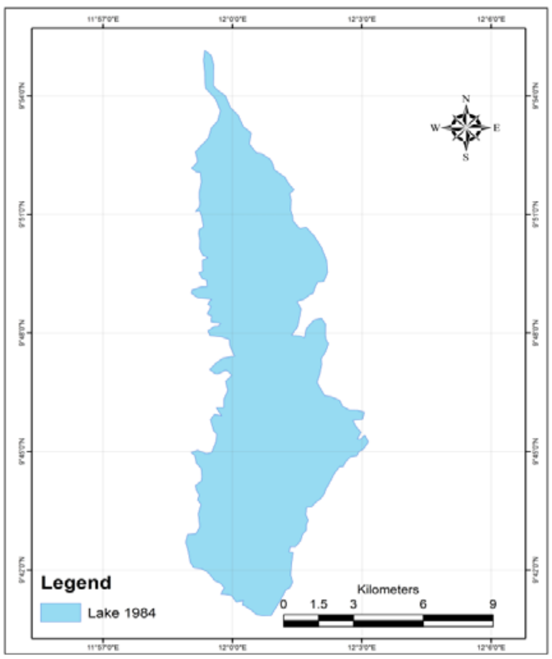

Figure 2: Spatial extend of Kiri Lake in 1984

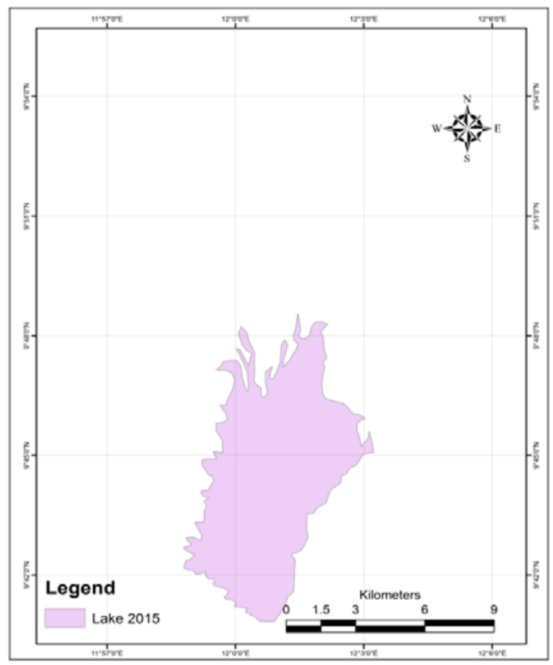

Figure 3: Spatial extend Kiri Lake in 2016

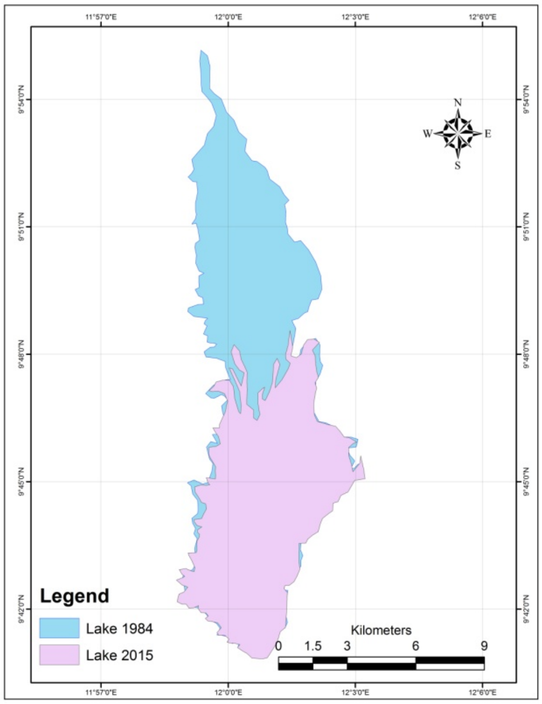

Figure 4: Extent of Spatial change of Kiri Dam between 1984 and 2016

Changes in the Depth of Kiri Lake

The depth at the bank of the reservoir is shallow due to the prevalence of mud and loosed materials. This therefore makes it difficult to get the correct depth of most part of the reservoir as the sinker weight usually sinks into the mud during measurement.

Water or reservoir level as at the time of measurement was 169.12 m above sea level which is different from normal reservoir level of the dam being 170.5 m. The initial depth of the reservoir at inception was 20 m deep (i.e., 150.5 m above sea level) which was subtracted from the normal water/reservoir level of 170.5m.

The siltation level therefore was calculated by subtracting the present depth from the initial depth.

Bench mark……………………………174.228 m above sea level

Normal water/reservoir level………….170.5 m

Initial reservoir depth………………….150.5 m

Present water/reservoir level…………..169.12 m

The level of water in the dam changes as a result of seasonal variations in rainfall. Hence, there is the need to get the difference in the lake's level for an accurate assessment of the siltation that might have occurred.

$$\text{Diff} = \text{NRL} - \text{PRL} \qquad (1)$$

Where;

NRL=normal reservoir level

PRL =present reservoir level

170.5M - 169.12 m = 1.38 m

To get the present depth (Pd) of the reservoir, the measured depth (Depth) taken during the fieldwork was adding to the result of the differences (Diff). The measurement taken at the deepest point of the lake was 11.7 m. Hence the present depth of the lake at its deepest point is:

Pd = Depth + Diff (2)

Pd = 11.7 m +1.38 m

Pd = 13.08 m

Reservoir siltation (S) was gotten by subtracting the present depth from the initial depth.

S = Initial depth – Pd (3)

S = 20 m – 13.08 m

S = 6.92 m.

Therefore the siltation level at the deepest point of the reservoir is 6.92 m. However, the average depth is 7.1 + 1.38 = 8.48 m. This shows that the average siltation level of the reservoir is 11.52. It can be concluded from this result that the reservoir has lost averagely more than half of its depth in the past 32 years. The approximate current depth of the reservoir was interpolated using kringing method as presented in Figure 5.

The rapid siltation of the lake will consequently affect both water quality and quantity which will further limit the use of the lake for water supply, storage, recreational, habitat for fish populations, and will also affect the ability of the lake to meet the Irrigation needs of the savannah sugar cane plantation thereby affecting the socio economic activities of the people around the lake.

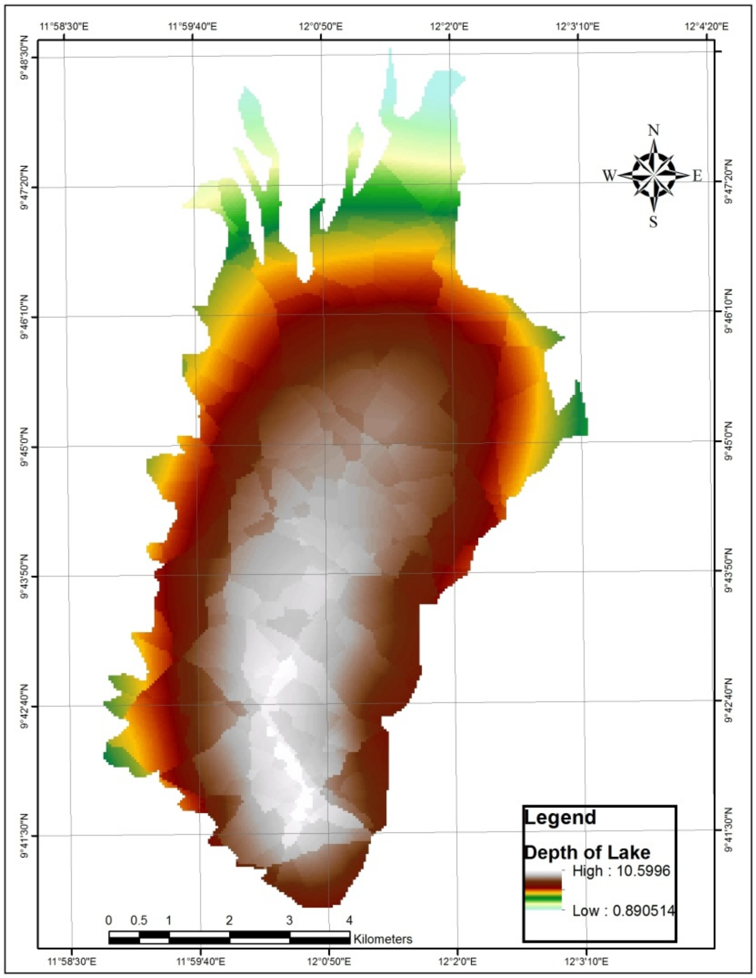

Figure 5: Present Depth of Kiri Lake

Conclusion

Silting of Kiri Dam seems to come from both natural and human factor. From this study, it was discovered that the effect of the dam siltation among others is the reduction in its storage capacity. Therefore, reduction in the volume of water invariably leads to the reduction in the social and economic function of the dam. These factors have constrained irrigation, navigation and fishing activities which the dam provides. The implication of this shrinkage will be devastating to the savannah sugar cane plantation that depend on the lake for its irrigation water thereby affecting the company's production and also will affect the economy of people that earn their living from it. Therefore, future development on the dam like hydro-electric power generation will not be very feasible unless measures are put in place to tackle the challenges posed by siltation of the reservoir.

Recommendation

This study recommends that efforts should be made to restore the initial depth of the dam through dredging so as to bring back the original volume of water. Silt or filter fences should be constructed in rivers leading to the dam in order to protect the water against pollution by sediment yield especially in storm water runoff. A buffer zone should be created around the dam check unsustainable human activities such as farming and building. Conservation activities such as tree planting and protection should also be encouraged within the buffer area. Furthermore the watershed that contributes water to the dam should be protected and well managed so as to reduce the rate of anthropogenic sedimentation of the dam. A yearly measurement of the dam should be encouraged in order to determine the rate of siltation of the dam for effective management.

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