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Shoreline Change Detections in a Humid Tropical Environment (Lake Bosomtwe in Ghana)

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Abstract

Lake Bosomtwe has been a source of socio- economic livelihood for thousands of people living in the three districts of Bosomtwe Atwima Kwanwoma, Bosome Freho District and the Bekwai Municipality. However, in the last few decades, the size and shoreline of the lake including the naturally endowed resources have been dwindling. The main objective of the study therefore was to assess the spatio-temporal changes in the lake level (shoreline). The study employed the mixed methods approach to undertake the research by triangulating primary and secondary source data. Landsat imagery analyses, field measurements, and data from the early 1970s-2010 were used. The main findings of the study are that the gradual depletion of the lake is being felt by the population who depend on the lake for their means of livelihood. There is also the gradual decrease in rainfall and increase in evaporation over the lake surface. It is recommended that an integrative research strategy is pooled together to undertake studies on the lake. Candidate areas may include limnology and sediment budget and alternative livelihood strategies for residents.

Keywords: Geomorphic, Ghana; Lake Bosomtwe; Digital Shoreline Analysis Systems, Shoreline; Geographic Information Systems

Introduction

Shoreline is the line of contact between the land and a water body (Alesheikh, Ghorbanali & Nouri, 2007). It could also be defined as the shifting line of contact between water and land while a broader term coastline refers to a zone in which coastal processes operate or have strong influence. Shorelines keep changing their shape and position continuously due to the influence of waves, tides, winds, periodic storms, water level change and human activities. Shoreline also depicts the recent formations and destructions that have occurred along the shore Winarso & Budhiman (2001) and Selvavinayagam (2002). A natural shoreline can therefore accrete or erode depending on the prevailing forces or elements of nature in the shore processes. A stable shoreline is one where mean position remains unchanged over a period of time.

This is also described as being in a state of dynamic equilibrium. When one or more of these natural forces or elements are disturbed or changed, it results in imbalance in sediment transport in the lake system and the shoreline will no longer be in dynamic equilibrium and a net erosion or accretion will take place. The major economic activities among the communities surrounding Lake Bosomtwe is fishing and farming on the steep crater slopes which provide them with their livelihood. However, the rapid pace of development in the area has resulted in a conflict in the need for immediate consumption and the need to ensure the long-term supply of these resources. This has resulted in host of problems such as increased erosion in the areas, siltation, and loss of resources and the destruction of the fragile marine habitat. These threats have exposed these shorelines to severe environmental and social stresses in the form of loss of habitat and biodiversity, decline in fish productivity and social problems for the surrounding communities (Amjad, Kasawani, & Kamaruzaman, 2007).

If these resources are to be maintained and preserved for the benefit of future generations, there is an urgent need to put in place proper planning and management tools so as to ensure sustainable development in the area.

Again knowledge on where the shoreline is and where it has been in the past is important, since it can be used to obtain quantitative estimates of the rate of shoreline change (erosion or accretion), which in turn can be used to identify areas of extensive accretion problems. This knowledge will provide the basis for the implementation of sound shoreline zone management strategies, environmental protection policies and sustainable shoreline development and planning schemes (Boateng, 2009). In addition, lake level records may serve as a proxy for understanding and reconstructing paleoclimatic data, providing insight of the climatic history of the sub-region and the consequence of climate change. Understanding the lake's hydrological components and the shoreline changes may also be used as the basis for climate change studies. It is on this basis that the paper sought to assess the spatio-temporal changes in the lake level (shoreline) of Lake Bosomtwe a humid tropical natural inland lake in Ghana. The paper, therefore, sought to detect the changes that had occurred during the period under consideration from 1972-2010.

Objectives of the Study

1. Detect the changes that have taken place in the shoreline of the lake from the early 1970s to date ;and
2. Make appropriate policy recommendations to the outcome of the changing shoreline in the future

Research Questions

1. What changes have occurred in the (rise or fall of the lake)?
2. What policy recommendations are appropriate for the management of the lake?

Significance of the study

The study is of significance for the following reasons outlined;

1. The Bosomtwe impact crater and the lake that fills it are not only of scientific interest, but also have the potential for the development of ecotourism in Ghana. This study will, thus add to the information on the need to conserve the water body for the generation yet unborn and improve on the sustainable use of the resource. Thus the need to replant native vegetation along the shore will be highlighted. The study is consistent with the national and global efforts to protect existing water bodies. Faced with dwindling water resources, there is a search for collective effort among nations to safeguard the remaining water bodies. Since, the study is related to the efficient use of the lake by both the locals and visitors; it will contribute to the general effort to protect water bodies. Thus, the study is in conformity with the environmental slogan which says 'talk globally and act locally'.
2. Again, to most residents of Ashanti, Lake Bosomtwe is noted for its Cichlidae fishery. However, there are indications that due to growing human populations and various developmental activities in the area, the fish stocks of the lake have come under intense and sustained pressure. Hence, the study will provide information by stressing the need to preserve and regulate activities in and around the lake.
3. It is necessary for a developing country like Ghana to protect the lake against the climatic effects of logging and slash-and-burn agriculture which are very evident now in the Lake Bosomtwe basin. The loss of rain forest canopy has resulted in soil erosion at the rims and slopes of Lake Bosomtwe, leading to adverse effects of siltation from runoff into the lake. Hence, investigation into factors influencing shoreline changes within the basin can inform planners on the need for ecotourism within the basin, thereby assisting them to select those developments that can minimize negative social impacts and maximize support for the acceptable alternatives.
4. Finally, the fish stocks in Ghana are generally thought to be at or near their maximum level of exploitation. Future expansion in production is likely to come from aquaculture as a possible adaptation strategy for the sustainability of the resources. Bosomtwe is also the only significant natural lake in Ghana, and is relatively easily accessible to people. The study will contribute towards the need for economic diversification.

Nature of Shoreline Changes

According to Haras and Bukuta (1976) the principal changes which affect shorelines are natural and anthropogenic. The natural changes in the case of erosion is the rates at which shoreline response take place to a large degree, under the direct control of both continuous and catastrophic changes associated with both climate and meteorological conditions. With regard to erosion, soil type, surface and groundwater, bluff height, vegetation cover, shoreline orientation, shoreline processes, wind and waves, climate and lake level fluctuations determine the erosion rate of a shoreline. The rate of erosion may be heightened during severe storm events, resulting in large losses of land over a very short period of time. In the case of accretion which means the gradual and imperceptible accumulation of land by natural causes from the sea, lake or river. Two types of deposition characterise accretion of land which are:

- by deposition of alluvium i.e. deposition of sand, silt, or other materials so as to create firm ground. The term ‘alluvium’ applies to the deposit itself while accretion denotes the natural process;
- by dereliction as when the sea or water body recedes below its usual water level.

These occur where water recedes from the land, or where land builds up by alluvial deposits as added by horizontal progression outwards from the bank (or shoreline). Accretion does not apply where there has been a vertical development over a wide area rather than a gradual extension of existing land. For example, where a fast flowing river deposits sand and silt in a fan shaped pattern at the entrance to a lake, so as to cause the lake bottom to appear above the water level and eventually join to the land, accretion does not apply (Haras & Bukuta, 1976). It is so even where the land becomes arable by the gradual advance of top soil across the raised lake bottom from the existing land. Again, where accretion is claimed, the opposite bank of the stream must also be plotted as defined in the existing current plan. The last form of shoreline change is expressed as floods.

Flooding means that there is too much water, so that it will end up in places where we do not want it to be (Haras & Bukuta, 1976). Natural flooding by streams and lakes is the most common type of flooding and is primarily caused by heavy rainfall or rapid melting of snow. It causes water in the stream to overflow its normal channel and to cover the neighbouring area. Areas that are expected to flood once in a while are called flood plains. People have settled on flood plains since the beginning of agriculture, because the soil is fertile and the water is readily available for watering of crops. Communities can use the water for transport and flood plains are suitable for buildings, highways and railroads, because they are flat.

Floods also recharge groundwater and fill up wetlands so that the ecosystems there will be sustained. The number of flooding has increased by human activities such as removing and replacing vegetation, which cause less water to infiltrate into the ground and all rainwater floods to the lakes and streams. Other human activities that can cause flooding are; overgrazing by livestock, forest fires, mining activities and urbanization. Each year flooding kills thousands of people and causes tens of billions of dollars in property damage.

Causes of Shoreline Changes

Shoreline change is caused by a complex interaction of various natural processes and in most cases is intensified by human activities. Human activities that could intensify beach erosion include sand mining, farming along the margins of the lake, and removal of vegetation along the water body.

Anthropogenic Stressor Affecting Shorelines

Anthropogenic stressors affecting inland lakes shoreline include the following: Agricultural activities which Nindi (2007) avers that, the Mount Livingstone catchment area was not spared by invasion by farmers , most farmers who moved to Mount Livingstone were from the Hagati Plateau in the Matengo Highlands, an area that normally conducted ridge cultivation. Cultivating ridges on such steep and rugged slopes provoked an intensive soil erosion and sediment runoff to river valleys and, consequently, to the lake itself. Itani (1998) argues that soil erosion from agricultural practices is a serious problem in mountainous areas that experience frequent heavy rains and in such environments, the removal of vegetation can easily erode surface soil; if the land is cultivated, erosion becomes more serious and the land may become barren within several years. People lamented the fact that uncoordinated and rapid deforestation of Mount Livingstone led to changes in river regimes, increased flooding and lake sedimentation, destroyed aquatic biomes, and caused further deterioration of the livelihoods and physical environment of the people residing along Lake Nyasa.

Changes in land use in catchment areas not only affect erosion and nutrient inputs to the lake, they also appear to have a significant effect on hydrology within the catchment. A review of historic data of Lake Nyasa water levels, rainfall records, and land use change by Calder, et al. (1995) indicated that between 1967 and 1990, forest cover in the Lake Nyasa catchment decreased from 64% to 51%. This loss of forest resulted in increased water input to the lake due to a decrease in terrestrial evapotranspiration rates. The implications for terrestrial systems and for streams and rivers are likely negative because stream flow tends to be less stable in deforested catchments and therefore input to the river becomes less.

Use of agrochemicals (pesticides and chemical fertilizers) in farming was observed by Nindi (2007) among the Matengo farmers in the upland catchment area that accessed large quantities of highly subsidised agro-chemicals for maize and coffee farming through the National Maize Programme. He avers that application of such agro-chemicals to steep slopes possibly led to the seepage of chemicals into the rivers that opened into Lake Nyasa, a situation that destroyed aquatic life in the rivers as well as along the lakeshore. People reported that it was at this time that villagers began to notice an unprecedented number of fish deaths along rivers and the lakeshore, possibly because the lives of fish in Lake Nyasa are closely related to the stability of the catchment and the river systems. Agrochemicals are therefore expected to increase as more farmers are turning to cocoa farming (Gerken, Suglo & Braun, 2001). That the use of pesticides presents a problem not only for the farmers who are exposed to them (Clarke, Levy, Spurgeon, & Calvert. 1997), but also for the consumers and the water supply, has been demonstrated by for example Ntow (2001, 2005), Otchere, (2005), Ntow, Gijzen, Kelderman and Drechsel, (2006), and Amoah, Drechsel, Abaidoo and Ntow (2006). These authors showed that in Ghana, pesticide and organochlorine residues (as well as fecalcoliform contamination) are found on vegetables, in soil, and in the water supply, constituting a serious health risk. In particular, Ntow (2005) and Otchere (2005) confirmed the presence of organochlorine (pesticides and polychlorinatedbiphenyls [PCBs] in water bodies in Ghana that are similar to Lake Bosomtwe only with smaller relative populations.

Land use (Farming) and Fishing

Turner (2004) reported that fishes, such as *Opsaridiummicrolepis (mpasa) and O. microcephalus (sanyika)* have a tendency to migrate from lakes into rivers to spawn in gravel beds, although some members of the latter species may also spawn in lakes. Other species, such as *O. tweddlorum*, live in rivers throughout their lives. *Opsaridium* species within the Lake Nyasa catchment are heavily exploited on spawning runs into rivers and may also be affected by erosion of the river catchment due to poor agricultural practices that have led to flash floods and siltation of spawning grounds. *Labeomesops (nchila)*, a large silvery fish that favours open sandy beaches, may also have been affected by this degradation. During the 1940s, this specie supported the second largest fishery on the lake after *Oreochromis species* (Lowe, 1952).

Increasing human activity close to Water Bodies

Beyond the vagaries of climate and land use practices, exploitation of the water resources of lakes, the surge in human population in the last few decades has also contributed to increased exploitation and degradation of the water resources of water bodies (Jonah & Adu-Boahen, 2015). Harden (1968) has long hypothesized that Africa's growing population is the major cause of the degradation and pollution of most of the continent's lakes. With marked population increases, human activities have begun to play a more significant role in accelerating lake-level declines (Ghana Statistical Service, 2013). Since the 1960s, human demands for water near Lake Chad have grown rapidly. Between 1960 and 2000, the number of people living in the lake's catchment area has increased considerably.

Natural Causes and Conditions Affecting Shorelines

Natural geological processes are constantly changing resulting in alternating periods of accretion and periods of erosion and inundation. These processes are influenced not only by daily or hourly changes in tides, etc, but also over longer timescales as lake level and climate change. Erosion and inundation brought about by water flows, tides, winds and rain are among the most important natural processes which determine the shape and dynamic character of the shoreline.

Global Climatic changes

Recent projections of global sea-level rise (SLR) and lake-level fluctuations due to climate-induced changes have generated an interest in coastal science to determine the response of coastlines to sea-and lake level change. A primary challenge in understanding shoreline response to water-level change is quantifying the important variables that contribute to coastal evolution in a given area (Pendleton, Thieler & Williams, 2010).

IPCC (2007) contends that human society will face new risks and pressures. Global food security is unlikely to be threatened, but some regions may experience food shortages and hunger. Water resources will be affected as precipitation and evaporation patterns change around the world. Climate change is regarded as the most important global change relevant to the Lake Chad basin. The dramatic decrease in the surface area and volume of the Lake has been attributed to regional and microclimatic change as well as water management practices. Climate change thus remains a major determinant of the future of the lake's volume and surface area.

In addition to having serious implications for the availability of fresh water in the basin, climate change has also impacted, and is still impacting, on vegetation cover. There has been a general decline and disappearance of large trees and woody species with declining rainfalls, as well as the disappearance of perennials of the field layer. But the effects on vegetation did not exactly parallel shifts in soil types but also had major effects in maintaining the status quo or in accelerating the rate of degradation, as do the effects of man and animals. Continuing degradation of the vegetation cover will have immediate direct implications for agriculture and livestock rearing. Odada, Oguntola and Oyebande (2004) stated that there has been a significant decrease in the direct lake rainfall since 1960s and this is responsible for the shrinkage of Lake Chad.

A severe drought in 1973 had major effects on the area with the Sahel moving approximately 100km south as a result. Overall, there has been a decrease in the number of large rainfall events and river inflows (47%). The Lake being shallow responds rapidly to changes in rainfall and river inflows. The lake water receded for more than 150km from its northern and eastern shores, and more than 80km from its southern shoreline.

According to United States Global Research Program (2009), freshwater ecosystems provide a wide range of goods and services. Wetlands exhibit extensive biodiversity, function as filters for pollutants, and are important for carbon sequestration and emissions. Rivers transport water and nutrients from the land to the oceans and provide crucial buffering capacity during droughts especially if fed by mountain springs and glaciers. Lakes serve as sediment and carbon sinks and provide crucial repositories of information on past climate changes. Climate change impacts on inland aquatic ecosystems will be caused by the direct effects of rising temperatures and rising CO_2 concentrations to indirect effects caused by changes in the regional or global precipitation and the melting of glaciers and ice cover (IPCC, 2007; Bates., Kundzewicz, Wu, &Palutikof, 2008;USGRP, 2009).

Conceptual Issues in Shoreline Changes

Models have been used to predict and study shoreline changes. A number of them are reviewed below to assess their strength and weaknesses. The commonly used approach to evaluate potential shoreline change in the future is based on the calculation of shoreline change rates based on changes in shoreline position over time. The shoreline change rates can then be used to extrapolate future shoreline positions at a specific location. In this approach a series of shorelines is assembled from maps for a particular area. In most cases these maps are either National Ocean Service T-sheets, aerial photographs, or derived from GPS surveys (Dolan, Fenster & Holme, 1991); the historical shorelines are then used to estimate rates of change over the time period covered by the different shorelines.

Several statistical methods including Brunn model, Sediment budget, Monte Carlo simulation, Coastal vulnerability index are used to calculate the shoreline change rates with the most commonly used being end-point rate calculations or linear regression (Dolan *et al*., 1991; Crowell, Douglas & Leatherman, 1997). End-point rate calculations are simply the rates determined based on the change in position between the oldest and most recent shorelines in a given data set. Linear-regression rates are the result of estimating the average rate of change using a number of shoreline positions over time. The shoreline change rates can then be used to extrapolate future changes in the shoreline (Crowell *et al*., 1997).

Because past shoreline positions are readily available from maps that have been produced through time and the relatively straightforward approach, the extrapolation of historical trends to predict future shoreline position has been applied widely for coastal management and planning (Crowell & Leatherman, 1999). In particular, this method is used to estimate building set-backs (Fenster, 2005). The estimation of future shoreline positions is often the result of multiplying the observed rate of change by the number of years to the projection. More specific assumptions can be incorporated that address the rate of sea-level rise or geological characteristics of an area (Komar, McDougal, Marra & Ruggiero, 1999).

Historical trend analysis has evolved over the last few decades based on earlier efforts to investigate shoreline change described in Crowell, Leatherman and Douglas (2005). Since the early 1980s, computer- based GIS software has been developed to digitally catalogue shoreline data and facilitate the quantification of shoreline change rates (Thieler, Connell, & Schupp, 2001). At the same time, thorough review and critique of the procedures that are employed to make these estimates have been conducted (Dolan, Fenster & Holme 1991; Crowell *et al*., 1999; Fenster, Dolan & Morton 2001).

The end point rate (EPR) is calculated by dividing the distance of shoreline movement by the time elapsed between the earliest and latest measurements (i.e. the oldest and the most recent shoreline). The major advantage of the EPR is its ease of computation and minimal requirement for shoreline data (two shorelines). The major disadvantage is that in cases (like Massachusetts) where more than two shorelines are available, the information about shoreline behaviour provided by additional shorelines is neglected. Thus, changes in sign or magnitude of the shoreline movement trend or cyclicity of behaviour may be missed. End point rate (EPR) was selected as the preferred method to assess the long-term rate of change statistic for the analysis of the satellite images due to its simplicity and ease of applicability. The spatio-temporal changes in the lake level (shoreline) are presented in this regard. Database can be used for information to develop management planning to the abandoned area in the study site and to develop conservation planning to protect the lake.

Material and Methods

Study site

Lake Bosomtwe is a natural inland freshwater lake in the Ashanti Region of Ghana. It is located about 30 km south-east of Kumasi in the northern tip of the Adansi mountains in the forest zone of Ghana. The lake has a centripetal drainage system; its diameter is 106 km^2, and is about 11 km at its widest part; it has a maximum depth of 78 meters. Lake Bosomtwe covers an area of about 52 km^2 (Turner, Gardner & Sharp, 1995). Studies by Jones, Bacon, and Hasting, (1981), (cited by Turner *et al*, 1995) confirm that the lake is the result of a meteoritic impact. The rim of the crater has been partly eroded, and is situated in dense rainforest, making it difficult to study and confirm its origin by meteorite impact. Shock features such as shatter cones are largely covered by vegetation or by the lake. However, drilling of the crater's central uplift beneath the lake floor has recently provided an abundance of shocking materials for scientific study (Koeberl *et al*, 2007) but tektites, believed to be from this impact, are found in the neighbouring Ivory Coast, and are related to microtektites that have been found in deep sea sediments west of the African continent (Koeberl*et al*, 2007). It is believed that, it was formed by an explosion of volcanic gases and was gradually filled with rain (Moon & Mason 1965).

Shanahan, Overpeck, Sharp, Scholz and Arko, (2007) opined that, periods of heavy rainfall filled the crater with water, causing the lake level to rise above the lowest points of the rim. Such periods are evidenced from fossils of fish found on hilltops. Water even flowed from the basin through an overflow channel. However, there were also times when the water level was so low that the rainforest probably had its way into the basin rendering the lake only a small pond. Such a period, according to legend and now proved by paleoclimatic records, lasted until about 300 years ago (Shanahan *et al*, 2007). Lake Bosomtwe shoreline provides a wide variety of physical and biological needs and performs functions related to fish and wildlife habitat, biological diversity, recreation, economic resources, aesthetic enjoyment, and so on. Each function is a product of the environmental structure and processes at work within the overall landscape.

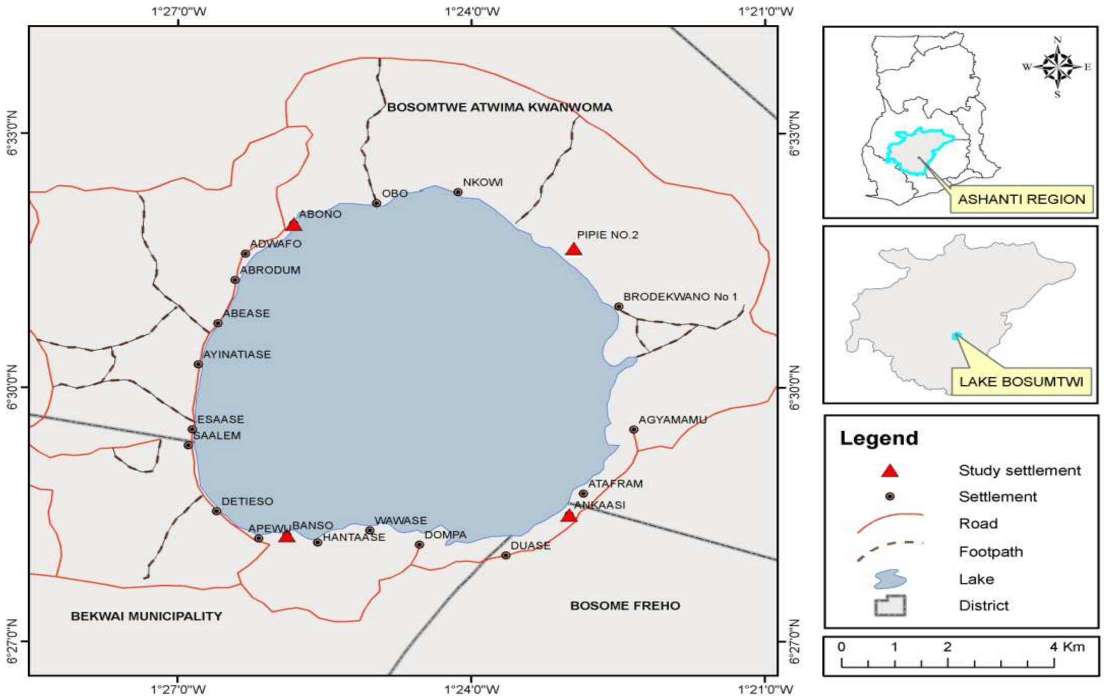

Figure 1: Map of Kumasi showing the study area in the national and regional context
Source: Department of Geography and Regional Planning, UCC, (2016)

Data Collection

Data for this study, spanning a period of 39 years were used. The base year being 1972 topographical sheet from Survey Department with a scale of 1:500000. The subsequent years analysed in the study were February 1986, February, 2003 and February, 2011 all being Aster satellite images. The toposheet was scanned and geo-referenced in Arcmap 9.3 with a root mean square error of about 0.00003. The satellite images went through a series of processes to prepare them for easy capturing of the boundary of the lake.

Pre-processing was performed on the aster images by running haze and noise functions on each of the bands of the images for each year. They were further re-projected into Ghana Meter Grid projection which is the coordinate system of the base year and also help in statistical analysis in Digital Shoreline Analysis Systems (DSAS). A detailed description on operating shoreline change analysis using DSAS has been provided by (Thieler, Himmelstoss, Zichichi, & Ergul, 2009). Boundary of the lake for each specific aster image was carefully digitized and all stored in a geodatabase in Arcmap 9.3 since DSAS version 4.2 only works well when spatial data is in geodatabase format.

To be able to run the shoreline change from DSAS certain steps had to strictly adhered to. A new baseline was generated from a buffer of the digitized 1972 lake boundary created landward which was then converted to a line feature. New fields were added to the attribute data of each spatial data generated for each of the study years and these fields are default fields DSAS uses and require in its analysis.

The process of analysis demanded the casting of transect from the new baseline generated from the buffer passing through all the boundary of the lake 1972, 1986, 2003 and 2011. Transects casted were edited and also topology enforced so that they intersect the shorelines at the appropriate area for calculation of change. Primary and secondary set data were used concurrently. The second aspect was the field measurements conducted on the former shorelines of the lake through an existing monitoring scheme. Topographical map was used as base map in this study. The end point rate calculation under the historical extrapolation model was then applied to obtain the accretion and erosion rate of change. DSAS were also used to generate the results from the images using the end point rate analysis. Maps were generated to show the shoreline changes, tables were also used to present the generated data.

Results and Discussion

Shoreline is the interface between land and water body in general. This is however, not a fixed or stationary line since it is affected by various factors such as storms, tides, waves, current, sediment transport, morphology of lake bed and lake level rise which vary in time. A natural shoreline can therefore accrete or erode depending on the prevailing forces or elements of nature in the coastal processes. The demarcation of the area extent of the sites of erosion and accretion during the period of 1972 to 2010 were made. These were done using a series of data set including topographic maps, Landsat TM and ETM^+ images to detect the changes in the area extent of Lake Bosomtwe shoreline.

The analysis of the topographical map of the lake indicated a total surface area of 49.65 km^2, in 1972. Landsat TM image of 1986 indicated that the total surface area was 50.09 km^2. When the two images are compared using post classification analysis, the areal extent of the lake had changed by 0.44 km^2. Similar comparison of the 1986 and 2003 Landsat images also shows changes in the area extent of the lake. For instance, in 1986 the total surface area of the lake was 50.09 km^2 and in 2003 it shrank to 48.69km,^{2} indicating a negative change of 1.41 km^2.The 2003 and 2008 images were also compared and the results showed that the area extent of the lake had increased from 48.69km^2 in 2003 to 48.97 $km^{2\ in}$ 2008. Finally, the 2010 Landsat image has a total surface area of 49.32 km^2 and that of the 2008 as 48.97km^2. Schneider, Hutchinson, Jackel and FEWS (1978) observed similar fluctuations on Lake Chad, then mega Chad but due to fluctuation in areal extent is now considered a bowl of dust.

As has been indicated in Table 1, since the total accretion was more than the erosion, the entire shoreline could be considered as the shore of progradation. The total accretion rate of 1.41 km^2 and erosion rate of 1.08 km^2 were recorded when the Landsat images were analysed. This analysis of the images indicates the rise and fall of Lake Bosomtwe shoreline. This confirms similar studies or observation by Shanahan, et al (2007) that state that the lake rises and falls.

Table 1: Satellite imagery of Lake Bosomtwe surface area

Years	Surface Area Km^2	Accretion	Erosion
1930	-	-	-
1960	-	-	-
1972	49.65	-	-
1986	50.09	-	0.44
2003	48.68	1.41	-
2008	48.97	-	0.29
2010	49.32	-	0.35
Total		1.41	1.08

Source: Fieldwork, (2016)

In Table 2, the graph shows the analysis of the shoreline in two different types of changes; accretion and erosion. Total changes for accretion is 1.42 km^2 and erosion is 1.08 km^2. In a whole, shoreline change analysis of the lake as indicated by the rate, there is increased accretion as compared to erosion in the 38 years under investigation. This means that, there was decreased inland net movement into the existing land between the years 1972 to 2010. In percentage terms the rate of change between the 38 years is about 76.05 which imply that much land is being given and hence, the lake is dwindling/ decreasing in extent and size gradually. Similar studies were conducted by Calder et al (1995) on Lake Nyasa which showed decreased in the lake levels. Figure two below discusses the total changes that have occurred on the shoreline with regard to the period under study.

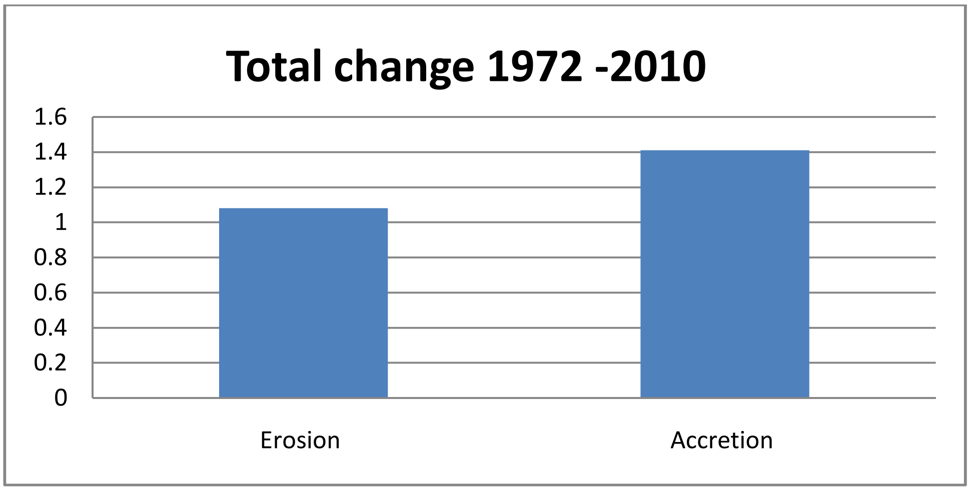

Figure 2: Graph of area analysis for shoreline 1972 to 2010
Source: Fieldwork, (2016)

Figure 3, depicts the area was analysed for shoreline in three different types of changes; accretion, erosion and unchanged. Total changes for accretion is 2116 transect per year, erosion is 966 per year and unchanged is 13 transect per year. In totality, for shoreline area analysis the accretion increased compared to erosion in 38 years. This means that there was movement upland in the year 1972 to 2010 giving much land for the local inhabitants as an agrarian land resource and food crop production. This dwindling lake had led to the reduction in fishing which used to be the main source of livelihood for the surrounding communities. As was remarked by Hardin (1968) with marked population increases human activities have begun to play a more significant role in accelerating lake level declines. Human demand for water have grown rapidly, the number of people living in the lake’s catchment area has increased considerably.

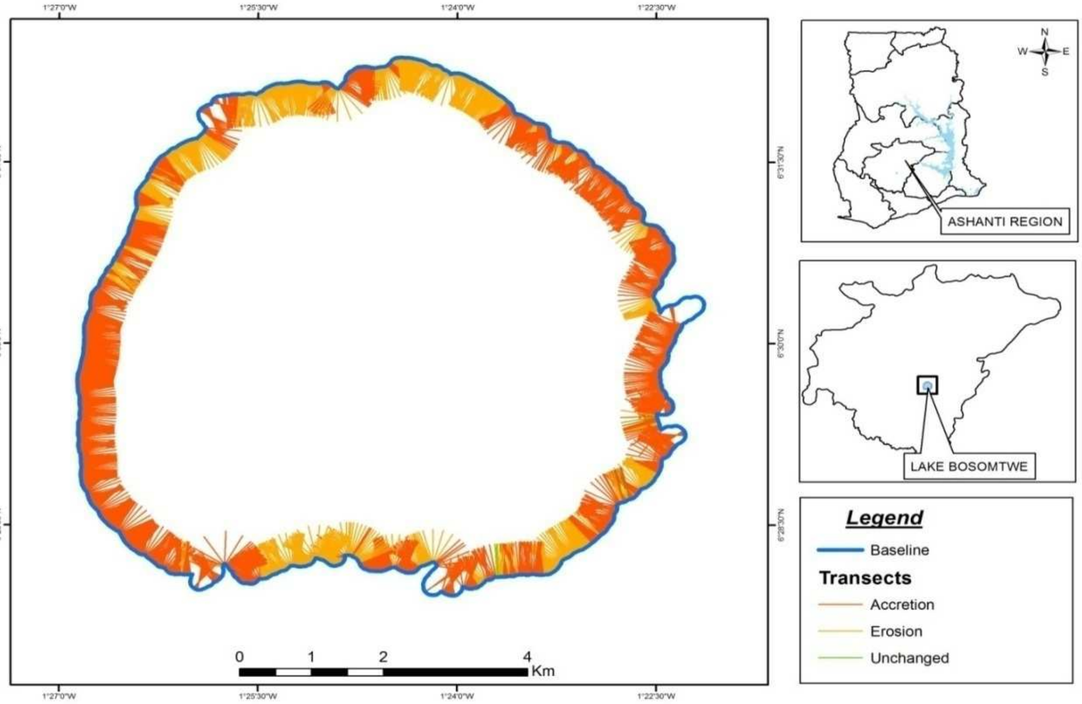

Figure 3: Transects of shoreline change
Source: Fieldwork, (2016)

Measurements showing Shoreline Changes based on Existing Monitoring System
A local non-governmental organisation, specifically Friends of the Earth and Water bodies put in place a monitoring system at Abono, one of the study sites to evaluate the gradual decline in the shoreline of Lake Bosomtwe. They erected pillars at the end of the exposed land to indicate the gradual changes in turns every four years. The baseline was 1994 and measured 8.3m as indicated in Table 2 from 1994 to 1998 the exposed land was 15.0m. The changing landmass and shoreline changes is attributed to the reduction in precipitation and increased in temperature as stated by Adu-Boahen, Dei, Antwi & Adu-Boahen (2015) in their study of Lake Bosomtwe shoreline changes with evidence from meteorological and historical records. Odada, Oguntola and Oyebande (2004) also recognised that, there has been a significant decrease in the direct lake rainfall since 1960s and this is responsible for the shrinkage of Lake Chad.

Table 2: Measurement of the receding shoreline of Lake Bosomtwe 1994 - 2010

Years	Measured(M)	Total Shoreline loss
1994	8.30	8.30
1998	15.0	6.70
2002	23.56	8.56
2006	30.09	6.53
2010	37.4	7.31

Source: Fieldwork, (2016)

Pendleton, Williams and Thieler (2010) were of the view that to understand shoreline response to water level changes it is important to quantify the important variables that contribute to the coastal evolution in the given area. It was therefore imperative to have quantitative evaluation of the rate of change of the lake. This means that the rate of change between 1994 and 1998 (baseline) was 6.70m. Between 1998 and 2002; the land gained was 23.56m. Between 2002 and 2006 the area extent of the lake reduced by 6.53m, thus a distance of 30.09m was gained. Finally, between 2006 and 2010 the measured distance was 37.4m and the total land lost was

7.31m. These exposed lands were seen as a good opportunity for farming, though the land was not enough for meaningful farming.

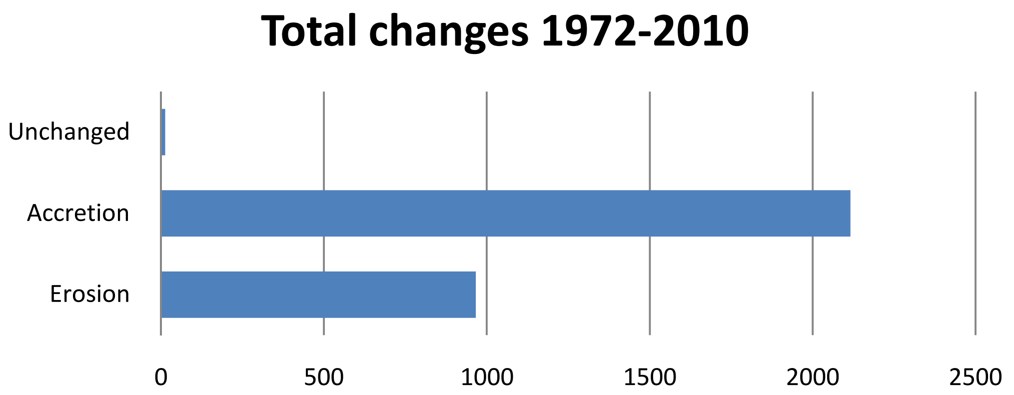

Figure: 4 Changes from 1972-2010
Source: Fieldwork, (2016)

Meteorological Evidence of Shoreline Changes
Climate change or fluctuation is one major factor influencing the changing shoreline of the lake. The impact of climate change on Lake Bosomtwe shoreline changes date back to few decades ago. The study of the hydrological history or cycle of the lake has shown that precipitation which is the main input to the lake has reduced and evaporation is continually increasing, hence the shrinking of the shoreline of the lake. IPCC (2007) retorted that water resources will be affected as precipitation and evaporation pattern changes around the world. These fluctuations may be seen as one of three different kinds: long-term, reflects shoreline retreat or advance over a period of about fifty (50) years or more; short-term which means changes that occur over about ten years or less and finally, seasonal which shows shoreline change within a year or less. They reflect variations in rainfall not only in the area of the lake itself but particularly in the watershed areas of the feeder streams.

There has been a decrease in the number of large rainfall events and in river inflows into the lake. Over the last twenty (20) years, the discharge from the streams such as Ebo, Aberewa, and Konkoma river systems has decreased considerably. Coupled with this reduced rainfall is the problem of intermittent droughts. The region has experienced reduction in rainfall, which left serious adverse effects on the lake such as decreased flows from the major streams that feed into the lake, thereby affecting the water level of the lake. Oyebande (2004) avers that significant decrease in direct lake rainfall since 1960 was responsible for the shrinkage of Lake Chad. Similar scenario could be attributed to the case of Lake Bosomtwe. Climate variability thus remains a major determinant of the future of the lakes volume and surface area. This is shown in figure 5.

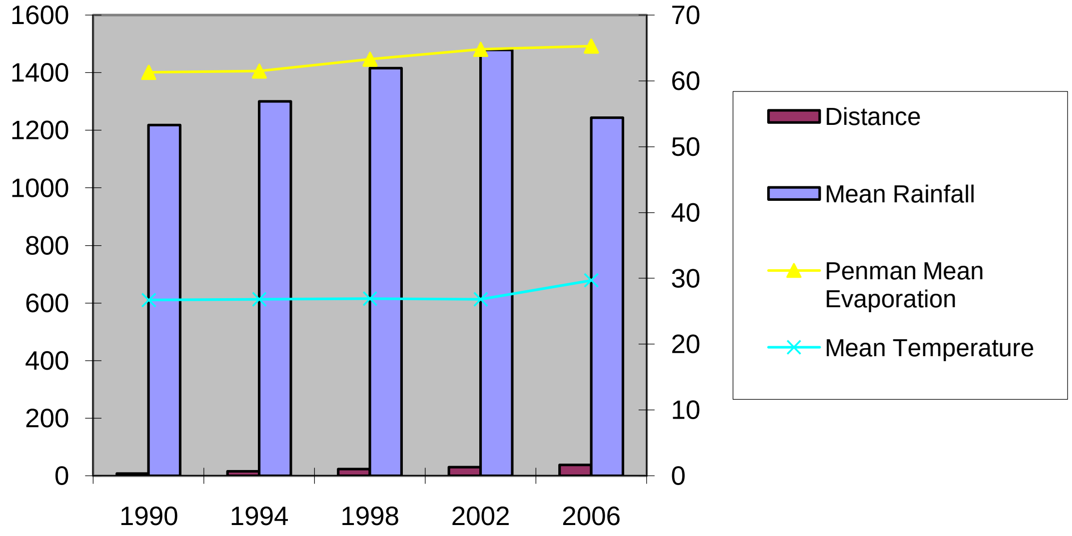

Figure 5: Relationship between the climatic variables and Lake Bosomtwe shoreline changes
Source: Adu-Boahen et al, (2015)

The relationship between Lake Bosomtwe shoreline changes and climatic variables are best shown by figure 5. Analysis of the climatic data which include mean rainfall, temperature, evaporation and the measurement of the shoreline (through a monitoring programme) at Abono one of the study sites from 1990 -2010 reveals that there has been variability in the weather parameters and this in the long run have affected the water level as well as the shoreline of the lake**.** According to the United States Global Research Programme (2009), climate change impacts on inland aquatic ecosystems will be caused by the direct effect of rising temperatures and rising carbon dioxides concentration to indirect effects caused by changes in the regional or global precipitation.

Penman Mean evaporation was high throughout the years under investigation ranging from 1400-1550 between 1990 to 2006. In the same period mean temperature was increasing during the period of investigation between the ranges of 27 degrees to above 30 degrees celcious. Precipitation or rainfall on the other hand was gradually decreasing with the range of 1200 mm per annum and increasing to 1400 and again reducing to less than 1200mm. The results show that there has been an increase in evaporation and mean temperature and a gradual reduction in precipitation in the catchment area of the lake**.** Reader (2001) made similar assertion on Lake Victoria with regard to declined precipitation. Odada et al (2004) reported the significant decrease in the direct lake rainfall will lead to the reduction of the lake and therefore the shoreline.

Conclusions

Inputs to the lake are only surface runoff and precipitation as the main source of water into the lake. Lake Bosomtwe water level largely depends on precipitation; the intensity of the rains affects the water level and therefore the shoreline and the output from the lake largely depend on evaporation. Thus, when the rainfall in the catchment area reduces, the water level also reduces and the area of the lake becomes limited. Rainfall is the major climatic element that regulates the changes in Lake Bosomtwe shoreline. Also, application of GIS and remote sensing technically could make a meaningful impact in monitoring the coastal environment and resources on Lake Bosomtwe. Finally, the Bosomtwe impact crater and the lake that fills it are not only of interest to scientist, but also have the prospective to be important for the growth of ecotourism in Ghana.

The lake is in a hydrologically closed basin, thus, all pollutants remain in the lake and concentrations will increase in the future. The other factors that can make accretion increase at the shoreline are vegetation depletion and alternately reduction in the plant species distributions.

Policy Recommendations

- The range of the lake shoreline change problems is so wide that a restricted research strategy is not feasible for the time being. Nevertheless, it would be interesting to start with a set of carefully selected pilot and experimental studies by scientists in which knowledge from different research groups could be pooled together. Candidate areas may include sediment core studies, water balance, limnology, and archaeological studies. This will help us to understand the various changes that occur within the Lake Bosomtwe, for proper attention to be given.
- It is further recommended that a close examination be made of the hazards that tourism and other human activities have on the ecology of the lake-side. This is important, considering the fact that, the unique habitats such as the littoral areas may also play greater roles in the future as tourism resources. Some activities of tourists and the indigenes are affecting the lake and these include organisation of funerals and other recreational activities along the shore of the lake. It is therefore recommended that they should be managed to ensure the sustainable use of the lake.

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