Long-term climate impact on the Lake Victoria region influences water level fluctuation and resource availability

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ABSTRACT

Historical climate parameters of the Tanzania part of the Lake Victoria region were studied focusing on rainfall variations and the lake water level. This study was prompted by the recent lake water recession after the big water level change which was observed in 1960s. Recorded rainfall pattern of the region was analysed for establishing their linkages to the changing lake environment. Similarly, community understanding of the observed changes in relation to climatic changes in the region was explored for comparison with recorded meteorological information for the past three decades from 1976–2005. It is presented that the region experiences an East–West rainfall pattern variation. The variations of rainfall relative to monthly average values indicated highest positive anomalies (529 mm) in March but this was during the second decade (1986 -1995) with lowest value (149 mm) during wet season. However the last decade (1996 -2005) had the highest anomaly value (~361 mm). Generally decade 1 and 3 showed higher rainfall availability than decade 2. These results implied linkage between rainfall variations with Lake water level. In addition, the observation was supported by the model prediction which indicated past (1961 – 2000) and future (2045 – 2065) trends of the regional rainfall pattern to be in a varying trends. The variation of rainfall is shown to affect all livelihood systems for communities in the region. Like in the past, the Lake Victoria region should expect similar changes of the water level which now increasingly brings about serious impact to their livelihood.

Key words: Climate impact, Water recession, Lake Victoria, community livelihood, model predictions.

1. Introduction

In recent years, Lake Victoria region has been undergoing ecological changes which have been linked to climatic changes. These changes have raised concerns to communities in the region since they have consequently affected the livelihoods of communities in the region. It is reported that since 1980s, there have been apparent indications of periods of prolonged drought and unpredictable rainfall patterns which have negatively affected food production in the region (Awange et al., 2007; Lehman, 1998). These are consequences that have threatened communities’ habitual living, equally impacting the region which has been experiencing fast population growth due to human in pursuit for reliable livelihood especially food (which has
Long-term climate impact on the Lake Victoria region influences water level fluctuation and resource availability

rarely been a problem of the region) as a result, communities in the region are now reported to be under food shortage exacerbated by climatic impacts experienced in the region although the high population densities (Ehrlich, et al., 1993), has been long endured by the region.

Major ecological changes have mainly been linked to rain scarcity, the most recent (2004 – 2005) indication being that of the Lake Victoria water level recession, which has become the second historically documented major after that of 1960s which as opposed to this one, raised the water level to a record higher level. In the recent change, the water has receded from the known background level of the 1960s to a record low level for over 40 years. Some reasons can be predicted based on our understanding of the geographical location Lake Victoria (a tropical lake) which allows high evaporation over its vast surface area (~68,800 km2). Evaporation is of high effect especially when not balanced by the replenishment through rainfall and river inputs. Drought has therefore been easily brought up to be the foremost factor that has affected the water balance of the lake and consequently the water level recession. Other reasons have been forwarded and later the abstraction of the lake water to support hydropower generation in Uganda (a riparian country) has been shown to be a significant factor that contributed to the change (Lake Victoria Basin Commission, 2006). Observations indicate that of the two factors that contributed to the water level drop, drought has been documented to have contributed about 45% whereas overuse through hydropower generation in Uganda contributed 55% (Kull, 2006). Together with this reason (use for hydropower generation) other reasons cannot be ruled out as these changes are shown to have existed long before the hydropower construction as portrayed by figure 1, which gives a historical water level changes over a span of about 100 years. It is clear that soon after the significant changes observed in 1960s, the water level already was gently declining. Although there are no documented data from communities in the region, overwhelmingly there is a general understanding that most rivers and wetlands were slowly reducing their runoff and now no longer providing water supply as it used to be in the past and this has been reported by Machiwa (2003) who indicated that water quality and flow into the lake have been reduced. These observations have been due to the impact of climate specifically the unreliable rainfall pattern in the region (Kizza et al., 2008).

![Figure 1: Historical water level fluctuation of Lake Victoria recorded at Jinja station. A sudden of water level occurred in 1960s following a referred heavy rainfall (redrawn from Lake Victoria basin commission special report on the declining of water levels of Lake Victoria, 2006).](image-url)
In addition to water level, there have been recent reports indicating the presence of ecological changes affecting the lake environment which include emergence of water hyacinths (Eichhornia crasipes) and increase of algal bloom frequency, (Awange and Ong’ang’a, 2006; Verschuren, 2002). These two phenomena scientifically are able to deplete oxygen from the water column and therefore can add to the impacts on the Lake region environment by threatening also the lake biodiversity and fisheries activities. These raise concerns to the Lake communities’ survival since they are predominantly dependent on the lake and its resources for their livelihood. For sure, it is already observed that the lake fishery production is excessively low. Communities need to cope with these changes for sustaining their life which is now under pressure related to failing livelihoods and linked to some health problems which has also been reported, like the increasing malaria incidences (Minakawa et al., 2008).

Although Lake Victoria is under various conservation programmes, it is important to note the enormous challenges affecting its aquatic and surrounding environments. Mostly, considerations have been on the ecological changes but it is important to be aware of the causes like climatic impacts which cannot be neglected as one of the factors contributing to the deterioration of the Lake Victoria environment. Good analyses and understanding of each of the available meteorological information should be emphasised since available literature and even future predictions provide evidence on the effect of climate to the lake region environment.

Apart from the analyses of observation data, global models (regardless of their accuracies) have become a major tool in enhancing our understanding of the past and predicting future climatic conditions. Model input parameters, geographical locations as well as different interactions among spheres have been fundamental to enhancing their prediction accuracy. Chapter 8 of the IPCC fourth assessment report lists 23 Atmosphere-Ocean General Circulation Models (AOGCMs) and highly supports the credibility of their future weather prediction. However, it has always been known that models fails to smoothly operate in Africa due to limited data related to various meteorological processes in the region. Nevertheless, there has been impressive testing to use various models in predicting or explaining various climate scenarios (e.g. Chervin, 1979; Sud and Fenessy, 1982; Laval and Picon, 1986; Cunnington and Rowntree, 1986; Sud and Molod, 1988 and Kitoh et al., 1988, etc.). Recently, there have been increased applications of the IPCC model as well in interpreting various African climate scenarios (Raible et al., 2008; Stier et al., 2005). Continued use of models and other data analyses methods may help to enhance our understanding of the climatic changes of the Lake Victoria region. With this understanding we are presenting results of the analyses of rainfall data and predicted trend of the past and future rainfall pattern in the Lake Victoria region. These are compared with narration of study area community so as to contribute to the understanding of various changes taking place in this region in relation to the Lake water level variation.

2. Materials and Methods

2.1 Study area

This study was undertaken in the Tanzanian part of the Lake Victoria region (Figure 2). This area encompasses three administrative regions namely Mara, Mwanza, Shinyanga and Kagera. These regions are part of the 51% of the Lake Victoria surface area within the territorial boundaries of the United Republic of Tanzania. The Lake Victoria region provides a reasonable size of the lake resources to communities and other parts of the country. Due to that the region is reported to have the highest population growth in Africa (UNEP, 2006). The
rain pattern of the region is bimodal, March – May (Heavy rain season) and October – December (short rain season) separated by a dry spell from June – September which is sometimes interrupted by occasional drizzle. Accessed information from the Tanzania Meteorological Agency indicates that the area has 52 weather recording stations (mainly for rainfall) including four synoptic weather stations, one in each of the administrative regions presented in this study. Economically, the regional population depends on fishing and subsistence agriculture which include cassava, sweet potatoes, banana, maize and other traditional crops all dependent on rainfall seasonality. From the 1990s to date fishing activities has emerged as an important economic activity in the region said to be the second to mining (LVEMP, 2000). Lake Victoria is similarly the major reliable source of portable water for domestic use in the region.

![Rainfall sampling stations](image)

**Figure 2:** Rainfall sampling stations (meteorological stations) in the Lake Victoria region. Samples provided at different time scales

### 2.2 Meteorological information

The time scale of sampled rainfall data varied from one station to another nevertheless, majority of the stations provided data of more than 50 years ago. The region was visited for physical survey of the area to establish climate related impacts later to be evaluated against meteorological data. Ukerewe Island shown in figure 2 being almost at the centre of the lake region was particularly intensively surveyed for community climate impacts knowledge. Meteorological data were accessed from fifty two (52) stations located in the named four regions (Kagera, Mwanza, Shinyanga and Mara).
Long-term climate impact on the Lake Victoria region influences water level fluctuation and resource availability

In this analysis, rainfall was considered to be one of the well documented weather observation in the region providing an assessment advantage for easy comparison and communities’ understanding due to its direct link to their daily life than other meteorological parameters, which can be only ascertained by instrumental assessment.

2.3 Model application and simulation

In this study, model outputs were considered for exploring regional climate. Rainfall future prediction was done by considering the quality of various GCM accessed from the Climate Systems Analysis Group (CSAG) of the University of Cape Town. The results are used for presentation of various scenarios as displayed by Climate Explorer (CCE) interface developed by the CSAG.

2.4 Community visits and information gathering

Communities from three villages namely Hamkoko, Busiri and Muhula with estimated population of 5286, 3349 and 4,026 inhabitants, respectively in the Island of Ukerewe were visited for narrative information of the existing climate impact evidence in the region. Data were collected through meetings and workshops where discussions were encouraged. Gathered information was authenticated by physical evidence where possible. Discussions among members were crosschecked by comparison with meteorological information and information on climate related events. A total of six visits to the communities were done over a period of eighteen (18) months successively to include

1. Major activities of the communities
2. Narrative documentation from the communities’ understanding of the existence of climatic impacts and their consequences to their daily life
3. Supporting incidences or physical evidences of climatic impacts known to communities
4. Vulnerable systems and potential/opportunities for adaptation.

3. Results and Discussion

3.1 Rainfall patterns

Our analyses of meteorological information indicate that the three regions consistently has been showing an east-west variation of rainfall pattern, where the western side of the Lake Victoria experiences higher rainfall compared to the eastern side. Southwards, the rainfall pattern shows a decreasing trend compared to the western and northern areas. This is a trend reflected in figure 2 where Bukoba region consistently maintained highest total annual rainfall intensity for 83 years (1922 to 2005). The trend of rainfall anomalies for three decades, 1976 to 2005 (Figure 4a - c) in the Lake Victoria region shows non-patterned variations for different months of the year. However, the variations show differences in the sensitivity of the anomaly values between rain seasons (short and heavy rain seasons) and dry season. Highest positive anomalies were observed during the month of March (heavy rain season) except during the second decade (1986 -1995). During the first decade (1976 – 1985) the highest value in March was 529 mm above decadal average, whereas in the second decade (1986 – 1995) the maximum value of anomalies in March was 149 mm. this was the lowest value for the wet season compared to the last decade (1996 -2005) which provided a maximum anomaly value of ~361 mm. This decade also registered a highest anomaly in May 2005
Long-term climate impact on the Lake Victoria region influences water level fluctuation and resource availability

where a value of 448 mm is observed. July, August and September are dry months of this region they therefore show no important variations of the anomaly trends for the three decades. The comparison of anomalies of the three decades in the figure presents that from 1986 – 1994 there was rain shortage followed by 1976 – 1985 period and from 1986 – 2005 the region experienced a wet decade, less rain shortage.

In-depth distribution of the rainfall patterns (figure 5) was established from 52 recording stations scattered in the Lake Victoria region. For even comparison a period with comparative rainfall data for all stations like those in figure 4 was selected. This was a period between 1974 and 2005 (three decades). The region indicates that although decade 1 and 3 showed a general higher rainfall, decade 2 (figure 5 b, 1986-1995) also had pockets of higher rain availability. All figures indicated higher rainfall contours in the western side with few appearances of exceptions. During decade 1, the western side received a maximum rainfall up to 1960 mm whereas the eastern side maximum rainfall was 1120 mm. Figure 5 b shows the same area with higher rainfall of about 1960 mm, which was higher than what is observed in Figure 5 a and the eastern side experienced up to 1260 mm of total rainfall than decade 1. Decade 3 exceptionally experienced an episode of highest total rainfall in the eastern side of the lake where up to about 2520 mm of rainfall was recorded. The western side recorded a maximum rainfall of about 1925 mm.
Long-term climate impact on the Lake Victoria region influences water level fluctuation and resource availability

Figure 4a: Lake region decadal rainfall anomalies (1976 – 1985) of four (Bukoba, Mwanza, Musoma and Shinyanga) regional synoptic meteorological stations

Figure 4b: Lake region decadal rainfall anomalies (1986 – 1995 of four (Bukoba, Mwanza, Musoma and Shinyanga) regional synoptic meteorological stations
The information provided emanates from land-based stations given in Figure 2. It is therefore important to note that rainfall information from the lake water surface shown in figure 5 is an extrapolation to the closest estimation of the value points of the Lake region. Again, it is important to note this because available information indicates that a significant water quantity entering the lake is from direct rainfall on the lake surface but similarly tributaries inflow are recognised to control fluctuations of the basin supply (Piper, 1986). Rainfall as a climate parameter is obviously observed to contribute to the water distribution and an important impacting factor of the lake water level. The total annual rainfall in figure 3 highlights the importance of the western region in the contribution of the land-based lake water inflows. From 1922 to 2005 the western region (Bukoba) maintained highest rainfall than the rest of the region. However, it is observed that from 1999 to 2005 the same region experienced reduction of total annual rainfall. This experience coincided with a period (2004 -2005) where the Lake water level was at lowest level ever recorded since 1960s. The importance of western side is amplified by the fact that river Kagera is one of few important rivers providing land flows to the Lake Victoria.

The water level reduction over the period can also be supported by the anomalies presented in figure 4a – c where during the same period, wet months (March – early May) reflected the reduction in rainfall but how can we relate these rainfall anomalies and the recent observed lake water recession? Hydrological and water balance studies of Lake Victoria has been showing that water level fluctuations have existed for many decades (Lyons, 1906) and there has been an explainable balance between water level and outflow. Rainfall is no doubt a controlling factor of other components in the water balance, i.e. Lake outflow through Nile and evaporation. Quoting various previous observations in reference to the 1961–1964 water

Figure 4c: Lake region decadal rainfall anomalies (1996 – 2005) of four (Bukoba, Mwanza, Musoma and Shinyanga) regional synoptic meteorological stations

...
level rise, Piper et al., (1986) emphasise that such changes were not unique as in the previous similar fluctuations had occurred.

**Figure 5:** Rainfall distribution of the Lake Victoria region for three decades in ten year intervals; a: 1974-1985, b: 1986-1995 and c: 1996-2005
Long-term climate impact on the Lake Victoria region influences water level fluctuation and resource availability

A report by Lyon (1906) goes back to incidences of 1878 where the water level was reported to rise in 1892 and 1895. Obviously, due to the relationship between rainfall and the Lake water level and such historical changes must have been a response of the lake to increased precipitation in the Lake region. In this study, the results do not provide exceptional anomalies to be used as an evidence for climate impact. What we find here like in the previous are normal variations of the regional weather pattern which obviously has been affecting the Lake water balance and thus the Lake water level.

3.2 Model predictions

Figure 6 and 7 are model outputs of precipitation based on two scenarios, control (modelled past 1961 – 2000) and modelled future (2045 – 2065) climate of the three regions as mentioned in the figures where data were accessed for model input. Data for Shinyanga region could not be accessed. Based on the model results, the annual precipitation trend is likely to increase for most months of the year. Figure 6 indicates that the period between May and July is predicted to experience the highest positive variability of precipitation up to ~2.0 mm. A period between January and April (except February in Mara region) similarly shows predicted increased precipitation though of less magnitude. Bukoba region is predicted to have negative anomaly during the month of November. Overall, the region is predicted to have increased precipitation during dry months and little variation is expected during wet seasons (i.e. March – April and October – November). Illustrated in figure 7 is the trend of daily precipitation along a year showing minor difference in the magnitude of precipitation. The future prediction indicates high precipitation in mid-April with predicted value of 6.2 mm. This is differentiated by the past record on the same period which recorded 5.4 mm.

![Figure 6: Anomaly of daily total rainfall for the model control (past record) and future model prediction (Echam5 model data) of the three regions of the Lake Victoria (Mwanza, Musoma and Bukoba), January to December](image)

Considering the long-term fluctuation reproduced in figure 1 we find evidence that some abnormalities/exceptional changes do occur as has been shown in figure 4a testifying that a period between 1960–1962 supports the documented water level change. It was the sudden increase in rainfall that made a complete change of water level, which has persisted for over three decades. The recent drop in water level can be considered to be part of the normal fluctuation of the Lake water level as from the historical figure 1, this has not gone down below the pre-1960s water level. On the other hand this lowering also cannot be considered to be permanent since models support an increased rainfall pattern in the future. Figure 6 and 7
supports changes which have also been reported by the Intergovernmental Panel on Climate (IPCC).

![Graph](image)

**Figure 7:** Modelled past (control) and modelled future daily rainfall total for the three regions (Mwanza, Musoma and Bukoba) from January 1 to December 31. (Echam5 model)

In its fourth assessment report of 2007, IPCC predicts that by the year 2080 tropical and eastern Africa may experience increased rainfall by 7%. In this observation the model similarly shows incidences of less precipitation in the region with anomaly values below the regional average. Interesting is to note that dry seasons of the future years will likely be wetter than present, a change which will have to be adapted and used by the region communities.

### 3.3 Community-based information

The visited village communities indicated to undertake two major activities, mixed agriculture (subsistence agriculture and livestock keeping) and fishing. It was observed that community members had knowledge of the existence of climatic changes in their region and cited climatic and non climatic factors affecting the region. These included i) changes of spatial and temporal distribution of rainfall ii) scarcity of portable water iii) disappearances of some fish species iv) periodical variations of the Lake Victoria water level and its quality v) diminishing trends of crop production and emerging crop diseases vi) declining forest cover vii) general loss of biodiversity indicated by the disappearance of some organisms. The communities provided historical accounts referring to climatic conditions dating back to the 1940s, explaining the scarcity of rainfall as their major observable climatic change. To support this, it was narrated that in the past rain season covered months of March, April, May, July, September, November and December whereas the Island experienced periods of dry weather in January, February, June, August and October. With such patterns, the Island enjoyed more wet months than dry ones. However, in recent years it has been observed that dry spell has increased resulting to water scarcity as observed. The disappearance of some fish species came out frequently with communities indicating that almost all species (over 150 species) of *Haplochromis* spp. declined to insignificance between 1970s and mid 1980s, a period which was also marked by the emergence of nile perches. Other factors were put forward to explain non involvement of nile perches in the lake Victoria. This was the changing climate of the region. A typical example was the disappearance of *Alestes* spp. and *Mommyrus* spp., which took place earlier before the appearance of the nile perches followed by *Clarias* sp. later. Two particular species, *Clarias* spp and *Alestes* spp., were linked to the deteriorating weather pattern. The disappearance of *Alestes* spp. was highly emphasised because this was one of the...
preferred delicacies of the communities, easily fished and of reasonable abundance. The species disappeared between the late 1960s and mid 1970s, before the boom of perches. Community participation provided authentication of how the impact of rainfall over the period has been felt and associated with the weather anomalies. Overwhelmingly, all the three village communities indicated rainfall to be an environmental factor affecting most of their livelihood. Six important systems were identified and of all these only two were not directly connected to rainfall availability. With the preferential arrangement of the affected systems in the table, agriculture, fisheries and water sources were observed to be the most important system for their livelihood. These are unfortunately, directly associated with rainfall.

Table 1: Summary of affected systems and associated factors as identified by the communities

<table>
<thead>
<tr>
<th>Affected system</th>
<th>Associated factor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Agriculture</td>
<td>Rainfall, pests, diseases, soil fertility</td>
</tr>
<tr>
<td>2 Fisheries</td>
<td>Rainfall,</td>
</tr>
<tr>
<td>3 Water sources</td>
<td>Rainfall, population</td>
</tr>
<tr>
<td>4 Wood fuel</td>
<td>Population, deforestation</td>
</tr>
<tr>
<td>5 Livestock keeping</td>
<td>Population growth</td>
</tr>
<tr>
<td>6 Lake water quality</td>
<td>Rainfall, fishing practices</td>
</tr>
</tbody>
</table>

It can be established changes in climate parameters occur at a long time scale such that each human generation establishes its baseline for the assessment of the changing events between past and present. A particular generation fails to acquire an ability of making reference to the past generation understanding, comparatively. This is what also was encountered in this study by getting more climate change references from aged population compared to young ones but even among the aged population good reference was limited to past seventy (70) years so, weather events of say past 90 years were beyond recognition for a narrative study. That highlights the need to use previously archived information to explain the effects of climatic changes. Apart from that still communities explained other changes which have been occurring to their witness. These include both ecological and biological changes. Available biological information indicates that, Lake Victoria has already been affected negatively by loosing some fish species. These include Haplochromis spp., Mormyrus spp., Protopterus aethiopicus, Alestes spp., Clarias spp. etc. There has been an explanation linking nile perch (Lates nilotica) appearance and loss of other species from Lake Victoria but during this study, it was interesting to note that communities considered the contribution of nile perches a recent incident (of the 1970s) which affected selected species like Haplochromis spp. It is obviously explained that the loss of wetlands significantly interfered with the reproduction patterns of Clarias spp. This argument can easily be linked to the biology of the species since Clarias reproduction is dependent on running waters which an environment which was disappearing.

The disappearance of Alestes sp. was testified by communities to be coinciding with the rainfall episode of between 1960 and 1962. According to communities’ narration, the rainfall incidence may have led to the collapse of the species because the increase of Lake Victoria water level inundated the lakeshores which were the breeding grounds for the species and subsequently the new water level formed after the rainfall became permanent resulting to the species disappearance. This was an unfortunate weather event which caused significant impacts because the new water level has been decreasing slowly offering no possibilities for ecological recovery.
Preferentially, agriculture was considered the major impacted system of the communities in the region. This showed the importance of agriculture for their livelihood. Apart from rainfall, other associated factors (i.e. pests, diseases and soil fertility) were related to rainfall scarcity as well but possibly these are consequences that has been lowering farm productivity, raising the need for bigger farms to meet food demand and since land is not abundantly available in the region, there has been short cycles of farming and harvesting of crops thus accelerating lowered soil fertility. It is obvious that fisheries were considered second to agriculture due to its importance to the Lake region communities. As mentioned before, the region observes fishing activities an important economic activity second to mining (LVEMP, 2000) and naturally availability of rainfall enhances fish productivity as more food flows in from inland (river inflows). More associated and proved factor impacting fisheries which should have been mentioned is overfishing which started some decades ago (Regier and Loftus, 1972) and currently a common phenomenon of the lake (Balirwa et al., 2003). This of course highlights the mixed nature of the factors impacting the Lake Victoria ecology which can easily be overlooked for climatic change impact.

Systems like water sources, wood fuel and livestock keeping are all associated to population growth in addition to some other factors. However it can be found that the fast growing human population of the Lake region is somehow linked to the abundance of resources in this region implying that somewhere as the resource scarcity decreases the lake region is blessed to receive more immigrants. Looking into the reality, most of these resources are scarce due to climate impact (Herring, 1979). In this document it is unfortunate that we are lacking historical documentation of human migration cycles which was to be compared with climatic calamities and especially rainfall scarcity in the region.

4. Conclusions

From these observations it can be concluded that the Lake Victoria region has been undergoing changes mostly related to climate. These changes have significantly affected the Lake environment physically, chemically and biologically but it is obvious that some changes are more dramatic than others. A typical example is the change of water level like a recent recession of water level. However, the water level recession has been appearing in a recurring manner making the recent recession phenomenon to be possibly due to the mixed effects of recurring climate variability and consequential events. Global models including the one used in this work predicts the region to be affected by climatic changes implying that the impact of climate should be considered to be an important factor that will likely be defining the livelihood of the region population.

Although the evidence presented here shows that these changes are not solely new in the region, the resulting impacts must have different magnitudes due to current existing conditions for example large human population in the region which exacerbate other impacting factors like food shortage which was not existing in the past. Now, although the current observations may be implying to be the normally observed historical rainfall variations cyclic events, possibly not falling into the classical definition of climate change, it is still conceivable that the impact of such changes have been resulting to more severe consequences than before and serious measures should be taken to support the region population. Rainfall pattern analysed in this study proved to be a defining parameter of the daily communities’ resource availability and general livelihood activities and it has also historically been a determinant of the current regional climatic changes likely to affect the quality of the Lake environment. The current water recession is indeed an alert for more attention to be focussed on the present Lake ecology and its future.
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5. References


Long-term climate impact on the Lake Victoria region influences water level fluctuation and resource availability


Long-term climate impact on the Lake Victoria region influences water level fluctuation and resource availability
