Advancing Capacity to support Climate Change Adaptation (ACCCA) Pilot Action

Implementation Report of Research Project:

ADAPTATION STRATEGIES FOR CHALLENGES ASSOCIATED WITH CLIMATE AND ECOLOGICAL CHANGES AFFECTING LAKE VICTORIA COMMUNITIES

Clavery Tungaraza[1]
Elisante Eliapenda[1]
Kajitanus O. Osewe[2]
Paul M. Palapala[3]

[1]Faculty of Science, Sokoine University of Agriculture, P.O Box 3038, Morogoro. TANZANIA
[2]Department of Aquaculture Development, Ministry of livestock and Fisheries Development, P.O Box 2462, Dar es Salaam, TANZANIA
[3]Family Poverty Elimination (FAPOEL), P.O Box Nansio Ukerewe, Mwanza TANZANIA

CONTENTS

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1.0 INTRODUCTION

Climatic changes have affected the environment of Lake Victoria region and consequently the livelihood of the communities in the region. The changes are exemplified in different ways including, changing rainfall patterns, emergence of crop diseases and therefore food shortage leading to shifting in preferences, water scarcity and Lake water level and quality changes, etc. The impacts to communities are similarly of different magnitudes depending on the community's location and activities into which it is involved. However, these communities share common livelihood characteristics that they all depend on environmental resources which are now affected. Their capacity to deal with these changes is also limited.

This report documents information on the understanding and community awareness of the existence of climate change, the historical trends of the changes as has been gathered and documented by communities, supporting events and their understanding of the possible causes of the changes in the lake Victoria region. It provides also impacts of climate change and community-based adaptation strategies. Climatic changes and impacts documentation were identified by participatory learning through meeting with communities. Communities' information is compared with climatological information from selected (out of fifty two stations in record) meteorological stations in the region where rainfall and temperature information were accessed. Various priority adaptation strategies were identified and how they are used by communities to alleviate the impacts of climate change. The report also provides survival and coping strategies that have been adopted by the communities over their lifetime. Priority areas of the impacted systems were suggested by the communities.

This study involved three pilot village communities located in the Island of Ukerewe, the largest of all the islands of the Lake Victoria in Tanzania. These communities practice different livelihood activities. However, all are beneficiaries of agriculture and fisheries as their livelihood activities and food security. The selection of villages was based on the understanding of the differences of the climatic conditions especially along the east-west direction and livelihood activities undertaken by communities of the Island. This helped to capture the impacts of the changing environment to the communities.

1.1 Background

The impacts of climate change to the environment and people have been manifested in different forms in different regions of the world. In the Lake Victoria region, the impact of Climate Change has been marked-up by various chronological events, unfortunately signifying the escalating impacts to livelihood of communities in the region. The impacts escalation is of concern since it has impacted on daily livelihood activities supporting the communities. It is reported that since 1980's, there have been apparent observable indications of climatic changes in the Lake Victoria region particularly exemplified by periods of prolonged drought and unpredictable rainfall

patterns therefore, negatively affecting food production in the region (Awange *et al.*, 2007; Lehman, 1998)

The Lake Victoria region is experiencing changes which are threatening communities' habitual living. This is a region which has historically been experiencing population growth due to migration from different parts mainly due to its reliable food security. Such migration has created pressure in some parts of the region in terms of food availability and other livelihood activities. Ecologically, there have been some changes mainly linked to rain scarcity. The most recent observable change has been the Lake Victoria water level change. The water has receded from the normally known shoreline back to areas used to be deeper waters. This change of water level has affected the shore ecology (Edgington *et al.*, 2002) and is observed to cause health problem like the possibility of increasing malaria (Minakawa *et al.*, 2008). In addition to water level change, there has been an emergence of water hyacinths (*Eichornia crasipes*) and increase of algal bloom frequency, which scientifically contribute to oxygen depletion at lower depths of the Lake (Awange and Ong'ang'a, 2008; Verschuren, 2002) and therefore, adding to the impacts on the Lake region environment by threatening also the lake biodiversity and fisheries activities. While drought has been said to be the major cause of these changes, on the other hand, the geographical location of Lake Victoria (tropical lake) allows high evaporation of the lake water over its vast surface area ($\sim$68,000 km^2) especially when the loss of water is not balanced with the replenishment by rainfall and river inputs. This is considered to have contributed to the unexpected fast decrease of water level. Other reasons have been forwarded but the abstraction of the lake water to meet electricity generation demand in Uganda (a riparian country) has now been shown to be a significant factor for the abrupt water level decrease (Lake Victoria Basin Commission, 2006) More long-term factors can also be included to contribute to these changes, which include agricultural activities in river basins (another important source of water into the lake) due to increasing drought which has reduced suitable land for agriculture. Although there are no reliable data on this, overwhelmingly, it can be agreed that most rivers and wetlands in the lake region are now under agricultural activities or used as pastureland which has reduced water flow and quality into the lake (Machiwa, 2003).

The major concern of these changes has been on the impacts to communities which have predominantly depended on the lake and its resources for their livelihood. Ever more, the Lake fishery production is excessively low. Artisanal fishers are becoming redundant and this has forced them to illegal fishing methods. It is obvious that one needs modern fishing gears for normal capture fisheries which unfortunately necessitates high initial investment costs. In short, it is observed that most communities have been deprived of their fishing tradition and this has greatly impacted on the communities' livelihood. Communities need to cope with these changes in order for them to sustain life not only through fishing activities, but in general, the availability of sufficient food, supporting income generating activities and availability of reliable water sources.

This study was undertaken in Ukerewe district, which is among the districts of the lake Victoria region. It used to enjoy good weather and therefore satisfactory crop production. This encouraged immigration of people to the Island mainly in search for food from surrounding areas which had been vulnerable to drought. Ukerewe district has been considered more secure in terms of food and water availability. Due to population increase, land has become limited among the increasing population subjecting available arable land to pressure by frequent cultivation resulting in reduced fertility. Communities are realising poor harvests of important food crops specifically cassava and sweet potatoes which have been traditional food crops for almost seven decades. Communities are realising that shortage of rainfall (increased drought period), crop diseases and loss of soil fertility are becoming undisputable reasons for food shortage.

This study explored the communities' understanding of the existence of climatic changes and its impacts in the region and enhancing knowledge of communities' adaptation strategies. Coping and adaptation strategies that have been adopted by communities in this region have been analysed and information on the changing climate have been compared with documented climatological information in the Lake Victoria region. This project recognizes the need for the communities' adaptation strategies. However, as the communities adopt various strategies, proper evaluation of the methods and selection of coping and adaptation techniques adopted by communities has been done in a prioritized manner and identify areas which communities need sustainable adaptation.

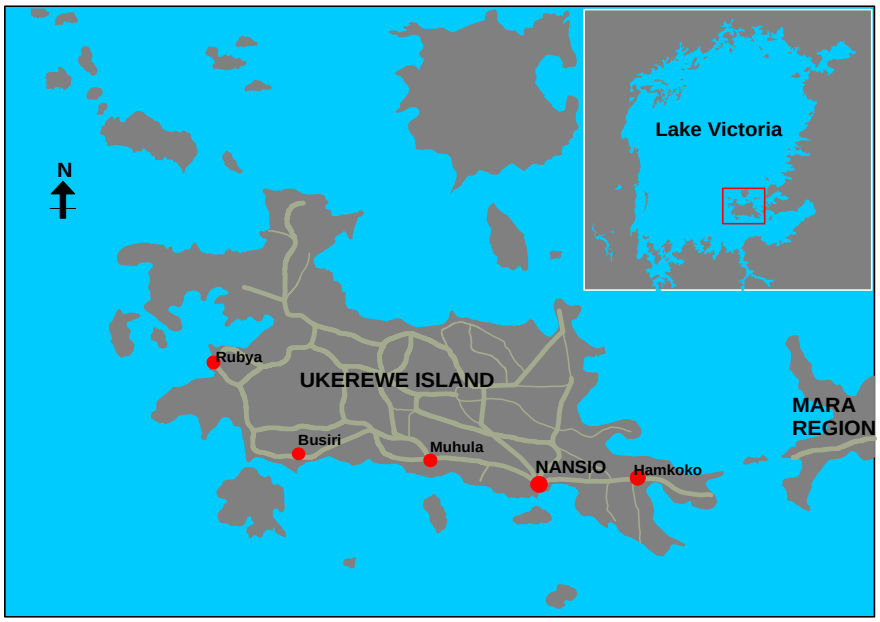

Figure1: Map of Ukerewe island in the Lake Victoria showing study communities (Hamkoko, Muhula and Busiri villages), major road network, and meteorological stations for weather information (Nansio and Rubya stations).

1.2 Profile of the study area

1.2.1 Geographical location and demography

Ukerewe district (Figure 1) is located in the Lake Victoria, in northern Tanzania. The district is a combination of 38 islands; fifteen (15) islands are permanently inhabited by people while the rest are temporarily inhabited particularly by fishermen. The district is located between latitude 1°30'S and 2° 20'S and between longitude 3° 30'E and 32° 50'E (Ukerewe District Council, 2008). The district has an estimated population of about 260,000 inhabitants (National census, 2002) in an estimated area of 640 km^2 of land. The total district area together with the water masses is about 6,400 km^2, which makes it one of the most highly densely populated districts in the country.

1.2.2 The district climate

The district agricultural department categorises the district climate as being bimodal rain pattern with an annual total average rainfall ranging between 900 mm and 1200 mm distributed mainly between two seasons namely, short rainfall season (October/November – January) and heavy rainfall season (March – May). The western side of the district enjoys more rainfall of the value of 1800 mm annually compared to about 900 mm on the eastern part of the Island. The average temperature trend for daytime is between 21°C and 28°C. Humidity is low with a minimum of 35% during the end of the dry season and maximum of 60% at the end of the wet season. Generally it has tropical climate. The district has two agro-ecological zones namely; the eastern and western zones. The eastern zone has short growing period extending from October to May with four humid months while the western zone has a longer growing season extending from September to July with six humid months.

1.2.3 District economic potential

The district has mixed production activities where households are involved in more than one activity. The major economic activities include agriculture, fishing and livestock keeping. The gross domestic product (GDP) for Ukerewe District is estimated to be Tshs 130,000/= (*ca* US$ 100) per capital (Ukerewe district Council, 2007). This is below the poverty line thus making the district among the poorest districts. According to the District Council, 92% of the district population depends on agriculture. The farming system is subsistence and crop production is done in mixed farming where there is no clear demarcation between cash and food crops. Major food crops are cereals, cassava and potatoes. The production trends for different crops has been varying due to two major reasons; changing weather and decreasing soil fertility. The fast growing population has exerted pressure on arable land (62,000 hectares) causing fast rate of deforestation and decreasing land productivity due to declining soil fertility. The poor soil fertility is also attributed to the poor parent material, poor soil management and rainfall which accelerate leaching of nutrients. Nevertheless, the district is the major producer of citrus fruits and mangoes in the region (Table 1). Ukerewe district has for years been a major food supplier to Mwanza city and other surrounding districts. It is a district that has managed to maintain internal food security. Major crops include; cassava, sweet potatoes, paddy, banana, legumes, maize,

sorghum, groundnuts, green vegetables, millet, bambara nuts, coffee, oil palm, cotton, simsim, sunflower and vanilla. Ukerewe has a high potential for fruits production which include; mangoes, oranges, tangerines, lemons, pineapples, paw paws and rosella. Ukerewe is the main supplier of such fruits to Mwanza, Shinyanga and Mara regions.

Being an Island, Ukerewe is endowed with abundant water. The lake water and significant amount of groundwater reserve and some seasonal rivers flowing from hills to the lake can be used as potential water sources which can be used for domestic activities, irrigation and fisheries activities. The district has three major irrigation schemes; Bugorola, Namagubo and Nakatungulu which are mainly for rice cultivation. Bugorola is the largest irrigation Scheme with a potential area of 200 ha of which only 74 ha are mainly currently used for rice production and sweet potatoes cultivation being undertaken alternatively with rice cultivation. The major market for sweet potatoes is the Mwanza city and Mara region, where they are considered to be of high quality and therefore fetching high prices.

Ukerewe environment is conducive for cattle, goat, pig, ship, poultry, duck, and rabbit husbandry. Because of high human population density, semi free range grazing and zero grazing is the common practise of livestock keeping. Livestock and their products (especially milk, eggs and chicken meat) are highly marketable and this has risen due to increasing population. It can therefore be concluded that livestock keeping is an activity with a reliable market and assured income for the district population. However, it is generally a household activity characterised by small low yielding herds of indigenous breeds. These include cattle, goats, sheep, pigs and poultry, ducks and rabbits. Exotic breeds of dairy cattle and dairy goats have also been introduced to improve animal production in the district, but poor veterinary services impede the survival of the animals. For example, all 16 dip tanks located in each ward have not been working for over past ten years and this is reported to be due to lack of funds for daily operations.

In addition to agriculture, fishing has recently (since late 1990's) become one of the major economic activities. Fishing has a significant contribution to the economy of the district through taxation and direct income to community members. Although there are problems of availability of comprehensive fish catch data, few data accessed during this study (Table 2) indicate higher potential of the fisheries sector in the economy of the district. The fishery potential of the Island is both for artisanal and industrial fishing. Artisanal fishing is limited to near shore water and boats or canoes propelled by paddle, sail and small outboard engines. Ukerewe District Council (2007) estimated that about 19,000 people depend partially on fishing and/or fish trading. Fish from artisanal fishing is used for subsistence to satisfy the local market and currently, processing industries are accessing the Island for the fish. Major types of fish include Nile perch, Tilapia, sardines, *Haplochromis* sp, Schilbe, *Synodontis* sp, *Bagrus* sp and *Labeo* sp. The water also is a habitant for wildlife resources. Examples of such wildlife are hippopotamus and crocodiles in sheltered bays, birds and small mammals. Assessment of these natural resources for potential income generation has not been done and no arrangements have

been done to tap the resources as major income generators. These animals can equally provide opportunities for tourism. The islands has good sites for recreational activities like sand beaches and some historical sites which unfortunately have not been promoted.

Table 1: Trend of crop production (tons) in the Island from 1976/77 – 2003/04. Both cash and food crops are provided for different years

CROP / YEAR	1976/77	1977/78	1978/79	1978/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/2000	2000/01	2001/02	2002/03	2003/04
Cassava	23057	72609	36290	16390	37240	42888	97180	39900	57360	44131	46440	16500	50628	23176	25538	28650	42860	47046	31543	28971	35509	21104	67229	71525	69093	58420	54143.4
S/Potato	11200	30345	8693	10673	14844	37476	59012	50036	45750	51040	54810	13157	12474	14094	17136	20810	32200	32486	24182	25100	22776	9558	28934	30124	29808	29290	22209
Rice	1222	3415	4457	467	526	1535	1459	1527	2291	3051	3605	3240	3398	4435	3326	3300	3700	7882	2503	2471	18554	463	990	13169	16243	10746	4219.2
B/Millet	520	264	1220	217	322	452	762	641	987	524	564	512	1376	1000	1249												
Maize	1507	891	861	562	570	584	687	674	706	694	704	522.6	1016	2300	2425	6450	6700	7588	1707	1451	9488	2523	3826	8360	8436	21648	26041.6
Sorghum	272	110	430	250	400	240	207	276	440	401	385	146	1000	950	700												
Legumes	970	356	255	140	195	484	288	326	488	764	754	793.4	911	1896	1517	420	375	548	772	549	1400	165	1182	1454	1275	2498	1705
Finger millet	-	-	-	-	-	-	-	-	-	147	-	89	180	-	-												
Sorghum/millet																910	385	601	1458	862	584	103	294	315	277	67.5	105
Tangerine/oranges	47200	47800	51800	64500	48500	49800	51000	47800	55000	52100	50900	71050	75550	78100	80500	56950	57500	58800	64200	72100	78700	72400	73700	74000	74100	74050	74050
Lemons	2750	3400	2480	3500	2950	2500	2675	4000	3700	2750	3000	3500	2810	2950	3200	2890	2920	3010	3600	5020	6550	6700	6800	6500	6100	6050	6050
Mangoes	22100	18500	24000	20500	21500	19800	18700	15000	14200	13800	12500	13750	11800	13600	10600	12220	11930	11740	11390	11060	10725	10210	11440	11200	10850	10420	10380
Pineapple	370	260	390	430	410	510	490	345	400	510	475	670	700	610	585	690	650	620	520	310	325	320	330	300	350	300	290
Cotton	1962.4	1530.9	1262.5	1809	1578.4	1315.98	1395.9	1409.9	452.52	1177.2	1514.7	1458	1292	117	1352	145.8	105	177.6	186.9	293.8	63.6	46	17.2	4	10	9.5	1.886
Coffee	75	64.6	41	51.3	21.2	41.7	82	92.8	91	92.5	88.4	98.6	97.2	75	81.8	164.6	170.8	174.2	64.1	174.5	163.2	6	22	24	55.1	151	155

Source: Ukerewe District Council, 2007

Table 2: Ukerewe fish catch statistics and financial values (in millions of Tanzanian shillings) for a period between July 2005 and August 2006 (source: IMFP-TAFIRI)

	Nile Perch		Cyprinid		Tilapia		Haplochromis		Others*	
	Tons	**Value**	**Tons**	**Value**	**Tons**	**Value**	**Tons**	**Value**	**Tons**	**Value**
Jul-2005	1520	1655.9	6553.4	9830	134.3	65.5	3123.3	406	16.1	11
Aug-2005	1648.8	1833.5	4206.9	6226	151.1	67.4	1111.4	147.8	26.3	16.5
Sep-2005	1630.2	1812.8	8317.8	12310	151.8	67.7	2943.5	391.5	17.4	13.1
Nov-2005	3087.2	3451.5	7724.9	8965	454.9	216.8	763.1	77	309.7	199.1
Mar-2006	2357	2083.8	10008	11920	577	291.4	52	7.3	288	129.5
Aug-2006	2426	1738.4	620	960	1049	629.4	316	37.6	95	73.6
TOTAL	**12669.2**	**12575.9**	**37431**	**50211**	**2518.1**	**1338.2**	**8309.3**	**1067.2**	**752.5**	**442.8**

*Protopterus, bagrus, synodontis and clarias

1.2.4 Energy use, sources and requirements

Natural forests have been the major source of charcoal and firewood for many years whereas plantation forests have been supplying timber to the Island and beyond. Ukerewe District Council (2007) estimated the sustainable use of wood from forest to be 389,870 m^3 per year. However, the estimated annual firewood requirement is 720,000 m^3. This requirement is expected to increase as the population increases and the fuel wood is likely to remain the major source of energy for cooking in both urban and rural areas. Kerosine is the main fuel for lighting purpose (kerosene lamp). Electricity from the national grid has recently (2005) been connected to the Island and is being used in Nansio (the district capital) and few trading centres along the transmission lines, mainly for lighting and powering small business machinery and office equipments. Although rural demands for electricity are very high, there has been a slow electrification process in the area. High electricity charges have also hindered villagers to access the electricity energy. There are also own initiatives to access solar electricity for lighting purposes in some households in villages although this alternative energy is similarly affected by high installation charges.

1.2.5 Water resources

Two major sources of portable water in Ukerewe district are the Lake Victoria and groundwater. Seasonal rivers, streams and rain water harvesting are also used by few inhabitants. Although communities can easily access the lake, there is limited infrastructure to provide quantifiable clean and safe water for domestic use. Ukerewe District Council (2008) reports that only 58,300 inhabitants of Ukerewe district are getting safe and clean water and the remaining majority of villagers depends mostly on traditional shallow wells, which are exposed to contamination due to lack of protection from external influence.

The Lake also provides major transport routes to the islands and other districts. This is facilitated by a good number of private and government owned vessels. Ukerewe district is connected to Mwanza by a number of ships and to Mara region by a ferry and these are the major entry and exit routes. The movements within the islands are by small powered boats and/or canoes which complicates transport networks and

movement of commodities among different islands resulting in higher prices of commodities originating from outside the district. The use of water resources for irrigation is not developed except for three government schemes, of which only one is operating.

1.3 Objectives

The objectives of this study were based on the climatic change impacts that have been observed in the Lake Victoria region. The changes have significantly impacted communities, especially those who have been dependent on agriculture and fisheries as their major livelihood activities. The effects of climate change has already exemplified itself in different ways including periods of prolonged drought and unpredictable seasonal weather patterns which have triggered some ecological changes. The changes include declining fish stock, emergence of invasive plant species in the Lake Victoria, excessive algal bloom, eutrophication and declining crop production due to pests. As these changes take place most communities has become destitute with no reliable economic and an assured food providing activity. Therefore, our major task was to facilitate the involvement of communities in creating awareness on climate changes, identifying and understanding community problems and their association to climate change and suitable adaptation strategies for the community. The communities involved represent those affected by the changes in the region which need coping strategies. The following are the objectives under which this study was implemented;

1. A list of practiced adaptation strategies by the communities around the lake
2. Inventory of problems and impacts of climate change and ways through which have affected the livelihood of the communities in the two districts.
3. Feasible and sustainable adaptation strategies for communities support to their livelihood
4. An ongoing dialogue with local community leaders, the NGOs/CBOs and representatives sharing knowledge on climate and climate-related impacts to livelihoods
5. A link enabling regular communication between communities and local government authority that will enable better policy formulation.

2.0 STUDY METHODS

2.1 Meteorological information

This study was initiated by accessing important climatic information from the Tanzania Meteorological Agency (TMA). Rainfall data from fifty two (52) meteorological stations located in the four administrative regions (Kagera, Mwanza, Shinyanga and Mara, on the Tanzanian side) bordering the Lake Victoria were accessed. Among these, included four synoptic stations, one from each of the regions where in addition to rainfall, temperature and evaporation information were also obtained. The Meteorological information dates back to 1920's for some stations and at least all stations provided information for more than the past forty (40) years. The data collected were compared with communities' narrative explanations, physical evidences and ecological effects which are associated with direct and indirect meteorological changes.

2.2 Community visits and information gathering

Preliminary general information defining the district was gathered from the study area. These included population and demographic information of the district, major activities of communities, potential of various sectors like agriculture, fisheries and animal husbandry. Medical information over the past years was also accessed for analyses.

This study was conducted in three villages namely Hamkoko, Busiri and Muhula which have a population of 5286, 3349 and 4,026 inhabitants respectively. Major methods of data collection were meetings, workshop and discussion groups. Narrative stories from individuals were documented from community members by video and text recording. Gathered information was authenticated by physical evidence where possible, discussions among members and crosschecked by meteorological information together with information on climate related events. A total of six visits to the communities were done over a period of eighteen months successively to include;

- major activities of the communities,
- narrative documentation from the communities' understanding of the existence of climate changes and their consequences to their daily life.
- supporting incidences or physical evidences of climate changes known to the community
- vulnerable systems and potential/opportunities fo adaptation
- adaptation strategies and prioritization

2.3 Climate change issues

Communities' awareness of the existence of climate change in the region was primarily explored from communities. Communities' testimony of the existence of various livelihood problems, time duration of existence in communities and various solutions or alternatives that have been employed in alleviating the impacts were the major elements for exploring community awareness of the existence of climate change. The relationship of the problems to causes was also necessary for understanding of natural and manmade impacts. Since evidence for most of climate change impacts and the existence of climate change itself were historical, physical evidences comparing past situation and the present were very useful. Due to this, it was necessary to consider age differences. While both youth and old people may have

similar knowledge and understanding of the existence of climate change, the baseline for acceptance of existence of climate change was different over their life history.

2.4 Impacts and identification of vulnerable systems

This was done through discussions where communities identified changes and the consequences to their environment and livelihood. Communities identified vulnerable systems in relation to their livelihood activities. These included water sources, energy/fuel (wood fuel), agriculture (cash and food crop production), fisheries and land fertility. Resilient and most vulnerable systems were identified in accordance to the levels of impacts. The impacts to the systems were measured by comparison of the current status and past status from records identified by communities. Occurrences of extreme environmental status indicating anomalies and their estimated time of occurrence were explored were also explored.

2.5 Prioritisation of adaptation strategies

After the identification of vulnerable systems as explained above, prioritisation of adaptation strategies in reference to the impacted systems were therefore needed. Various impacts to communities were established through discussion where each village community identified priority areas and methods or adaptation actions against the impacts (first, those which affect them most followed by those with less impacts) to their daily livelihood. Information from the three village communities were compared with those from the three communities.

2.6 Ecological changes

The ecological changes were assessed by site evaluation of important ecological areas. These included; shoreline structure, river flow and catchments status and deforestation rates. These assessments were based on the evidences given by communities indicating changes which have been taking place and the time of occurrence. Therefore, historical information was necessary for establishing changes and their effects to various ecological systems.

2.7 Model applications

Model applications have become a major tool in understanding past and future climate. Various models have been developed by different researchers to suite different geographical locations as well as different spheres and associated interactions. The accuracies of these models are also different depending on the input parameters so as to enhance their prediction accuracy and more researches are now being concluded based on models outputs. 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 Fennessy, 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 and Stier *et al*., 2005.

In this study, model outputs were considered for exploring regional climate especially for parameters not detected by direct observations. Data derived from eleven downscaled GCM were downloaded from the Climate Systems Analysis Group (CSAG) of the University of Cape Town, which has been used for presentation of various scenarios as displayed by Climate Change Explorer (CCE) interface developed by the CSAG. Different models provided varying output trends.

2.8 District administrative plans

A summary of findings from the communities was submitted to the district administration for exploring planning strategies on different issues identified. The report summarised four items on which the research was based on. These were;

i. Evidence for existence of climate change in the region
ii. Problems arising from such changes
iii. Techniques used for solving the problems
iv. Needs which are out of communities' reach requiring external support

The district administration addressed the issues to communities representatives and members of FAPOEL Non-Governmental Organisation by presentations in a workshop and explained government plans towards providing solutions to the problems of different sectors namely, agriculture and livestock, fisheries, forestry, general community development and the water sector.

3.0 STUDY RESULTS

3.1 Indicators, impacts and vulnerable systems

It was observed that communities had a clear knowledge of the existence of climate change in the study area and cited the following major indicators which can be classified as climatic and non climatic;

1. Climatic indicators

i] changes of spatial and temporal distribution of rainfall
ii] scarcity of portable water
iii] disappearances of some fish species
iv] periodical changes of the Lake Victoria water level and its quality
v] diminishing trends of crop production and emerging crop diseases

2. Non-climatic indicators

vi] declining forest cover
vii] general loss of biodiversity indicated by the disappearance of some organisms.

These seven indicators were universally accepted by community to have occurred and some are still occurring. The major concern of the communities was the effect to their livelihood.

Different livelihood activities were identified being vulnerable to climate change impacts in the communities. The sensitivity of communities to the impacts is high whereas the adaptive capacities have been found to be low mainly due to poor economic capacity of the communities and the district government as outlined before. Therefore, our observation was that communities' adaptations to the raised impacts were generally hampered by poverty. Apart from the above indicators observed in this study, there are other factors which are linked to these but are causes or outcomes of the above and are directly or indirectly linked to human activities. These include;

i] population growth
ii] deforestation
iii] loss of soil fertility
iv] water pollution especially eutrophication in the Lake Victoria
v] over fishing

Others included social problems like poverty, poor health system and lack/poor infrastructures have also been observed to exacerbate communities' exposure to the impacts. Based on these, it can be summarised that the climatic impacts were found to mostly affect, agriculture related activities, fisheries and water resources in the district. The summary is given in table 3 below together with associated factors.

Table 3: Summary of affected systems and associated factors as identified by communities

Affected system	Associated factor(s)
Agriculture	Rainfall, pests, diseases, soil fertility
Fisheries	Rainfall,
Water sources	Rainfall, population
Wood fuel	Population, deforestation
Livestock keeping	Population growth
Lake water quality	Rainfall, fishing practices

3.2 Water systems

Rain scarcity has affected communities' water availability which depends mainly on flowing water i.e. rivers and springs. The scarcity of water is known to have been taking place over a long time. Changes of rainfall pattern were indicated to have affected large part of the Island communities. It was indicated that, Ukerewe island used to enjoy more rainfall frequencies than it is today. This historical account was referring to climatic conditions dating back to the 1940's (narrated by people of over 70 years old). To support this, it was indicated that, in the past the 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. This has increased rainfall scarcity and therefore, affected the availability of portable water sources.

The Island mostly depends on two types of water sources for domestic use; lake water and shallow wells. All three villages involved in this study have unreliable water sources with little capacity to support the existing communities' population. Evidence show that more and more traditional water sources (wells) are drying and those in operations have reduced water flow rates. The lake water likewise has become of poor quality for domestic use mainly due to eutrophication and algae bloom which has long been proven (Awange and Ong'ang'a, 2008; Verschuren, 2002). Due to such problems, villagers have resorted to private shallow wells which unfortunately are poorly constructed, with no protections to ensure good quality water as shown in figure 2. Such wells were found especially in Busiri village where community villagers used to depend greatly on the lake water. However, due to deterioration of lake water quality they have resorted to private wells. The private wells are seen as an adaptation strategy. This strategy is however not a success due to the quality problem and family safety problem especially to children since the wells have been causing falling accidents to household members. The villagers indicated to have requested support from the government to facilitate construction of wells but these have not been successful. On the other hand, government support has been reported to be limited by available resources and the little support which has been observed cannot suffice the water requirement of the communities. Figure 4 is a typical example of the only government supported well at Muhula village (population of 4,000). The well is serving the demand of a large village community beyond its capacity leading to daily water rationing.

Figure 2: A private water source (left) constructed within a living compound for household use. On the right is a woman drawing water from one of the wells in Busiri village.

Figure 3: Bukanda river which has changed from the second largest river in the district to a small channel with vast dry valley is now used for agricultural activities and as pasture land. The picture shows a paddy farm in March which is the beginning of heavy rain season.

Rainfall scarcity has similarly affected the ecology of the Island. Wetlands which were valued areas for agriculture during dry and wet seasons can no longer provide such support. The loss of wetlands has taken place together with the loss of traditional water wells. On the other hand, the trend of population growth of the district (3%, according to the 2002 National census), may also have contributed to increased population pressure on the wetlands especially with increasing demand of arable land for agriculture and livestock keeping. The use of wetlands for agriculture on the other hand may be viewed being triggered by the rain scarcity problem. Highlands became less productive due to rain scarcity and lowlands including wetlands became the alternatives. Wetlands were invaded for agriculture and other activities due to their high productivity. This investigation observed wetland areas which are currently used for agriculture although available documents do not provide documentation to prove the previous size and status of such areas. However, based on communities' narrations, those which used to be permanent wetlands have now become seasonal,

filled with water during the rainfall season. A prominent example is the Bukanda river (Figure 3), the second largest river which has now lost its annual flow rate.

Figure 4: Water collection has become one of time consuming activities. Here, women of Muhula Village queuing for water from one of the public constructed wells. The well is supervised by the village authority.

3.3 Disappearances of fish species

From documented scientific information, 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 (1970's) which affected selected species like *Haplochromis* spp. Communities indicated that almost all species (over 150 species) of Haplochromis declined to insignificance between 1970's and mid 1980's, 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. A typical example was the disappearance of *Alestes* spp. and *Momyrus* 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 abnormal weather pattern. 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 and this is linked to wetlands. The unreliability and scarcity of rainfall which was mentioned might have affected the availability of running water and consequently poor species reproduction. Generally, communities had an understanding that as the numbers of wetlands were affected, clarias population was similarly affected.

The disappearance of *Alestes* was also not associated with the appearance of nile perches in the Lake Victoria. This was highly emphasised because *Alestes* spp. was one of the preferred delicacies of the communities, easily fished and of reasonable abundance. The species disappeared between the late 1960's and mid 1970's, before

the appearance of perches. The reason that led to the species disappearance was related to the heavy rainfall of between 1960 and 1962. The rain led to the collapse of the species based on the theory narrated by the community members, linking the effect of the 1960's heavy rainfall to the increase of Lake Victoria water level that flooded the lakeshore that used to be covered by cyperus plants (*Cyperus laevigatus*) The increase of water level can be viewed in figure 5. These plants were known for providing natural feeding grounds and refuge sites for the species. These plants were endemic and as the water inundated the Lakeshores, the plant ecology was disturbed and disappeared. This was an unfortunate weather event which caused significant impacts because the new water level formed after the rainfall became permanent and has been decreasing slowly offering no possibilities of ecological recovery. From figure 5, even after the recent lake water recession, the current level does not match to the pre 1960 water level. However, recent observation during this study, shows that this species has re-appeared in the Lake Victoria, although not at the pre 1960 quantity. This may be considered a come-back following the recent water recession although during this study, the ecological sites which were referred to by the community were not observed to have re-appeared. This may also be a recurrence phenomenon that needs another biological investigation which is beyond this study.

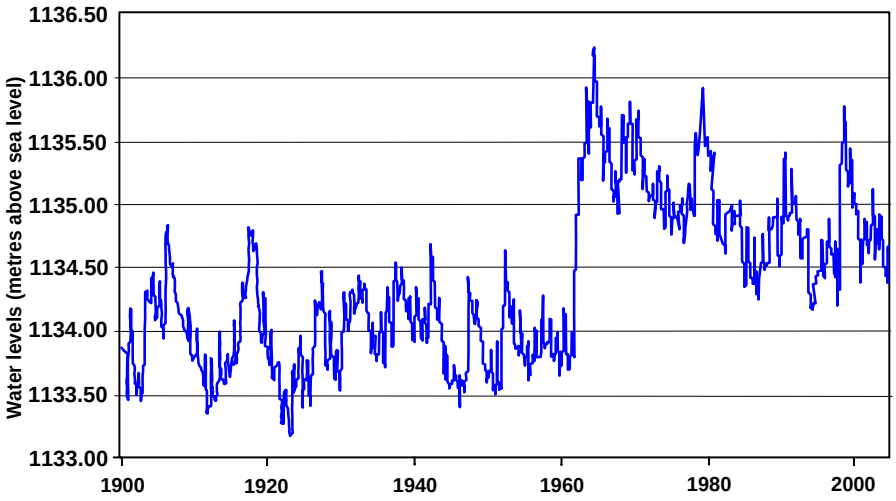

Figure 5: Historical water level fluctuation of lake Victoria recorded at Jinja station. A sudden change of water level occurred in 1960's following a referred heavy rainfall. (Figure from Lake Victoria basin commission special report on the declining of water levels of lake Victoria, 2006)

Figure 6: Impounded illegal fishing nets in front of the Magu district fisheries office. Fish shortage has encouraged rampant illegal fishing techniques in all riparian countries. Gears like these are normally destroyed by the authority.

Fishermen in these communities have shown behaviour emergence of deliberate use of pesticides and unauthorised fishing nets in the fishing activities which is seen as an adaptive survival strategy to sustain themselves with economic hardship as well as food shortage after the normal traditional fishing gears have failed. As these practices become common, government enforcing bodies are in constant conflict with the communities, impounding illegal fishing gears and sending culprits to court for legal procedures. Village communities are also in constant conflict with those using poison fishing. It is unfortunate that these practises are taking place in the whole region of Lake Victoria in all East African countries bordering the Lake. Although communities were informed of the danger of such practice, it was observed that the sustainable solution should be related to empowering fishing community with the capacity to legal fishing methods.

3.4 Water level fluctuation and ecological change

As outlined earlier, the Lake Victoria water level has been changing. However, communities reported two significant level changes, the first one happened in the 1960's and the second change of 2005. In 1961/62, the water level increased affecting even the geography of the district islands. During this investigation, it was reported that before 1960's the distance between Ukerewe island and the mainland on the eastern side was less than half a kilometre. The impact of the reported heavy rainfall was the inundation of part of the Island dry land making the water pathway between the Island and Mara region in the eastern to be more than three kilometres. Since then, it became necessary to have sophisticated transport vessels between the Island and the mainland in the eastern and thus increasing transport costs. The major factor which has influenced the water level decrease is mainly inadequate rainfall over the period. However, various human activities were noted being undertaken in low-lying areas which are important for the lake inflowing water. These activities especially agriculture have increased water abstraction denying the Lake from receiving additional water through rivers.

The recorded trend in figure 5, indicates that the 1960's rainfall affected the water level significantly from a baseline level of less than 1134 metres above sea level (asl) to maximum level of over 1136.50 metres asl. From 1960's to 2005 when another significant water level decrease was observed, the lakeshore changed its ecological characteristics long enough to have new ecological baseline characteristics. Wetland plants like *Cyperus papyrus*, have been permanent features of the lake Victoria shores. This investigation observed that papyrus have disappeared significantly leaving fertile dry land now under agriculture. The disappearance of papyrus has also affected breeding grounds and refuge for various fish species. Like many wetlands, papyruses were important water filters, retaining most of the land particulate matter flowing into the Lake. It was observed that turbidity has increased along shores waters. Communities testified that shore waters have become unsuitable for direct domestic use and therefore, dependent on wells as alternative sources of portable water. The lake shore is also being affected by the invasion of ambatchi plant (*Aeschynomene* sp.) which is now growing at a fast rate making it a possible next ecological nuisance. It is not clear why this plant which has been moderately growing in some parts of the lake shore is now massively spreading in almost all open beaches in the Island. This can be associated with high plant nutrients which have been reported in the lake (Verschuren, 2002).

3.5 Loss of biodiversity

The disappearances of fish species from Lake Victoria which is cited above is one of the examples supporting the climate change impacts to the biodiversity of the region. Climatic changes have also affected other biodiversity in the district and this was supported by historical events narrated by communities. Organisms like locusts and birds were good indicators of the communities to testify the existence of climate change. Locusts are no longer a nuisance in the region as was in the past (in the 1930's and 1940's) where swarming events of green locusts were common. Ukerewe district has also lost birds like cranes which were endemic in the islands. Similarly the collapse of banana and coffee plantations was reported and associated with increasing dry months than wet months.

The disappearance of organisms which were previously abundant in this area may have been contributed by the destruction of their natural habitants and other biological sensitive parameter which are always not easily detectable. The effect on forest cover has aggravated the problem by exposing wild animals and depriving them of their natural habitants. Wild animals like monkeys have reportedly showed adaptation to different crops for example oranges and some green vegetables as a result becoming new pest animals. In this case therefore, these organisms have become useful indicators of the changing environment to the community. How fast the communities detect the existence of changes depends on the importance of the affected system. For example, repeatedly, communities mentioned the emergence of cassava mealy bug disease and the collapse of banana farming because cassava and banana were the major food crops in the district. The destruction of these crops especially cassava has left many families at the verge of hunger disaster and this is considered in respect to agriculture which is one of the sensitive systems. Other changes like disease emergence (cholera in 1970's) could not easily be explained

due to lack of proper documentation from the district government hospital. In general, these changes (except the disappearance of locusts) impacted on the communities negatively.

3.6 Energy/Fuel problem

The energy problem was found to be another major factor affecting communities. The major energy need is for cooking purpose and the main source has been forests. The main energy source in the Island has been and is still wood and charcoal. Wood is the fuel source used in villages and charcoal is predominant in town and small business centres. Available information indicates that in the past, Ukerewe island exported charcoal and other wood products to Mwanza city and other regions in the Lake zone (no particular figures are available). This has resulted in district land cover change from evergreen with thick mountainous forests to bare hill-lands (for example Figure 7), which has led to shortage of firewood. Although wood and charcoal are still the main source of energy for domestic use in the Island, poor quality of wood which is currently available is exacerbating other social problems, worsening the village life. Figure 8 shows a typical example of poor quality wood for cooking currently used but of low biomass values and therefore, tasking women and children to spend longer time in collecting wood and cooking activities (as part of their social responsibility). Unexplored health consequences may exist due to prolonged exposure to kitchen smoke among women and children. Due to this problem of wood shortage, fruit trees like mango and orange trees are being used as sources of firewood in some areas. Figure 9 shows a typical example of mango trees chopped down for firewood. Although communities indicated the clear importance of such fruit trees for their livelihood, cutting such trees for firewood has become inevitable because of lack of alternatives. The loss of forests is not directly linked to the changes in climatic conditions, but the effects of climate change can be linked to poor regeneration rates of some previous forested areas.

Figure 7: Bare hill-land observed from the lake showing stony land after heavy deforestation for wood fuel, typical situation for most part of the Island.

Figure 8: Young girls arriving in the late evening from wood collection as part of their daily family supporting activity.

Figure 9: Felling of trees includes useful trees like these mango trees which have survived for many decades, some for centuries, chopped mainly for firewood demand.

3.7 Crop productions

Production pattern of crops in the Island indicates that there have been successive changes of the main food crops. In the 1920's, the main food crop was finger millet which was then succeeded by bulrush millet which became a major food crop for a long time. In the early 1940's the colonial government introduced cassava as the major food crop. The introduction of cassava was meant to save the Island's population from frequent recurrence of hunger following the falling harvest of bulrush millet from one year to another, necessitating the need for large farms as population increased. Although the Island communities resisted accepting this alternative, the introduction was done forcefully. Cassava proved to be a drought resistant crop with high productivity per area and became a staple food in the Island supporting large communal families.

This study found that in recent years, cassava production has declined following the emergence of pests and diseases. Communities indicated that the appearance of the cassava mealy bug disease in the 1980's destroyed the crop production and this has

continued until recently (in 2000's), when the disease was eradicated by biological control. However, another disease has recently appeared which has not yet been identified. The district authority has also reported the existence of this disease which attacks cassava tubers and scientific investigation is still underway to identify the disease simultaneously with identification of the disease resistant strains of cassava. The current fear within the communities is the return of hunger due to lack of assured future alternatives. At present most families are currently, experiencing food shortage.

The major cash crops of the Island up to early 1980s' were cotton and coffee. The Island ceased to produce cotton because of high production cost and lack of reliable markets. High production cost was due to various changes including pesticides and fertiliser requirements which became inevitable due to the appearance of pests, diseases and poor soil fertility, respectively. During this study, it was evident that prolonged periods of drought contributed to poor cotton production as well. Currently, the Island does not have a specific cash crop for communities except fruit production (oranges and mangoes) which are also under explained in section 3.6. Other fruits like pineapples and tangerine also contribute to the total fruit production mostly transported outside the Island as commercial crop. Although this Island is still the main producer and supplier of fruits to other parts of the lake zone, other demands particularly increasing population and consequent land requirements for food crop production are threatening this potency.

The trend of production of almost all crops is generally decreasing and this is testified by all communities which were involved in this study. One clear indication is that there is poor statistical data collection. For example, this investigation failed to access historical fisheries production trend in the Island. Similarly, although table 1 indicates crop production for over the past thirty years, the values cannot be authenticated as they do not reflect the general public assertion that crop production is decreasing. The table values also do not portray the real crop yields which are found to have no specific pattern. With the cultivation of cassava, the drought resistant crop, the current decreasing rainfall would have not significantly impacted the community had it not been the emergence of pests and diseases. To some extent, lack of reliable rainfall is considered a factor that has exacerbated susceptibility of crops to diseases. Other crops like rice and sweat potatoes have also been affected by droughts since they require high soil moisture content. Communities like those of Busiri and Muhula villages are close to the lake where irrigation fed agriculture could be the best alternative. However, lack of capital for the schemes has hampered their efforts regardless of the motivation to do so among the communities.

4.0 METEOROLOGICAL INFORMATION

4.1 Rainfall trends and variations

The analyses of meteorological information helped to further authenticate issues raised by the communities on the existence and effects of climate change. This information improved our interpretation and understanding of climate change impacts in the area. For concise evidence, weather parameters like rainfall, temperature and evaporation from different stations in the region have been analysed over the period in question. From this investigation our observation indicates that communities presented the changing rainfall pattern being especially referred to as the most important parameter that has mostly negatively affected their livelihood both in the past and in recent years. Figure 10 below indicates the coinciding Lake water level variations with that shown in figure 5 where peak values of lake water level coincided with the period when rainfall in the three regions surrounding Lake Victoria, i.e. Mwanza, Musoma and Bukoba was also at its highest intensity. This was clear evidence that indeed, the heavy rainfall of the 1960's was the major factor that affected the water level. Similarly, like the water level, since then there has been a decreasing trend of rainfall in the region.

This influencing factor is further observed from Nansio meteorological station, a station within the Island (Figure 11) indicating that between 1950 and 2004 the peak rainfall value was recorded between 1961 and 1962. This implies that in the Lake Victoria region, there was an increase in rainfall pattern as was narrated by the communities and since then there has been a decrease in rainfall. Whereas the increase in rainfall of the 1960's was considered abnormal based on the history before that, the change that has recently taken place is not considered by communities to be an abnormal event. This is because the communities had reservations that what has happened on the water level (recession), is a normal change to the level of the lake which existed before1960's. The community may have correctly submitted the argument however, the concern of this investigation was the rate of water level decrease. Officially this was also linked to the hydroelectricity dam project in Uganda and the drought problem in the region. This was therefore an abnormal event linked to climatic changes.

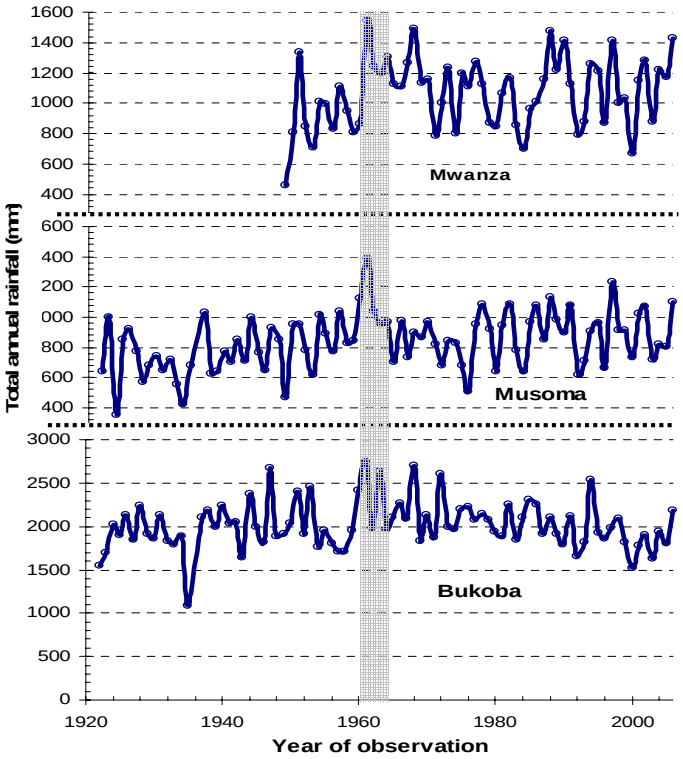

Figure 10: Total annual rainfall trend from 1922 – 2006 (Bukoba and Musoma stations) and from 1949 – 2006 (Mwanza station). Note the difference in scale.

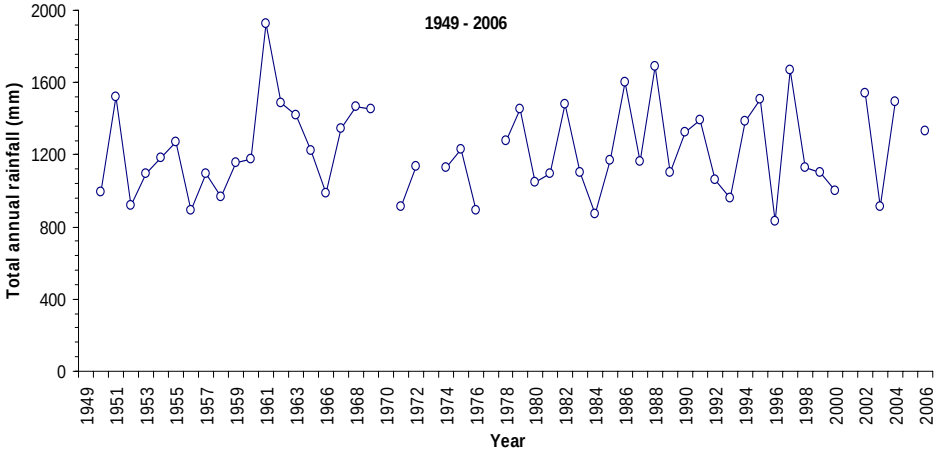

Figure 11: Total monthly rainfall recorded at Nansio station from 1950 to 2004 with average trend line of rainfall pattern. Average total peak value was recorded in November 1961.

Table 4 shows monthly average rainfall in two stations in Ukerewe district calculated by averaging the total monthly rainfall from 1949 – 2006 (Nansio) and 1958-2006 (Rubya). The data indicates that June, July, August and September received less rainfall than other months as was also testified by the villagers. Also the data shows the East – West rainfall increase where Rubya station (in the western, lat. 1º43´S; and

long. 31º 37´E) had higher recorded rainfall than Nansio station (in the eastern lat. 2º 07´S; and long. 33º 05´E).

Table 4: Monthly average rainfall (mm) at Nansio (1949-2006) and Rubya (1958-2006) stations in Ukerewe island.

Month	Nansio station	Rubya station
January	128.9	146.6
February	118.6	132.5
March	161.7	191.3
April	205.1	249.2
May	121.0	124.0
June	24.2	31.7
July	15.8	20.6
August	23.6	38.7
September	34.0	49.0
October	75.3	122.0
November	157.7	207.6
December	168.1	204.9

The analyses of rainfall patterns data of the two stations in the Island (Rubya and Nansio) were correlated with communities' narrative information. We explored the rainfall patterns for different seasons for about 50 years and anomalies which have existed. The anomalies were calculated as measures of divergence of the total monthly rainfall values from monthly averages (Figures 12 a and b). Rubya station (Figure 12 a), is observed to have recorded more rainfall above averages from 1958 to 1967. This trend is more visible during rain season (March – May) and short rain season (November – February).

The general observation indicates that during the rainy months (January, February, March, April, May, November and December) from 1958 to 1965 there was increased rainfall, above monthly averages (positive values). The pattern changed to negative values below the averages after 1965 including months of heavy rainfall (i.e. March, April and May) especially from 1970's to 2003 and March, May and December, between 1978 and 1980 to 2006. Decadal variation shows the trend of increasing monthly rainfall and from 1988 the decadal average of March was above the average. Although the dry months (June, July, August and September) do not have significant contribution to the total annual rainfall, the divergences were on average negative as indicated by the decadal trend line.

Figure 12 b presents anomalies trend for Nansio station. Unlike Rubya station this presents an insight of the rainfall condition even before 1958. In deed, the trends support the observation that the heavy rainfall of 1960's was abnormally higher compared to years before and after. Although Nansio station was normally recording relatively less rainfall compared to Rubya station, the recorded rainfall at this station was higher significantly to show the abnormal rainfall during the period. During this period the divergences seem to have been affected by the heavy rainfall which showed that, most years before and after to have received below average rainfall especially during heavy rainfall season i.e. March April and May compared to months of little rain occurrence. This also implied that although, generally, the area received heavy rainfall, the incidence was prominent during heavy rain

seasons. Dry season did not show significant difference when compared among different years.

The scarcity of rainfall and its association with poor crop production was frequently cited by communities as a consequence of the changing climatic conditions. It became evident that in most cases, communities cited crop destruction as indicators of climatic changes. This is because agriculture is the major activity for communities' livelihood. Although this is associated with other factors like emerging diseases and pests, rainfall was considered the major weather parameter affecting crop production as well as a factor that aggravate vulnerability of their crops to diseases when they are scarce. Our graphical presentations show various occasions in different years where there have been negative divergences. Consistently, the negative trend appeared between 1970 and 1980 during rain season i.e. March – May and November – January. Communities cited this being a period in memory that the Island and the Lake Victoria region at large suffered serious food shortage due to low rainfall in the region. It can therefore be interpreted that there is seasonal sensitivity of the impacting factor. Although there were several incidences of negative divergence, there was a particular season when communities suffered most from the impact of rain scarcity. For communities in the Lake Victoria region, the negative divergence observed between June and September does not seem to show any impact to the communities' since this is not a growing season of the region

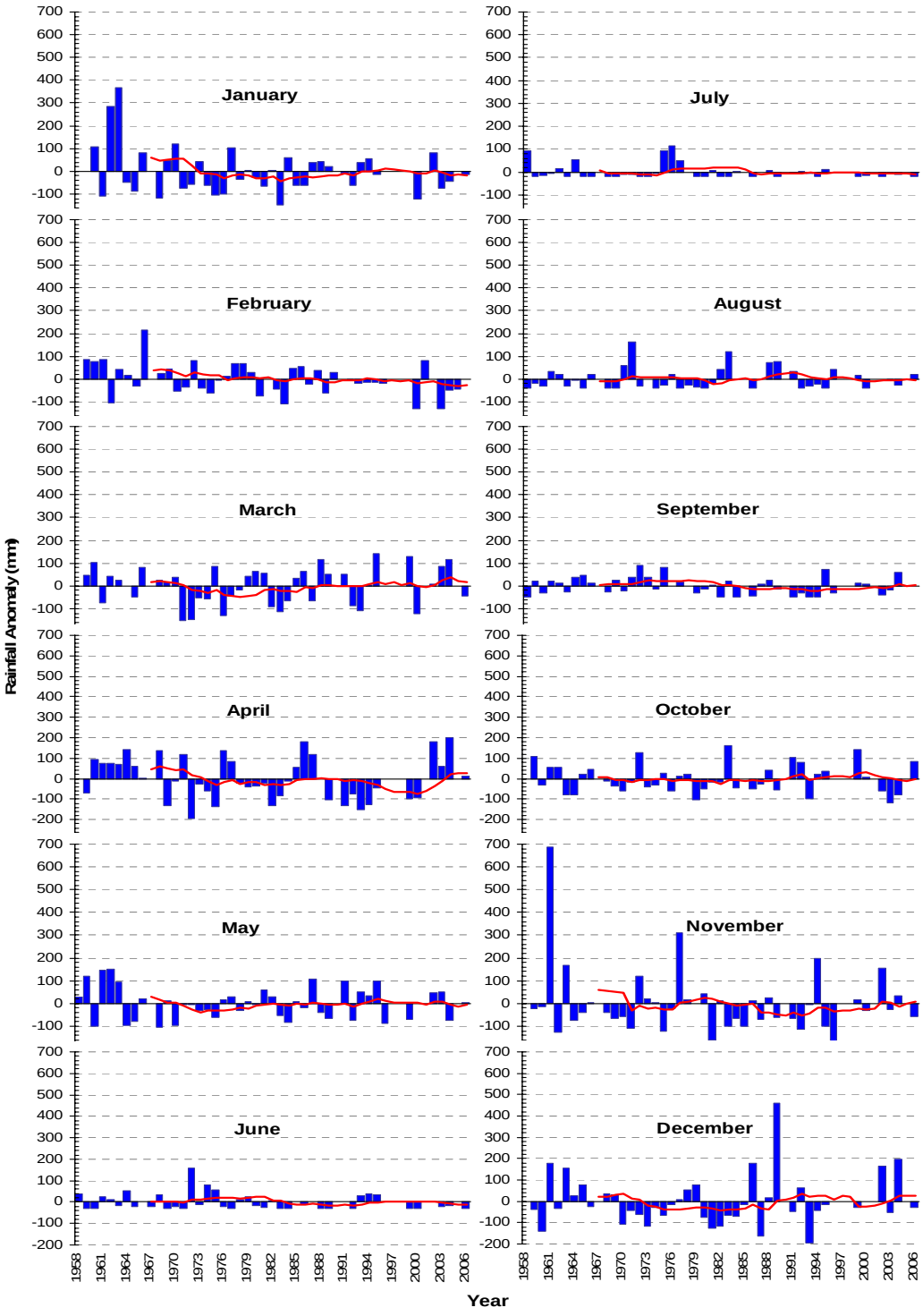

Figure 12 a: Rubya monthly rainfall anomalies (1958 – 2006). The solid line indicates decadal rainfall (mm) variations.

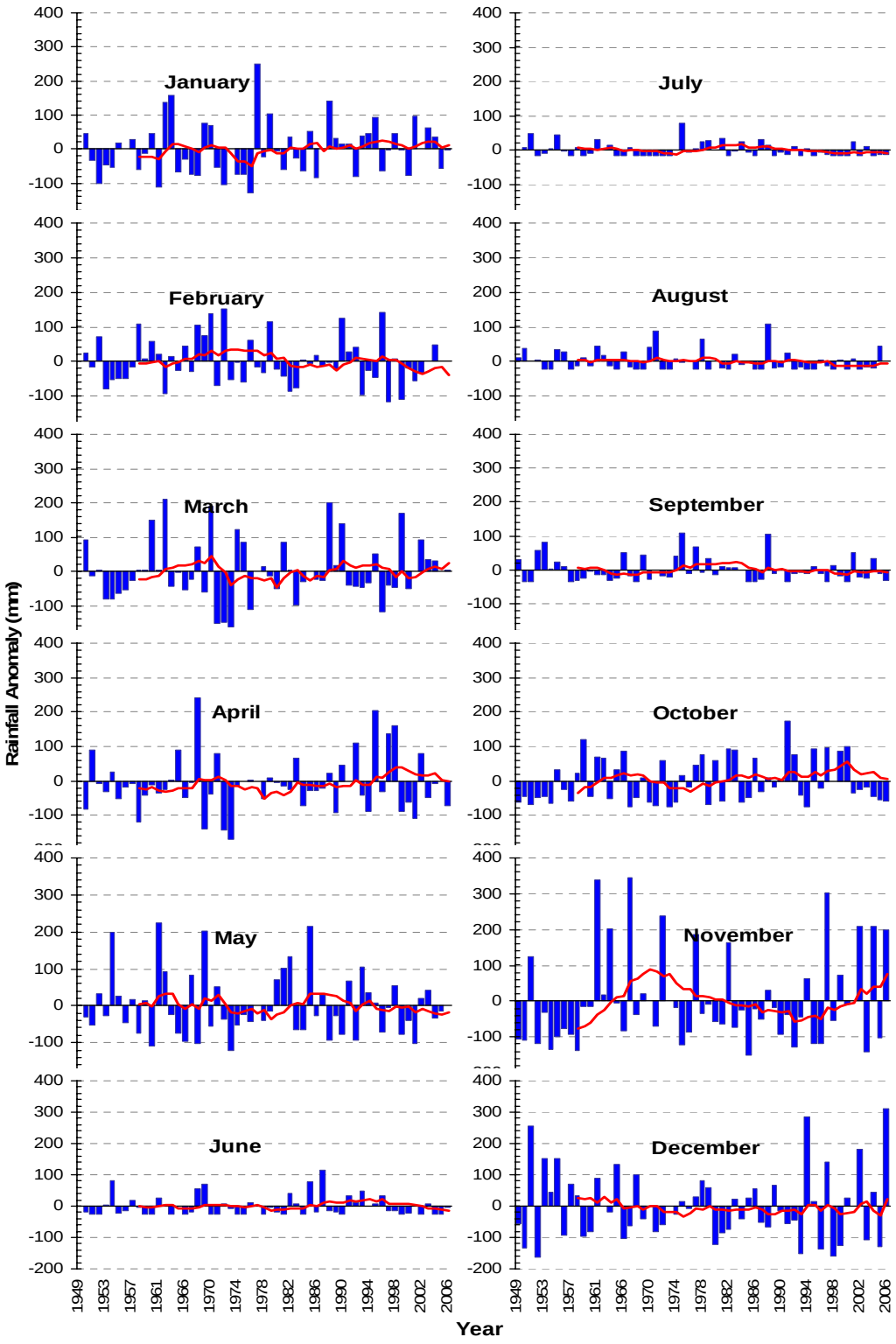

Figure 12 b: Nansio station monthly rainfall anomalies (1949 – 2006). The solid line shows Decadal trend variation.

4.2 Regional temperature trends

From the communities' perspective, temperature was not considered to be one of the factors indicating climate change. This is because, in this tropical climate one fails to have noticeable senses of temperature changes. Although the concept of global warming was known to a significant number of villagers, there was no evidence whatsoever among the communities to be associated with temperature changes in their daily life. Temperature variations are correctly probed by scientific equipments. Communities like this in tropics will always lack experiential evidence of temperature changes especially considering that temperature variations (minimum and maximum) within a day are also showing big differences of almost always 8°C (Figure 13). Nevertheless, the current scientific understanding is the general global warming phenomenon. In this investigation, the trend of temperature variations over a long period in the region using data obtained from the Tanzania Meteorological Agency is presented. The presentations in the figure provide the temperature trends which have been observed in the region. The general observation indicates that the minimum temperatures have remained almost constant over the period. From October to May the region experiences higher minimum temperatures compared to dry months i.e. June to September where the minimum temperatures are lower by an average of about 1°C.

The trend shown in figure 13 is the maximum temperature variations. It indicates some variations for some months with increasing values for the past over ten years. The consistence of temperature increases during these months over years is indicative of regional temperature increase. The maximum temperature increases are observed in February, April, May, June, July, August, September and October. Generally the temperature increases were significant from 1993 to 2006. In February 1993 the recorded monthly average was 27°C which slowly increased to 29°C in 2005, a difference of about 2°C higher for a period of about ten years. In April, the temperature increase was noted in 1989 with the value of 26°C which increased to 29°C in 1996 and 28°C in 2005. The overall trend for April was the increasing temperature values from 1989 to 2005. May and June average temperatures also showed some increasing trend whereas May average temperatures increased from 26°C in 1979 to 28°C in 1996 and the average temperature values for this month was on average maintained at about 27°C over years and never decreased to 26°C value as it was before 1979.

The trend observed in May was almost replicated in June where the average temperature also increased from 26°C in 1979 and maintained spiralling increase to 28°C between 1988 and 2006. The phenomenon of maximum temperature increase can also be noted in August where the average maximum temperature in 1994 was 27°C, 29°C in 1995 and 1997 and in 2005 it was just over 28°C. In September the same maximum temperatures increased from 1975 to 2006. In 1975 the temperature was 26°C and slowly increased to 29°C in 1987, 30°C in 1997, 29°C in 2002 and in 2006 the temperature was 28°C. In October the temperature increasing trend started earlier in 1967 with average temperature of 26°C. Except for the low value temperature observed in 1983 (~27°C) the temperature for this month kept on increasing to 29°C in 2003 and 2004. The increasing trend was not smooth for all

cited months but overall the average monthly temperatures were noted to increase without any relapse.

From the above it was observed that these temperature increases were permanent not showing a decrease although in most cases there were durative temporal changes. For example, in March a point of highest temperature was recorded in 1992 (30.4°C) which was never recorded before in this month from 1959 to 2006 and from that point the average maximum monthly temperature never went below 27°C. It is obvious that these changes signify regional temperature increase. However, these observations contradict the general presentation made by King'uyu *et al*. (2000) where they indicated that eastern Africa was observed to have decreasing trends in temperature from weather station measurements located close to the coast or to major inland lakes. Our study in the Lake Victoria region, one of the major inland lakes is not showing such a general trend. Temperature decrease was not observed instead, since few months show approximate stable temperature condition whereas some months indicated clear temperature increase.

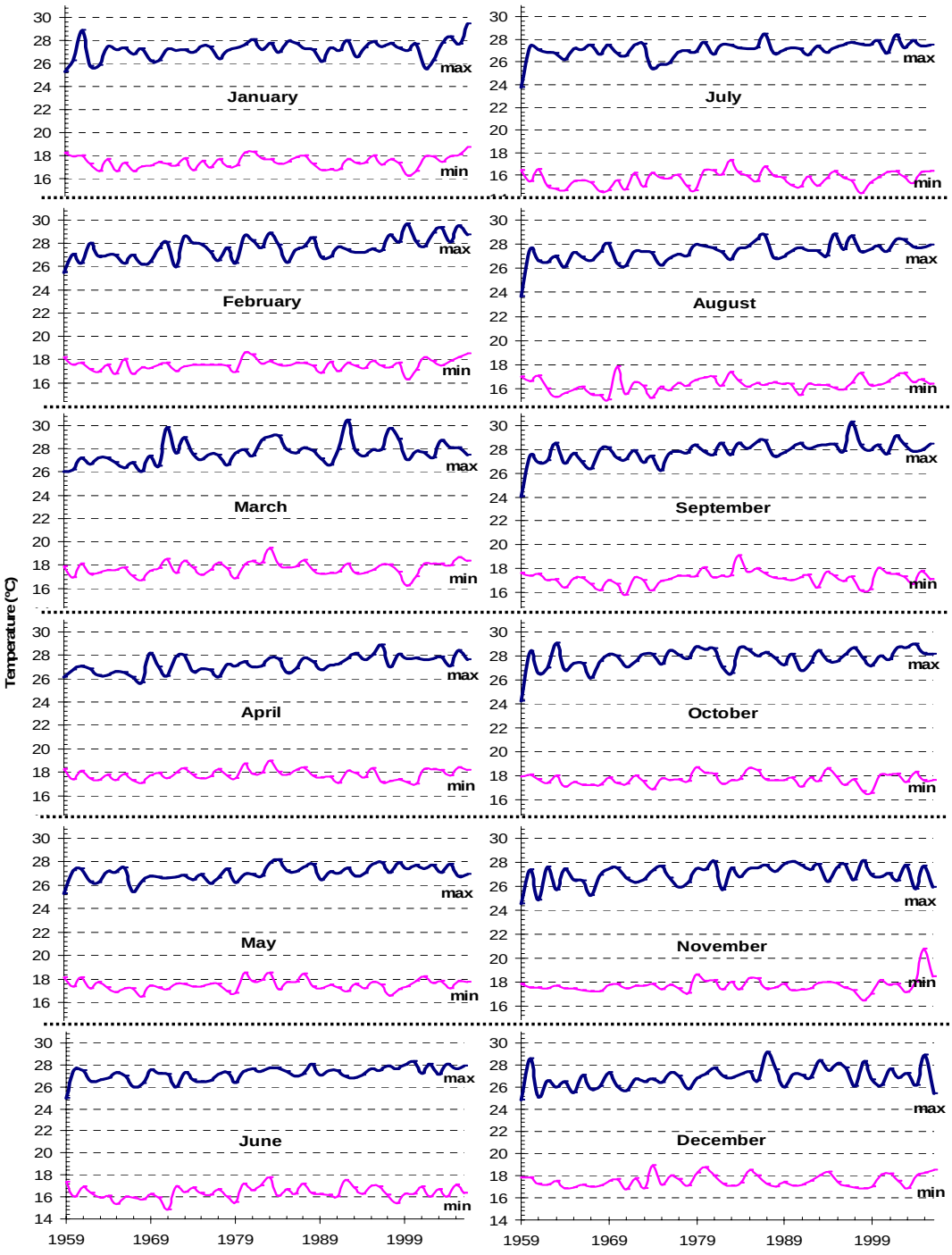

Figure 13:. Average monthly maximum and minimum temperature profiles for the three regions bordering Lake Victoria (Bukoba, Mwanza and Musoma) for the past over four decades (1959 – 2006)

5.0 MODEL PREDICTIONS

In this investigation, data downscaled by ECHAM5 model of the Max Planck Institute for Meteorology was used for climate prediction. The model was favoured for this region following various applications which have been showing promising predictions of the model in this region. Temperature and precipitation model outputs are presented based on two scenarios, control (modelled past 1961 – 2000) and modelled future (2045 – 2065) climate of the three regions.

Based on the model results, the annual precipitation trend is likely to increase for most months of the year. Figure 14 indicates that the period between May and July will experience the highest positive variability of precipitation and January to April (except February in Mara region) will similarly show 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. This trend has also been reported by the Intergovernmental Panel on Climate Change (IPCC). In its fourth assessment report of 2007, IPCC predicts that by the year 2080 tropical and eastern Africa may experience increased rainfall by 7%. Such change is expected to significantly affect the hydrological patterns especially on the coastal areas.

The projected phenomenon is based on the trend of precipitation between the past and future (Figure 15), where the daily precipitation trend, throughout the a year will not show changes. The only difference depicted in Figure 15 is on the magnitude of precipitation. The impacts of the predicted increased precipitation to the district will be an increase in floods which will likely also take place during the current dry months.

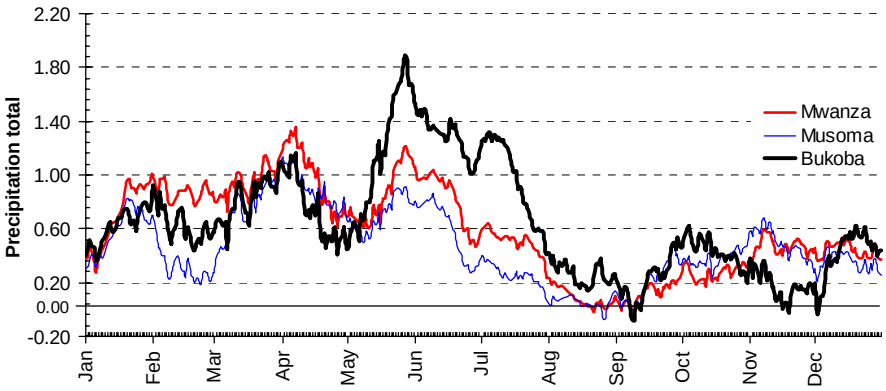

Figure 14: Anomaly of daily rainfall total for the three regions of the Lake Victoria (Mwanza, Musoma and Bukoba), January to December. Differences between model control (past record) and future model prediction (Echam5 downloaded data)

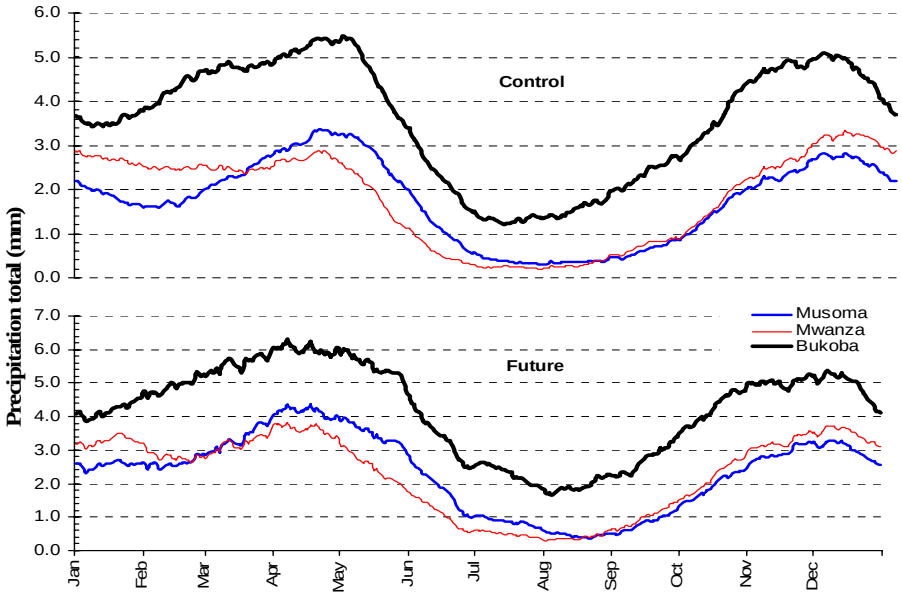

Figure 15: Modeled past (control) and modeled future daily rainfall total for the three regions (Mwanza, Musoma and Bukoba) from January 1 to December 31. (Echam5 model)

The minimum temperature anomaly presented by the model indicates a stable condition except in June and July where there are amplitudes (Figure 16). This trend predicts a general future rising of temperature of the region for all months of the year. In reference to figure 13 the minimum temperature did not show notable increases compared to maximum temperature, however, the model projects increases of minimum temperatures. Under these predictions, obviously the impact of climate in the lake Victoria region will certainly be notable especially the hydrological processes which are likely to undergo modification although in yet an unknown trend since there are many environmental changes being predicted in this region. There are many complex processes presented by different authors which show uncertain ending (Bounoua *et al*., 2000; Mitchell *et al*., 2000; DeFries *et al*., 2002; Arnell *et al*., 2002; Conway *et al*., 2005; Christensen *et al*., 2007 etc.).

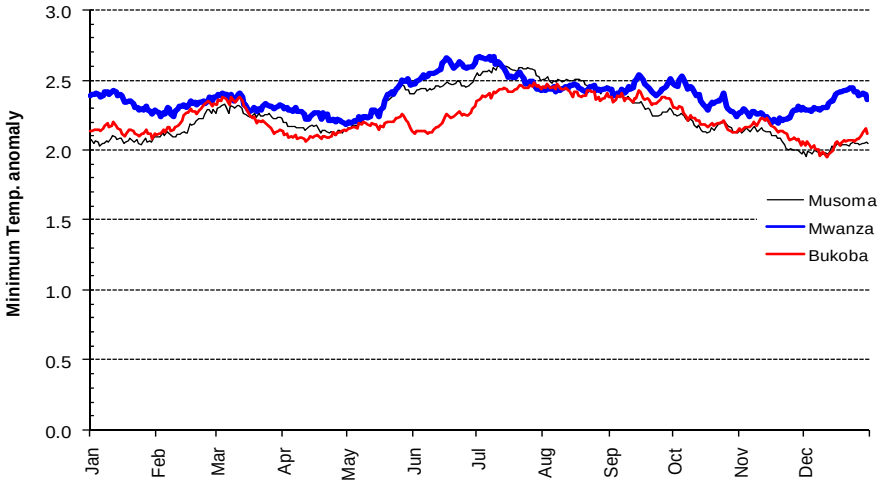

Figure 16: Daily minimum temperature anomaly for the three regions

6.0 DISTRICT DEVELOPMENT PLANS

A summary of preliminary results of this investigation was submitted to the district executives indicating findings from the communities which needed attention. The report summarised four items on which the research was based. These are;

i. Evidence for existence of climate change in the region
ii. Problems arising from such changes
iii. Techniques used for solving the problems
iv. Needs which are out of communities' reach but are needed to solve the problems

Based on the above, the district government addressed official planning on different issues identified by communities.

6.1 Economic activities

Provided information indicated major problem facing the district to be related to the two major livelihood activities, agricultural and fisheries sectors. The agricultural sector is facing land shortage problem due to increasing population and decreasing fertility. The fisheries sector was reported to be affected by poor catches due to the declining fish stock in the Lake Victoria, as a result of which the district local government tax collection has similarly declined. While the communities need support from the government, the district local government is failing to provide basic social services to communities. The district government is constrained by high costs of services due to the geographical location of the district, which makes communication with all the islands in the district more difficult.

6.1.1 Strategies

The district administration has identified the following strategic plans in order to alleviate the problem of food shortage;

i] Introduction of alternative food crops where sorghum (a drought resistant) farming is now being encouraged
ii] The division of agriculture is also preparing to ensure good and profitable agriculture practices in the district. This will increase yield per unit area and reduce the need for large farms.
iii] More islands are being connected to the main Ukerewe island by reliable transport vessels in order to minimize transportation costs of various items including food.
iv] Control of fishing practices and especially illegal fishing methods are being implemented under the regional Lake Victoria management strategies which is planned to start officially in January 2009.

The district government considers improving agriculture and fisheries outputs the two most important activities. This is in recognition of the contribution of the two activities on the livelihood of the district's population. The contribution of fisheries in the total income of the district is very significant. For example, in 2007/2008 the district expected revenue collection of about 540,476,224 Tanzanian shillings where 440,742,540 Tanzanian shillings (~82%) were contributed by the fisheries sector.

Therefore, the district fisheries office considers the declining fisheries output a major challenge to the district local government and the population.

Two strategies were considered to alleviate the problem are; encouraging fish farming practices in order to reduce fishing pressure on the lake and enhancing supervision of regional and national strategies for sustainable fisheries development.

6.2 Water sources and sanitation

The water sector is also affected by various problems which have resulted into unreliable water sources. There have been special programmes to rehabilitate and improve natural water sources in different parts of the district in the past. One of the recent programmes managed to improve 15 natural water sources in 2005/2006 and 6 sources in 2006/2007. The District Community Development department proposes another special programme to modernise some of the existing water sources to make them serve more people compared to the current situation. However, the Department suggests that further project evaluations need to be done due to the fast increasing water demand and the decreasing water availability in order to ensure sustainability of the services.

6.3 Challenges

Agricultural activities are challenged by two factors; budget limitation and few agricultural experts to provide needed services. The emergence of cassava disease has become an unimaginable problem for the past ten years as well. The district needs more extension officers in order to improve communities' agricultural production methods. The solution being sought is to introduce more productive and resistant cassava breed(s) but this is not yet successful and may take many years before it is realised.

The introduction of fish farming practices in the district was reported being challenging due to the absence of fingerlings production centre in the region of the Lake Victoria in Tanzania and also lack of trained personnel. Currently, the country has only one established fish farming centre located about 1000 km from the lake Victoria region, while the requirement for the fingerings is increasing countrywide. The request from the district fisheries office is to be provided with the capacity to have fish farming centre within the district or in this region for easy transportation of the fingerings to farmers.

7.0 PROPOSED SUPPORT FOR COMMUNITIES ADAPTATION

7.1 Background

Communities in Ukerewe district have shown dependence on natural resources. The natural resources have been affected by climatic and ecological changes and therefore the resources are limited, while communities' requirements are expanding due to population increase and development needs. The population of the Island in 1967 was about 88,000 inhabitants and the average population density was estimated 159/km^2. The recent (2002) estimated population is 260,000 inhabitants, a three times population increase in a period of 35 years. Population increase regardless of other changes has exacerbated the impact of climate changes in the district. Like other poor communities, the adaptive capacities of the communities are limited by resources availability. Widespread poverty, lack of alternative resources and ignorance are among the factors limiting adaptation capabilities. The study communities in Ukerewe district have shown dependence on natural resources exploitation and on traditional production methods which entirely depend on weather conditions. Agriculture is rain fed and there are negligible irrigation systems. Fisheries activities are dependent on capture fisheries in the Lake Victoria, energy source is based on forest products and water sources are traditional wells. These expose the communities to impacts of climate changes.

From this study three priority areas were accepted by communities being critical for their livelihoods. These include;

i] Food availability
ii] Water quality and quantity
iii] Energy sources

Our observation on both communities and the district local government capacities indicated that they are both limited by resources availability. The communities need support from the government whereas the government has overwhelming social and economic problem to be resolved. It is obvious therefore that the district government also seeks external support to various development plans.

7.2 Food Production

7.2.1 Agriculture

The problem of food inadequacy requires a combination of efforts especially from the agriculture and fisheries sectors. The major impacting factor on agriculture is drought which has been on the increase, although most communities in the Island live along the lake shores where irrigation can be practised. Additional to this is the problem of poor soil fertility and reduced farmland due to population increase. As presented by the District administration, modern agriculture techniques will be necessary for improved production, where small land area will be able to produce adequate food for families. Community indicated their willingness to have irrigation schemes which will enable them to cultivate their land throughout the year especially in farms along the lake. The only problem indicated by both communities and the district administration is lack of capacity for irrigation infrastructures. Communities indicated their quest even for simple irrigation equipment like hand pumps which are not available due to scarcity of resources.

Given the current structure of leadership in villages and the willingness of the communities to undertake irrigation agriculture, it will be important to initiate community-based group which can be supported with simple irrigation equipments. Such support will enable communities to grow alternative crops like green vegetables which are now highly marketable within and outside the Island. Irrigation agriculture will reduce communities' dependence on cassava farming which at the moment is highly affected by the hostile disease whose solution is not known. As was expressed by the communities, irrigation agriculture will increase potatoes production which has been supplementing cassava as the major food crop. This is because, the disease is not a big problem in lowland areas with enough water for the crop although potato was also mentioned to be attacked by a disease which is not yet known. With reliable water for irrigation and other crop production techniques crop yield will be improved and reduce the need for large farms.

7.2.2 Livestock Production

Communities appreciated the good climate in the Island which has been supporting animal husbandry. Lack of space has hindered animal keeping especially cows and goats which need more grazing space. Though traditional breeds of cattle and goats are hard and can tolerate difficulty weather, it has been difficulty to maintain big herds as it was in the past due to lack of pasture and grazing space. Most community members have reduced their number of animals. The current manageable maximum number of animals was estimated to be between 5 and 10 cows per family. This number is not encouraging to communities because of low productivity of these traditional breeds, animal products like milk and meat no longer suffice local needs. There has been involvement of Non Governmental Organisations (NGOs) like FAPOEL in collaboration with donors, which have introduced improved breeds of cows, chicken and goat to some community organisations and individual households in order to improve productivity. These initiatives have shown success but they are hampered by limited resources, poor veterinary services and infrastructure which are important for sustainability of these initiatives.

During this study it was encouraging to learn that communities were eager to have alternatives to traditional animal husbandry. The idea to introduce new animal breeds is mainly undertaken by NGOs in the Island. However, they have limited resources which cannot fully support all communities which need both training and resource support in order to initiate the projects. Our suggestion for the government and donors is to enhance the capacities of NGOs in the Island in terms of resources and education.

7.2.3 Fish

Fish farming has been accepted to be an alternative to capture fisheries. It is a new hope for improving the socio-economy of the communities which have been dependent on fishing activities. With available statistics, introduction of fish farming will help to resolve the problem of fish scarcity in the Island. In other neighbouring countries like Rwanda, this has proven successful. Hishamunda, *et al*., (1998) indicated that fish farming practice has been successful to the extent of being considered a cash crop in which the majority (over 50%) of the fish farmers considered it a major activity.

Mpawenimana (1991) also admits that Rwanda has become a good example of success initiative. But significant effort and support were provided by the government and donors for initiation of the projects.

In Tanzania, fish farming is encouraged and promoted by the Fisheries division under the Ministry of Livestock and Fisheries Development. However, due to shortage of fisheries staff especially at regional and district levels, funds and transport means to undertake extension services efficiently are not available. Some initial efforts have shown that communities are receptive to the practice although little efforts have been put to promote fish farming in the regions. We are proposing the introduction of fish farming in the Island as requested by the communities. However, it will be necessary to provide support in order to enhance the capacity of the District fisheries office and local NGOs to be able to produce fingerings in the district. This will also be enhanced by providing education to willing farmers.

7.3 Water quality and scarcity

Although the Island is surrounded by the lake, less than 5% of the population received piped water from the lake. This is why availability of safe and clean water has been ranked by the villagers as well as the district executives as one of the problems to the communities. As indicated, Lake water used to be one of the reliable sources for communities along the lake. Communities like Hamkoko depended much on ground water i.e. shallow wells and spring water. Due to the deterioration of Lake water quality all communities have shifted to groundwater sources which are unfortunately not adequately available for the communities.

These communities requested support primarily as was indicated by the Busiri villagers, on the improvement of the existing water sources. Most of the existing sources need construction and proper design in order to ensure clean and safe water supply. Also the community need to be supported in ensuring safe extraction of groundwater. Communities like Busiri need protected shallow wells. The need for secure wells was requested by the communities and needed support on the already shown effort to construct private wells within their living compounds.

In general, the lake can no longer be the source of portable water for the villagers due to pollution which may require unrealistic treatment processes for the communities. We are therefore suggesting a need for increased groundwater extraction in hygienic manner that avoids surface contamination.

7.4 Energy Sources

As was presented, the energy requirement of the district has increased significantly while the available forestry resources can no longer support the current energy needs. The major use of energy among the communities is for cooking and traditionally this has been done by using firewood. Due to this, there has been deforestation of all forested areas including reserved forests in the Island. During this study, communities indicated a need for alternative energy sources which will be sustainable. At a household level it was agreed that communities can introduce woodlots systems. This may take some years

before it really supports the family wood requirements but it will be part of the solution in the future. In addition, the District forestry office was requested to provide technical support in identifying proper establishment of woodlots which was identified as a new practice in the Island.

It was also agreed that for most families, there are possibilities of introducing biogas for cooking and lighting. However, two obstacles were identified; lack of knowledge and lack of resources. Biogas systems need special construction and management knowledge but this can be done within the country provided that communities' financial capacity will be enhanced. A combination of these alternatives will help the communities from the energy problem.

8.0 REFERENCES

Arnell, N.W., M.G.R. Cannell, M. Hulme, R.S. Kovats, J.F.B. Mitchell, R.J. Nicholls, M.L. Parry, M.T.J. Livermore and White A., 2002. The consequences of CO2 stabilisation for the impacts of climate change. Climatic Change, 53, 413-446.

Awange, J.L. and Aluoch, J. and Ogallo, L. and Omulo, M. and Omondi, P., 2007. Frequency and severity of drought in the Lake Victoria region (Kenya) and its effects on food security. Climate Research 33 (2): 135-142.

Awange, J.L., Ong'ang'a, O., 2006. Lake Victoria : ecology, resources, environment. Springer.

Bounoua, L., G.J. Collatz, S.O. Los, P.J. Sellers, D.A. Dazlich, C.J. Tucker and D.A. Randall, 2000. Sensitivity of climate to changes in NDVI. J. Climate, 13, 2277-2292.

Chervin, R.M., 1979. Response on the NCAR general circulation model to changed land surface albedo. Report of the JOC study Conf. on Climate Models, Vol. 1, 563-5S1. GARP Publ., Ser. No. 22, WMO.

Christensen, J.H., Hewitson, B., Busuioc, A., Chen, A., Gao, X., Held, I., Jones, R., Koli, R.K., Kwon, W.T., Laprise, R., Rueda, V.M., Mearns, L., Menéndez, C.G. Räisänen, J., Rinke, A., Sarr A. and Whetton, P., 2007: Regional climate projections. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, Eds., Cambridge University Press, Cambridge, 847-940.

Conway, D., Allison, E., Felstead R. and Goulden, M., 2005. Rainfall variability in EastAfrica: implications for natural resources management and livelihoods. Philos.T. Roy. Soc. A, 363, 49-54.

Cunnington, W.M. and Rowntree, P.R., 1986. Simulations of the Saharan atmosphere-dependence on moisture and albedo.

DeFries, R.S., Bounoua, L. and Collatz, G.J., 2002. Human modification of the landscape and surface climate in the next fifty years. Glob. Change Biol., 8, 438-458

Hishamunda, N., Thomas, M., Brown, D., Engle, C. and Jolly, C., 1998. Small-scale fish farming in Rwanda: Economic characteristic. CRST Research Reports 98-124.

IPCC Report Working Group II. Fourth Assessment Report. Climate Change 2007: Impacts, Adaptation and Vulnerability.

King'uyu, S.M., Ogallo, L.A. and Anyamba, E.K., 2000. Recent trends of minimum and maximum surface temperatures over Eastern Africa. J. Climate, 13, 2876-2886.

Kitoh, A., Yamazaki, K. & Tokioka, K., 1988. Influence of soil moisture and surface albedo changes over the African tropical rain forest on summer climate investigated with the MRI-GCM-I. J. Meteor. Soc. Japan 66, 65-85.

Lake Victoria Basin Commission. Special report on the declining of water levels of Lake Victoria. EAC Secretariat Arusha, Tanzania April 2006.

Laval, K. and Picon, L., 1986. Effect of a change of the surface albedo of the Sahel on climate. J. Atmos. Sci. 43, 2418-2429.

Lehman J. T., 1998. Environmental change and response in East African lakes. Kluwer Academic Publishers Group.

Machiwa P. K., 2003. Water quality management and sustainability: the experience of Lake Victoria Environmental Management Project (LVEMP)-Tanzania. Physics and Chemistry of the Earth vol.28 (no.20-27).

Minakawa, N., Sonye, G., Dida, G.O., Futami, K. and Kaneko, S., 2008. Recent reduction in the water level of Lake Victoria has created more habitats for *Anopheles funestus*. Malar Malar J. doi: 10.1186/1475-2875-7-119.

Mitchell, J.F.B., Johns, T.C., Ingram, W.J. and Lowe, J.A., 2000. The effect of stabilizing the atmospheric carbon dioxide concentrations on global and regional climate change. Geophys. Res. Lett., 27, 2977-2980.

Mpawenimana, P., 1991. Rapport Annuel du Service Pisciculture National. Miméo. Butare, Republique Rwandaise, 27 pp.

Nkomo, J.C., Nyong, A.O. and Kulindwa, K., 2006. The impacts of climate change in Africa. Report prepared for the Stern Review on the Economics of Climate Change, 51 pp.

Raible, C.C., Saaroni, H., Ziv, B., and Wild, M., 2008. Winter synoptic-scale variability over Mediterranean basin under future climate utilizing ECHAM5. Geophysical Research, 10: EGU2008-A-02023.

Riebeek, H., 2006. Lake Victoria's falling waters. Earth Observatory Features,NASA. http://earthobservatory.nasa.gov/Study/Victoria/printall.php

Stier P., Feichter, J., Kinne, S., Kloster, S., Vignati, E., Wilson, J., Ganzeveld, L., Tegen, I., Werner M., Balkanski, Y., Schulz, M., Boucher, O., Minikin, A., and Petzold, A., 2005. The aerosol-climate model ECHAM5-HAM. Atmos. Chem. Phys., 5, 1125–1156.

Sud, Y.C. and Fennessy, M. 1982. A study of the influence of surface albedo on July circulation in semi-arid regions using the GLAS GCM. J. Climate 2, 105-125.

Sud, Y.C. and Molod, A., 1988. A GCM simulation study of the influence of Saharan évapotranspiration and surfacealbedo anomalies on July circulation and rainfall. Mon. Weath. Rev. 116, 2388-2400.

Verschuren, D., Johnson, T.C., Kling, H.J., Edgington, D.N., Leavitt, P.R., Brown, E.T., Talbot, M.R. and Hecky, R.E., 2002. History and timing of human impact on Lake Victoria, East Africa. Proc. R. Soc. Lond. B 269, 289-294.