The Republic of Uganda
Ministry of Water and Environment
Directorate of Water Resources Management

Vulnerability Assessment of Ugandan Water Resources to Climate Change

Project:
Climate Change Vulnerability Assessment, Adaptation Strategy and Action Plan for the Water Resources Sector in Uganda

By
OneWorld Sustainable Investments

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appreciating your financial, social and ecological assets

Submitted by:		Submitted to:
OneWorld Sustainable Investments		***Directorate of Water Resources Management***
Postal address: PO Box 8359 Roggebaai 8012 South Africa		**Postal address:** P. O Box 19 Entebbe Uganda
Physical address: Unit 604 4 Loop Street Cape Town South Africa		**Physical address:** Plot 17 Mpigi Road Entebbe Uganda
Prepared by:		**Prepared for:**
David Woods / OneWorld Consortium Tel:+ 27 (0)21 421 6996 Fax: + 27 (0)21 418 5726 dave@oneworldgroup.co.za		Eng. Nebert Wobusobozi Tel: +256 (0)414 323 531 Fax: +256 (0)414 321 342 nebert.wobusobozi@mwe.go.ug

Authors: Arthur Chapman, David Woods, Mandy Antzoylatos, Stephanie Midgley, Belynda Petrie

Executive Summary

Climate change and variability have already been observed in Uganda and are projected to increase considerably over the course of this century. Impacts of these changes are manifesting in various forms, most notably floods and droughts. All sectors of Uganda's economy will be affected, water, agriculture (and natural food producing systems), health and energy as well as natural ecosystems. Since water is central to all these sectors, the Directorate of Water Resources Management is responsible for identifying potential water-related vulnerabilities and for implementing and enabling adaption to climate change within its sphere of influence.

This report identifies key water-related and cross-sectoral climate change vulnerabilities in Uganda, and concludes with recommended focal points for adaptation to be explored in the subsequent phase of this project (*Adaptation Strategy and Action Plan*). The main areas of vulnerability are:

- institutional (institutional arrangements and capacity);
- fluctuations of Lake Victoria's water levels;
- water quality and human health, particularly on lake shorelines near urban areas or river mouths;
- hydropower generation;
- potential over-exploitation of groundwater by agriculture (the *Water for Production* programme);
- limited data, information and technology to provide critical information for optimal decision-making and policy-making;
- transboundary issues (potential conflict over water resource management in the Nile Basin).

The resultant recommended focus areas for the Adaptation Strategy and Action Plan are:

1. ***Establish an institutional network in line with Integrated Water Resources Management principles*** that enables active community participation in water resources management and climate adaptation, and raises awareness of water and climate issues;
2. ***Strengthen fisheries***, especially in Lake Victoria, through research to improve understanding of the Lake water budget, proactively engaging in transboundary fora (such as the Nile Basin Initiative and Lake Victoria Basin Commission), and managing inshore water quality;
3. ***Improve human health through better management of water quality***, both surface water and groundwater; and
4. ***Work with the Water for Production programme*** in order to secure groundwater as a natural asset through appropriate management actions.

A willingness to engage inter-sectorally will be necessary for these approaches to prove successful. The Action Plan will lead the DWRM to the point of implementation, with a view to developing funding proposals.

Contents

1.INTRODUCTION

> ***"We are still daunted by the disconnect of converting policy strategies into action and real development results in communities." (Uganda MFPED, 2007)***

The goal of this project is to *position the Directorate of Water Resources Management (DWRM) to implement* climate change adaptation actions, through partnership-based strategies for accessing funding. Though previous projects have investigated climate change impacts and vulnerabilities in Uganda, they have not resulted in tangible results. This report reviews vulnerabilities of Uganda's water sector (and the cross-sectoral impacts thereof) and concludes with recommendations that will form the basis of the development of the adaptation strategy and action plan (the subsequent phase of this project) in order to accomplish our goal.

Uganda is significantly exposed to climate variability, for example the La Niña drought event of 1998-2000 and the El Niño-Southern Oscillation (ENSO) wet phase and floods event of 1997-1998. The negative impacts of these weather systems were felt strongly in both the economy and society. Climate change, driven by global warming, is expected to alter the frequency and intensity of the events which characterise natural climate variability. The IPCC considers that the effects of climate change will be a highly unevenly distributed, particularly in low-latitude and less-developed regions (including Uganda). These regions are generally at greatest risk because of both higher sensitivity and lower adaptive capacity (IPCC WGII, 2007).

Vulnerability increases as a nation's capital stock increases, leading to greater losses when a disaster strikes. Growth leads to concentration of stock in hazardous areas. Also, as systems become more complex and inter-dependent, costs of damage rise.

The key objective of this report is to define the vulnerability of the water resources sector to climate change. It does this by:

- Setting the scene (background);
- Describing a model or framework of vulnerability by which the assessment will be undertaken;
- Assessment of the primary climatic hazards to which the vulnerable water resource entities are exposed;
- Identification of the vulnerable water resource entities; and
- Providing an analysis of possible risk mitigation measures.

1.1. Terms of Reference

The purpose and goals:

- Understand the potential vulnerabilities of the water sector in Uganda to climate change;

- Work towards outlining adaptability mechanisms and strategies for combating and mitigating impacts of climate change on water resources and water-related sectors;
- Identify vulnerable areas and draw conclusions from existing vulnerability assessments;
- Propose capacity building modules, identify training requirements;
- Rapid assessment of floods, droughts, water availability and demand, and establish the role of climatic variability in driving such occurrences.

2. BACKGROUND

Uganda has an area of about 241,000 km^2, of which 67,000 km^2 is Lake Victoria and 15.3% of the total surface area of the country is open water. About 9.4% are seasonal wetlands (areas of periodic flooding and also a prime location of agricultural production) and 3.0% area permanent wetlands. There are 162 freshwater lakes. By many standards, Uganda has a wealth of freshwater resources (Uganda National Water Development Report 2005).

2.1. Defining Features of Ugandan Climate

The defining feature of Uganda's rainfall is a bimodal (twin-peaked) annual distribution of rainfall as the inter-tropical convergence zone (ITCZ) oscillates back and forth across the equatorial region with the change of seasons, creating the "short" rains in October to December and the "long" rains in March to May (McSweeney *et al*. 2008). The movement and positioning of the ITCZ is sensitive to variations in El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD – an ENSO-like condition of the Indian Ocean). El Niño usually is associated with a wet phase and flooding in Uganda, usually in October, November and December (OND). The converse, La Niña, is usually associated with a dry phase or drought, but this relationship is sometimes disturbed by the independent influences of the IOD.

Because of the differential heating and vapour transport effects of the large lake and adjacent landmass, Lake Victoria also controls rainfall patterns across Uganda. Rainfall ranges from less than 450 $mm.a^{-1}$ in the north-eastern Karamoja sub-region where it is a dry rangeland to over 1600 $mm.a^{-1}$ over most of the rest of the country. Topography also affects rainfall, such that elevated areas like Mt Elgon in the east the Ruwenzori mountain range in the west also receive high rainfalls (> 2000 $mm.a^{-1}$), while in the north-eastern Karamoja region is semi-arid, as is the south west and the lower-lying areas of the western and eastern African Rift valleys.

Trends have been observed in surface temperatures, with a ~1.3°C increase in mean temperatures since 1960 (0.28°C per decade on average); the months of January and February have warmed at 0.37°C per decade (McSweeney *et al*. 2008). The frequency of hot days has increased significantly while that of cold days has decreased, although with no observed change in the December, January and February (DJF) season.

Climate change projections

Projections of Global Circulation Models (GCMs) are that temperatures will continue to rise, particularly in the semi-arid areas because atmospheric moisture vapour pressure deficits at the planetary boundary layer cannot be met by the soil water storage. These conditions affect the drier north-eastern and south-western areas but are of less concern to the areas adjacent to Lake Victoria (which has a significant moderating effect on air temperatures).

GCMs broadly predict an increase in rainfall, with the largest increased in the OND "short" season (McSweeney *et al* 2008). However, the biggest impact should be expected from an increase in the frequency of intense rainfall events and a decrease in the frequency of low intensity events, for the reasons given by Trenberth *et* al. (2003) which are largely based on the increasing water content of the atmosphere. The other major influences of rainfall are the ENSO and IOD dynamics and there is little agreement among GCMs regarding the trends of these sea-surface-atmosphere coupled systems (e.g. Christensen *et al.* 2008).

Rainfall quantities are affected by the amount of atmospheric moisture transported into the region. Global and meso-scale circulation patterns that affect this are the El Niño / Southern Oscillation (ENSO) conditions of the western Pacific and the Indian Ocean Dipole (IOD). Both ENSO and IOD play a role in Ugandan rainfall and determine whether moist air or drier air from the sub-Saharan region is preferentially advected into the Ugandan region. Very moist air usually results in wet or very wet seasons (bringing with it flooding), whilst very dry air results in drought.

A rise in air temperature allows the air to hold a lot more moisture. For every 1°C air temperature increases, the air can hold ~7% more moisture and this is a significant increase in the potential energy of the atmosphere which manifests itself in the intensity of storms as latent heat is released. Trenberth *et al*. (2003) show how a warming atmosphere will result in the change in frequency and intensity of droughts. Their key finding is that storms will become greater in intensity and droughts of longer duration.

We believe these effects are already manifest in Uganda, with apparent changes in flood and drought frequency and intensity. South-eastern Uganda's climate is also heavily influenced by changes in mesoscale circulation caused by Lake Victoria. The lake obtains most of its water from precipitation directly onto the lake surface and the rates of evaporation and precipitation are about equal. The residual of the water budget of the lake is provided by runoff from the Lake Victoria basin, which occurs in the surrounding countries of Kenya, Tanzania and Rwanda, but is relatively small compared to the rainfall and evaporation fluxes.

The fact that most of the water input into Lake Victoria comes from rainfall onto the lake surface makes the lake volume sensitive to relatively small changes in the balance between precipitation and evaporation. Regional changes in atmospheric circulation that result in a drop in rainfall on the lake surface are translated into declining lake levels.

2.2. Surface Hydrology

Having a relatively high rainfall over most of the country, Uganda has an abundance of surface water. Fifteen percent of the country is open water. The levels of Lake Victoria strongly influence flows in the Nile, which is of great concern to the downstream countries of Sudan and Egypt. Flows in the Nile are highly variable from year to year, suggesting sensitivity to climate variation. Long-term average outflow of Lake Victoria at Jinja is 840 $m^3.s^{-1}$, with a minimum of 345 $m^3.s^{-1}$ in 1933 to a maximum in 1720 $m^3.s^{-1}$ in 1965. These changes in lake levels over time are emulated by similar changes in the levels of Lake Kyoga and Albert, reflecting the regional nature of short-term climate variation. The long-term trend appears to be downward towards the 63-year mean outflow of 700 $m^3.s^{-1}$ of Lake Victoria.

Rainfall-runoff ratios (a measure of the water production) of the region vary widely. Karamoja region and the south-west, Bushenyi, Mbarara and Rakai have ratios of less than 5% (rainfall converted to runoff). In the west, around the Ruwenzori Mountains, significant river runoff occurs down the Semliki River to the Albertine Rift and Albertine Nile. Ostensibly, water is not in short supply for much of Uganda and the country could make substantial use of its water resources for economically and socially beneficial purposes.

The per capita water availability is expected to decline towards 2015 (the target date for achieving the Millennium Development Goals) and beyond as demand increases. This trend is already especially evident in the Karamoja region but will spread into the other catchment areas of Lake Kyoga. In the south-west, in the Bushenyi, Ntungamo and Mbarara districts (also semi-arid) similar trends are evident. These districts already have the lowest annual runoff of 310 $mm.a^{-1}$ or 10 $L/s/km^2$. Administratively, Uganda is divided into eight sub-basins, all of which flow into the Nile[1].

2.3. Groundwater

Three basic types of groundwater system in Uganda:

- Fracture systems in the granite-gneiss Archaen crystalline basement, which can be high-yielding in the fracture systems but low to very low elsewhere;
- Unconsolidated regolith (soils and weathered zones) – the primary groundwater source systems in Uganda;
- Weathered rock systems of the Buganda and Karagome-Arbolean series, containing pellitic schists, and mostly low-yielding.

Other geological types which contain groundwater are the basalts in the regions of more recent volcanic activity (Mt Elgon in the east and parts of the Western Rift, including the Ruwenzori Mts.) Groundwater produced in these zones tend to have high concentrations of fluoride and usually are a challenge to human health but these cover less than 10% of the country. There is little interaction between the crystalline basement fracture systems and the regolith aquifers.

Recharge rates vary widely across Uganda and are also thought to be extremely localized. In some places, recharge can reach amounts of 40 $mm.a^{-1}$ in river channels and along geological faulting zones (e.g. the Aswa lineament in Teso sub-region) for example, but regionally is as low as 1 $mm.a^{-1}$ in the Karamoja region although mean annual rainfall is about 650 $mm.a^{-1}$. Low recharge could be related to low permeability of soils and regolith if they have a high clay content, but also of importance in regions where pastoralism is practiced, the development of soil crusting that results from poor land use and consequent reduction in infiltration capacity. High surface runoff and flash-flooding is the result, causing

[1] There is also a narrow strip of land along the border with Kenya, running roughly from Karita (in Nakapiripirit) to Mt Zulia on the Sudanese border, that drains eastwards into the Rift Valley.

flooding down the channels draining the Karamoja region into Soroti district and ultimately Lake Kyoga. The unconsolidated regolith that exists in the river valleys is the prime source of groundwater utilized by people. Some groundwaters exhibit naturally higher levels of aluminium, chloride, iron, manganese, zinc and fluoride (in the basalts). Recharge is highly susceptible to rainfall quantity and intensity, as well as landuse.

Groundwater development

Groundwater is the prime source of water in all rural areas and especially in the semi-arid and arid areas. Groundwater as a resource is of generally good quality which usually needs no treatment to bring it to potable standards (unlike most surface water sources). Groundwater as a resource has been developed with shallow wells of < 15 m and deep boreholes > 30 m. Shallow wells have usually been excavated by hand and have low yields. The Rural Water Supply Investment Plan focuses on the safety of water, which means the central thrust is increasing groundwater as a resource. However, the lack of data and information on groundwater resources in the country results in little understanding of what protection of groundwater resources is required.

Notably, groundwaters are increasingly contaminated by the poor siting of latrines and influent poor-quality surface waters. These problems are further aggravated by relatively low levels of expertise.

Figure 1: Villagers queue for borehole water at Lebuje Camp[2]

[2] http://commons.wikimedia.org/wiki/File:Water_Lebuje_camp,_Uganda.jpg, public domain, accessed 4 March 2009.

2.4. Socio-economic Development

In 2005, Uganda's Human Development Index was ranked 154 out of 177[3]. The socio-economic development of Uganda is heavily dependent on water resources because of the relatively high levels of dependence on primary production in the economy, as follows:

- Rainfed agriculture;
- Livestock water supply;
- Industrial waste supply;
- Hydropower production;
- Fishing and aquaculture;
- Marine (lake) transport;
- Waste discharge (dilution of untreated effluents);
- Tourism.

Thus sound management of the water resources in Uganda is critical for its socio-economic development. The remainder of this section provides an agricultural perspective of socio-economic development in Uganda. For a broader background on the socio-economic status of Uganda, refer to Inception Report (OneWorld, 2008).

The role of agriculture in the economy

Agriculture is the most important sector of the Ugandan economy. Abundant natural resources, including mostly fertile soils, regular rainfall over most of the country and abundant surface and groundwater, and diverse topographies and ecosystems provide rich opportunities for crop and livestock farming, as well as fishing/aquaculture and forestry. However, water resources are not evenly distributed in space or time, which creates limitations to productivity in certain parts of the country. Nevertheless, natural resources constitute the primary source of livelihood for the majority of Ugandans and will continue to do so in the foreseeable future.

Uganda has a high proportion (88%) of its total population in rural areas, and rates of urbanisation are slow compared to the rest of Africa (FAO). About 80% of the economically active population are employed within the agricultural sector, and are thus highly dependent on its success. Of the total GDP, agriculture contributes about 32% (FAO 2004), decreasing progressively (29% in 2008, CIA factsheet); growth in agricultural GDP has been somewhat slower (3.9% from 1994-2004) than the national total (6.2%). Similarly, the Agricultural Production Index (FAO, 2004) has slowed down since 2003/04 following a period of growth from 1985-2002 which was faster than the global average. This has been

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[3] Source: http://hdrstats.undp.org/countries/country_fact_sheets/cty_fs_UGA.html. Accessed 4 March 2009.

attributed in part to increasingly variable, unpredictable and extreme climatic conditions, as well as conflicts in the northern regions.

Where agriculture used to provide almost all foreign revenue from exports (99% in 1979-1981), its share has decreased to 40% (FAO) due to a combination of reduced cash crop production during the civil war years, disease outbreaks, and volatile international markets, especially for coffee, the primary export. Of the total national imports, agricultural commodities only account for 14%.

Since the end of the civil war (from 1986), the government, with the support of foreign countries and international agencies, has acted to rehabilitate and stabilize the economy, with the primary aim of reducing inflation and strengthening production and export earning. This was partially achieved by currency reforms, raising of producer prices on export crops, increasing prices of petroleum products, and improving civil service wages (CIA). There was also investment in the rehabilitation of infrastructure, a gradual improvement in domestic security, and the return of exiled Indian-Ugandan entrepreneurs, many of whom had owned and managed agri-businesses in the pre-war years.

Population demographic trends

Population growth in Uganda is high, at 3.6% per year (CIA, 2008 figures) and the country currently supports a population of 31.4 million people. Of these, 50% fall into the 0-14 year age group. This means that demand on natural resources and requirement for food is projected to increase significantly in the near future, putting ecosystems and their services at great risk of further degradation. An assessment of climate change vulnerability in the context of land use and food production must take cognisance of this. The fact that population growth is highest in arid areas (Uganda NAPA, 2007) where the population is most vulnerable to climate change is great cause for concern. There is also high population pressure in the fertile southern regions around Lake Victoria.

National security issues

Uganda has been plagued by armed fighting among hostile ethnic groups, rebels, armed gangs, militias, and various government forces that extend across its borders (CIA), particularly in the north and north-eastern border regions. Notably, the 21-year-long insurgency by the Lord's Resistance Army has resulted in approximately 1.3 million people being displaced, the so-called Internally Displaced People (IDP). Uganda hosts numerous Sudanese, Congolese and Rwandan refugees. Progress on peace talks has allowed about 350 000 IDP to return to their homes (2006).

Refer to Appendix 1 for a *status quo* assessment of the agricultural production in Uganda.

2.5. Previous Vulnerability Studies in Uganda

This report attempts to enhance (rather than repeat) existing climate change related studies in Uganda by further examining the key vulnerabilities and impacts thereof for the water sector so as to identify priority focus areas and a clear way forward. A sample of the literature drawn upon follows.

Climate Change: Uganda National Adaptation Programmes of Action (NAPA), published by the Ugandan government in 2007, reviews the national circumstances and resources of Uganda, examines vulnerabilities to climate change. It goes on to present adaptation strategies together with implementation arrangements for nine profiled projects, and the barriers to implementing them. Water resource management is a crucial ingredient to the success of most of these projects, two of which are focused specifically on water and one on drought. (Five of the top 17 prioritized intervention strategies identified were in the water sector.)

Water Resources Management in the Era of Climate Change (Kabasa, 2008) is a study of climate change impacts, vulnerabilities, adaptation and the way forward in terms of proposed strategies and actions for water resources management in Uganda. However, there are too many proposed actions that exist in possibly separate components and are not specific enough to create "bankable" projects. These would need to be drawn together.

Climate Change in Uganda: Understanding the implications and appraising the response (Hepworth and Goulden, 2008) reviews climate change vulnerability, adaptation and mitigation, as well as what other institutions (including donors and UN agencies) are doing about climate change in Uganda. Its conclusion highlights some noteworthy points and makes valuable suggestions.

Other studies have examined vulnerability of the Ugandan water sector to climate change to a greater or lesser extent, including:

- The Poverty Eradication Action Plan (PEAP), which is to be superseded by a National Development Plan under the auspices of the Ministry of Finance, Planning and Economic Development at the end of 2009;
- The Uganda Human Development Report by the UNDP (2007);
- Livestock development project;
- Flood disaster management report;
- World Water Development Report (UNESCO, 2006).

3. APPROACH

3.1. Models of Vulnerability

A formal method of examining vulnerability of a system to the forces of change is required. We find the model of Pelling (2001) particularly persuasive for our purposes and this is described briefly below (also see Figure 2).

We propose to use an adaptation of Pelling's (2001) model of environmental risk in developing the vulnerability assessment in the water resources sector of Uganda. One of the most important outputs of this vulnerability assessment will be to understand probable trajectories of future climate as they relate to natural hazards and human vulnerability. Therefore we will need to develop some scenarios of how exposure to these hazards and human resistance and resilience with respect to the water resources sector will also play out in the future. These scenarios will guide us in the development of adaptation and mitigation projects with the objective of reducing vulnerability.

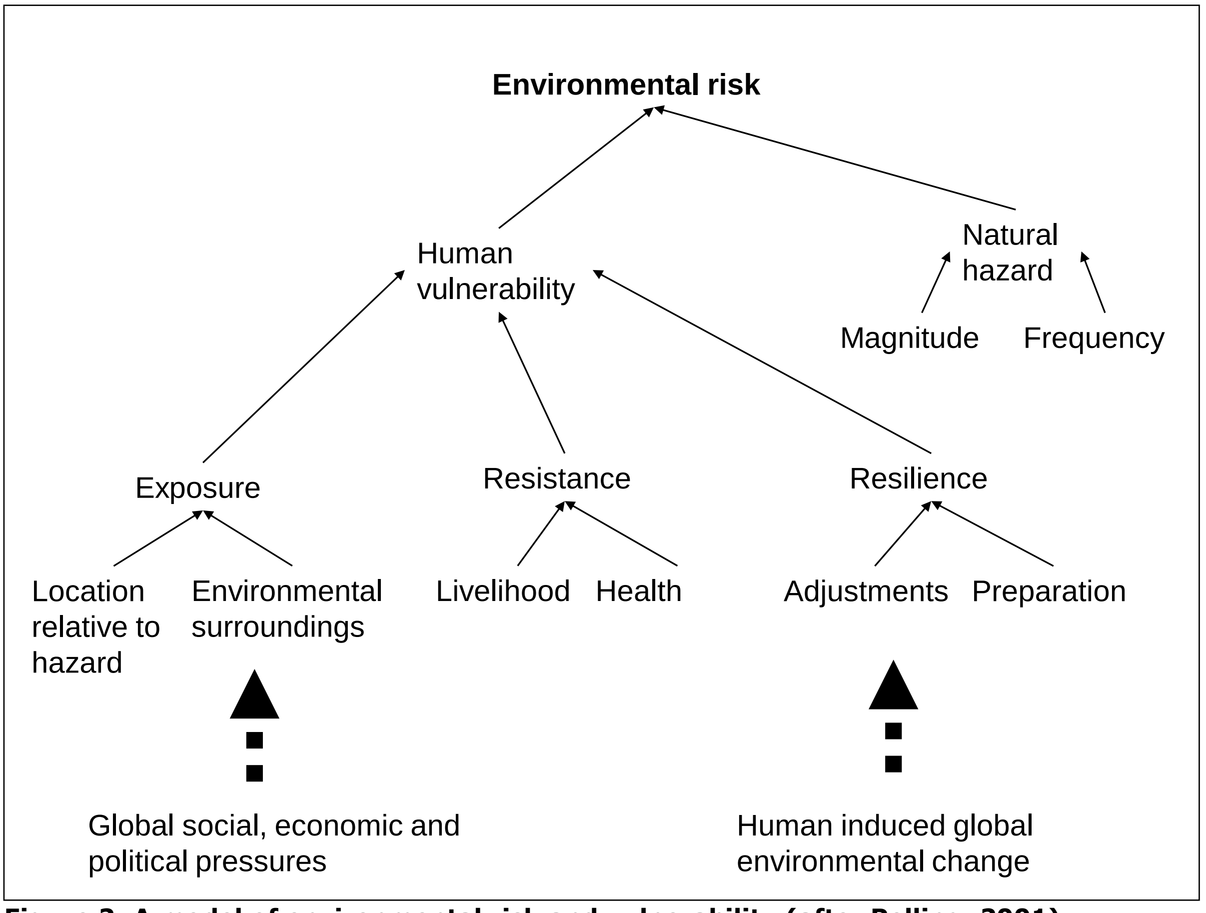

Figure 2: A model of environmental risk and vulnerability (after Pelling, 2001)

3.2. Hazard Identification

The equatorial regions of the world experience specific climatic activity. As the atmosphere warms, global circulation becomes more vigorous. Increasing convergence (with its inherent rainfall) is therefore expected in equatorial regions. With increased global temperatures, Uganda is expected to experience increased rainfall. IPCC reports anticipate a future of precipitation increases in the region. These have not been detected yet, but anecdotal evidence is that the frequency of floods and droughts is increasing.

Our interpretation of the hazards to which the water resources sector in Uganda are being exposed, and will be increasingly be exposed in the future, is that the changes in the frequencies of extreme events are how the effects of climate change will be experienced. The key understanding this is to recognize that small shifts in the frequency distributions of rainfall will result in substantial changes in the relative frequencies of events in the tails of their extreme value distributions, as shown in Figure 3.

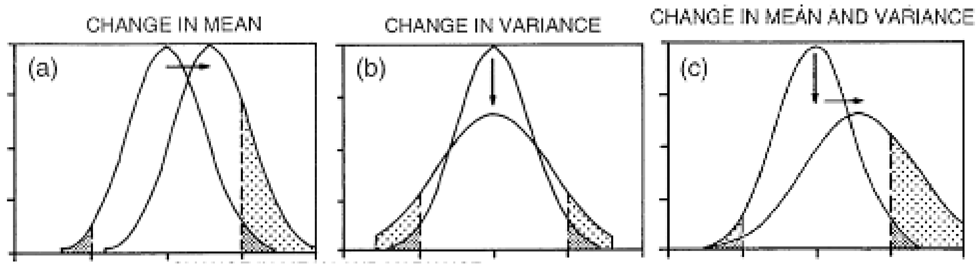

Figure 3: Shifts in the mean and variance will result in large changes in the frequencies of events in the tails of their distributions. Dashed lines indicate nominal coping thresholds, beyond which (the stippled area) systems such as health, agriculture, and ecosystems begin to fail. (Source: Meehl et al., 2003)

It is not really instructive to look at the outputs of global climate models (GCMs) which mostly produce estimates of changes of the mean, for example (see panel (a) in Figure 3 above). Firstly they operate at a coarser scale than in which we are interested. Secondly, such outputs of changes in the distribution of the mean values are not particularly useful for examining the impacts and vulnerabilities of systems to the predicted climate changes, since it is usually the extremes that cause the most damage, not the means.

3.3. Causes of Hazard

Ocean temperature and atmospheric pressure systems

Recent research has indicated that the driving force for cyclicity in the east African region has primarily been the El Niño / Southern Oscillation (ENSO) phenomenon, the anomalous warming of the eastern equatorial Pacific Ocean and associated global scale atmospheric pressure and wind changes across the western Indian Ocean (Goddard and Graham, 1999; Hoerling *et al*. 2006). Wet phases and flooding in east Africa can be correlated to ENSO events when the eastern Pacific undergoes substantial warming, and the Southern Oscillation Index becomes negative, otherwise known as El Niño. The reverse, La Niña, occurs when reversing wind systems blow the warm pool of water to the western part of the Pacific Ocean. The change in the perturbation of the climate there has knock-on effects (teleconnections). A dry phase, and very often regional and deep droughts may be experienced in east Africa, is the result of a La Niña event.

This picture is somewhat complicated by the influence of the Indian Ocean Dipole, which is an ENSO-like event that occurs in the Indian Ocean (Goddard and Graham, 1999). The position of the warm pool of water in the Indian Ocean is represented by the Dipole Mode Index (DMI). When the DMI is positive, there is a warm pool of water in the western Indian Ocean adjacent to the east African coast line (Saji et al. 1999). The region then receives very heavy rainfalls and flooding occurs.

ENSO and Indian Ocean dipole events do not necessarily coincide with one another (Marchant et al. 2006; Saji et al. 1999). The lack of synchronicity of these two sea surface temperature-driven events possibly lead to the failure of drought predictions in southern Africa during the 1997-1998 ENSO event. These failures led to severe economic consequences for countries which responded to the drought predictions by reducing plantings of staple food crops and the slowdown in agricultural investment in that year. It indicates that the global circulation and its drivers are still not well understood and poses a cautionary tale to the need to predict seasonal weather in the east African region.

It seems apparent that dry El Niño and wet La Niña phases are modulated by the IOD modes (Marchant et al. 2006, Washington and Preston, 2006). The impacts of future climate change will depend on how global warming influences the frequency and intensity of the ENSO and IOD events, as well as their interrelationships. Some projections are for increased frequencies and intensities of ENSO and IOD, as well as a general warming of the Indian Ocean, that would lead to concomitant effects on flood and drought frequency in Uganda (Goddard and Graham, 1999; Hoerling et al. 2006). The cycles between wet phases and drought phases would likely quicken and this could have severe consequences for Ugandan water resources.

Global warming increases precipitable water in the atmosphere

With every 1°C increase in air temperature there is a 7% rise in atmospheric water vapour (as determined by the Clausius-Clapeyron equation). The increasing moisture content of the air must result in changing rainfall. Trenberth et al. (2003) describes how, with the increase in precipitable water, rainfall intensities increase faster than the average increase in specific humidity therefore there will be a concomitant decrease in the frequencies of low intensity rainfall. The impact of these changes is that the frequency of intense rainfalls will increase and the duration between rainfall events will also increase (Trenberth et al., 2003). These projections appear to be supported by observed data, but not climate models (see Wentz et al., 2007). The trend to more intense rainfall events has significant implications for design flood calculations and flood disaster management.

3.4. Future Hazard Frequency and Intensity

Uganda Climate and Drought and Flood sequences

Lake Victoria is sensitive to differentials in inflow and outflow – the changes manifest quite visibly such as the dropping lake levels in 2006. Evaporation from the reservoir and the water balance with regard to rainfall directly onto the surface of the lake appear to be an important part of the water budget. This sensitivity has important implications for the hydropower generating capacity in Uganda. In 2006 there was a loss of hydropower generation capacity because of low lake levels.

4. VULNERABILITIES IN THE WATER RESOURCE SECTOR

4.1. Water Levels of Lake Victoria and Associated Vulnerabilities

Lake Victoria covers an area of about 67,000 km^2 and is the world's second largest freshwater lake. One third of its catchment area of ~ 190,000 km^2 is covered by lake surface itself. The 17 key tributaries contribute only ~13% of the total inflow (Nicholson 1998). Mean annual precipitation is about 1200-1600 mm per year, as gauged by stations near and on the lake. *True lake rainfall is however not known*. Mean water depth is about 40 m and maximum depth is about 92 m.

More than 30 million people depend on Lake Victoria for their livelihoods, including the generation of power that is consumed as far as Rwanda and Tanzania. Lake transport and fisheries are also significantly affected by water levels in Lake Victoria. The region experienced receding water levels from 2001 to 2006. After the strong 1997-1998 El Niño, a drought prolonged drought led to the lowest water levels in Lake Victoria since the 1960s[4]. 2004-2006 power shedding took place because prolonged drought resulted in decreased power production at the two power stations. There are now several other hydroelectric schemes being built.

Lake Victoria has a long history of significant water fluctuations, with low water levels indicating regional drought and high water levels indicating regional flooding (Nicholson, 1998). Correlations with other African lakes such as Turkana and Naivasha give a semblance of coherence, indicating regional wet and dry periods. The dry periods are typically remembered in oral histories of the region as times of severe famine. Nicholson's (1998) research indicates that during the early 19th century the Lake had low levels (an extended dry period), rising very significantly in the 1870s, reverting back to low levels in the 1880s until the 1960s when Lake levels suddenly rose again as a result of great increases in regional rainfall.

The eruptions of the volcanoes Tambora (1815) and Krakatoa (1883) are known to have caused a global cooling (due to reflection of sunlight off aerosols in the atmosphere) and it is possible that this effect was manifest in an especially large change in regional equatorial rainfall. It seems from Nicholson's (1998) record that equatorial cooling could have resulted in regional drought and lowering of Lake levels. Long-term trends of Lake level and regional rainfall trends cannot be discerned from the fluctuations, but it is clear from Nicholson's (1998) paper and other literature that regional drought, for example, posed very significant hardship on people in those times. Famine, large-scale human migrations and cattle disease were linked to regional droughts, indicating the close link between climate and human wellbeing in the region.

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[4] There is also disputed evidence that increased outflows via a new hydroelectric scheme, Kiira, at Jinja affected the Lake's water levels.

Figure 4: Fishing Boats at Ggaba Landing Site on Lake Victoria[5]

Lake Victoria itself has a diurnal pattern of mesoscale atmospheric circulation (Yin and Nicholson, 1998) which apparently enhances rainfall over the lake. A strong nocturnal land breeze creates convergence over the lake at night through differential heating between land and the lake surface, leading to convective storminess over the lake. Much of the rainfall over Lake Victoria then occurs at night during strong thunderstorms (Yin and Nicholson, 1998). Some of this rainfall occurs on land in the north and west of the lake areas, i.e. increasing rainfall in terrestrial Uganda, indicating that Ugandan rainfall is influenced by its relationship to Lake Victoria.

Low lake levels are related to drought (Nicholson 1998, Mistry and Conway 2003). There is also an increase in demand for fresh water by an increasing population around the edges of Lake Victoria. There are questions as to whether the lake levels are sensitive to small changes in runoff and evaporation. (Phoon et al. 2004; Sene et al. 2001).

Outflow from Lake Victoria has been measured for more than a century at Owen Falls (now Nalubaale) and the long-term lake level and discharge readings have been developed into a rating curve. Calculated annual inflow to the Lake by Yin and Nicholson (1998) is about 343 mm, ranging from 199 mm to 539 mm, with a standard deviation of 106 mm. Yin and Nicholson (1998) believe that rainfall onto the lake is about equal to evaporation, which they put at about 1370-1600 mm per year.

The outflow of the lake through the power generating turbines is apparently maintained to emulate the original lake level/discharge curve. 87 percent of water in the lake is lost by evaporation, the residual 13% being discharged via the outlet at Jinja. Daily losses of water by evaporation from Lake Victoria should equal about

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5 http://commons.wikimedia.org/wiki/File:Ugandan_fishing_boats.jpg. Attribution: sarahemcc. Accessed 4 March 2009.

28.8 million m^3 and one expects outflow from Jinja to be about 2.9 million per day (with a corresponding discharge of 33 $m.s^{-1}$).

Climate change will affect the ratio of lake rainfall to evaporation. Low rainfall is likely to result in higher evaporation, especially if drought conditions bring with it higher temperatures and increased advection, resulting in declining lake levels. Climate change impacts are also multiplied in the runoff signal (Chiew and McMahon, 1996) in that stream flow shows a greater response fractionally than changes to rainfall (e.g. a decline in rainfall of 10% can lead to a change in runoff of 15%). Relatively small reductions of runoff in the terrestrial catchment areas surrounding the lake are likely to have larger impacts on the lake water budget. We expect that regional rainfall is strongly affected by El Niño/Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). If climate change results in changes in the mesoscale circulation, drought frequency over the lake may also change and this will noticeably affect the lake water budget.

4.2. Water and Power Generation

The Nalubaale hydroelectric power station was built in the 1960s and in the 1990s it was upgraded from 150MW to 180MW. From 2000-2006 the Kiira power station was commissioned to 200MW, giving a combined installed capacity of 380MW. This is equal to a water flow rate of 1150 $m^3.s^{-1}$ through the turbines. Although Uganda is short of electrical power, the generators cannot be run at maximum output for several reasons. Firstly, power outputs must be optimized. A spinning reserve is required so as to allow load following. Increased load on the line results in a frequency drop. If the power frequency drops below critical level, all systems drop out and this causes severe problems when trying to restore power. The frequency tolerance is 0.5 Hz. One turbine dropping out will be quickly followed by the others as the load on them quickly exceeds individual capacity to generate power.

The stations run at ~1000-850 $m^3.s^{-1}$ (where 1000 $m^3.s^{-1}$ produces about 265 MW). During the extended drought of 2006, power generation came under severe pressure. On Feb 2006, Eskom received an instruction from DWRM to reduce water outputs to 850 cumecs. In August, flows were reduced to 750 cumecs because of declining lake levels.

A 1 cm change of lake level equates to about 64 million m^3. Eskom operates within three specified power bands during the day, each with its own water let down rate. The new dam at Bujagali will generate 250MW. This will allow Nalubaale to be retired – it is showing its age and cannot be fixed due to structural problems.

Measurements at the Jinja pier have been taking place since 1913. Since October 2006 lake water levels have been appreciating. However, unmetered abstractions in Kenya and Tanzania may cause lake levels to drop and Eskom / DWRM can do little about it except through negotiation. It is also noted however that the East Africa Global Water Partnership and Nile Basin Initiative representative in Entebbe indicated that the abstraction of water by these neighbouring countries is "negligible"[6].

4.3. Water and Fisheries

During long droughts, the receding water levels affect the breeding grounds of fish in the lake, reducing recruitment and biomass production as there are less nutrients or vegetative cover found at lower levels in the lake. Further, declining lake levels strands or otherwise makes inaccessible the jetties over which fish catches are landed. Fish catches must then be hauled ashore through shallow contaminated edge waters which compromises fish hygiene within the supply chain. Bacterial loading of fish carcasses result in high or total catch rejection by European fish importers and results in significant post-harvest losses.

While fish harvests from Lake Victoria are increasing, there has been a substantial drive to increase protein intake among non-lake edge dwellers by the introduction of aquaculture in wetland ponds using species such as tilapia. Droughts usually result in a loss of these ponds as they dry up, reducing protein intake, resulting in declining health. Increasing frequency of droughts or increased drought duration therefore not only reduces protein intake from grazing livestock but also from aquaculture as well and there is a general decline in food quality.

There are also links between fish harvests and the area covered by water hyacinth (Kateregga and Sterner, 2008). Increased areas covered by hyacinth reduces fishing pressure because the hyacinth prevents access to fishing grounds. We can expect that with increased temperatures and more frequent heavy rainfall events, which leads to more frequent nutrient loading events (along with rising populations around the shoreline), hyacinth could increasingly be a problem to artisanal fishers, meaning loss of livelihoods (Kateregga and Sterner, 2008).

In 2008, a large international research team identified Uganda as having one of the most vulnerable national economies of 132 countries to potential climate change impacts on their capture fisheries (Allison et al, 2008). "This vulnerability was due to the combined effect of predicted warming, the relative importance of fisheries to national economies and diets, and limited societal capacity to adapt to potential impacts and opportunities." (ibid) The article goes on to say "These countries also produce 20% of the world's fish exports and are in greatest need of adaptation planning to maintain or enhance the contribution that fisheries can make to poverty reduction. Although the precise impacts and direction of climate-driven change for particular fish stocks and fisheries are uncertain, our analysis suggests they are likely to lead to either increased economic hardship or missed opportunities for development in countries that depend upon fisheries but lack the capacity to adapt."

[6] Simon Thuo, pers comms, Mali, February 2009

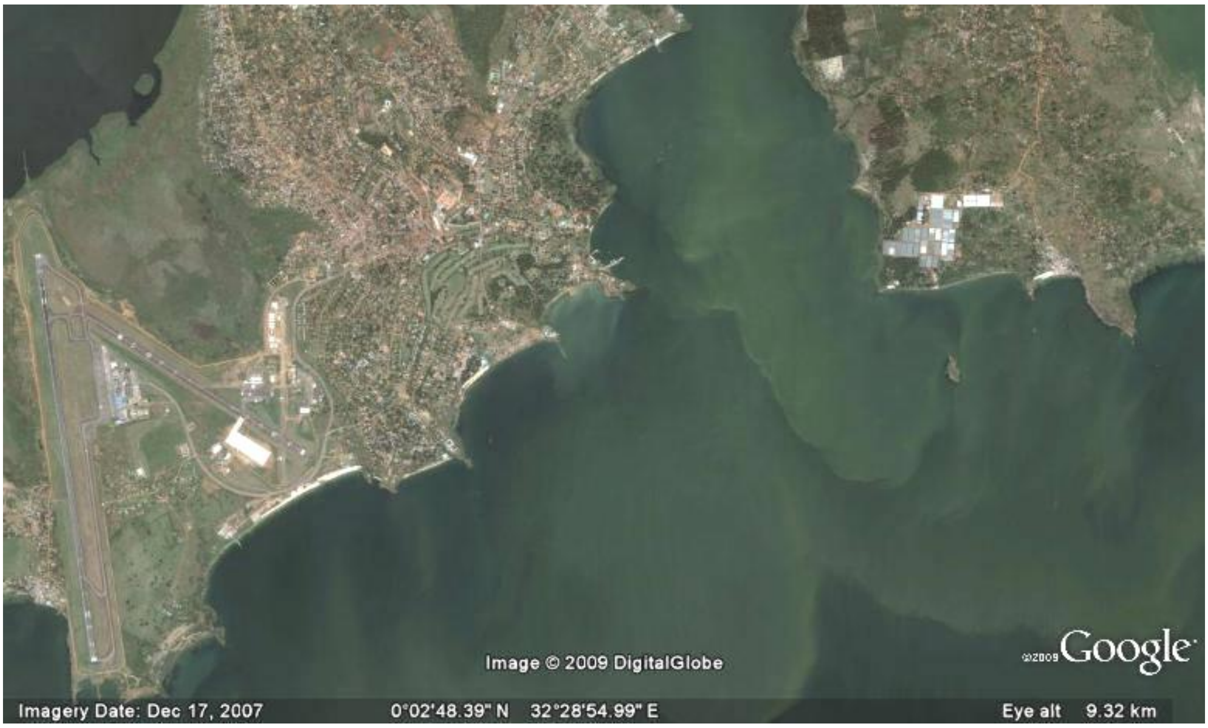


Figure 5: Severe nutrient loading from human waste and agricultural fertilisers results in eutrophication which de-oxygenates the water, thereby depleting populations of fish and other species. (Image locality: Lake Victoria near Entebbe.)

4.4. Groundwater

About 80% of the Ugandan population live in rural areas and the vast majority of them are dependent on groundwater at some or other time during the dry season. The change in climate to more intense rainfall events and longer dry periods may lead to an increasing reliance by the population on groundwater. During heavy rainfall events, shallow groundwater resources become contaminated when surface water enters the shallow wells. Cholera is then a frequent occurrence.

Naturally occurring groundwater constituents also affect quality through influences of geological conditions. Fluoride concentrations are above global health standards in the Busia, Tororo and Kapchorwa (Mt Elgon) districts. This is likely caused by groundwaters circulating through rocks of volcanic origin, which are naturally enriched in fluorine constituents. In the south-west, in the Rakai and Mbarara districts, iron enrichment of the groundwater renders it undrinkable. However, the greatest challenge to groundwater quality is the seepage of sewage and effluent constituents from the many pit latrines and the result of these are elevated chlorides and nitrates. High levels of bacterial contaminants occur in many unprotected springs and shallow wells.

Groundwater development will be focused where drought frequency is increasing, along with increasing demand by people. Existing groundwater records are short and not of sufficient length to usefully indicate trends. However, in some cases, water levels in wells and boreholes have clearly declined as a result of exploitation. Pressure on water resources is increasing because of a rapidly expanding population. Aquifers are becoming increasingly polluted and collection, analysis and dissemination of groundwater data is lacking.

Climate changes in the manner discussed earlier (more intense rainfalls, longer durations between rainfalls and greater variability in timing of the rainfalls) will have a significant impact on groundwater resources. Firstly, more intense rainfalls are usually beneficial for groundwater recharge because heavier events allow an increased soil water pulse to get past the root systems of the vegetal cover and percolate to groundwater (Cavé *et al*. 2003). However, longer duration dry periods and increased variability will increase human dependence on groundwater resources, potentially leading to over-use if not controlled. The ability of local aquifer to sustainably deliver good quality water is also unknown for most boreholes, despite the requirement for licensing and regulation. (It is noteworthy that the licensing and related regulations are difficult to implement regardless of climate impacts, and that there is little data available on groundwater. The European Union is currently funding a project in Uganda to map groundwater resources throughout the country. Once the project data is available, it should assist in enabling the regulatory framework.) Additionally, flooding is known to lead to pollution of groundwater resources when contaminated surface waters are washed into wells. Since heavy rainfall events are becoming more frequent, increased contamination of wells can be expected, with associated health impacts.

4.5. Water and Human Health

Water-borne and sanitation-related infections are a major contributor of disease burden (Hunter, 2003 citing Pruss and Havelaar, 2001). With its abundant surface water bodies and poor sanitation standards, water borne diseases including dysentery, cholera and typhoid are a leading cause of mortality and morbidity in Uganda, particularly amongst children, pregnant women and those already compromised by other infections such as AIDS. When lake levels are high, for example, inundation of the near-shore floods human settlements. In most of these areas, pit latrines at these settlements are flooded and the human waste and faecal matter are entrained in the rising waters, which floods into shallow wells used for drinking water. The nutrient enrichment of the inshore water causes algal blooms and cyanobacterial toxins are known to affect people whose livelihoods are closely associated with lake-related activities. Figure 6 shows a village on the shores of Lake Victoria near Jinja, whose inhabitants depend on charcoal trade from the Lake's islands.

Figure 6: Lakeside charcoal-trading village near Jinja. Note the water hyacinth.

The Ugandan population is mostly poorly served by sewer networks and many rely on shallow pit latrines for waste disposal. Water quality in urban areas is also of concern, especially with growing informal settlements around urban nuclei. Pit latrines are common, and in times of heavy rainfall, floodwaters become contaminated with human and industrial waste.

The availability of fresh water is a key determinant of human health. Fresh water is a socio-economic good but is also finite and a vulnerable resource. The availability of fresh water is challenged in Uganda by urbanization, industrialization and increasing population pressure. These pressures have led to poor sanitation, pollution, deforestation and intensive cultivation which affects the quality and quantity of available freshwater.

Climate change is manifest in the increasing frequency and intensity of extreme events which will contribute substantially to the problem of declining quality of the water resource. Flooding leads to the contamination of drinking water resources through contact with surface waters or the movement of contaminated water into freshwater lake systems

The key issue here is that, while historically there have been phases of increased flooding, the impact of a rapidly increasing human population without concomitant increases in treatment and safe disposal of waste water will result in significant declines in the quality of fresh water in future. Historically, flooding had less impact on water quality because of the lower population density. The combined increases in frequency of flood events *and* population density will have substantial impacts on water quality and human health. There is no matching coping capacity for managing poor quality water. Declining water quality translates directly into more widespread illness and child mortality under the age of five from diarrhoeal diseases (including cholera).

Droughts reduce the availability of good quality surface water in some regions, especially the semi-arid Karamoja and south-west Rakai/Bushenyi regions. People are usually forced to use lower-quality water when better quality sources dry up, with resulting impacts on human health. The higher temperatures expected with the projected climate changes will have only negative effects on water quality.

4.6. Water and Agriculture

Uganda is a net food importer and issues of food security are already of concern. Political imperatives for increased food production exist and are driven at Presidential executive level and this has led to the Water for Production programmes. Constant grazing, disturbance of soil surface, and loss of vegetative cover all result in soil crusting. Infiltration rates decline and intense storms result in excess water runoff. Recharge to groundwater is diminished and the excess surface water causes flooding. The net effect is that overuse of the land in the Karamoja district, for example, results in declining groundwater levels because recharge to groundwater is reduced despite the apparent increasing intensity of rainfalls. Most rural people in Uganda are dependent on groundwater for a part of the year. The whole of the cattle belt is probably vulnerable to this type of change.

The increasing frequency of droughts make life in the arid north-east particularly difficult and combined with the increasing population there, a migration of people to urban centres and particularly towards the south-west, is taking place. This places a further demand for water resources in the urban centres, as well as sanitation capacity.

Irrigation

In general, the surface waters are chemically of good quality and have no problem with salinity, but saline water is found in the semi-arid areas of the north (Aquastat). In case the need arises for irrigation in these areas, blending of the water with surface runoff or use of tolerant crops should be considered. *Groundwaters mostly contain dissolved calcium and bicarbonate, with saline water containing sodium and chloride*. Spring waters generally have low mineralisation levels and are comparable to surface waters with respect to water quality.

The *most important quality problems for groundwaters are related to poor sanitation*, which results in high levels of faecal coliforms and nitrate. Currently, fertiliser is not used extensively in agriculture, so the main sources of nitrate are of domestic and urban origin (latrines and market waste). As the use of agricultural chemicals is expected to rise in future, concentrations of nitrates in groundwaters could rise. Groundwaters from the shallowest wells (often those dug by hand) and with high water tables are most at risk from pollutant inputs. Deeper groundwater abstracted from boreholes is less at risk of contamination. Siltation and sedimentation, and wetland loss and degradation, also reduce water quality.

Currently, less than 1% of arable land (9000 ha or 90 km^2) is irrigated (FAO, 2003). Crops, even commercial cash crops, are almost entirely rainfed. Traditional low-tech *in situ* water harvesting techniques are employed for most of the plantain/banana and coffee crops. Tea estates enjoy the benefits of the cool highland climate, while much of the sugar cane is produced under wetland conditions. Crops like cassava, sweet potatoes, millet and sorghum are grown under rainfed conditions due to their high resistance to drought and low value.

Smallholder production of crops under dry-season irrigation, especially rice, vegetables and fruit, is becoming increasingly prevalent, using "informal" irrigation, characterised as spontaneous, with little technical assistance, and using basic technology. The majority of these areas are located on the *fringes of swamps*, and mostly in the south-east of the country. *53 350 ha of fringes of swamps are cultivated, of which 3 570 ha are equipped for irrigation*.

Nationally, the irrigation potential has been estimated at 90 000 ha (FAO, 2003), 10 times the current irrigated area, located mainly in the Lake Kyoga catchment, the western region, the Albert Nile Valley, and the Jinja and Iganga districts on Lake Victoria. *Formal irrigation development* has taken the form of various types of schemes, mostly for rice production (including one swamp rice irrigation project), and some for sprinkler irrigation of citrus orchards. Formal irrigation is currently used for 1650 ha rice, 560 ha vegetables, 100 ha sugar cane, and 20 ha citrus, although more capacity is available. Greenhouse-based floriculture around Kampala is also dependent on irrigation. The area equipped for crop irrigation is mostly in the south-east between Lake Victoria and Lake Kyoga. Of the 5580 ha equipped, 2330 ha are actually irrigated.

The main type of irrigation employed is *surface irrigation* (5350 ha, 96%), followed by sprinkler irrigation (230 ha, 4%). Localised (drip) irrigation is being tested in pilot schemes for clonal coffee and is also used for flower production. Supplementary irrigation technology ranges from small-scale systems (1-4 ha) using treadle pumps, to motorized pumps with surface or sprinkler irrigation, the latter being more successful for many crops.

The *source of irrigation water is almost exclusively surface water* (as opposed to groundwater). The success of irrigation schemes has depended strongly on farmer participation (bottom-up approach); farmer-based schemes have been considerably more successful than those imposed top-down.

Aquaculture and livestock watering depend in many areas on the more than 1000 dams and valley tanks (surface water reservoirs). Current development policies make provision for the construction of many more valley tanks. However, partial and total sedimentation of dams and valley tanks has occurred in most structures of the 1960's, especially in areas with sandy soils. This has substantially curtailed valley tank and dam construction in some areas.

Aquaculture

Aquaculture provides a significant amount of dietary protein in the rural areas. Altogether, fisheries account for four percent of the agricultural GDP (MAAIF, undated), and aquaculture is only a small fraction of this. It should be noted that aquaculture data are often merged with fisheries data so that information on aquaculture specifically is lost in the combined statistics.

During droughts, aquaculture is placed under significant stress as the ponds dry and stock die. An increase in the frequency of droughts can be expected to place severe challenges on the aquacultural production, such that in already marginal areas it can be expected to collapse with increasing climatic changes.

In times of flooding, cultivated fish often escape from the 350 wetlands where aquaculture is taking place. Flooding also causes species migration, with Nile Perch being found in inland water bodies where they had never existed before.

Vulnerability of land agriculture

Historical trends and future climate projections

Over the last four decades or so, there have been significant shifts in rainfall variability, amount of rainfall (decreasing), occurrence of heavy rainfall (rising), and temperature (rising), as well as increases in the occurrence of landslides (highlands), flooding (lowlands) and droughts (country-wide). This has already had major impacts on livelihoods and the economy (Uganda NAPA, 2007).

The following climate trends and future projections were used for the purposes of this assessment:

Climate variable	**Recent history (since 1960) (source: UNDP)**	**2020's (source: adaptation learning.net)**	**2050's (source: adaptation learning.net)**	**2060's (source: UNDP, NAPA)**
Mean temperature	+1.3°C Most rapid in Jan-Feb	+0.5 to +1.25°C Most rapid in highlands	+1.0 to +3.25°C Most rapid in highlands	+1.0 to +3.1°C Most rapid in coolest season (JJAS)
Frequency of hot days	+74 p.a., most rapid in JJA			Increases
Frequency of hot nights	+136 p.a., most rapid in JJA			Increases
Frequency of cold days	-20 p.a., most rapid in SON			Increases
Frequency of cold nights	-42 p.a., most rapid in DJF			Increases

Annual rainfall	Significant decreasing trend	Increases	Increases	Increases; ensemble median +7 to +11%; Wetter areas become wetter
Rainfall inter-annual variability				Increases; Future El Niño event frequency highly uncertain
Rainfall in the "short rain" season		Strong increases	Strong increases	Strong increases
Rainfall in the "long rain" season	Significant decreasing trend			
Onset and cessation of rain: duration of season	Later onset, earlier cessation, shorter duration of "long rain" season			
Proportion of rainfall in heavy events	Non-significant increasing trend in 1- and 5-day maxima			Increases; increases in 1- and 5-day maxima; Largest increases in the rainy seasons
Frequency and intensity of flood	Increasing trend			Increases in wetter areas
Frequency and intensity of droughts	Increasing trend			Drier areas experience more frequent and longer droughts

Most important climate variables for crop and livestock production

Rainfall patterns are and will remain the most important climatic influence on agriculture and food security in Uganda since the all-important agricultural sector is primarily rain-fed. The adverse effects of climate change will mainly be through extreme weather events and their consequences, such as droughts, storms, floods, extreme high temperatures and landslides (UGANDA NAPA, 2007), as well as increased climate variability manifesting as erratic timing, duration and quantity of rainfall.

Impacts on food production: identification of most sensitive crops

Climate change will impact on crops differentially depending on physiological heat and drought tolerance, tolerance to diseases and pests (current and new), and whether they are grown under supplemental irrigation or purely rainfed conditions.

- *Plantains/bananas:* The main risk is that of epidemic diseases, such as banana bacterial wilt disease, which has decimated crops in recent times. Warmer and wetter conditions could increase the frequency and severity of disease.
- *Cassava:* In some part of the country, cassava yields have plummeted due to increasing temperatures and erratic rainfall patterns, and the crop can no longer be grown. Cassava is one of the crops at highest risk.
- *Maize* is particularly sensitive to erratic rainfall (late start to the rainfall season, lack of sufficient follow-up rains), and is also sensitive to high temperatures during critical reproductive periods.
- *Rice and sugar* are grown in wetland areas and are at risk during periods of drought and low wetland water levels, but also during flooding when fields become waterlogged or crops are washed away.
- *Potatoes and sweet potatoes, millet, sorghum:* these crops grown primarily in the northern half of the country, are at risk of erratic rainfall and drought,

since they are all grown under rainfed conditions. They are, however, relatively resilient to high temperature and water stress. Yields may decrease somewhat.

- *Beans and soya beans* are sensitive to high temperatures and drought, and have already shown declines in yield.

Figure 7: Heavy rains led to waterlogged soils and hence crop losses in the 2007 floods in Uganda (Source: BBC News[7])

The first rainfall season ("long rains") from March to June has become particularly unreliable, with rains starting late, ending in April already, and thus resulting in crop failures for this season, where crops require three months of rainfall to develop to maturity. This trend is likely to continue under modelled future climate change projections. In contrast, in the second rainfall season ("short rains") the rainfall has become more intense, leading to flooding, washing away of crops and landslides in mountainous regions. This also agrees with modelled future projections.

These shifts from what has historically been quite a predictable rainfall pattern, has made planning for the planting of crops very difficult. Where farmers employ rain-harvesting techniques or other forms of supplemental irrigation, crops are likely to be at less risk.

Impacts on export commodities: most sensitive crops

Coffee: a recent study showed that whilst the current climate of Uganda is suited to growing robusta coffee in most regions (on average 25°C), a warming by 2°C will reduce the suitable area to only the south-western corner of the country. This high-altitude region is currently too cool for coffee growing but will become suitable in a warmer climate. However, this does not mean that the terrain is

[7] http://news.bbc.co.uk/2/hi/in_pictures/7004296.stm, accessed 5 March 2009.

suitable for coffee planting, and that land (probably forest) will have to be cleared. This study thus predicts serious effects on the agricultural and national economy unless other crops can replace coffee in importance.

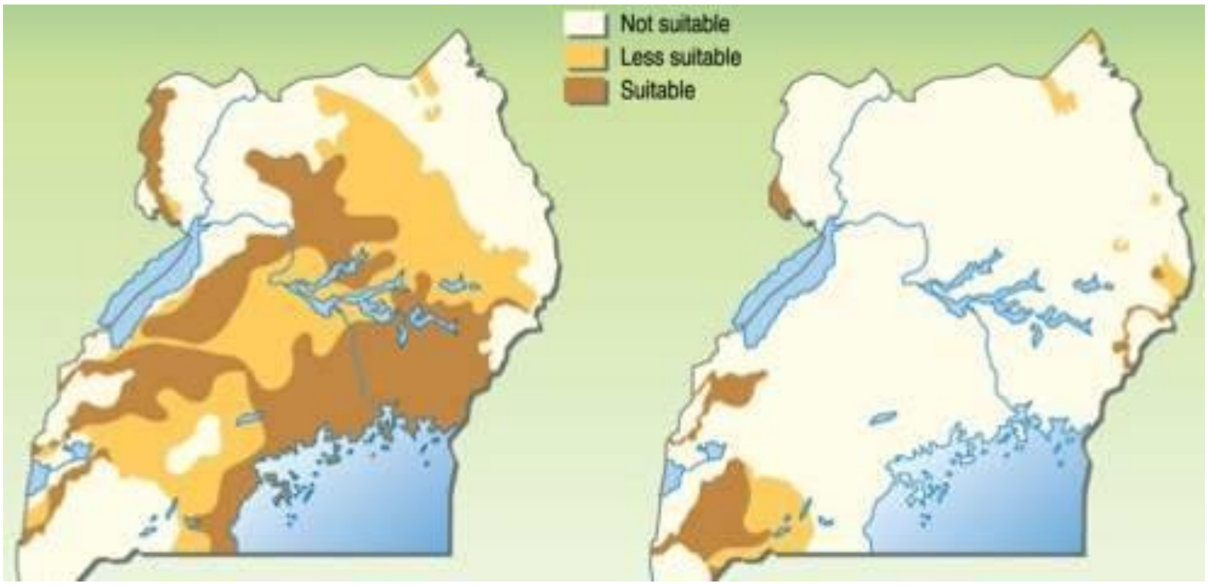


Figure 8: Impact of temperature rise on robusta coffee in Uganda: The map on the left shows suitability of the current climate to coffee growing; the map on the right shows the suitability under a 2°C warmer climate. (Source: Otto Simonett, UNEP/GRID-Arendal[8])

Coffee requires specific growing conditions with distinct wet and dry seasons, and thrives during the rainy cool period (November to February). Out-of-season heavy rains disrupt flowering. Yield and quality are diminished by drought or heat. Where coffee used to be grown as an under-storey crop amongst forest, now, due to de-forestation for firewood and charcoal, coffee is often grown in unshaded conditions which exposes the trees to higher temperatures and would make these plantations even more sensitive to warming than shaded plantations.

Cocoa beans: This crop has been introduced as an alternative export crop to coffee. It will be susceptible to drought and disease.

Tea: It is predicted that the highland areas will warm at a faster rate than the rest of the country. Since tea is grown mainly in the cooler highland climate, and has an optimum temperature of about 22°C, the crop would be pushed upslope in future or suffer significant yield reductions in current production areas with rising temperature.

Cotton, tobacco, vanilla, sesame seed: all of these crops generally do well under tropical/sub-tropical rainfed conditions throughout central Africa, but they are at risk of reduced yields given current and projected shifts to unpredictable and irregular rainfall, earlier cessation of rainfall leading to a reduction in the length of the growing season, and drought.

8 http://maps.grida.no/go/graphic/impact-of-temperature-rise-on-robusta-coffee-in-uganda, accessed 5 March 2009.

Shifts in crops

Although some crops may all but disappear (e.g. coffee), most of the current crops will remain important and it is unlikely that they will be replaced by completely new crops. However, different cultivars (either existing or newly bred) with improved heat-, drought- and disease-resistance will have to be introduced. Also, geographic shifts may occur for particular crops, as some production areas become too warm or too dry.

Impacts on livestock

Current livestock breeds are mostly indigenous and generally well suited to the climate. Most of the cattle production, especially throughout the "cattle corridor", is highly dependent on rainwater, streams and wetlands, as well as shallow groundwater sources, which dry up during droughts.

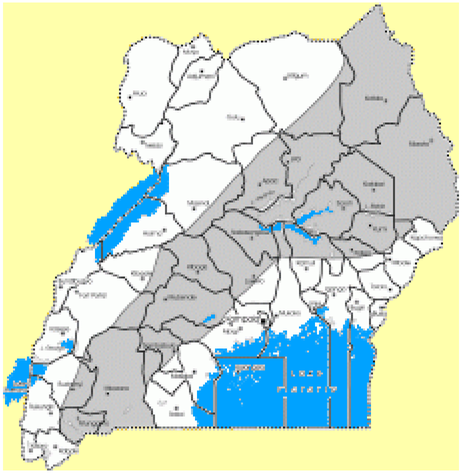


Figure 9: The cattle corridor (shaded in grey) in relation to Uganda.

Climate change could increase the frequency and duration of water scarcity and severe drought, especially in the semi-arid areas. This will lead to loss of animals, reduced milk production from dairy cows, and reduced meat for human consumption. Pastoralists move their stock into neighbouring districts in search of pasture and water, which leads to conflict with communities in those districts and loss of production. These migrations could in future start earlier and lead to increased pressure on areas with perennial water sources, thus exacerbating land degradation.

Food security

Potential increases in the frequency, duration and intensity of drought, especially in the semi-arid areas, could lead to severe water shortages for crops, humans and livestock, and result in devastating food shortages. This would be exacerbated by high population pressures based on current population growth rates, and resulting poverty. Per capita food production will have to increase in order to achieve poverty reduction and some resilience of the food system to climate change impacts.

One of the most devastating potential shocks to food systems as experienced in Uganda are outbreaks of pests and diseases. It is likely that outbreaks of known and new pests and diseases could increase under climate change, for both crops and livestock. Early detection and control / eradication will become even more important than it already is.

Figure 10: Food security is crucial to achieving the first Millennium Development Goal – and several others

Civil insecurity currently plays a large role in food insecurity. Continuation of insurgencies in the face of increasing climate change pressures would place unbearable strain on food systems in the northern regions. If peace efforts can restore civil security, access to land is restored, government programmes to control livestock diseases are successful, and efforts to eliminate widespread poverty are successful, food security should improve substantially. This should provide some resilience to expected impacts of climate change on agricultural production.

General

Rising temperatures increase the demand for water by crops by increasing both the rates of evaporation from the soil and transpiration through the leaves. This leads to more rapid soil drying and a greater requirement for soil water replenishment. Where water deficits occur, this will increase the risk of crop drying, unless supplemental irrigation is available. Areas which are currently receiving enough rainfall for rainfed cropping may in future become reliant on some form of irrigation, thus increasing the demand for agricultural water supplies over and above those estimated under current climatic conditions with increasing productivity as envisaged by the Water for Production (WfP[9]) programme.

The projected future increases in rainfall, especially during the second "short rains" season, could lead to rising water levels (in lakes, rivers, wetlands, and groundwater) and flooding, with serious impacts on agriculture. Some farmlands will require *increased drainage infrastructure*. Rates of siltation of natural water sources and built storage facilities will increase. Should flooding of and damage to rural roads and waterways become more frequent and prolonged, transport of agricultural produce to markets will become increasingly disrupted, leading to high post-harvest losses, failure of food distribution to areas in need, and reduced returns from local and export sales. Damage to infrastructure such as loss of property, damage to irrigation facilities, and to water and electricity services, can take years to repair.

Climate change will intensify the impact of droughts on the agricultural sector, with further social and economic disruption especially in the most vulnerable rural areas. In addition to direct effects of droughts and floods on ecosystems, human responses could place added pressure on natural resources and aggravate environmental degradation and loss of ecosystem services. The high dependence of Ugandan livelihoods and the economy on natural resources requires a particularly strong focus in any climate change strategy on integrating the need

[9] Not to be confused with the World Food Programme (WFP) of the United Nations.

for socio-economic adaptation with the need for conserving the very resources that underpin the system.

First-to-fourth order climate change impact scenarios

The phenomenon and impacts of climate change are wide-ranging and highly complex. It is common practice in climate change assessments to take a sectoral approach, but this invariably leads to lack of cross-sectoral integration, which is so critical when assessing economic and social system responses. In this situational summary we prefer to take a more hierarchical ("inverted pyramid") approach, starting with the basic climate parameters, and gradually scaling up to organism and system levels. We define the impact levels as follows:

1st order impacts: changes in atmospheric CO_2 concentration, temperature, rainfall parameters, humidity, wind and sunshine hours (basic meteorological conditions)

2nd order impacts: consequences of 1st order changes for agro-climatic conditions and agricultural resources (water/soil) – and biodiversity

3rd order impacts: crop and livestock responses and effects on production

4th order impacts: rural economies and livelihoods – interaction with other stressors and drivers of change

Up and down arrows (↑ and ↓) indicate 'increase/more' and 'decrease/less' respectively. The broad arrows show the links from one level of impact to another, and positive feedbacks are indicated by the upward, curved arrows. For example, in Case Study 1, ↑ *Migration of pastoralists in search of grazing and water* (a fourth order impact) may result in an increase in livestock diseases and mortality (↑ *Livestock diseases*; ↑ *Livestock mortality*), which are third order impacts. The feedback arrows merely indicative, not explicitly showing specific feedbacks.

CASE STUDY 1: Erratic rainfall and more frequent drought in the semi-arid north-east

1st order impacts:
↓ Rainfall
Shift in rainfall seasonality
(Later start, shorter rainy season, longer dry season)
↑ Rainfall variability
↑ Temperature

2nd order impacts:
↑ Evapotranspiration
↓ Soil moisture
↑ Drought
↓ Ephemeral river flows
↓ Groundwater
↓ Water for domestic use, crops and livestock

3rd order impacts:
↓ Rangeland productivity
↑ Grazing pressure
↑ Land degradation
↓ Water quality
↓ Livestock productivity, milk
↑ Livestock diseases
↑ Livestock mortality
↑ Crop pests and diseases
↓ Crop yield
↑ Yield variability

4th order impacts:
↓ Stock numbers (sell/slaughter)
↓ Food from livestock
↓ Food from crops
↓ Income and food buying ability
↑ Food prices
↑ Poverty and food insecurity, malnutrition
↑ Migration of pastoralists in search of grazing and water
↑ Risk of conflict between migrating pastoralists and resident communities
↑ Shift towards harvesting of other natural resources
↑ Exploitation of wild foods for alternative income-generating activities and food

CASE STUDY 2: Heavy rain and soil erosion in the highlands

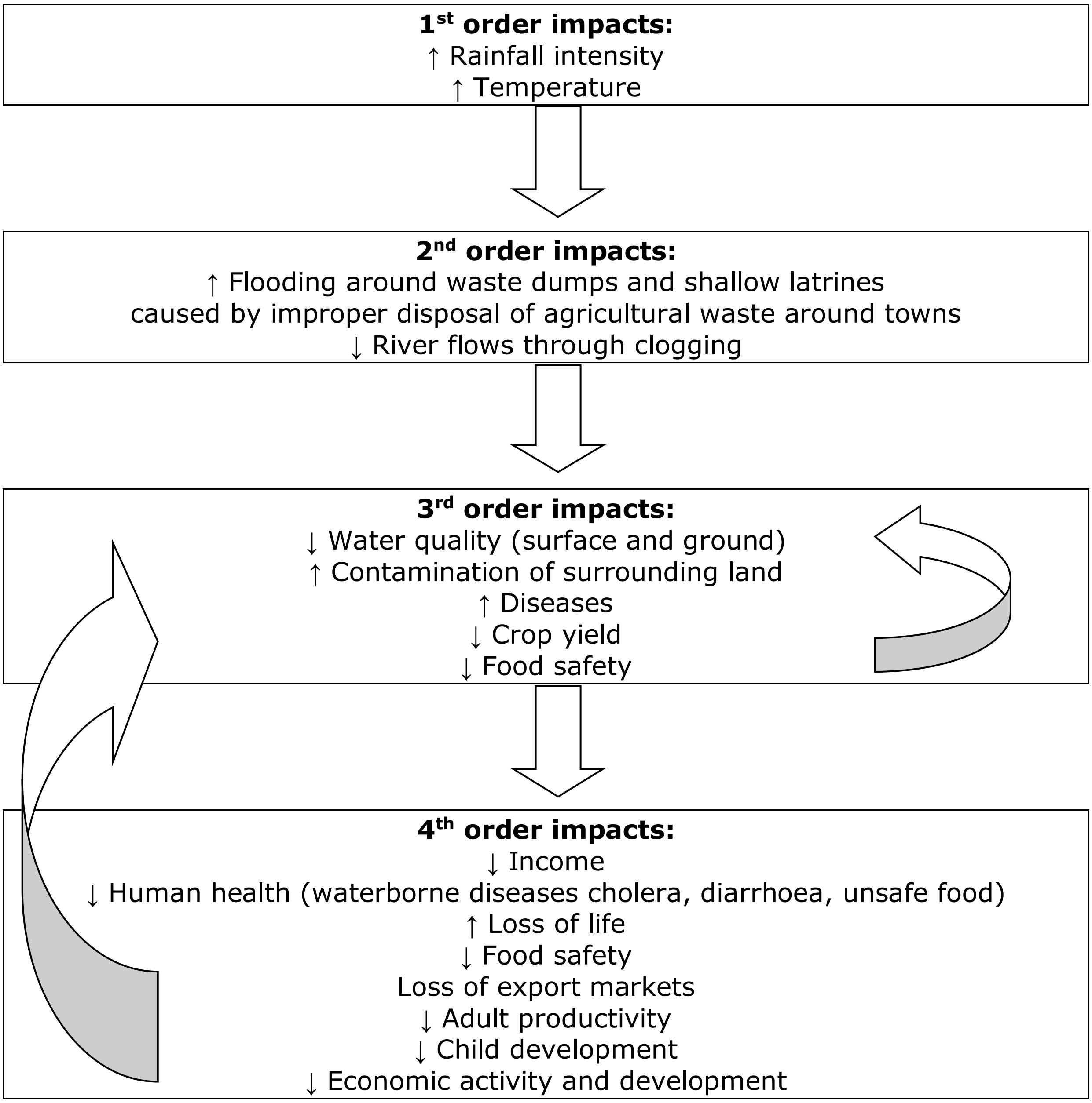
1st order impacts:
↑ Rainfall intensity
↑ Frequency of heavy rainfall

2nd order impacts:
↑ Soil erosion
↑ Landslides
↑ Severe land degradation
↑ Siltation and pollution of water bodies (rivers, lakes, dams, valley tanks)

3rd order impacts:
↑ Loss of annual and permanent crops
↓ Food production
↓ Cash crop yield
↓ Forest productivity
↓ Biodiversity
↓ Water quality (mainly surface)
↓ Water supply due to siltation

4th order impacts:
↓ Food supply
↑ Food prices
↑ Destruction of and damage to transport network
↓ Access to fields and markets
↓ Income from export cash crops
↑ Poverty
↑ Failure of large capital investments
↓ Macro-economic success
↑ Loss of life
↑ Migration of rural population to town to look for employment

CASE STUDY 3: Contaminated water resources near human settlements (Lake Victoria region)



Water-related adaptation in agriculture

Any set of policies runs the risk of failure if climate change is not factored in. Uganda currently has a good framework of policies for the eradication of poverty (PEAP), recently updated by the National Development Plan (NDP). These policies rest heavily on the development of the agricultural sector (PMA), with particular emphasis on growth of agricultural exports. In support of achieving this, the Water for Production (WfP) programme aims to promote the development of cost-effective and sustainable water supply for crops, livestock, aquaculture and rural industries. None of the above policies have explicitly incorporated climate change projections or impacts. On the other hand, the successful implementation of Uganda's overarching policies will help the country to buffer itself successfully against climate change impacts.

Water-related adaptation options could include the following:

Upgrading rainfed agriculture

Rain-fed agriculture will remain the dominant system in Uganda. Basic technologies for the local improvement of soil moisture using available rainfall, should be encouraged. Rainwater harvesting refers to the local collection and use of run-off, including structural storage facilities (valley dams, valley tanks), and the digging of trenches/pits in the ground. In-field rainwater management refers to the reduction of run-off by increasing infiltration of rainwater, soil storage, and thus crop uptake. Examples are reduced/zero tillage practices and mulching.

Groundwater represents a significant potential supply of water for most rural communities. Expansion of groundwater utilization could be economically viable for high value crops. Increasing utilization of groundwater will require careful monitoring of recharge rates as part of Integrated Water Resources Management (IWRM).

Irrigation infrastructure (schemes)

Improved performance of existing facilities, increased irrigation efficiencies, and improved capacity and resources of communities to manage and maintain existing schemes should be achieved before new schemes in new areas are considered. Small-scale Community Managed Irrigation Schemes (CMI) are often more successful than large schemes.

Crop development

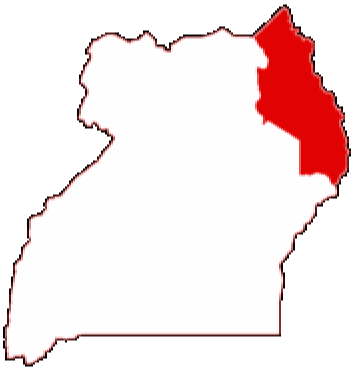
Through targeted breeding and selection, varieties can be developed which are more water use efficient, more drought resistant, and require a shorter season.

Supporting pastoralists

Pastoralists have increasingly become restricted in their movements as migration routes become blocked and access to watering points is lost. New irrigation projects could further impinge upon traditional grazing lands. Continued and improved access to watering points must be ensured.

4.7. Transboundary Issues and State Security

Between 1994-2003 IDA spent US$141 million on water supply, sanitation and flood protection in Uganda's towns. The lack of essential services increases the probability of water-borne diseases. In Kampala and Jinja over fifty percent of the population have access to piped water. Only 20% or rural households have adequate water supply (in spite of the relatively high rainfall in the region).



The Karamoja area is one of the driest and least developed provinces in Uganda. Karamoja comprises the five districts of Abim, Kaabong, Kotido, Moroto and Nakapiripirit. (See Figure 11.)

Figure 11: Location of Karamoja sub-region within Uganda

Drought here has led to climate refugees as people are forced to move around in search of grazing and food resources as drought impacts increase. The semi-arid region experienced drought every 5-10 years since 1960 but since about 2000 droughts have become more frequent in intense. Surface water is non-existent and dryland crops fail. In 2007 floods also damaged harvests. Severe malnutrition is leading to stunting of children. Often, when resources are scarce, inter-tribal and inter-clan warfare occurs as raiding parties clash and this region has seen some of this violence. The Karamojong people of Uganda and Turkana and Pot of Kenya (all semi-nomadic) clash over natural resources.

Uganda is a primary beneficiary of the Nile River Basin and is a closely watched Nile Basin Initiative member state. 90% of Uganda's water is transboundary and therefore anything the country does has implications for other Nile Basin countries. The potential for conflict over shared water resource management and resource availability is an already significant human rights and political factor in the basin, even without climate change impacts being considered. Equally, the Ugandans are concerned about their neighbours' water abstraction and management activities, although Simon Thuo of the Nile Basin Initiative and Head of the Global Water Partnership for East Africa says that "water abstraction (from the river flowing into Lake Victoria, allegedly affecting the Lake's water levels and hence fisheries) by Uganda's neighbours, Kenya and Tanzania, is negligible".

The Lake Victoria Basin Commission has a clear *Protocol for Sustainable Development of Lake Victoria Basin* (EAC, 2004), which covers all the key vulnerability-related issues presented in this report[10] though *without* any consideration of climate change. The challenge for Uganda is twofold: to bring climate change onto the LVBC's agenda, and to *implement* the articles presented

[10] For example, Article 5 on water resource management, Article 6 on conservation (including "protecting and improving water quantity and quality within the Basin"), Article 9 on sustainable agriculture and land use practices (including irrigation), and Article 24 on exchange of data and information.

in the Protocol. (An *Operational Strategy* has been prepared for the member states in regard to the latter (LVBCS, 2007).)

4.8. Institutional Analysis

Uganda Water Sector Institutional Analysis

An assessment of the DWRM is the departure point in the institutional analysis. The Directorate has a robust and sophisticated structure covering all the key aspects of effective water resource management. However, as evidenced in the section on DWRM Structures below, many of the posts within this structure are vacant, meaning that the institution cannot be as effective as its structure implies or facilitates. There appears to be healthy cooperation between the Directorates and Departments within the Ministry of Water and Environment, as demonstrated in the wide participation and co-operation in the two workshops held to date for this project (Inception Workshop, 4 December 2008, and Vulnerability Mapping Workshop, 28 January 2009) and other meetings with OneWorld.

This analysis further uses Integrated Water Resources Management (IWRM) as the recognised international benchmark of an appropriate water resource management structure. It is evident that Uganda has some way to go in attaining these standards, although much analysis and work has been done in proposing appropriate structures. For example, 'the policy framework for catchment-based water resources planning and management is put forward clearly in the Water Resources Management Sub-Sector Reform (2005). This follows the key principle laid down in Agenda 21 that water should be managed at the lowest appropriate levels, where the catchment is the desired level' (Metzger, 2008). The benefits of this decentralized approach to water resource management are clearly stated and are based on the principles of an IWRM approach:

> **'Stakeholder-driven, catchment-based, water resources management will maximise the economic and social benefits from water and related resource uses for the people of Uganda in the most equitable and sustainable manner.'**

The recommendations of the Water Resources Management Sub-Sector Reform Study[11] and experiences elsewhere, show that the key to successful and sustainable water resources management is that it is based on a participatory process being both:

- *bottom-up* (i.e. stakeholder/beneficiary-driven) *and*
- *top-down* (facilitated and supported by central, regional and district governments).

Uganda began the process of decentralising resource management around seven years ago, starting with constitutional amendments that aimed to devolve resource management responsibilities to decentralised agencies (decentralised in

[11] Refer also to *Water Resources Management Sub-Sector Reform Study*, Final Report, Vol. 1, January 2005.

that the agencies are established in key natural resource geographic locations throughout Uganda, with incremental implementation and roll-out plans). This applies to the key resource management sectors such as water and forestry management. In this model, the related district agency offices are intended to operate as an extension of local government, with the central office through Technical Support Units (TSUs) providing "on the ground" support and extension services. Although the regulatory framework is in place, implementation of these structures is lagging, with evidence that central control over resources remains strong, with central institutions, such as the DWRM, expressing reluctance to hand over critical resource management to agencies that do not have adequate capacity[12]. DWRM is attempting to address these issues through their drive to operationalise decentralisation, through:

- Ensuring catchment distributions (spatially) and catchment delineation;
- Managing transboundary issues through, for example, the Nile Basin Initiative (NBI).

Figure 12: Stakeholders at the Vulnerability Mapping Workshop, 28 January 2009. One group of participants focussed on institutional matters.

At grass-roots level Water User Groups are being established, which work through Water Committees. The Catchment Management Agencies (CMAs), an example of decentralised natural resource management agencies, are in the early stages of being developed. As mentioned, the implementation plan is incremental, with the first CMA being established in the Ruizi catchment area. The Lake George and Lake Albert catchments are the next two planned CMAs.

Agency officials are selected through a stakeholder election process from a range of criteria including water resource management expertise, local socio-economic insight and gender representation to mention a few. The mandates for the CMAs are evolving, hence not entirely clear, and there is the usual tension[13] between

[12] GWP and NBI, *pers comm*. Feb 2009.

[13] Tension between the roles of CMAs, district municipalities and national departments is common around the world where catchment boundaries do not 'match' political (in this case district council) boundaries, and a water catchment area often comprises a number of district councils or local

their role *vis a vis* the roles of district councils (local government), the different sector agencies/government departments and who they report to, and national departments and interest groups. Sector agencies include the National Environment Management Agency (NEMA), the National Forestry Authority and the Wetlands Management and National Water and Sewage Corporation. Typically, these agencies report to their respective national government departments.

The need for implementation of the IWRM approach is heightened when considering the impacts of climate change. It is evident from the vulnerability assessment conducted to date that climate impacts in the water sector (and its dependent sectors and livelihoods) are felt at different levels of government, in aspects of the private sector and on certain livelihoods and specific socio-economic conditions. For example, changes in the level of Lake Victoria is likely, *inter alia,* to affect fisheries (private sector and livelihoods), whereas impacts on water quality may well affect economic productivity and human health, particularly in the densely populated areas covering the region along the northern shores of Lake Victoria (including Entebbe, Kampala, Jinja), eastwards into Tororo and the extreme south west covering Kabale and parts of Rukingiri, Bushenyi and Kasese. An advantage of implementing the IWRM approach is that it allows for the directly-affected stakeholders and water users to have a 'voice' in improved water resource management, access and quality. Moreover, the IWRM advocated decentralised approach, if effectively implemented, can facilitate discrete geographically-specific action plans and related funding proposals and the effective implementation of related actions.

Civil society is active in the Uganda water sector, providing the basis for good governance and accountability. For example, UWASNET (Uganda Water and Sanitation Network), is a significant organisation in the Ugandan water sector. A representative attended climate change project workshops with the following input: (UWASNET has) *"many cultural institutions that can help with adaptation strategy in conjunction with religious institutions".* UWASNET has structured working groups that focus on specific areas within the water sector, and the organisation has a network of NGOs that work across all districts in Uganda. Coordination between DWRM, the NGOs, and the scientific institutions and universities is less clear, raising questions as to the effectiveness of current government-science dialogue in Uganda, a dialogue that will need strengthening considering climate impacts.

WaterAid is another active non-government agency, assisting vulnerable groups in establishing safe water supplies and sanitation. One intervention is the 'Skyloo', a composting latrine which prevents contamination of groundwater, and turns human waste into fertiliser[14].

The Global Water Partnership East Africa, (GWP) is active in Uganda and is strongly represented through the Nile Basin Initiative (NBI). For example, Simon Thuo, head of the GWP East Africa Branch, is an active NBI member.

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authorities. The Lake Ruizi catchment management area for example shares boundaries with five district councils, namely Busheyeni, Mbarara, Kiruhura, Isingiro and Ntungamo.

[14] WaterAid website: http://www.wateraid.org/uganda/news/5461.asp, accessed 4 March 2009.

DWRM Structures

A review of the DWRM organogram and human resource capacity *status quo* indicates that 39% of the posts are vacant. Some of these are critical to the vulnerabilities that have been identified, such as the following: Senior Water Officer – International (Transboundary Relations); Senior Water Officer – Pollution Control (Health); and Senior Water Officer – Abstraction permits (groundwater level, access, quality and availability). It is evident that Uganda is attracting international expertise and the donor community is active with DANIDA, for example, funding and providing key technical advisors with the objective of strengthening human resource capacity in the country's water sector. There are still gaps however, some of which will need to be urgently addressed if the sector is to strengthen its resilience to climate impacts. Human resource capacity however needs to be reviewed in the context of institutional structures. That is to say, the appropriate institutional arrangements should be a key driver in determining human resource capacity decisions.

4.9. Information and Technology

The Concept Note on the Revision Process of Uganda's PEAP (Uganda MFPED, 2007) discusses how crucial the "Knowledge Economy" is in any country's economy. It goes on to discuss the importance of the quality of data and information for policy decision making: "*Better statistical data and improved analysis create the political will for policy changes to take place. Good quality data is crucial for the process of better measuring, monitoring and managing for development results. Without good statistics, Government cannot deliver efficient administration, good management, and evidence-based policy making*."

As a member of the Lake Victoria Basin Commission, Uganda is obligated to "exchange readily available and relevant data and information on existing measures and on the condition of the natural resources of the Basin" (EAC, 2004). Moreover, Uganda is expected to "provide an environment that is conducive for facilitating collaboration in research and the exchange of data, reports and information" (ibid.)

How does information relate to vulnerability?

Decisions are based on the best available information. The DWRM and other decision makers in the water sector cannot make good strategic decisions without good information. Good information must be of good quality, must be readily accessible, and must be properly managed in order to be useful to decision makers. Without these three key ingredients in place, ill-informed decisions are inevitable, potentially leading to poor proactive and reactive responses to climate change. Hence *adaptive capacity* is diminished by poor information, and enhanced by good information. Since vulnerability is a function of adaptive capacity, it is therefore also dependent on information.

Vulnerability depends on adaptive capacity, and adaptive capacity depends on information to enable decision-making.

According to The Access Initiative, Uganda fares poorly both in the *quality and accessibility* of water data (The Access Initiative, 2004), with each category being classified as "Weak".

Data quality

Standards, standards, standards! Standards are vital to establishing good quality databases in support of good decision making. Data quality comprises a wide range of data facets, including completeness, consistency, currency, and metadata (all discussed below), as well as standards for making measurements or observations, for capturing data, and for processing it.

Completeness

It is clear from meetings held at Entebbe in December 2008 and January 2009, and from information provided by the DWRM, Meteorology and Energy that vital information for decision makers is incomplete. Three examples follow:

- A spreadsheet of hydropower installations in Uganda:
    - lacks the co-ordinates of the sites;
    - includes information on installed capacity for only 11 of 46 installations;
    - is missing information on the maximum power potential of eight of the installations;
    - has no indication of when each measurement was recorded (indicating its currency);
    - only has *estimates* of maximum power outputs for 17 of the installations.
- Discussions with representatives from the Meteorology Department revealed a number of problems related to completeness of meteorological data in Uganda, for example:
    - spatial coverage is incomplete, both on land and on the large water bodies. Most meteorological stations are in or near towns;
    - Nile Basin Initiative (NBI) has meteorological stations on three of Lake Victoria's islands, but sponsorship changed and the project ended some time ago. Hence the record is incomplete to date.
- The DWRM datasets are also incomplete, for example:
    - records of groundwater depth and abstraction for consumption;
    - locations and size of dams;
    - stream water levels at flow stations in Uganda;
    - stream flows for rivers flowing into Lake Victoria from Kenya and Tanzania, as well as water abstraction from these streams.

Consistency

Data consistency is also a concern. Aside from the issue of different datasets being in different formats (word processing documents, spreadsheets, databases and hardcopy records), the means of making measurements is not clearly documented.

Figure 13: Measurements of Lake Victoria water level have been taking place since 1913 at the Jinja pier. This long-term monitoring record provides a sound basis for management decision-making.

Instrument calibration for automatic weather stations needs to be checked from time to time, and manual techniques for recording weather also need monitoring for conformity (e.g. how gauges are read). These activities are somewhat lacking in Uganda, especially with respect to the Davis automatic weather stations. For example, one of the automatic weather stations is known to record temperature wrongly, yet has not been re-calibrated presumably because of resource limitations. Moreover, according to a representative from the Meteorology Department, data from the automatic weather stations cannot practically be integrated with data from conventional meteorological stations.

Another important point to note is that many of the rain gauges in Uganda are run by volunteers who may not be adequately trained and may not record the rainfall *every* day and at the same time. The regularity of recording rainfall is becoming increasingly important as extreme weather events grow in frequency and intensity, in association with climate change.

Hence, decision makers cannot be confident that the data informing their decisions has been derived through uniform methods. Another problem with inconsistent data is that statistical summaries are difficult or impossible, resulting in limited options for concisely deriving and representing key information from the raw data.

Currency

Some important datasets do not have date-stamps on individual records, or even the data on which the dataset compilation was last updated. It is clear that many datasets are outdated. Hence decision makers may have limited confidence on the data they would like to make use of. This is particularly pertinent in terms of disaster response, when there is not time then to capture the necessary data, and the link between disaster response and climate change is growing stronger through extreme weather events.

Metadata

None of the data provided to the consultants have any sort of metadata – "data about data" – such as who captured it, when it was captured, any methodologies used to capture it, the format of the data, the ownership and copyright of the data, and so on. Metadata is foundational to effective information systems which, as will be seen below, are central to providing useful information to decision makers.

In terms of taking corrective action on metadata standards, the DWRM and Meteorology could consider the Dublin Core metadata elements (see http://dublincore.org/documents/dces/) for a starting point – but would have to consider additional custom elements – or could review international metadata standards for the specific types of information they are capturing, e.g. from the World Meteorological Organization (WMO).

Information management

Sharing of information is central to enabling adaptation.

Data ownership and custodianship

There is a need for clarity on who (i.e. which organization) owns each dataset and who is the custodian, or steward, of each dataset. This needs to be in the metadata of each dataset, which it currently is not, since metadata are absent. By assigning responsibilities for data custodianship, the problems of duplicate (and inconsistent) datasets and data processing are avoided. By clearly indicating who the data belong to, and how it may be legitimately accessed and used, the matter of giving credit to the appropriate institution is greatly simplified.

Data sharing

There must be willingness to share data freely except where security issues arise. Free supply of data to the public attracts researchers and enables the public and private sector alike to make better decisions, thereby strengthening the economy. Moreover, the data are collected with taxpayers' money, so unless the data are truly confidential, there is good reason to share data. Another benefit of information sharing is improved co-operation amongst user groups (including academics, among others), and development of highly processed end-products for the benefit of all users. The situation at present is that data are not made freely available; in some cases it is difficult or impossible for potential end-users to access, even if willing to pay for it.

Several issues around data sharing were raised at the Vulnerability Mapping Workshop in Entebbe, 28 January 2009. These include the fact that data sharing is inadequate between government ministries, departments and other stakeholders, and that data sharing policies are weak; strategies are required to overcome these barriers.

Once data ownership and custodianship issues have been addressed, data sharing options should be considered. Data sharing requires not only **agreements**, but action plans on for implementing these such as request and delivery protocols. These action plans require data flow plans, and these depend on data requirements (which need to be assessed), on data quality and on metadata. The Memorandum of Agreement between Meteorology and the DWRM was labelled by one interviewee as ineffective since the Agreement has (according to this individual) not been implemented.

There is limited sharing between the DWRM and other government directorates or departments, and this needs to be addressed urgently. Even where there is willingness to share data, there are not always the mechanisms to do so, especially due to limited information management (discussed below).

The quotation below could be applied to almost any developing country, and indeed, government's provision of information to the public is problematic even in developed countries where technology is adequate. Schwarte's report was focussed on forestry and oil production, but the quote may be applicable to the DWRM also.

> "... in general there is a considerable lack of awareness in Uganda of the legal rights related to accessing environmental information. Whilst the law is underutilised the main barrier in practice appears to be a 'culture of secrecy' – the general reluctance of government officials towards disclosing information.
>
> "The value of transparent and accessible information systems is generally recognised as a basis for sustainable development. But officials, non-governmental organisations (NGOs) and the media alike struggle with key barriers such as the general lack of resources and capacities as well as the politics of patronage. The relationship between civil society and certain levels of government often prevents proper collaboration and participation." (Schwarte, 2008)

The fact that the DWRM does not have a website for disseminating information is itself a barrier to sharing data and informing the general public about itself, its mandate and its activities.

Data communication and processing

> ***Information is only useful if it is accessible.***

Data communication and processing is pivotal to turning data into useful information. Uganda's limited IT infrastructure hinders these activities. For example, there is a Meteosat receiver at Entebbe airport but it's out of order. The computer for the MSG (Meteosat Second Generation) is out of order. Staff are trained to use the imagery but there is no processing capacity because software licensing has expired. A water resources project installed a Meteosat receiver for Cold Cloud Duration (CCD, which is correlated with rainfall) but it failed. There is no clarity on who is in charge of the project, and no communication between DWRM and Meteorology on the matter. Moreover, Meteorology does not have the bandwidth needed to download sea surface temperature (SST) data that it needs for forecast models. The proposed shift to decentralized catchment management in Uganda places additional stress on the need for efficient communication of data from remote offices to DWRM's head office in Kampala.

Pre-processing and processing of data is central to generating information from data. Pre-processing entails data formatting, validation and cleaning, and metadata capture. Processing includes deriving statistics or running models. These statistics, models and other products must have additional metadata captured regarding the assumptions, formulae/functions, and methodologies used to derive them – otherwise their reliability for decision making is unknown.

Retrieval and dissemination

How data are retrieved from a database and disseminated to end users is fundamental to information usefulness. Finding the right data/information in a database requires good metadata and search tools, as well as software that can summarise the data as meaningful information. Software interfaces are necessary for programmes to interact with each other (e.g. a model application connecting to a database management system). User-friendly graphical user interfaces are essential to enable users to acquire the data they need. Security layers are also important to protect classified information. All these elements have yet to be developed in Meteorology and the DWRM. Consequently strategic decision making is constrained by limited mechanisms for accessing available information.

Vulnerability of Uganda's water sector relating to information

In conclusion, Uganda's capacity to adapt to climate change is severely compromised at every step in the information chain, from data recording to provision of information to decision makers.

Possible solutions will be explored further in the Adaptation Strategy, but at least need to address the abovementioned issues which hamper effective decision making.

5. RECOMMENDATIONS TO REDUCE VULNERABILITY

Based on the vulnerabilities identified in the preceding section, a very large number of adaptation activities could be identified. However, such an approach is likely to result in unco-ordinated responses that lack cohesion and that each fail to secure the necessary funding for implementation. Indeed, this is one reason why so little planned adaptation has taken place to date in Uganda. Instead, we propose to identify a few priority areas in which to develop adaptation strategies and plans for implementation ('action plans'). Figure 14 illustrates four strategic areas related to the water sector in Uganda in which adaptation to climate change is needed. Notice that, with one exception, they do not fall squarely in the water sector; instead, the DWRM will be required to bridge with other sectors, critically the agriculture (including fisheries) and health sectors. A key to building these initiatives is the streamlining of institutional issues within the DWRM and this can best be done through re-aligning its structures to conform to 'industry standard best practice', which is IWRM. The DWRM has already identified the need to move towards the IWRM model of institutional structures, and this assessment both supports the need for this and adds a sense of urgency for it, since successful adaptation will hinge upon it. This is reflected by the orange arrows in the figure, indicating dependence on DWRM functioning effectively as per IWRM principles.

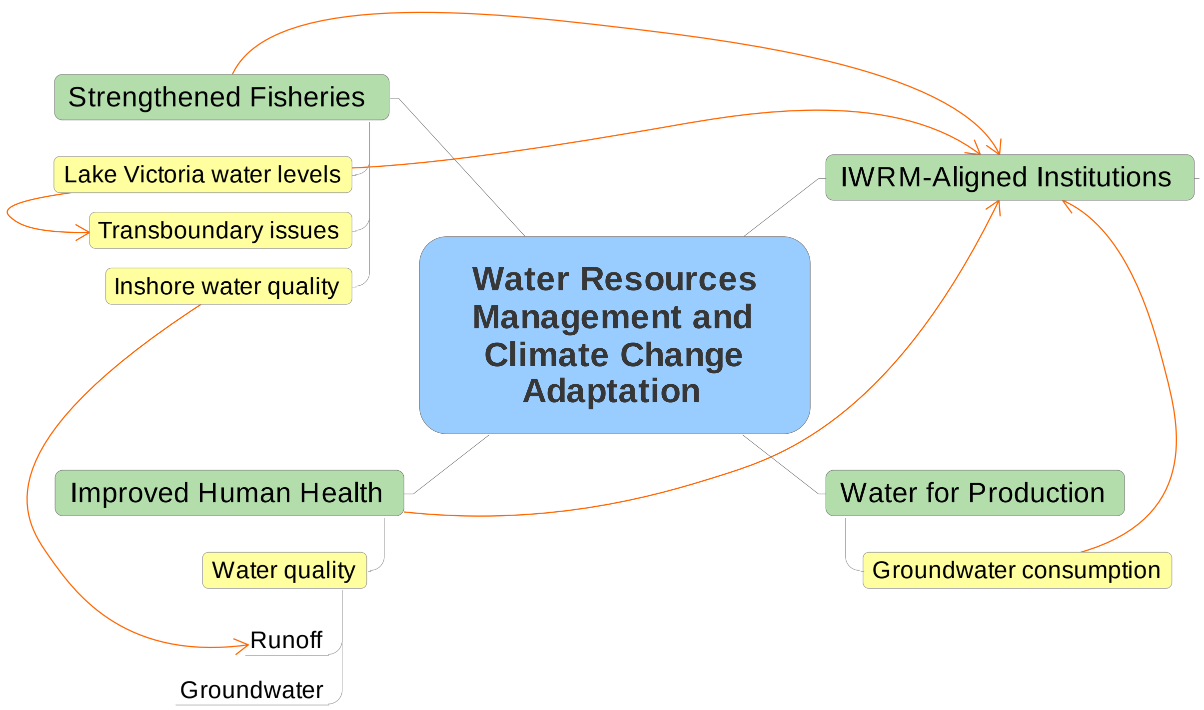

Figure 14: Strategies for adaptation (with green background) in relation to water resources management and adapting to climate change. Note the importance of aligning institutions according to Integrated Water Resources Management (IWRM) best practices. Issues of concern are shown with a yellow background.

The four strategic priorities (to strengthen fisheries, to improve human health through improved water quality, to manage groundwater consumption risks in the *Water for Production* programme, and to align DWRM to IWRM standards) comprise the specific adaptation issues discussed below. Note that there are other facets to these four areas that are not within the mandate of the DWRM, such as strengthening fisheries through education on over-harvesting for example. This means that *cross-sectoral integration is crucial*.

- IWRM-aligned institutional structures in the DWRM: One key to IWRM is the decentralisation of water authorities so that catchments are managed at a catchment level, and smaller areas are managed at grassroots level. IWRM structures enable community participation and decision-making with the support of a centralised national body providing technical guidance and training.
- Lake Victoria water levels: An improved understanding of Lake Victoria water budget is required, including rates of evaporation, quantity of rain falling directly into the lake, and rate of water flowing into the lake from tributaries. The potential increase in water abstraction from influent tributaries translates into a transboundary and international issue, and Uganda needs to be able to work with the upstream states in determining how much water is flowing into Lake Victoria. These issues affect Uganda's relationships with Sudan and Egypt, and also have an important role to play in managing hydropower production at Jinja. Participation in the newly launched Lake Victoria Basin Commission should be of significant value in this vein.
- Surface water quality: A strong focus on issues of surface water quality is important. The relationship between water quality and human health is direct and specific. When there is too little water, crops fail, grazing is depleted and malnutrition becomes rife. Immune systems are compromised and other opportunistic infections further debilitate people. It is usually more useful and cost efficient to deal with the causes of an effect than the symptoms. The degradation of water quality and the challenges provided to human healthcare are caused by population pressure, urbanization, industrialization and land degradation. The slowing of population growth can only be dealt with by economic growth and by providing social services such as health care and education, though economic growth brings its own environmental challenges. Urbanization and industrialization are an unavoidable part of the process. Therefore, the environmental risks should be managed. A key intervention then is the improvement of surface water quality – particularly in urban centres – through the construction of waste water treatment plants or systems. This requires substantial inter-departmental co-operation and is a part of the developmental growth path which cannot be avoided. Similarly, rural areas need better means of dealing with effluents in order to avoid surface water (and groundwater) contamination.
- Groundwater protection: Focus on protecting groundwater from over-consumption through managing irrigation projects. This requires significant inter-departmental work and communication, particularly relating to the national *Water for Production* programme. Groundwater quality also needs management through avoidance of contamination from pit latrines which leads to human health issues in areas where groundwater is abstracted for human consumption.

- Data and technology: Improve data collection, management and distribution through implementation of data quality standards. Sharing of data needs to be encouraged. In particular, the Ministries of Water and Environment (MWE), Health, Agriculture, Animal Industry and Fisheries (MAAIF) and Energy need to be able to share data more freely and on demand.

Given the transboundary sensitivities of Uganda's water sector, develop a concise communication brief and comment on the strategy and its transboundary implications and disseminate this through existing partnership networks such as the Global Water Partnership East Africa and the Nile Basin Initiative.

To reiterate, a key to effective adaptation is to focus on the priority areas instead of trying to address every individual concern. OneWorld has identified four crucial adaptation strategies which will be explored further in the remainder of the project with a view to preparing funding proposals to support their implementation. Specific details will emerge during the *Adaptation Strategy and Action Plan* phase, starting with the Adaptation Workshop scheduled for 12 March 2009.

A preliminary opportunity assessment of the potential benefits of climate change for Uganda (and its neighbours) indicates that the country could become a food basket for less fortunate neighbours in a climate impacted food security scenario in East Africa. The agricultural assessment revealed that there is an abundance of natural resources in Uganda, ideal for crop and livestock farming, as well as fisheries and forestry. A critical success factor for Uganda is going to lie in the country's ability to harness these resources effectively, to manage the localised impacts of climate change and to strengthen preparedness for and resilience to increased frequency and intensity of extreme events.

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Appendix 1: Agricultural supplement

Climate and agro-ecological zones

Uganda is endowed with rich and diverse natural resources, providing a range of agro-climatic zones. Most of the country lies on a plateau at an altitude of 900-1500 m, surrounded by a rim of mountains. Large areas of the country (18% of total area) are open water (lakes, rivers, swamps). The southern half of the country experiences high and regular rainfall and is generally fertile, thus supporting most of the country's agricultural production.

Uganda has an equatorial tropical climate, moderated by its high altitude. Temperatures and humidity vary little throughout the year, but mean temperatures range from about 18°C in the cool south-western highlands to about 30°C in the warm north-east where the elevation decreases toward the Sudanese plain.

Except in the north-eastern part of the country, rainfall is fairly high with a national annual mean of about 1180 mm, ranging between 750 mm in the north-east to 1 500 mm on the shores of Lake Victoria and in the highlands. The southern region has two rainy seasons per year (bimodal rainfall): the first ("long rains") from March/early April until May/June, and the second ("short rains") from August to November. There is no pronounced dry season. Two crops are possible annually, the first is harvested in July/August, and the second is harvested in November/December. Towards the north and north-east, rainfall is reduced and less predictable and merges into one longer rain season between April and September/October (unimodal rainfall), with a prolonged dry spell from November to March. There is only one harvest from September to November.

Four major agro-ecological zones can be distinguished according to the FAO Aquastat report:

- High altitude zone - temperate zone crops;
- Southern and western tall grasslands/savanna zone - tall-grass areas, perennial and annual crops in mixed farming systems;
- Northern and eastern short grasslands/savanna zone - short grasslands, cotton-finger millet mixed farming systems;
- Pastoral dry to semi-arid rangelands - pastoral systems.

Within these broad zones, seven different farming systems can be identified (EWUAP, 2008, figure below), based on soils, topography, rainfall and major crops grown. Mixed farming systems predominate, with food crops as the major activity supplemented by some export cash crops. In the pastoral farming systems, livestock production is the major activity, supplemented by some food crops.

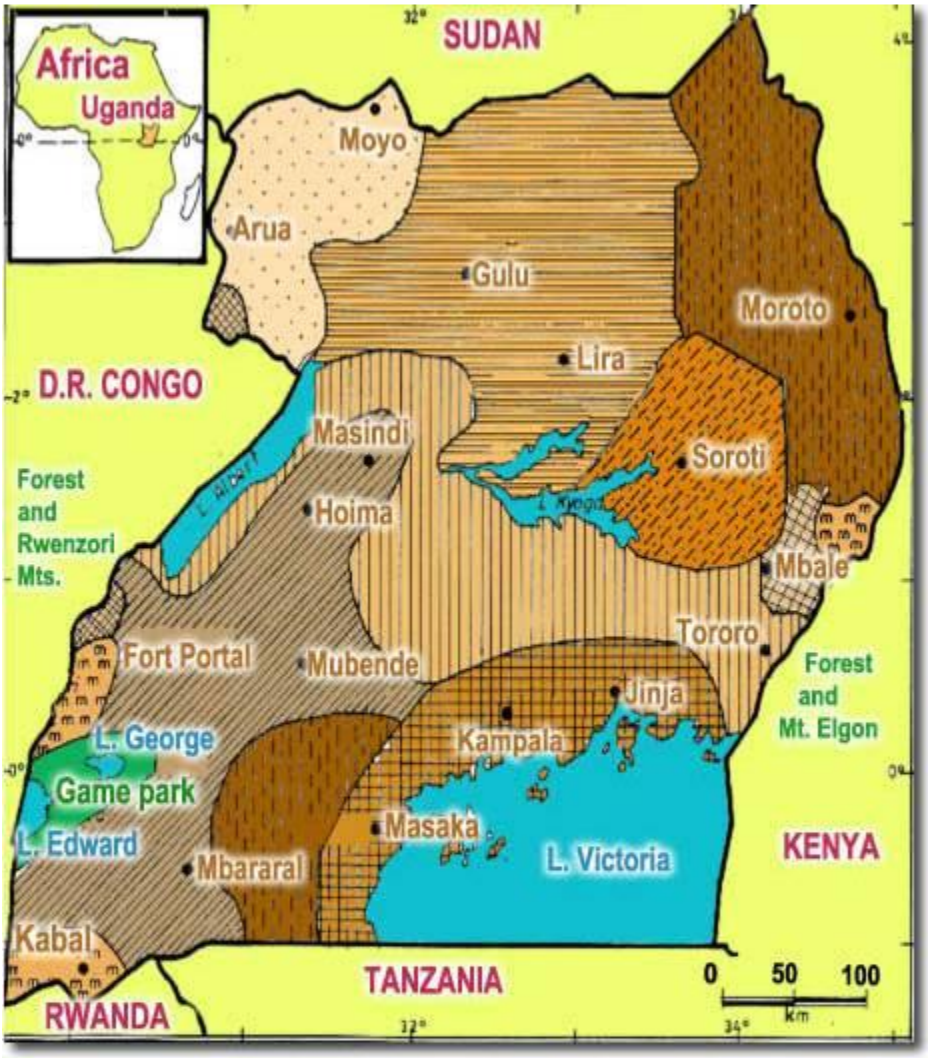

Figure 15: Farming systems in Uganda (Source: Mwebaze, 1999)

Approximately 30% of the area of the country is cultivable (arable land and permanent crops), comprising 7.2 million ha (Aquastat, FAO, 2002 data). Of this, arable land comprises 5.1 million ha and permanent crops 2.1 million ha. Of the remainder, 5.1 million ha is suited for pasture.

Current crop and livestock production

Current crop and livestock types and distribution

Crop production is concentrated in an arc around the shores of Lake Victoria and the regions south and east of Lake Kyoga, as well as in the south-west of the country. Food and export crop production contribute about 80% of agricultural GDP. The main food crops by area are: plantains and bananas (28% of cropped areas), cereals (maize, rice, 25%), root crops (17%), pulses (14%); oil seeds (8%); vegetables and fruits. Food crops are grown primarily for own consumption (two-thirds). The main export cash crops are: coffee, cotton, tobacco, vegetables, fruits, cocoa, vanilla, sugar cane, tea, flowers (8% of cropped areas).

The distribution of the main crop types is as follows (IFPRI, EWUAP):

- *Coffee* is grown across the southern half of the country but mainly in an arc around Lake Victoria.
- *Plantains/bananas* and *vanilla* are wide-spread especially in the southern region.
- *Tea* is restricted to the cooler highlands.
- *Cotton* is wide-spread throughout most of the southern regions (mainly between Lakes Victoria and Kyoga, and north of Lakes Edward and George) and also extends into the northern/north-western regions.
- *Maize* is concentrated in the central regions surrounding Lake Kyoga.
- *Paddy rice* is grown in wetland regions across the country, and *upland rice* has been introduced in the west/south-west.
- *Sunflowers, sesame, potatoes and sweet potatoes, millet, sorghum and cassava* are grown in the northern half of the country.
- *Cut flowers* are restricted to intensive greenhouse production around Kampala and Entebbe, close to the international airport.
- *Vegetables* and *pulses* are grown almost everywhere.

Livestock production contributes 5.2% and 12.7% to total GDP and Agricultural GDP, respectively. Mixed farming smallholders and pastoralists own over 90% of the cattle herd and 100% of the small ruminants and non-ruminant stock. Cattle are the most important of the livestock. Commercial ranches occur in areas that have been cleared of tsetse-fly infestation. In contrast to food crops, two-thirds of livestock products are marketed, and livestock sales are thus used strongly for monetary income. It is regarded by the rural population as a commodity in which wealth is invested for future use.

Cattle and buffaloes currently stand at about 6.1 million heads (FAO), and sheep and goats at 9.3 million heads. Pigs and poultry are also important. Indigenous breeds account for over 95% of the national herd/flock, notably the Ankole longhorn breed which dominates cattle population. The proportion of cattle has decreased and the proportion of non-cattle livestock has increased recently, particularly pigs and poultry, but also sheep and goats.

Pastoralists are mainly found in the north-eastern districts, where human population density and rainfall are low, and in western Uganda, where people given freehold and leasehold title to their land are increasingly practicing mixed farming. In the other areas of the country, agro-pastoralism and mixed farming systems dominate, along with fattening farms and some thousand dairy farms, mainly located in Mbarara district and around Kampala.

The livestock sector incurs heavy animal losses as a result of epidemic diseases, especially in the northern and north-eastern regions. Civil war in these regions has led to a breakdown of disease control and the spread of tsetse flies.

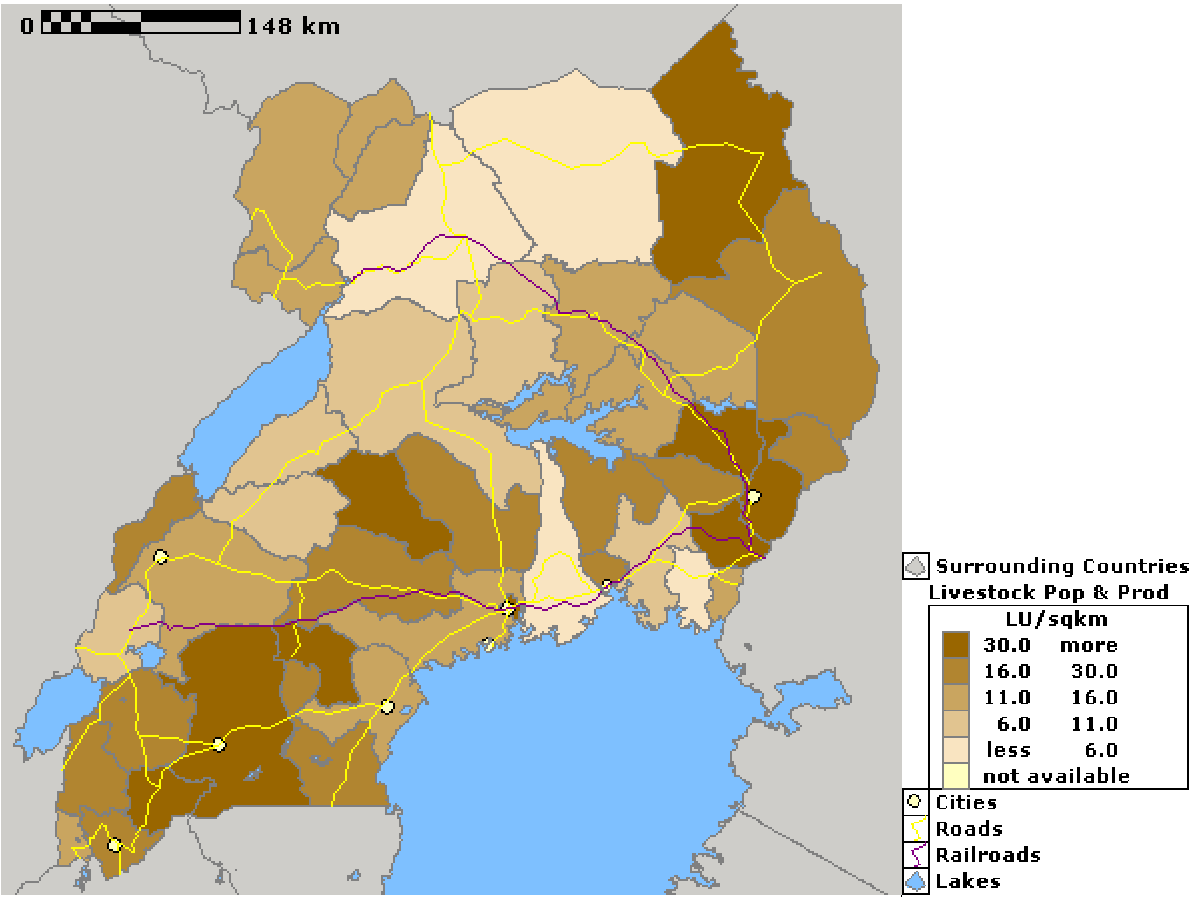

Figure 16: Livestock densities (all species, livestock units per km² in 2002). Densities are calculated on total land area. (Source: Global Livestock Production and Health Atlas[15])

The Cattle Corridor links the semi-arid regions of the north-east and the south-west, where agriculture is predominantly pastoralist, although rainfall in some regions of the Corridor is sufficient for food crop production. Pastoralists migrate with their herds in search of pasture and water in times of drought and during the dry season. Large annual migrations take place towards perennial water sources, resulting in degradation of rangelands during the dry season on these routes. Valley tanks meet the short-term needs of livestock, and are usually sufficient for 3-6 months, but many areas have not been well supplied. Uganda has recognised the problem and has located strategic supplies of livestock water within these traditional routes in an effort to prevent disruption to agriculture and conflict between the pastoralists and the agro-pastoralists. However, maintenance and payment for water at these sites is a major constraint, with pastoral communities unwilling to take responsibility for sources that they use seasonally and that are also utilised by others.

[15] http://www.fao.org/ag/aga/glipha/index.jsp, accessed 4 March 2009.

Commercial and subsistence crop production

Agricultural output is largely dependent on small- and medium-scale producers (about 3 million farmers) on farms with an average of 2.5 ha of land (FAO Aquastat). Mainly coffee and tea are grown in large modern estates, and there are also commercial livestock, vegetable and cereal farms. About 35% of coffee production is by high input rainfed farming systems, with the remaining 65% produced by small-scale farmers (low input rainfed) (IFPRI). In the case of cassava, beans, pulses, groundnuts and millet, roughly 70-85% of national production is by subsistence or small-scale farmers. For maize the proportion is about 55% (IFPRI).

Current production trends

Although yields vary from year to year, the main commodity types in terms of national tonnage are fruits and vegetables, roots and tubers, cereals and sugar cane (FAO, 2004).

Commodity	**National yield (1000 tonnes)**
Cereals	2 625
Meat	259
Fruits and vegetables	11 124
Roots and tubers	8 723
Pulses	711
Oilseeds	139
Sugar	1 600
Milk	700
Eggs	20
Stimulants	226
Tobacco	33
Fibre crops	22

Production and value of the individual commodities were as follows in 2005 (FAO):

Commodity	**Value (calculated) (US$ 1000)**	**Production (FAO estimate) (megatonnes)**
Plantains	2,195,919	9,900,000
Cassava	396,330	5,500,000
Sweet potatoes	266,298	2,650,000
Beans	237,435	545,000
Beef	219,313	106,037
Milk	186,158	700,000
Maize	156,870	1.350,000
Coffee	152,066	186,000
Millet	119,357	700,000
Sesame seed	97,306	110,000
Bananas	87,644	615,000

Potatoes	83,114	573,000
Groundnuts	74,902	155,000
Vegetables	74,122	395,000
Chicken meat	61,442	52,676
Pork	60,759	60,000
Tobacco leaves	60,166	33,000
Sorghum	51,236	420,000
Goat meat	43,844	28,796
Tea	38,970	36,000

Recent trends in yields (ESSGA, 2006, for the period 1979-2004) show strong increases in production from the mid-1980's through the 1990's, but a reduction in growth rates since about 2002. Food production per capita has thus decreased since the early 2000's.

Uganda's plantains and bananas are mainly of the cooking variety, popular amongst East African consumers but not elsewhere. This restricts the potential for export of this main crop, except to Kenya.

Growth rates (%) of selected commodities or agricultural indices from 1980 to 2004 were as follows (ESSGA 2006):

Commodity or index	**1980-1990**	**1990-2000**	**2000-2004**
Plantains	2.8	2.0	0.8
Cassava	2.9	3.0	2.1
Sweet potatoes	2.8	2.6	2.2
Agricultural production	3.0	2.5	2.2
Agricultural production per capita	-0.4	-0.6	-1.0
Food production	3.1	2.1	2.0
Food production per capita	-0.3	-0.9	-1.2

Export crops and value

In 2007 Uganda's main export partners were the Netherlands, Belgium, Germany, France, Rwanda and Kenya (CIA factsheet, Market Analysis). The most important export crops in order of value are coffee, tobacco, tea and cotton. However, coffee's share of export value has dropped from 98% (1979-1981) to 34.5% (2004), the most rapid drop occurring in the period from the mid-1980's through the 1990's (ESSGA 2006). Tobacco leaves and tea's share have risen from 0.1/0.2% to 11.3/10.4%, respectively, in the period 1979 to 2004. However, both peaked in 2002 and have since lost share. During the late 1980's government policies aimed to both increase production of traditional cash crops, and to diversify the export economy by promoting the production of non-traditional agricultural exports, such as maize, beans, groundnuts, soybeans, sesame seeds, a variety of fruit and fruit products, and flowers. Growth in the young flower industry has been impressive, making it currently the fifth most important export. The leading importers are The Netherlands and UK. Non-traditional export crops have recently overtaken (>60%) traditional export crops (<40%).

Regional export markets include the EAC (East African Community) and COMESA (Common Market for Eastern and Southern Africa). In 2003, COMESA superceded EU which had until then been Uganda's largest global trade partner. There has also been growth of the Middle East and North American markets. Whilst cash crops are exported mainly to other continents, food crops have a strong market within the region: for example, maize is exported to Zambia, Burundi, Kenya, Rwanda and Tanzania. Initiatives such as the "Upland Rice Project" aim to improve Uganda's commercial production of rice both for domestic and export (COMESA) purposes. Regional markets also absorb increasing volumes of agri-based processed goods such as soap (Uganda market strategy).

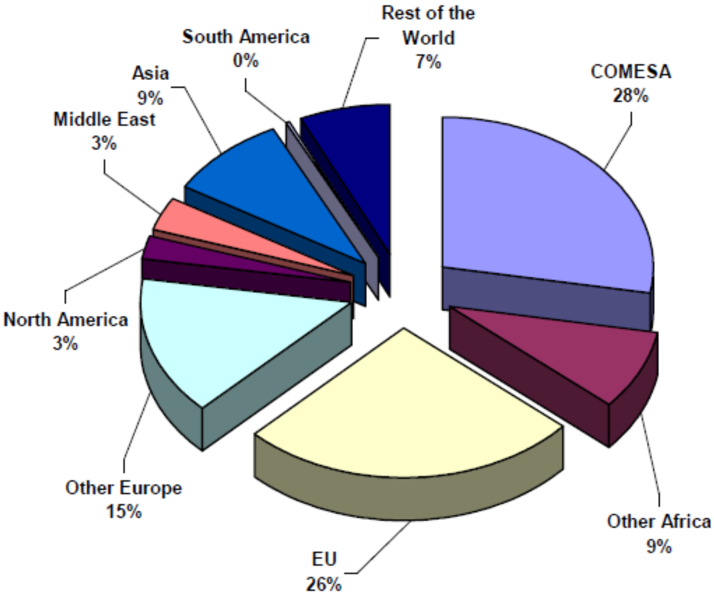

Figure 17: Uganda's exports by region (percent, in 2003). (Source: Uganda Export Promotion Board, 2004)

The tonnage and value of Uganda's commodity exports in 2004 were as follows (FAO statistics):

Crop	Value (US$ 1000)	Quantity (megatonnes)
Coffee	123,878	153,275
Tobacco leaves	40,685	27,93
Tea	37,256	36,856
Cotton carded	31,526	15,513
Maize	10,435	63,029
Cotton linter	8,147	5,051
Cocoa beans	6,801	5,154
Maize flour	6,765	23,129
Cotton lint	6,742	3,245
Vanilla	6,119	64
Beans, dry	4,097	13,090
Oils hydrogenated	4,049	71,491
Peas	3,238	9,305
Sesame seed	2,788	4,282
Flowers	22,000*	

*Not listed by FAO. Given value is from Market Analysis, 2003.

Coffee has long been and remains Uganda's most important cash crop. Its cultivation is concentrated in southern and south-eastern Uganda (robusta coffee) with a much smaller amount of arabica coffee in high-altitude areas of southeastern (Bugiso) and southwestern Uganda (Country Study). Following a period of highly volatile coffee prices and resultant national financial crisis, Uganda embarked on a policy to diversify export crops to reduce Uganda's dependence on world coffee prices, even though expansion of coffee export volumes was still encouraged. Recent production has, however, declined because of drought, management problems, low prices, and a shift from coffee production to crops for local consumption. Top importers of Uganda's coffee beans are Switzerland, UK and Spain (Market Analysis). Top importers of roasted coffee are France, USA, Canada and Germany. Apart from Switzerland, growth of these markets for Ugandan production has been negative in recent years.

Cotton was Uganda's first traditional cash crop and second only to coffee in the pre-Amin period, but underwent a serious decline (1970's to early 1980's) before being revived in the mid-1980's by various government initiatives. However, production again declined, as violence plagued the major cotton-producing areas of the north. With the gradual improvement in security, cotton is again showing signs of growth. Displaced people returning to northern Uganda are being encouraged to start farming cotton (including organic cotton) (USAID). Cotton is exported in various forms, but also provides the raw materials for several local industries, such as textile mills. The leading world importers of Uganda's cotton are UK, South Africa and Kenya. Uganda is attempting to position itself more strongly in the international organic cotton market, a niche product with growth potential.

Tea: Uganda produces some of the world's best quality tea, owing to a highly suitable climate and soils. Production almost ceased in the 1970s, however, when the government expelled many owners of tea estates, mostly Asians. Many tea farmers also reduced production as a result of warfare and economic upheaval. Successive governments after Amin encouraged owners of tea estates to intensify their cultivation of existing hectarage. Tea is produced both commercially on large plantations, and by thousands of smallholder farmers. There are several tea processing factories. 91% of Uganda's tea is sold on the Mombasa auction, and the leading importer is Kenya.

Tobacco production, like all cash crops, was drastically reduced during the turmoil of the 1970's and early 1980's, as well as the ensuing violence in the north-western regions where tobacco was mainly grown. Revival of this industry has been slow but has picked up strongly in recent years and tobacco is once again a major export.

Food security

Ugandans rely primarily on plantains/bananas (19%), cassava (13%) and maize (11%) for the bulk of their daily dietary energy supply (ESSGA 2006). The remainder is provided mainly by sugar, sorghum, milk, rice, wheat, potatoes and beef or pork (FAO).

Although Uganda had an overall positive food balance in the past, per capita food production has declined mainly because of rapid population growth and the conflicts in the north and north-eastern parts of the country. The growth rate in food production, estimated at 1.5%, cannot cope with these circumstances and in response the government has continued to import food, such as 4000 tonnes of rice per year. Increased rice production is seen as a key to food security and increased household income.

The underlying factors impacting on food security are civil insecurity, poverty, unreliable climatic conditions, and epidemic crop and livestock diseases (USAID/FEWS NET). Food insecurity is chronic amongst pastoralists and agro-pastoralists in the northern and north-eastern regions (particularly Karamoja), with its high numbers of internally displaced persons (IDPs), and recent erratic rainfall patterns. IDPs have suffered from limited access to land to cultivate crops over many years, resulting in a breakdown of traditional livelihoods. Poorer households without livestock are most affected as they lack livestock to exchange for cereals. The northern areas are also naturally at higher risk of periods of food shortage towards the end of the long dry period between November and March, when the food stores of the last harvest are depleted. Food insecurity can start as early as December if previous harvests have been poor.

In other parts of the country, the outbreak of Banana Bacterial Wilt has resulted in householder food insecurity, given the high dependence on home-grown bananas as a daily staple and source of income. At disease peak, 24% of the rural population in eastern, central, western and south-western Uganda were affected, The disease has been ably controlled and reduced in many areas, but still needs to be monitored.

The distribution of food internally is hampered by lack of access to markets and market information, and poor transport infrastructure. This leads to food surpluses in some parts of the country but food deficits in other parts.

Food imports and aid

Uganda's major import partners include the USA, Malaysia and Australia, and the main import commodities are wheat, palm oil, sugar and rice. During the period 1979 to 2004, wheat imports (share in agriculture) have risen from 1.4% (1979-1981) to 26% (2004) (ESSGA 2006). Palm oil imports have risen from 0% (1979-1981) to 14.8%, and sugar imports have dropped from 46% (1979-1981) to 6.6% (2004) as local production capacity was rehabilitated. The agricultural trade balance (exports – imports) has dropped from US$ 305 million to US$ 78 million in this period. The recent sharp rise in wheat and rice prices on international markets creates a shock which is difficult to absorb in the national economy.

The tonnage and value of Uganda's food imports in 2004 were as follows (FAO statistics):

Crop	**Value (US$ 1000)**	**Quantity (megatonnes)**
Wheat	72,963	236,678
Palm oil	41,531	68,954
Sugar refined	18,462	44,270
Oils hydrogenated	14,101	13,758
Maize	13,847	53,875
Maize flour	13,757	48,370
Rice broken	13,290	45,692
Fatty acids oils	12,361	21,940
Peas	6,532	14,205
Beans	6,498	12,542
Barley malt	6,454	11,685
Food prepared	6,080	20,900
Sorghum	5,260	20,515
Flour/meal of oilseeds	4,599	12,893
Rice (milled paddy)	4,449	14,723

Although Uganda's climate and natural resources should allow the country to grow most of its food requirement, the combination of more frequent and prolonged droughts in many parts of the country, and violence and insecurity in the northern parts, have led to almost perpetual dependency on food aid. The World Food Programme supplies virtually all the food in some arid northern areas (UGANDA NAPA, 2007).

Food trade balance

In spite of having large agricultural potential for almost all commodities, Uganda still imports food. During 2001-2003, for example, production of cereals was 2.32 million tonnes of which 52 000 tonnes were exported (mainly maize), 0.94 million tonnes used for stock feed and 1.55 million tonnes consumed (FAO). The shortfall was made up with 0.22 million tonnes of imports, mainly wheat and rice. There was also a dependence of 78% on imports of vegetable oils, and a smaller (16%) reliance on sugar imports. The country is self-sufficient for roots, tubers, fruits, vegetables and pulses, with these foodstuffs comprising a large proportion of the diet. Uganda is also self-sufficient for meat and milk, although consumption is low by developed country standards.

Value added (agro-processing industries)

Much of the manufacturing/industrial sector relies on agricultural products for raw materials, thus its output is strongly linked to that of agriculture. There is capacity for the processing of cotton, coffee, tea, sugar, food crops (including vegetables), and milk. Mills process wheat and maize and edible oilseeds (cotton, sunflowers, peanuts, and sesame seeds) into flour, and oilseeds also provide by-products for the manufacture of soap. Uganda also produces textiles, cigarettes from tobacco, and beverages (alcoholic beverages and soft drinks). Current policies encourage continued rapid growth of value added agricultural export.

Limiting factors to agricultural production

Land

Although population growth has created pressures for land in the southern areas, especially in the arc surrounding Lake Victoria, land shortages have been rare, and a large proportion of arable land is not used for cultivation.

Climate

Over many parts of the country, the seasonal and spatial variability of precipitation is often highly disruptive to agriculture. There are not only differences between wet and dry years, but there are also considerable variations in the timing of the onset of the rainy seasons, the duration of the rainy seasons, and in the amount of rainfall. Even in the high rainfall areas there are periods of moisture deficit. El Niño episodes usually cause greater than average rainfalls in the short rainfall season, whilst cold phases (La Niña) bring a drier than average season.

Climate does not impose significant limitations on agricultural production, apart from the erratic rainfall discussed above (especially in the north-east). The length of the growing season is generally greater than 270 days per year except in the north-east. The high altitude areas around Mount Stanley and Mount Elgon are too cool for tropical and sub-tropical crops.

Soils

The geology of Uganda is dominated by ancient crystalline rocks, also some younger volcanic (west and east borders) and sedimentary rocks (BGS). Over most of the country there is generally a thin (20-30 cm) topsoil and a deep (5-10 m) subsoil. Organic matter and nutrients are strongly concentrated in the topsoil. These soils range in texture from clay loams to sandy loams, although red clay loams tend to predominate in the wetter regions (Aquastat). Large parts of Uganda are regarded as fertile. In small areas around Mount Elgon and Mount Stanley and in the south-west the soils are unsuited for cropping, and steep slopes of the mountainous areas cannot be cultivated.

Soils are prone to erosion, and severe land degradation has occurred over much of the southern regions, particularly where bush and forest clearing for agriculture has proceeded unchecked. High human population density is the primary reason for degradation of these highlands and the higher rainfall areas. Soil erosion leads to silting of rivers and lakes (see below). On the other hand, livestock degrade marginal lands such as the "cattle corridor".

Water availability and quality, and irrigation

Uganda is a well-watered country, and rainfall has been generally sufficient for rain-fed agriculture. There are extensive lakes (major and minor), rivers, wetlands and aquifers. Nearly one-fifth of the total area, or 44,000 square kilometres, is open water or wetland (Aquastat). Total renewable water resources are estimated at 66 cu km (1970), of which only 0.3 cu km/year are withdrawn. Of this freshwater withdrawal, 40% is used by agriculture, 17% by industry and 43% for domestic use.

For agriculture, the wetlands have particular importance. They are numerous and widespread, mostly in the southern and central regions. In the south and west, wetlands have a permanent core and relatively narrow seasonal wetland edges. In the north, they take the form of broad flood plains. Wetlands reduce the effects of floods and droughts, provide fish resources and support cropping and grazing along their margins, and they are centres of high biodiversity and productivity as well as valuable refuges and sources of food for fish. Furthermore, they are active biological filters in the treatment of effluents, but due to this function they are also sensitive to the accumulation of pollution. Many of the seasonal wetland edges are used for smallholder agriculture, and some have been drained for larger-scale cropping. Because it is often poor people who settle in or close to wetlands, they are particularly vulnerable to flooding events.

Groundwater represents the main source of potable domestic water supply, especially in the rural areas, where it provides at least 80% of the water supply (BGS). It is also important for livestock use particularly in the drier regions. Groundwater extraction takes place from springs (protected and unprotected, especially in the south-east and the mountainous areas), boreholes, and to a lesser extent from protected hand dug wells. The potential yield from deep aquifers is above 3 m^3/hr in the south-west, south-east, north-west and along the eastern border of the country. In large areas of the central parts potential yields are between 2-3 m^3/hr, while in some areas it is below 1 m^3/hr. The shallower aquifers are seen as a useable resource, since they show good yields, and are cheaper to exploit compared to deeper groundwaters.

Technology, infrastructure and energy

Owing to the political and economic crisis of the 1970’s and early 1980’s, agricultural production plummeted and technological improvements were delayed. Agricultural production continued to use primarily unimproved methods on small, widely scattered farms, with low levels of capital outlay. Other problems facing farmers included the disrepair of the nation's roads, the nearly destroyed marketing system, increasing inflation, and low producer prices (Country Study). These factors contributed to low volumes of export commodity production and a decline in per capita food production and consumption. Currently, government policies are strongly geared towards rehabilitating infrastructure, reducing poverty, modernising agriculture, and the sustainable use of natural resources for improved productivity, especially in the export sector. Nevertheless, progress is slow, and the use of inputs and modern technologies in agriculture is still low. In 2003, there was about 1 tractor per hectare of cropland. National fertiliser consumption was also low at 9 306 tonnes (2002), translating to about 2 kg/ha. The use of other agricultural chemicals, e.g. pesticides and herbicides, also limited. Most farmers still use the hand-hoe for cultivation of food crops.

Agriculture-based industries have also suffered from intermittent energy rationing resulting from low lake water levels which affect the generation of hydropower.

This results in the disruption of economic activities and a decline in manufacturing outputs. The processing and storage of perishable products such as fruit and vegetables requires reliable cold stores. The planned installation of new generating capacity in rural areas will alleviate this problem.

Internal transport is by road, rail and waterway, and although the rehabilitation of transport infrastructure has received much attention recently, the network is still underdeveloped. More than 90% of the road network is not paved, making for a rough ride and damage to the produce, and many rural feeder roads are impassable during the rainy seasons. There are also inadequate facilities to handle quality exports and an inadequate airline system, which constrains export potential in this land-locked country (Transaction Cost Analysis 2002). Inland international freight systems (e.g. rail transport to ports in Kenya and Tanzania), especially for cotton and coffee, require improvement. The railway system is currently being privatised, which should alleviate rail transport constraints.

Telecommunications systems are seriously inadequate, particularly in rural areas. Mobile cellular service and e-mail and Internet services are increasing rapidly, but the number of main lines is very deficient. In the past, agricultural information flow to farmers has been inadequate, unreliable and untimely. However, dissemination of market price information to rural areas by mobile cellular service is improving (Transaction Cost Analysis).

Human resources

Uganda has made significant progress in reducing the prevalence of HIV/AIDS (Aquastat). The effects on agricultural production are evident in the high number of child-headed households in some districts. This results in losses of skilled and unskilled labour that would otherwise be employed in production, research and extension service. However, effective government policies have reduced the impact of HIV/AIDS in other parts of the country.

There is still not sufficient capacity in agricultural extension, so that extension services reach few farmers, messages have not been effectively communicated, there is pervasive lack of access to knowledge and information, and thus rates of technology adoption are low. There is also a need to train many more technical staff to support government policies (Plan for Modernisation of Agriculture) for the adoption of modern technologies, including irrigation.

Although men and women are equally employed within the agricultural sector, women tend to bear the burden of crop cultivation, processing and water harvesting (often requiring the fetching of water over long distances). Water scarcity places increasing pressure on women and children searching for water further away. Adoption of new technologies is lower amongst women farmers, and they often have less access to farming income than men in the household.

Land tenure

The 1995 Constitution establishes that every person has a right to own land, and that land can be held under customary, freehold, *mailo* or leasehold tenure (FAO Livestock report). Despite these laws, the land tenure pattern is still uncertain: in the fertile central area of Buganda, there are both leaseholders and landowners; the remainder of the land is under the authority of the Uganda Land Commission, and farmers often have not registered titles and tenure insecurity is pervasive. In other parts of the country, farmers have acquired freehold or leasehold title to their land.

Government policies and market factors

Following the near-collapse of the economy, including most commercial agriculture, during the Amin era in the 1970's to mid-1980's, the new government embarked on an Economic Recovery Programme starting in 1987, followed by the Structural Adjustment Policies in the early 1990's. These policies have managed to stabilise the macro economy. From an agricultural point of view, the policies focused on the rehabilitation of infrastructure for traditional export cash crops, the development of non-traditional exports, removal of constraints for agricultural development such as restrictive tariff and non-tariff barriers, substantial upward adjustments in agricultural pricing, liberalisation of trade and marketing and processing, the abolition of taxes on agricultural exports, improved agricultural research and extension, and improved security (EWUAP 2008).

Despite steady progress, a number of constraints still exist, including marketing infrastructure, finance (credit and payment systems), on-farm and off-farm storage, lack of information and skills on financial management and marketing opportunities, and high costs and low price bargaining power at markets. Access to markets is severely constrained by the road and other transportation networks, and poor communication and information systems. This makes the marketing of agricultural produce particularly difficult for the majority of rural subsistence farmers. The second most important constraining factor to market access is the means and cost of transport: 70% of agricultural produce is carried on the head (mainly by women), with 20% by bicycle, 2% by donkeys and ox-carts, and only 8% by motorised transport. Distances to markets are often long. Markets for purchasing farming inputs and selling produce have insufficient infrastructure, such as shelter, secure storage, safe water and healthy sanitation facilities.

It is estimated that 5-15% of non-perishable crops (grains), 20-35% of semi-perishables (root crops) and 40% of perishables (fruits, vegetables) are lost following harvest due to impassable roads in the rainy season, inefficient processing facilities, lack of storage facilities, and poor cold storage facilities for perishables. The warm, humid and wet climate creates ideal conditions for post-harvest losses.

By the late 1980's, only one-third of food crop production was marketed, and two-thirds of livestock products. This meant that the monetary agricultural GDP was only about 60% of the total agricultural GDP. Current policies are aimed at increasing the proportion of production which is marketed, especially on the export market.

Future demand – national and international

National demand for food is rising in parallel with the rapidly growing population. Especially in the north-eastern regions where the population growth rate is highest, food shortages and malnutrition are becoming the order of the day and this will only worsen in future if agricultural productivity does not improve rapidly.

International demand for high quality cash crops is likely to grow, but prices are volatile and heavily influenced by production trends and climate disasters elsewhere in the world (e.g. coffee, vanilla), and international trade agreements. Increased production and export from Uganda will only reap economic rewards if markets can absorb it.

The Ugandan Market Analysis and Entry Strategy (2004) developed by the Uganda Export Promotion Board has identified numerous opportunities for new and niche export products, e.g. many sub-tropical fruit types and honey.

Agricultural adaptation to climate change

Context: Current government policies

Poverty Eradication Action Plan (PEAP, 2005): provides a framework for the eradication of poverty through multi-sectoral interventions. The primary objectives of macro-economic management are inflation control and private sector-led economic growth. The agricultural sector presents great opportunity for poverty eradication because it employs 80% of the population, and increasing agricultural incomes will also boost non-agricultural rural production. The strategic imperative is to strengthen agricultural exports, with a major involvement of the private sector. This will be done by encouraging the growth of commercial farming amongst the rural poor and reducing the dependence on subsistence agriculture. Allied to this is continuing improvement of the transport network, electrification especially of rural areas, provision of micro-finance, conservation of natural resources, clarification of land rights, and strengthening disaster preparedness, amongst others.

Plan for Modernisation of Agriculture (PMA): this policy is part of the broader strategy of poverty eradication (PEAP). Modernising agriculture will contribute to increasing incomes of the poor by raising farm productivity, increasing the share of agricultural production that is marketed, and creating on-farm and off-farm employment. The objectives of the PMA are to (1) increase incomes and improve the quality of life of poor subsistence farmers; (2) improve household food security; (3) provide gainful employment; (4) promote sustainable use and management of natural resources. The mission of the PMA is "eradicating poverty by transforming subsistence agriculture to commercial agriculture", i.e. a re-orientation of production towards the market. Acceleration of agricultural growth is to be achieved by introducing technological change, thereby keeping food prices down, which will in turn boost incomes, agriculture-based industry, labour intensive exports, and competitiveness on international markets. Government undertakes to provide conditions and services that are in the "public good", whereas the private sector will be encouraged to invest in the provision of agricultural inputs, the processing and marketing of outputs, the provision of credit to farmers, and the construction of large irrigation infrastructure. The development of non-traditional exports is encouraged.

Water for Production Programme (WfP): this is one of four sub-sector strategies aimed at reforming the water sector. It includes the components water for crops, for livestock, for aquaculture, for rural industries, as well as institutional co-ordination and capacity development. WfP facilities include dams, valley tanks, aquaculture and irrigation facilities, many of which are multi-purpose. The overall objective is "To promote development of cost-effective and sustainable water supply and water management for increased production and contribution to the modernisation of the agricultural sector in Uganda with a focus on poverty reduction and minimal environmental impacts". The strategy guides the most appropriate and affordable methods of water supply.

Estimates of required future water storage facilities for livestock watering include an increase in the proportion of livestock supplied with water facilities from 63% (current) to 80% (2035) in the cattle corridor (CC), based on utilisation of 100% of the carrying capacity by 2035 and assuming some natural water supplies to cover the remaining demand. In non-CC areas, the proportion of livestock supplied with water is estimated to increase from 35% to 60%, based on 50% carrying capacity.

For crop irrigation, a distinction is made between areas with favourable soil conditions close to the main open water sources (A), and areas of arable land that could be irrigated provided bulk water supplies including water storage in the dry season would be available (B). The former require investments in pumping stations whereas the latter require dams, which are much more costly. The proportion of irrigation potential utilised is estimated to rise from 19% to 50% in 2035 (A) and from 0 to 6% (B). There will also be a shift towards more efficient irrigation technologies, with surface irrigation being reduced from 81% to 50% (areas A), and more efficient technologies dominating (75%) in areas B due to the higher cost of providing water.

The investment estimates take into account drought and flood by adding 50% additional storage capacity to the capacities required to cater for the annual variations in rainfall. "The proportion added is a technical variable that can be varied when better information is available on the catchments and predictions of changing climatic conditions."

There is also a strong focus on functionality of existing facilities, some of which have become only partly functional or non-functional due to faulty abstraction systems, failure of the structure, and siltation. Restoring functionality where possible is important, as is the learning from past mistakes when planning new facilities.

The following figures illustrate the investments that would be required assuming a high priority in food production and food security with fairly ambitious targets for irrigation and livestock facilities, for the period 2009 to 2035:

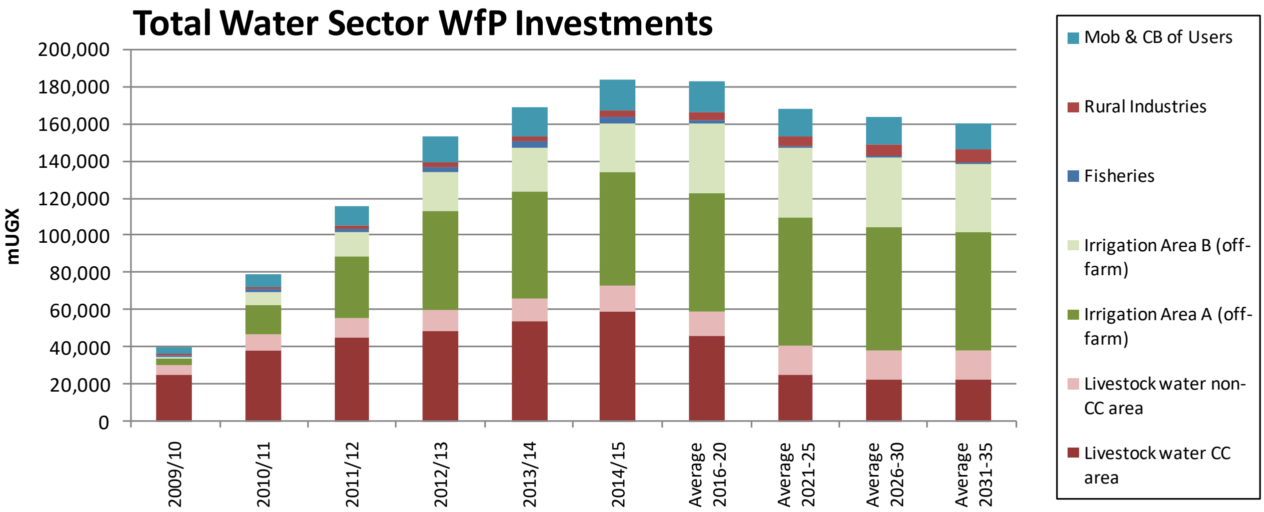

Figure 18: Scenario A WfP Investment Needs under Water Sector (Source: MWE, 2009)

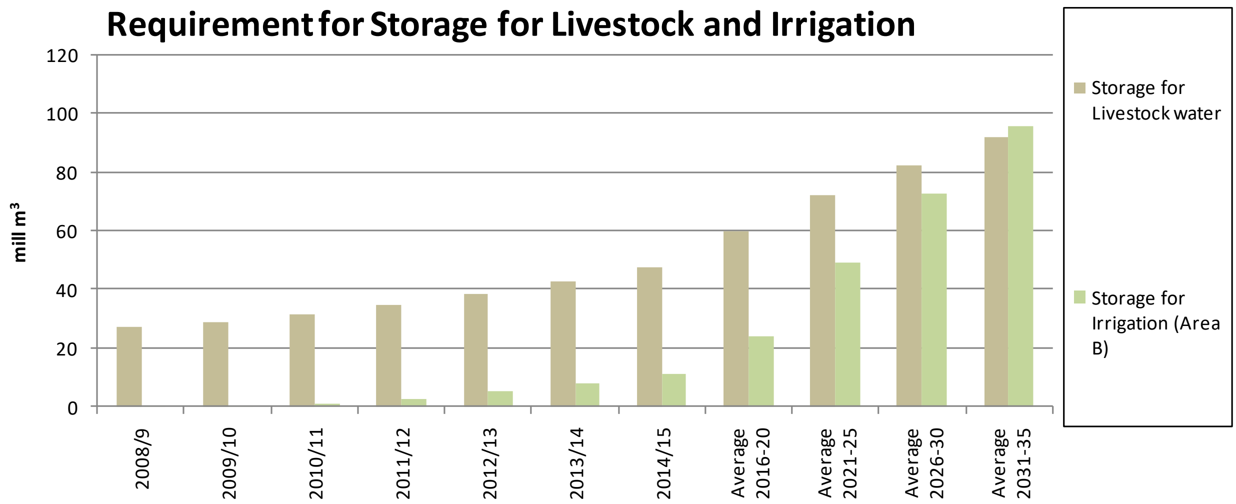

Figure 19: Scenario A Storage Requirement for Livestock and Irrigation (Source: MWE, 2009)

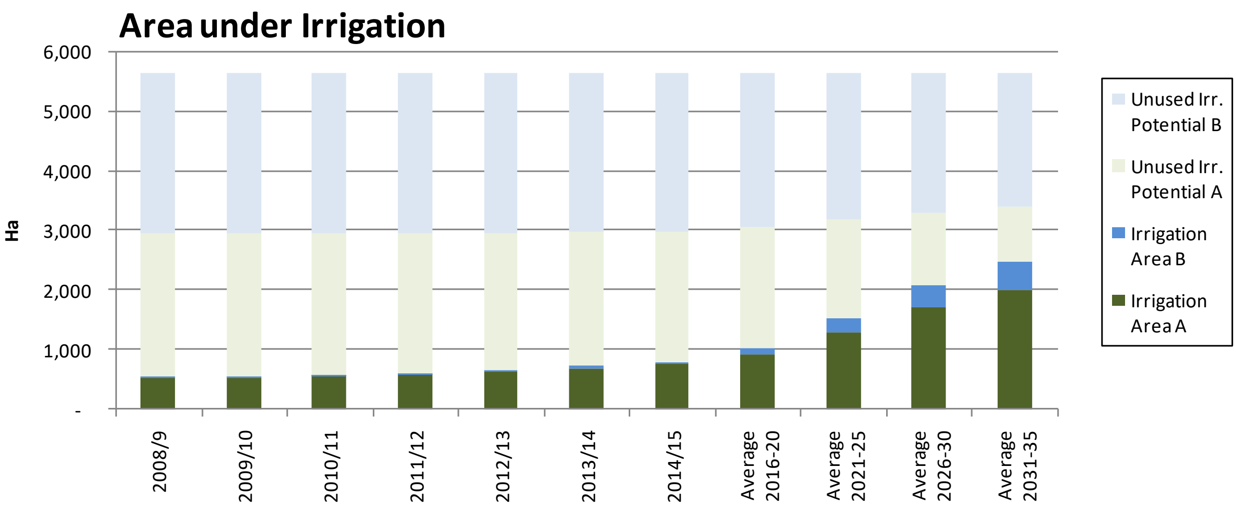

Figure 20: Scenario A Area under Irrigation (Source: MWE, 2009)

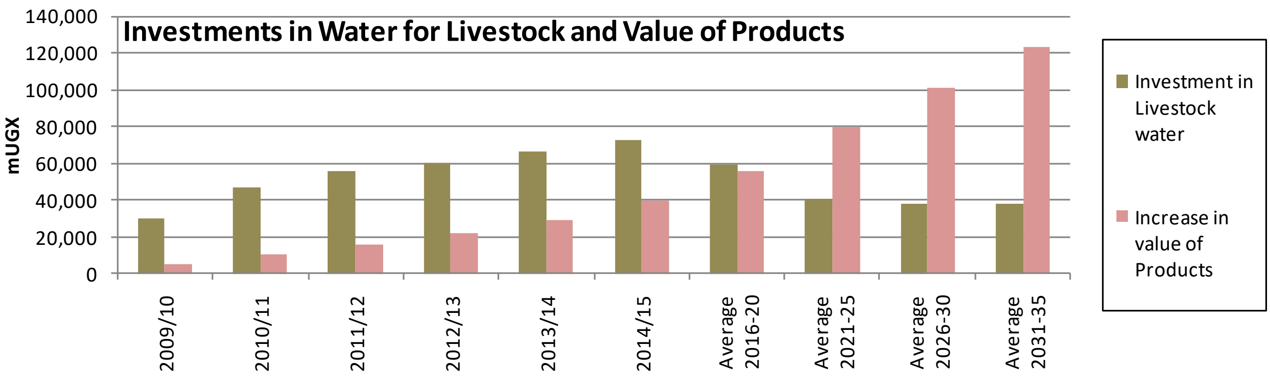

Figure 21: Scenario A Investments in water for livestock and value of products (Source: MWE, 2009)

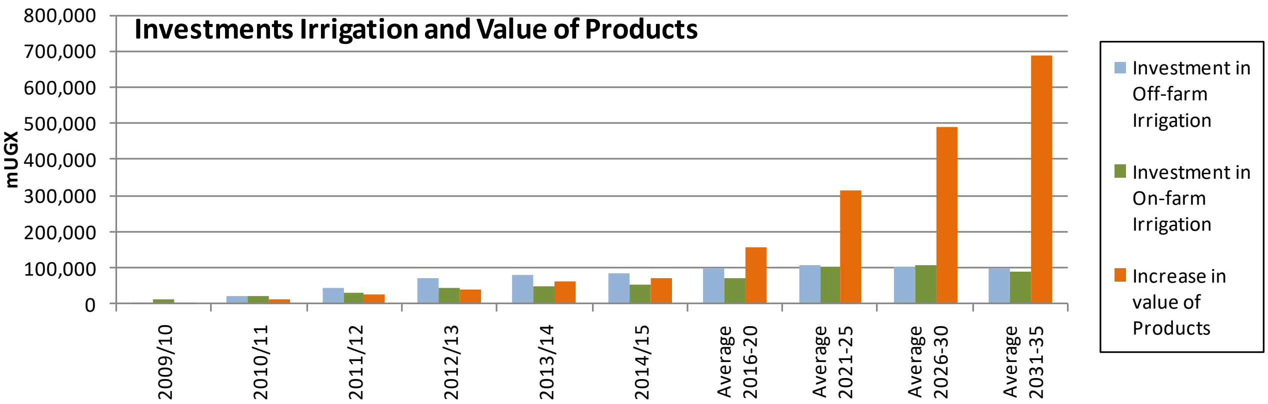

Figure 22: Scenario A Investments in Irrigation and Value of Products (Source: MWE, 2009)

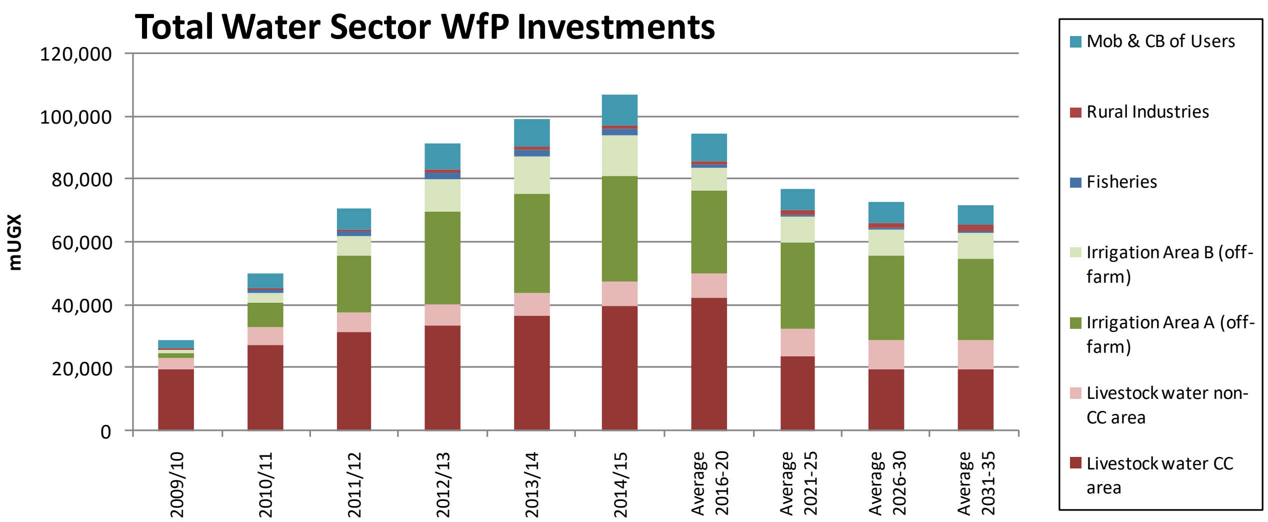

Figure 23: Scenario B WfP Investment Needs under Water Sector (Source: MWE, 2009)

National Wetlands Policy (1995): The policy calls for no drainage of wetlands, sustainable use, environmentally sound management, equitable distribution of benefits, and the application of environmental impact assessment procedures. The implications for agriculture are, in summary, that no removal or exclusion of water from a wetland is allowed (e.g. no more drainage for large rice schemes), only non-destructive sustainable uses are allowed (e.g. fisheries, wetland edge gardens, limited grazing), and that no wetland will be leased to any person or organisation and only communal use will be permitted (i.e. no land tenure in wetlands). The aim is to conserve and restore, where feasible, wetland ecosystem services.