

in some regions. In the northernmost areas of the country above the equator, these two seasons merge into a single long rainy season (Luziraa *et al.*, 2007; Phillips & McIntyre, 2000).

The wettest districts are located within the Lake Victoria Basin, eastern and the northwestern parts of Uganda (including Kalangala, Kampala, Mpigi, Mukono, Jinja, part of Masaka and Bugiri (Lake Basin), Mbale and Kapchorwa (eastern) and Arua (northwestern)) (Luziraa *et al.*, 2007). The western, northern and northeastern districts are the driest regions of country, with the eastern region receiving moderate rainfall (including Pallisa, Kumi, Soroti, Tororo, Busia and Bugiri) (*ibid*). The average long-term annual rainfall for Uganda is about 1318 mm, which is adequate to support agricultural activities.

The movement of the ITCZ is sensitive to variations in Indian Ocean sea-surface temperatures and varies from year to year; hence the onset and duration of these rainfalls vary considerably interannually. One of the most well documented ocean influences on rainfall in this region is the El Niño-Southern Oscillation (ENSO). 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.

Key climate vulnerabilities: Drought; flooding/landslides; food security; infectious disease epidemics; biodiversity.

Observed Climate Changes²

Temperature

- Mean annual temperature has increased by 1.3°C between 1960 and 2003; this increase in temperature has been most rapid in January and February.
- Daily temperature observations show increasing trends in the number of hot days³, increasing by 74 days (equivalent to +20 percent). The rate of increase is seen most strongly in June, July and August ('JJA').
- The average number of 'hot' nights per year increased by 136 (equivalent to +37 percent); the rate of increase is also seen most strongly in JJA.
- The frequency of cold days⁴ has decreased in all seasons except December, January and February ('DJF'). The average number of 'cold' days has decreased by 20 (equivalent to -6 percent of days) between 1960 and 2003, decreasing most rapidly in September, October and November ('SON').
- The frequency of cold nights has, however, decreased more rapidly in all seasons. The average number of 'cold' nights per year has decreased by 42 (equivalent to -11 percent of days); this rate of decrease is most rapid in DJF.

Precipitation

- Observations of rainfall over Uganda show decreasing trends in annual and MAM rainfall. Annual rainfall has decreased at an average rate of 3.4mm per month (+4 percent) per decade, but this trend is strongly influenced by particularly high rainfall totals in 1960-61. MAM rainfall has decreased by 6.0mm per month per decade (-5 percent).
- There is no significant trend in the proportion of rainfall occurring in heavy events⁵.

Current Climate Vulnerability

Uganda suffers periodically from both too little and too much rainfall. Table 1 shows the natural hazards that have most affected Uganda in the past 20 years, and drought and flood on average affect more Ugandans than any other natural disaster.

² McSweeney, C. *et al.* (2008) unless otherwise stated

³ 'Hot' day or 'hot' night is defined by the temperature exceeded on 10% of days or nights in current climate of that region and season.

⁴ 'Cold' days or 'cold' nights are defined as the temperature below which 10% of days or nights are recorded in current climate of that region or season.

⁵ A 'Heavy' event is defined as a daily rainfall total which exceeds the threshold of the top 5% of rainy days in current the climate of that region and season.

The implications of such rainfall variability are serious for agriculture and food security. Drought in 2008 caused an average reduction in yield of 50 percent of simsim, sorghum, groundnuts, cassava and maize (Ocowunb, 2009). The resulting increase in cereal prices and famine affected Uganda into 2009, with 51 districts (accounting for around 37 million people) had appealed to the government for food (Lirri, 2009a; Ssenkibirwa, 2009). As of March 2010, for example, at least 900,000 people in Karamoja, northeastern Uganda, were facing severe food insecurity as a result of four consecutive years of failed rains and poor harvests (IRIN, 2010). Karamoja is particularly vulnerable to famine, where at least 81 percent of the estimated 1.1 million food-insecure people in Uganda live (ibid).

Floods and landslides not only claim lives directly, but indirectly through disease outbreaks associated with lack of clean water and sanitation facilities. They also damage and destroy homes, roads, crops and communication links, causing devastation to communities. Thousands of people were displaced by the Bududa Landslide in March 2010, for example, and had to take shelter in the Red Cross camp at Bulucheke (Edyegu, 2010).

Uganda is also at risk from other extreme weather events, such as hailstorms. In April 2010, for example, a three-day hailstorm destroyed homes, schools and crops in the Mpigi and Sembabule, leaving over 800 families in need of relief aid (Jaramogi, 2010).

Hazard	Number of Events	Deaths	Total of Population Affected
Drought	5	194	2,831,000
<i>Average per event</i>		39	566,200
Earthquake	1	7	50,000
<i>Average per event</i>		7	50,000
Epidemic (unspecified)	2	28	19
<i>Average per event</i>		14	10
Epidemic (bacterial)	20	665	11,050
<i>Average per event</i>		33	553
Epidemic (viral)	4	356	106,360
<i>Average per event</i>		89	26,590
Flood (unspecified)	4	1	20,900
<i>Average per event</i>		0	5225
Flood (general)	11	227	938,425
<i>Average per event</i>		21	85,311
Landslide	3	419	16,161
<i>Average per event</i>		140	5,387
Storm (unspecified)	3	-	10,105
<i>Average per event</i>		-	3,368

Table 1 – Natural Hazards in Uganda (1991-2010) (CRED, 2010)

Lake Victoria and the Equatorial lakes are very important to Uganda and their levels have fluctuated through much of the 20th century; since a period of high rainfall in the early 1960s, the level of Lake Victoria has declined steadily (Sene & Plinston, 1994; Conway, 2005). Recent extreme rainfall events have resulted in increases in lake levels – including a 1.7m increase during the 1997-98 warm ENSO event – but these were not sustained (Conway *et al.*, 2005; Tate *et al.*, 2004).

High rainfall events can have both positive and negative effects on Lake Victoria. Extreme rainfall in 1961-62 and 1997-98 resulted in widespread flood damage to infrastructure, homes and livelihoods around the lake (Hepworth & Goulden, 2008). However, the increased rainfall boosted lake levels, fish stocks and led to a reduction in water hyacinth – a species of ornamental aquatic plant that was accidentally introduced to the lake in 1988 and subsequently spread to clogs many of its bays (Hepworth & Goulden, 2008; Ntiba *et al.*, 2001).

Climate Change Projections⁶

Temperature

- The mean annual temperature is projected to increase by 1.0 to 3.1°C by the 2060s, and 1.4 to 4.9°C by the 2090s.
- Projected rates of warming are greatest in the coolest season (from June to September, or 'JJAS') increasing by 1.5 to 5.4°C by the 2090s.
- All projections indicate increases in the frequency of days and nights that are considered 'hot' in current climate.
- Annually, projections indicate that 'hot' days will occur on up to 43 percent of days by the 2060s, and up to 73 percent of days by the 2090s.
- Nights that are considered 'hot' are projected to increase more quickly than hot days, occurring on up to 84 percent of nights by the 2060s and up to 97 percent of nights by the 2090s.
- All projections indicate decreases in the frequency of days and nights that are considered 'cold' in current climate. These events are expected to become exceedingly rare, and do not occur at all by the 2090s in any projections under some climate change scenarios.

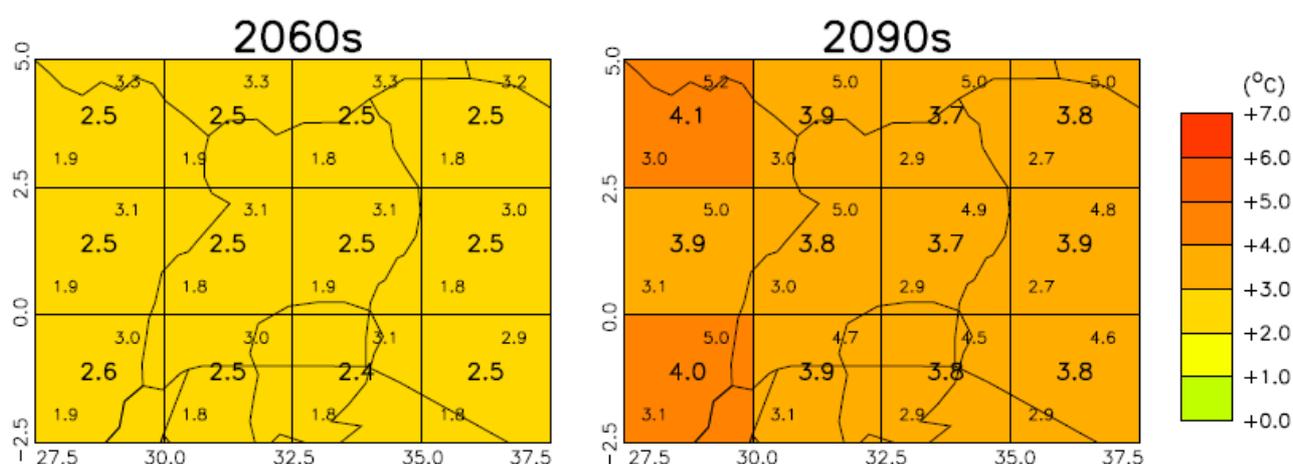


Figure 1 – Projections of mean annual temperature for Uganda for the 2060s and 2090s (the central value in each grid box gives the central estimate of the model projections, and the values in the upper and lower corners give the maximum and minimum) (McSweeney *et al.*, 2008). See 'A note on the projections' at the end of this document for more information on these maps.

Precipitation

- Projections of mean rainfall are broadly consistent in indicating increases in annual rainfall, with central estimates projecting changes of +5 to +11mm per month (equivalent to +4 to +8 percent) and +9 to +14mm per month (equivalent to +7 to +11 percent) for the 2060s and 2090s respectively. Increases are largest in eastern areas (see Figure 2).
- Projected increases in rainfall are largest in the short-rain season, OND, with increases of 10 to 22mm per month (equivalent to +5 to +9 percent) and 15 to 30mm per month (+10 to +13 percent) for the 2060s and 2090s respectively. The upper end of the projections show maximum increases of 54mm per month by the 2090s, equivalent to an extra 35 percent of rainfall (see Figure 4).
- The proportion of rainfall that falls in heavy events is projected to increase, from 0 to 15 percent in annual rainfall by the 2090s, affecting the whole country throughout the year, but particularly in eastern areas (see Figure 5).
- Maximum 1- and 5-day rainfall totals are projected to increase; by up to 27mm in 1-day events, and up to 37mm in 5-day events by the 2090s. The largest increases are seen in the rainy seasons, MAM and OND.

⁶ McSweeney, C. *et al.* (2008) unless otherwise stated

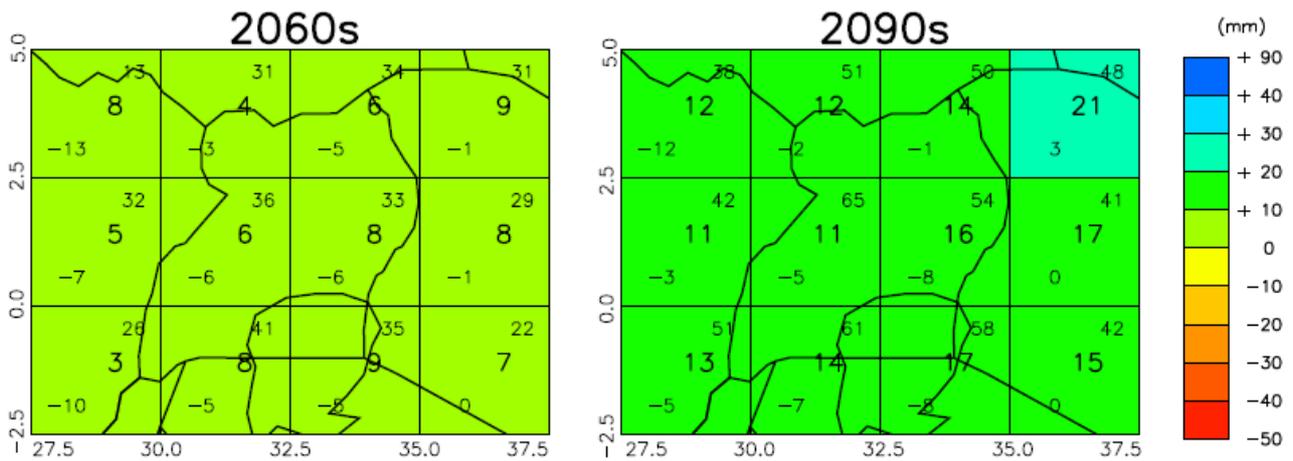


Figure 3 – Projections of change in annual rainfall (in mm per month) for Uganda for the 2060s and 2090s (see Figure 1 for details) (McSweeney *et al.*, 2008).

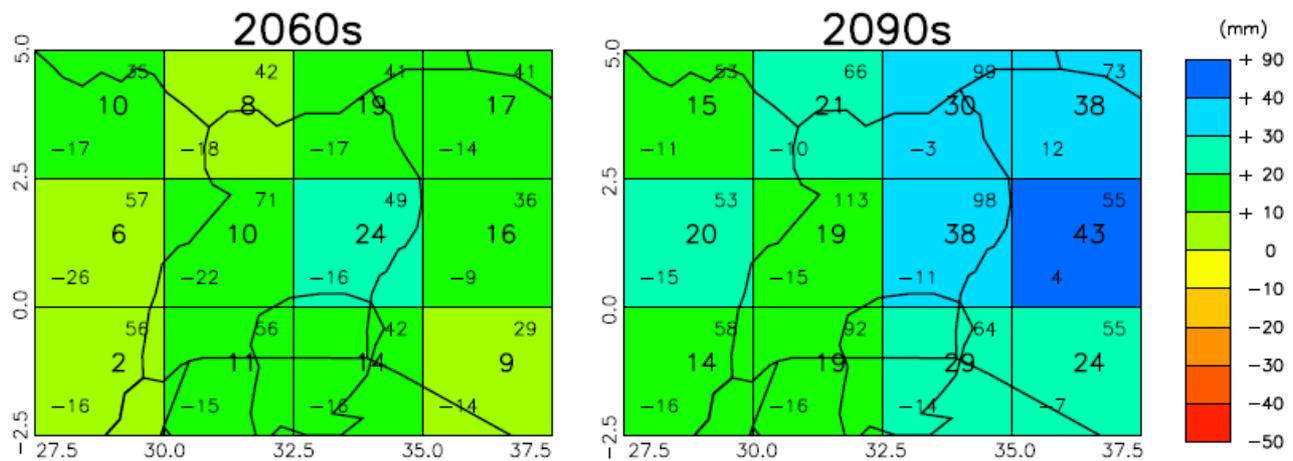


Figure 4 – Projections of change in SON rainfall (in mm per month) for Uganda for the 2060s and 2090s (see Figure 1 for details) (McSweeney *et al.*, 2008).

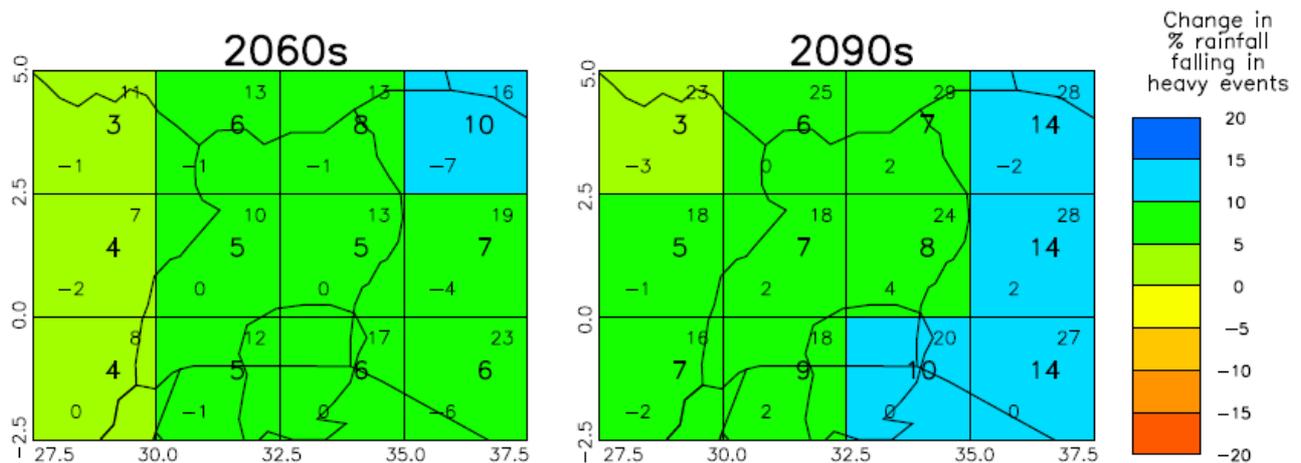


Figure 5 – Projections of percentage changes in the amount of rainfall falling in 'heavy' events during the OND season for Uganda for the 2060s and 2090s (see Figure 1 for details) (McSweeney *et al.*, 2008).

Climate Change Impacts

Flooding

Uganda suffers regularly from flooding events and associated landslides; 2007, for example, saw severe flooding in northern Uganda following the heaviest rain in 35 years (Vaughan, 2009). Climate change projections show an increasing trend for heavy rainfall events, particularly in the late wet season of OND., putting Uganda under increasing threat from flooding throughout the 21st century.

Water Resources

Uganda has abundant resources of water, although not evenly distributed across the country. Around 15 percent of Uganda's total area is water, though 80 percent of this Lake Victoria (Luziraa *et al.*, 2007). Rural communities in the semi-arid areas (e.g. the northeast) rely heavily on streams, which can dry up in periods of drought. The frequency of these droughts is already noted to be increasing; indeed, Uganda as a whole has experienced seven droughts in the 1990s, compared to just 8 between 1911 and 1990 (Vaughan, 2009). Increasingly frequent droughts have lowered the water table in many areas, leading to more regular drying up of streams and boreholes (Luziraa *et al.*, 2007).

Projections show a broad increase in annual precipitation totals; however, this is offset by rising temperatures and a greater loss of water to evapotranspiration. With increasing seasonal and annual rainfall totals, there is an increasing need for water storage in preparation for drier periods.

Agriculture & Food Security

Over 80 percent of Uganda's population is rural and depends on rain-fed agriculture (Luziraa *et al.*, 2007). Harvests have been increasingly affected by lack of rain; drought in 2008, for example, caused an average reduction in yield of 50 percent in simsim, sorghum, groundnuts, cassava and maize (Ocowunb, 2009). Such crop failures result in dramatic increases in cereal prices, and this combination of food shortage and high prices can cause widespread famine (Ssenkibirwa, 2009). The area of Karamoja (in the northeast), for example, has experienced 14 droughts in the past 25 years; it has a malnutrition rate of 19 percent and 88 percent of its population (970,000 people) rely on UN food aid (Nyakairu, 2009).

Climate change is projected to cause an overall reduction in staple crops; for example, yields of maize are likely to decrease by 15 percent by 2020 for much of sub-Saharan Africa (Nyakairu, 2009). A changing climate will affect seasonality and increase uncertainty with regard to appropriate seeding times for growing seasons (Ocowunb, 2009).

The cash crop coffee is also at risk from the impact of climate change. A small black beetle, *Hypothenemus hampei* (or 'Coffee Berry Borer'), causes millions of dollars of damage to coffee producers worldwide – particularly in East Africa. A recent study has shown that rising global temperatures may increase the populations of the beetle, expanding its habitat and putting wider areas of coffee crops in danger (Bosire, 2009).

Climate change is also likely to livestock farming in Uganda. The cattle corridor, stretching from the northeast to the southwest is a fragile ecosystem, and depends on rainwater for human consumption and production (Luziraa *et al.*, 2007). Rising temperatures and more variable rainfall is likely to affect the quality and quantity of pasture, which in turn will have an impact on livestock productivity, and the distribution and incidence of animal and plant disease.

Public Health

Uganda's variability in rainfall has implications for public health, with flash flooding resulting in outbreaks of waterborne diseases such as diarrhoea and cholera, and droughts resulting in outbreaks of respiratory diseases (Luziraa *et al.*, 2007). With increasingly variable rainfall, and an increasing number of extreme events, Uganda will be at a higher risk of such disease outbreaks. With increasing pressures on agriculture, the risk of malnutrition – particularly in children – will increase.

Uganda has already begun to see a spread of mosquito habitat further into the highlands, in response to warmer mean temperatures, and the associated spread of malaria – the disease responsible for the highest number of deaths in the country. This has serious consequences as the population of these areas does not have the same level of natural immunity as the historically endemic areas. Malaria outbreaks do not just endanger lives but also reduce labour and agricultural productivity. As temperatures continue to rise, an increasing proportion of highland areas will become endemic for malaria, causing higher morbidity and drug resistance. Endemic areas of other infectious diseases will also increase with temperature, such as African sleeping sickness (Trypanosomiasis), which is spread by the bite of the tsetse fly.

Housing & Communities

Housing and communities are regularly damaged or destroyed by flooding and landslides. Washing away of roads also can hinder emergency response and provision of aid. With the projected increase in extreme rainfall events, the risk of flood events and landslides is likely to increase.

Biodiversity & Conservation

Forest products (timber, poles, rattan, bamboo, food, fodder, medicine, and firewood etc) contribute around 6 percent to Uganda's GDP (Luziraa *et al.*, 2007). They are particularly important for rural communities, with over 99 percent using wood or charcoal as fuel (*ibid*). With expanding agriculture, population growth and urbanisation, Uganda has lost 30 percent of its forest cover in the 15 years between 1990 (5 million ha) and 2005 (3.5 million ha), and at the current rate, Uganda will lose all of its forests in the next 41 years (Lirri, 2009b). Deforestation, when combined with increasing temperatures and more irregular rainfall patterns will worsen soil erosion and accelerate desertification.

The combination of more extreme rainfall events and deforestation and clearing of vegetation will also increase the risk of landslides in hilly areas. Landslides in the Bududa district in early 2010, for example, were partly attributed to lack of vegetation on the slopes (Watala, 2010).

The combination of loss of habitat and increasing stress of climate change will put Uganda's rich biodiversity at greater risk. The country has lost at least 7 percent of its wetland, for example, which have been converted to other uses. Wetlands (excluding open water) currently cover around 13 percent (330,000 sq km) of Uganda; however, important habitats such as these will come under increasing stress from rising temperatures (Lirri, 2009b).

Uganda's population of the endangered Mountain Gorilla is likely to be at an increasing greater risk of forest fires as rainfall becomes more unreliable. A fire in Mugahinga National Park, on the border with Rwanda, in 2009 required over 100 hectares of forest to be gutted in order to extinguish it (Mukombozi, 2009).

The glacial water reservoir Ruwenzori in Uganda is gradually depleting, and the total area of the 'mountains of the moon' glacier has halved between 1987 and 2003. A recent study carried out suggests that all glaciers in the Ruwenzori Mountains could disappear within the next two decades. The melting of the ice cap will have a negative effect on both the water catchments and eco-tourism, as well as on the overall economy.

Livelihoods

Agriculture is key to Uganda's economy, providing as it does approximately 42 percent of GDP, over 90 percent of export earnings and constituting over 80 percent of employment (Luziraa *et al.*, 2007). However, its contribution to the economy has decreased, from 45.7 percent in 1995-96 to 41.5 percent in 1999-00; this has not been caused by diversification in the economy, but rather from increasing pressure from environmental factors (*ibid*).

The recent famine has caused a dramatic increase in the price of cereals and meat; pork and beef, for example, have increased by an average of 1,000 shillings per kilogram in a year (Omurungi, 2009). Other staple foods such as matooke, mangoes, sweet bananas, tomatoes and cassava increased by an average of 6 percent in the month of August 2009. The inflation of food prices (to 22.3 percent, up from 19.4 percent in July) had a knock-on effect of increasing headline inflation to 12.4 percent, up from 11.6 percent in the previous month (Businge, 2009). In response, the government has stepped in to purchase food in affected regions; however, this is a short-term measure that does not reduce the vulnerability to famine in the long term (Omurungi, 2009).

Rising temperatures will also affect the suitability for growing coffee, Uganda's main cash crop (Tenywa, 2009). A 2-degree rise in mean temperature would cause a decline in production of 85 percent, with only mountainous areas such as Mbale, the Rwenzori and the former Kigezi districts maintaining suitable conditions (*ibid*).

Energy

97 percent of Ugandans rely on biomass (firewood, charcoal and crop residues) for daily household needs (Vaughan, 2009). Increasing severity of drought periods could cause greater drying of forests and a higher risk of forest fires, causing damage to biodiversity and also a loss in firewood. However, the impact on forests would be secondary compared to the high demand for fuel wood that continues in Uganda. Electricity generation is primarily from hydropower installations at Lake Victoria and along the upper reaches of the Nile. Reduced levels of Lake Victoria have been attributed to both increasing drought in the region and an increase in water released for electricity generation (above the 'agreed curve') since the extension of the hydropower dam at Owen Falls in 2000 (Sutcliffe & Petersen, 2007; Mangeni, 2006; Kull, 2006; Mubiru, 2006). Increasingly variable seasonal rainfall and increasing evapotranspiration under

climate change will make water resource planning more difficult and hence find a balance between electricity generation and water provision.

Transport

Roads, bridges and transport links are at risk from flooding and landslides; residents of Ishasha and business people using the Rukungiri-Ishasha-Goma Road, for example, have appealed to the government to replace the Inchwera Bridge, which was washed away in flooding in early 2010 (Mulondo, 2010). With increasingly heavy rainfall under climate change, the risk of damage to transport links from flood events will increase.

Government Response

Recent problems with flooding and landslides, as well as the ongoing debates on Lake Victoria levels for hydropower generation have pushed climate change adaptation up the agenda (Hepworth & Goulden, 2008). The National Adaptation Programmes of Action (NAPA) has been completed by the Ugandan government and was submitted to the UNFCCC in 2007. However, there is a perceived lack of vulnerability assessment beyond the sectors of agriculture, water resources and forestry (Twinomugisha, 2005). Regarding mitigation, the government has developed a national inventory of GHGs, and has also established a National Climate Change Steering Committee as a multi-sectoral and multi-disciplinary Committee to advise the Minister of Water, Lands and Environment on Clean Development Mechanism projects and climate change policy issues (ibid).

The government are to reintroduce indoor spraying of the insecticide DDT in order to combat the deaths of malaria (Naturinda, 2010). Research had shown that only 47 percent of pregnant women received a complete treatment for preventative malaria treatment, and only 40 percent of the country has insecticide-treated bed nets (ibid).

Likely Adaptation Options

The following are a selection of possible adaptation options for Uganda (see Luziraa *et al.* (2007) for more details on potential adaptation projects):

- Alternative livelihoods: these could be explored to reduce dependency on rain-fed agriculture. This would need to be incorporated into community development and also use sustainable techniques – charcoal burning, brick and craft making, for example, often have negative effects on the environment.
- Promotion of drought tolerant and early maturing species and varieties of crops.
- Food preservation: provision of information to communities on improved indigenous food preservation methods, training community-based technicians in indigenous and appropriate food preservation technology.
- Improve on safe water supply through construction of more protected water sources and gravity flow schemes.
- Scale up preventive public health programmes including vector control, such as mosquito control and management of malaria.
- Renewable energy: exploitation of considerable potential renewable energy resource (such as hydropower, solar and biomass residues from agricultural production) would help ease pressure for fuel wood and protect forests.
- Reforestation/afforestation projects: help prevent the occurrence of landslides when flooding occurs. Other options to help soil stability and degradation include planting grass cover, dug trenched to divert runoff, and terrace farming.
- Rainwater harvesting: collection of rainwater for both household and agricultural use will help offset the increasing unpredictable nature of rainfall.
- Concrete housing: promote the use of concrete for housing where possible; by subsidising the cost of concrete, this could provide more structurally sound buildings that can withstand flood events.
- Early-warning systems: implementation and improvement of such systems can help with preparedness for drought and flood events.

Useful Websites

- UNDP Climate Change Country Profiles: <http://country-profiles.geog.ox.ac.uk/>
- UNFCCC NAPAs from Non-Annex I Countries: http://unfccc.int/national_reports/napa/items/2719.php

- UNFCCC First Communications on Climate Change for Non-Annex I Countries: http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php
- Adaptation Learning Mechanism: <http://www.adaptationlearning.net/>
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A note on the projections...

The climate change projections used in this profile were developed as part of a UNDP project, carried out by McSweeney *et al.* (2008), to produce a series of climate change projections for individual developing countries. The study uses a collection, or 'ensemble', of 15 General Circulation Model (GCM) runs to produce projections of climate change for three of the SRES emissions scenarios (see Nakićenović & Swart (2000) for more details on emission scenarios). The three emissions scenarios used in the study were 'A2', 'A1B' and 'B1', which can be broadly described as 'High', 'Medium' and 'Low' respectively (McSweeney *et al.*, 2010).

The figures quoted here refer to the 'central estimates' (i.e. the median results) from the 15 GCMs across the 3 emissions scenarios. Where maximum figures are also quoted, they refer to the 'High' (A2) scenario model results. The maps shown are for just the 'High' scenario. Both figures and maps are described for two future 'timeslices' – i.e. decadal averages for the 2060s and 2090s.

For a more detailed description of the UNDP Climate Change Country Profiles, please see McSweeney *et al.* (2010). Complete projections (with maps, plots, supporting text and data files) for all 52 countries are available to download via the website at <http://country-profiles.geog.ox.ac.uk/>.

Note: This profile is designed to give a brief, non-technical overview of the current and future climatic conditions of Uganda. The key climate impacts are summarised by sector; however, this should not be taken as an exhaustive list, and the corresponding list of adaptation options are as a guide of likely or possible strategies.



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