ZAMCOM

ZAMBEZI WATERCOURSE COMMISSION

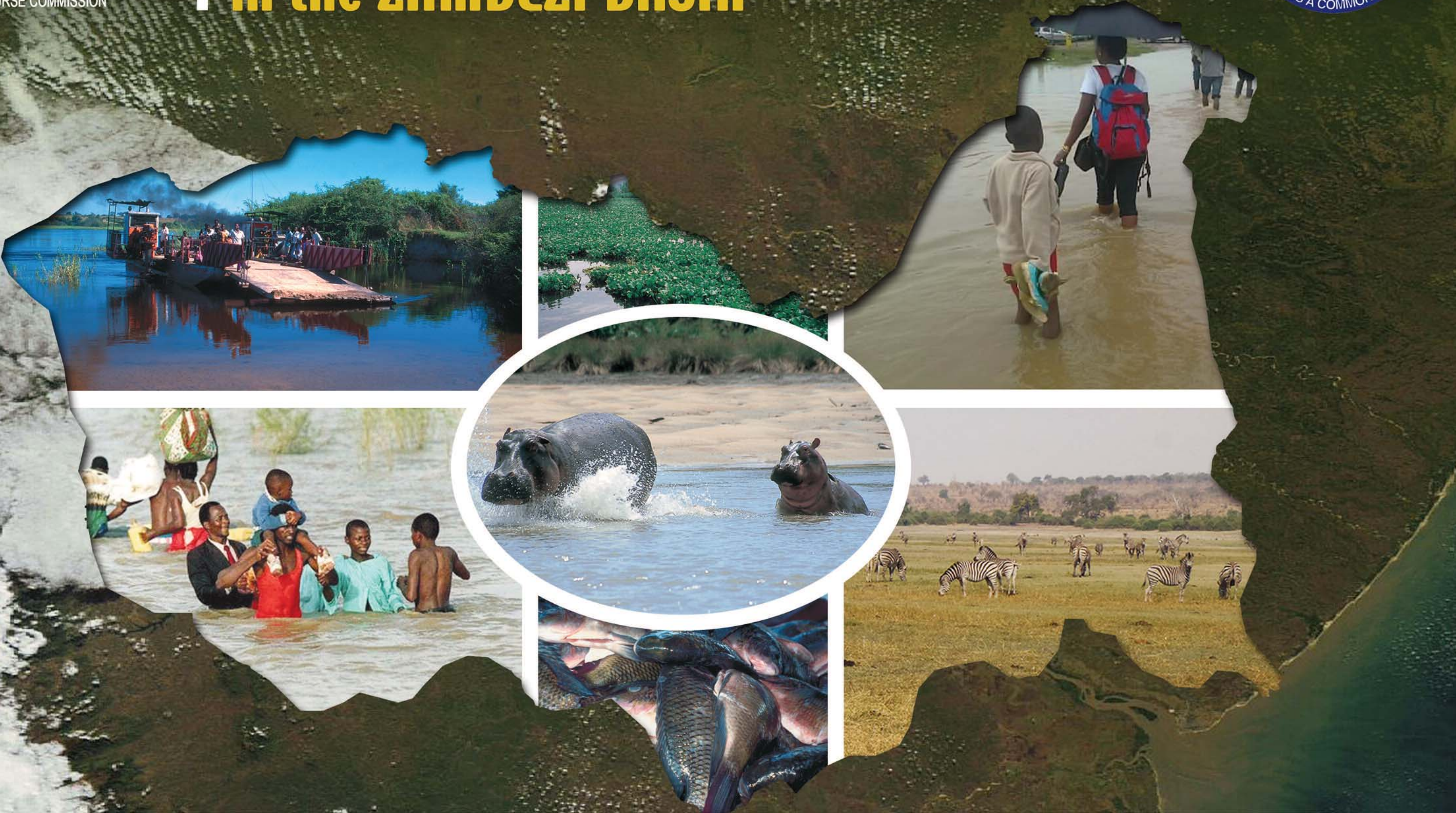
Status Report on

Integrated Flood and Drought Mapping in the ZAMBEZI BASIN

SOUTHERN AFRICAN DEVELOPMENT COMMUNITY

SADC

TOWARDS A COMMON FUTURE



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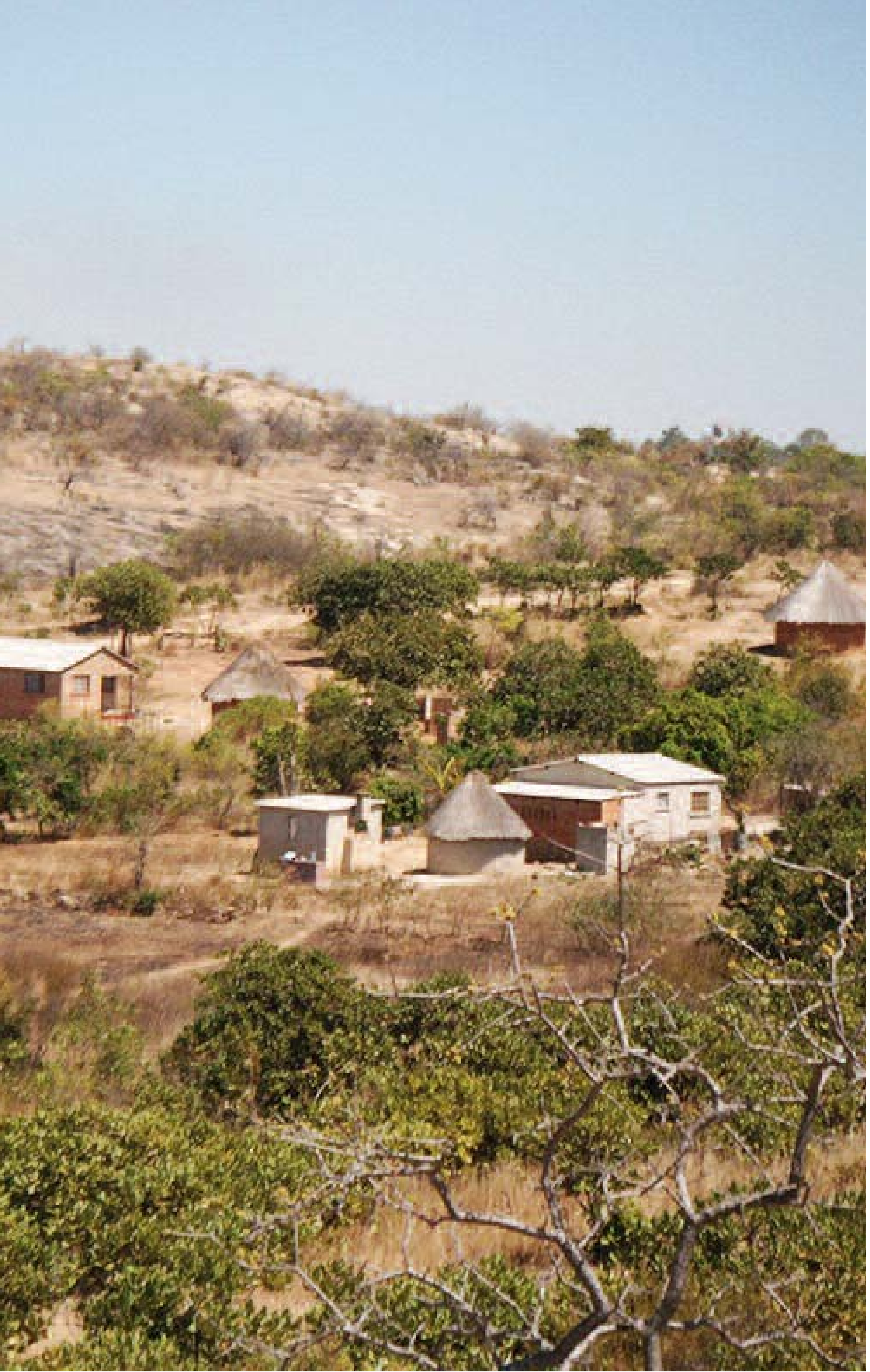

Southern African Research and Documentation Centre (SARDC)
I Musokotwane Environment Resource Centre for Southern Africa (IMERCSA)
15 Downie Avenue, Belgravia, Box 5690, Harare, Zimbabwe
Tel +263 4 791141 /43 Fax +263 4 791 271 Email imercsa@sardc.net
www.sardc.net Knowledge for Development

Southern African Development Community (SADC) Water Division
SADC Secretariat, SADC House, Private Bag 0095, Gaborone, Botswana
Tel +267 395 1863 Fax +267 397 2848 /318 1070 Email registry@sadc.int
www.sadc.int A Shared Future within a Regional Community

Zambezi Watercourse Commission (ZAMCOM)
128 Samora Machel Avenue, Harare, Zimbabwe
Tel +263 4 253361/2/3
Email zamcom@zambezicommission.org
www.zambezicommission.org

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Acronyms and Abbreviations

DRR	Disaster Risk Reduction
DRWS	Directorate of Rural Water Supply, Namibia
EWS	Early Warning Systems
FEWSNET	Famine Early Warning System Network
FANR	Food, Agriculture and Natural Resources Directorate
IKS	Indigenous knowledge systems
INGC	Instituto Nacional de Gestão de Calamidades (National Institute for Disaster Management)
IRDNC	Integrated Rural Development and Nature Conservation
ITCZ	Inter-Tropical Convergence Zone
NASA-EO	National Aeronautics and Space Administration - Earth Observatory
SADC	Southern African Development Community
SANF	Southern African News Features
SARCOF	Southern Africa Regional Climate Outlook Forum
SARDC	Southern African Research and Documentation Centre
UEM	Universidade Eduardo Mondlane (The Eduardo Mondlane University)
UNEP	United Nations Environment Programme
WIDSAA	Women in Development Southern Africa Awareness
ZAMCOM	Zambezi Watercourse Commission
ZAMWIS	Zambezi Water Information System
ZEMA	Zambia Environment Management Agency
ZRA	Zambezi River Authority

1. Introduction

The Zambezi River Basin is endowed with vast tracts of fertile land and soils for agriculture, an abundance of various natural resources and diverse habitats for wildlife including water resources which are all at the heart of important socio-economic activities such as agriculture, forestry, manufacturing, mining, tourism and conservation in Southern Africa. Environmental processes and management of water resources across the basin greatly affects the use of other natural resources and economic activities that come from using those resources. In most cases women are the direct users and managers of these natural resources actively contributing to these economic activities, such as in the agricultural sector where women constitute the majority of the workforce in large-scale agriculture activities and they are also the primary food producers in small-holder cultivation schemes (SADC/SARDC and Others 2012; SARDC WIDSAA 2008). The basin's water resources are largely dependent on rainfall as in most of southern Africa, although the main Zambezi River is perennial because of wetland areas in the headwaters region of the river source (SARDC and UNEP 2009). Environmental flows that affect rainfall and changes in temperature, precipitation, radiation and wind, all of which affect water resources, will have great socio-economic, cultural and environmental implications on livelihoods in the Zambezi River Basin (SARDC and HBS 2010).

Violent storms from Tropical Cyclones, regular flooding and droughts are some of the most prominent environmental phenomena that greatly alter livelihoods throughout the basin. The extensive droughts of 1991/92 and 1994/5 in southern Africa greatly disrupted livelihoods and reduced economic activities, with several Zambezi Basin municipalities rationing water such as in Bulawayo and Harare, the two biggest cities in Zimbabwe (Chenje 2000). Over the past two decades the basin has also experienced extreme flooding due to abnormally high rains and tropical cyclones such as Cyclone Eline (1999-2000) and Cyclone Favio (2007), which caused severe damage and loss of life throughout the basin (SADC/SARDC and others 2012).

Key risks predicted for the Zambezi River Basin over the next century:

- The basin is expected to experience a significant warming trend of 0.3–0.6°C.
- Increases in temperatures across the basin will result in an increase in open-water evaporation.
- Multiple studies cited by IPCC estimate that rainfall across the basin will decrease by 10–15%.
- Significant changes in the seasonal pattern of rainfall across the basin are predicted, including delayed onsets, as well as shorter and more intense rainfall events.
- All Zambezi Basin countries will experience a significant reduction in average annual stream flow.
- Multiple studies estimate that Zambezi runoff will decrease by 26–40% by 2050.
- Increasing water stress is a serious concern in the semi-arid parts of the Zambezi Basin.

(Beilfuss 2010)

With one of the most variable climates of any major river basin in the world characterised by an extreme range of conditions across the catchment and throughout time, the Intergovernmental Panel on Climate Change has categorized the Zambezi River Basin as being one that exhibits the "worst" potential effects of climate change among 11 major African basins (Beilfuss 2012). Some of the most notable changes predicted to occur according to these climate change studies are a decrease in rainfall across the basin, which is estimated to decrease by 10–15 percent; an estimated decrease in run-off and significant changes in the seasonal pattern of rainfall across the basin, including delayed onsets, as well as shorter and more intense rainfall events, implying an increase of frequency in floods and droughts (SARDC and HBS 2010).

Considering the different roles that women and men occupy in society, vulnerability, impact and opportunity will vary across gender .The death toll during the devastating floods caused by Cyclone Eline in 2000 was higher amongst women than men, owing to cultural norms that inhibited women's movement without a man present, women not having learnt how to swim and lack of access to early warning. These gender inequalities are often exacerbated in the face of disasters because of the traditional allocation of household duties, which tend to increase during periods of distress forcing school girls to drop out (SARDC and HBS 2010). During drought periods women and children tend to travel longer distances and spend more time collecting household water.

Purpose of the Report

The Southern African Environment Outlook (SADC and SARDC 2008) states that climate change is well underway with average temperatures in southern Africa having risen by 0.5○C over the last century, and the 1990s deemed the warmest and driest decade ever. This report seeks to enhance efforts in coping with climate change impacts by increasing access to flood and disaster risk information. This is a component of the Zambezi Environment Outlook project whose main goal is to strengthen access to environmental knowledge, and provide a well-functioning distribution channel, for the promotion of sustainable national and transboundary natural resource management in the Zambezi basin among decision and policy makers at national, regional and sectoral levels. The publication is intended for use by various groups of people including the media, researchers, parliamentarians and other policy makers, and civil society including the private sector and the general community.

Method

A literature review of academic journals, technical reports and relevant studies was conducted in order to understand the different phenomena of droughts and floods as well as acquire background knowledge of previous efforts. The literature review was accompanied by brief conversations with some of the authors who gave further input and advice. This was followed by extensive collection of geospatial data including satellite images from reliable data custodians. Data visualisation and manipulation was conducted using Quantum GIS, MapInfo and Discovery software packages. PCI Geomatica Viewer was used to view satellite images. Review of data description documents, technical manuals and published papers was used to assess the quality and utility of the dataset. In most cases the dataset chosen was informed by data used in previous widespread studies. Processing of data involved scanning, digitising and geo-referencing of images. Basic mathematic calculations were applied to various datasets in QGIS in order to come up with the relevant indices. A team from SARDC IMERCSA travelled to selected sites in order to conduct ground surveys and get views from the communities in Kazungula, Zambia; Caprivi Strip, Namibia and Muzarabani, Zimbabwe. This process was facilitated by local partners that include Zambia Environment Management Agency (ZEMA), Integrated Rural Development and Nature Conservation (IRDNC) and the District Administrator of Muzarabani District, Zimbabwe. A questionnaire and guided interviews with district officers and people from the community as part of the survey were conducted.

Structure of Report

This report is divided into eight sections. The first section is an introduction providing an overview of the basin, describing the scope and target of the publication as well as linking the phenomena of droughts and floods to climate change trends in the basin. The second section attempts to define floods and droughts in the context of the basin. The third section addresses the different social, bio-physical and environmental characteristics that are important for understanding the impact of droughts as well as inform future climate-change adaptation planning in the basin. The fourth section is a continuation of describing attributes that influence droughts and floods in the basin but with a focus on climate. The fifth section focuses on identifying droughts by looking at rainfall, vegetation and moisture patterns, speaking to the definitions of droughts introduced in the second section. The sixth section shows historical flood events which are used as a proxy to determine flood prone areas. The seventh section presents views from communities from the site visits, highlighting the challenges and suggestions from communities for drought and flood management strategies. The final section highlights the key findings and policy options that were derived from this study.

2. What are Floods and Droughts

Floods

Flooding is part of river processes and environmental flows in the basin. Large floods play an important role in the environment by mobilising sediment and depositing silt, that bring nutrients providing food for aquatic species. Small floods that help spawn fish, flush out poor quality water and provide moisture bring both environmental and social benefits (Brown and King 2002). People in the basin who live in floodplain areas take advantage of the flooding to enhance their well-being.

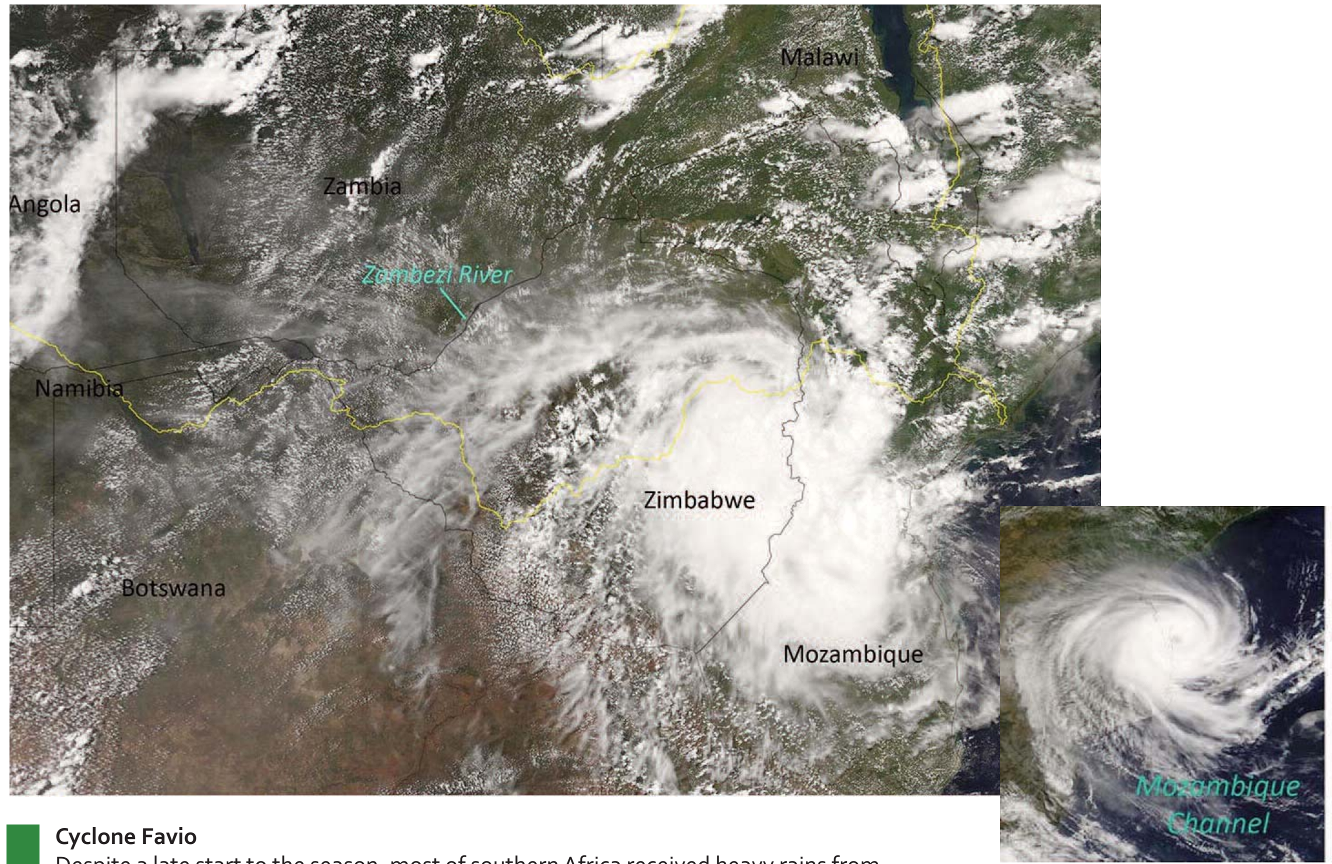
Extreme rainfall and subsequent flooding has almost become an annual event in the basin. The flooding of an area can result in loss of lives of people and animals, disruption of agricultural and economic activities, as well as outbreaks and transmission of water-borne diseases. Basin states have strengthened capacity to deal with floods as evidenced in Mozambique during the 2012/2013 flooding season where existing systems reduced potential sever impacts. The 2012/2013 season saw regional cooperation through institution such as the Zambezi River Authority (ZRA) which announced ahead of time the opening of the Kariba Dam floodgates

Intense flooding in Caprivi Strip during 2009
The 2009 rain season saw thousands of families affected by flooding in the Eastern Caprivi strip of Namibia. The top image shows the Caprivi during the dry season in 2002, the bottom image shows intense flooding during March 2009. (NASA-EOS 2009)

Floods in the Zambezi River Basin can be characterized into two different types, the seasonal floods and cyclone floods.

Seasonal Floods

Spatial and temporal variations in rainfall patterns result in seasonal floods with unique subsequent run-off in each of the Zambezi sub-basins. Seasonal floods tend to be frequent annual events occurring between January and March and at times late into the rainy season and early dry- season (Madamombe 2004; Beilfuss and dos Santos 2001). Run-off from precipitation is also affected by topography of the area. Extensive flat areas such as in the Middle Zambezi Basin are prone to flooding from surface run-off. However, large extensive floodplain areas such as the Zambezi (Barotse) and Kafue attenuate river flow and delay peak discharge until late in the season. After the construction of the Kariba and Cahora Bassa dams, reservoir induced floods has affected the middle Zambezi Basin.



Cyclone Favio
Despite a late start to the season, most of southern Africa received heavy rains from December 2011 into 2012, resulting in flooding in several countries.
Tropical Cyclone Favio came ashore on the coast of Mozambique on the morning of February 22, 2007 as it travelled further inland towards the Zambezi River valley; the storm brought heavy rains to Zimbabwe. (SANF 2012; NASA-EO 2007)

Cyclone Flood

Extreme tropical rainstorms from the Indian Ocean have become a frequent occurrence causing flooding within the Zambezi Basin. In February 2000 cyclone Eline hit the basin bringing with it intense storms and in March 2003 the basin was again hit by cyclone Japhet which also caused Flooding (Madamombe 2004). In 2007 extensive flooding in Mozambique and Zimbabwe was caused by cyclone Favio while Malawi and Mozambique were heavily affected by Cyclone Funso in January 2012 (SARDC and HBS 2010; Joint Typhon Warning Center 2012).

Droughts

Drought conditions have been a regular occurrence throughout southern Africa. Droughts are considered to be the most crucial environmental disaster that affects the Zambezi Basin often triggering serious hydrological imbalances and causing loss or damage to crops, shortage of water for people, livestock and wildlife as well as famine and disease (Chenje 2000; Hirji and others 2002). Some of the most notorious droughts in recent history hit the region during the period 1991-1992 and 1994-1995, in which the former was said to be the worst to occur in living memory.

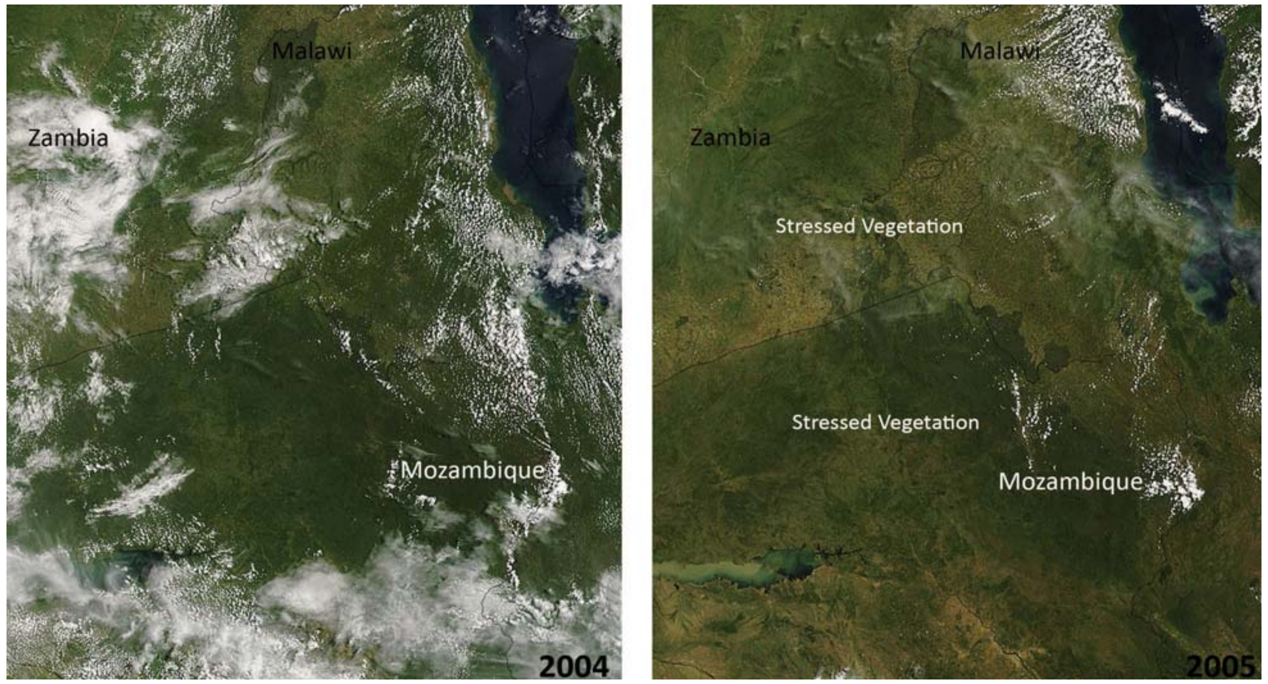
Different stakeholders such as economists, hydrologists, meteorologists and farmers define and respond to droughts in different ways. In general a drought can be described as a consequence of a reduction in the amount of precipitation that is received over a season (SARDC and UNEP 2009), this reduction in precipitation means that there is an insufficient supply to meet the demands of human activities and the environment (Wilhite and Buchanan-Smith 2005). Human activities alter and shift the demand for water such that despite water availability or the perceived 'normality' of the present season, human activities can still result in insufficient water supply (Wilhite and Buchanan-Smith 2005). Another characteristic that challenges the aforementioned description of a drought is that it is tricky to demarcate the beginning and end of a drought.

Meteorological drought
Refers to a reduction in rainfall supply compared with the average over a specified period.

Hydrological drought
Refers to the impact of a reduction in precipitation on natural and artificial surface and substance water resources. It occurs when there is a substantial deficit in surface runoff below normal conditions or when there is a depletion of groundwater supplies. Hydrological drought reduces the supply of water for irrigation and hydroelectric power generation.

Agricultural drought
Refers to a reduction in water availability below the optimal level required by a crop during its different growth stages, resulting in impaired growth and reduced yields. Agricultural drought relates to an imbalance in the water content of the soil during growing season, which although influenced by other variables such as the crop water requirement, the soil water-holding capacity and degree of evaporation, is also largely dependent upon rainfall amount and distribution.

(Source: SARDC & UNEP 2009)



Drought Conditions in the Lower Zambezi Basin
Following the SARCOF prediction of normal to below normal rainfall for the 2004/5 season, many Southern African countries faced food shortages in 2005, with Zimbabwe, Malawi and Botswana declaring a state of disaster.
The satellite taken on 6 March 2005 shows stressed vegetation levels in rain fed areas compared to the image on 3 March 2004 showing slightly better conditions. (NASA-EO 2005; SADC Today 2005)

3. Elements Essential to Mapping Floods and Droughts

Floods and droughts, while they occur naturally with intensity and frequency being increased by climate change, they are exacerbated by changes in population, land cover and use, soils, topography and hydrology. An analysis of these elements is therefore essential to understand the mapping of floods and droughts in the Zambezi Basin.

3.1 Population

Human activities such as poor agricultural practices and uncontrolled land clearances exacerbate the impacts of droughts and floods. Increase in population is therefore a major driver to increased impacts of droughts and floods.

Population within the basin is distributed unevenly with some parts densely populated such as in Malawi while some large areas are sparsely populated as shown in Figure 3.1 and Figure 3.2. Majority of the population is located in the middle to lower portions of the Zambezi River Basin with Malawi, Zimbabwe and Zambia being the top contributors. The basin's population growth has been increasing steadily with the average density moving from 24 people per sq km in 1998 to 30.26 people per sq km in 2008 (SADC/SARDC and Others 2012). Figure 3.3 shows the population growth in the last decade using national census numbers. Majority of the administrative districts have experienced population growth across the basin. The basin's growing population has reached 41 million and is projected to reach 51 million by 2025 (SADC/SARDC and Others 2012).

The large portion of the Basin's population remains rural with proportion varying from country to country, from over 50 percent in Zambia to around 85 percent in Malawi (SADC and ZRA 2007). Water consumption in these rural areas will differ in quantity and purpose as compared to urban areas. The main activities in the rural areas in the basin centre on agriculture especially crop cultivation. Subsistence farmers tend to resort to extensive cultivation techniques to increase yields as intensive techniques such as the application of fertiliser can prove to be costly. Poor cultivation techniques can lead to widespread land degradation thereby exacerbating the impact of droughts and floods in those areas (SARDC and UNEP 2009).

Rural community

Several communities throughout the basin have adopted various coping techniques. Women from various communities in Zimbabwe that have adopted conservation agriculture have reported increase in harvests without having to extensively increase the land under cultivation (SARDC and HBS 2010).

Population is a significant driver for environmental changes across the basin. Pressure from population and urbanisation has resulted in water resources degradation or pollution. These changes have exacerbated the threats of water scarcity, complicated equitable water resources allocation and have challenged environmental security in the basin (Shela 2000). Regular occurrence of droughts and floods coupled with wide spread human induced changes significantly increases the risk of natural hazards.

Figure 3. 1 Population Density per District Administrative Area

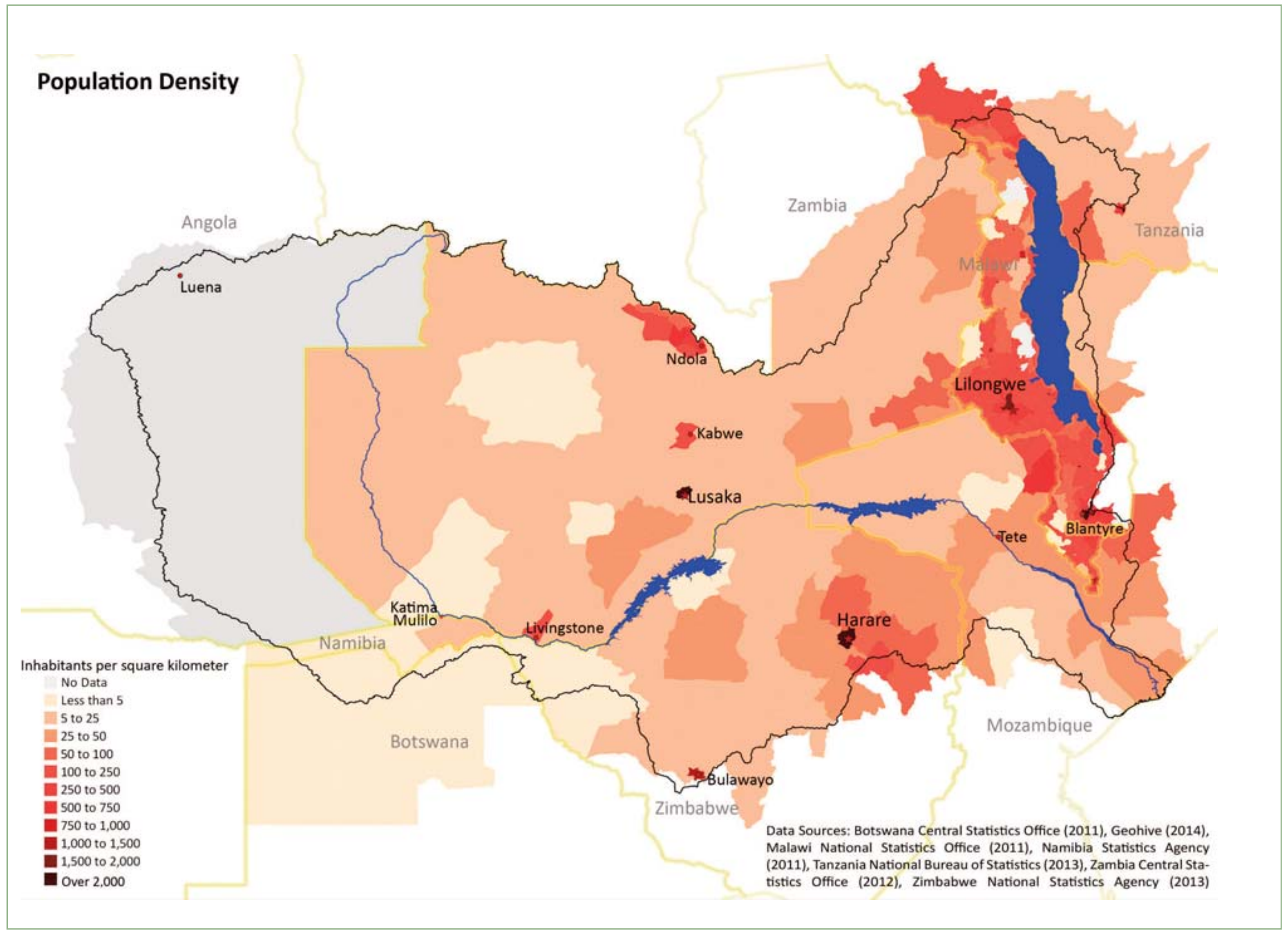


Figure 3. 3 Population Growth per District Administrative Area

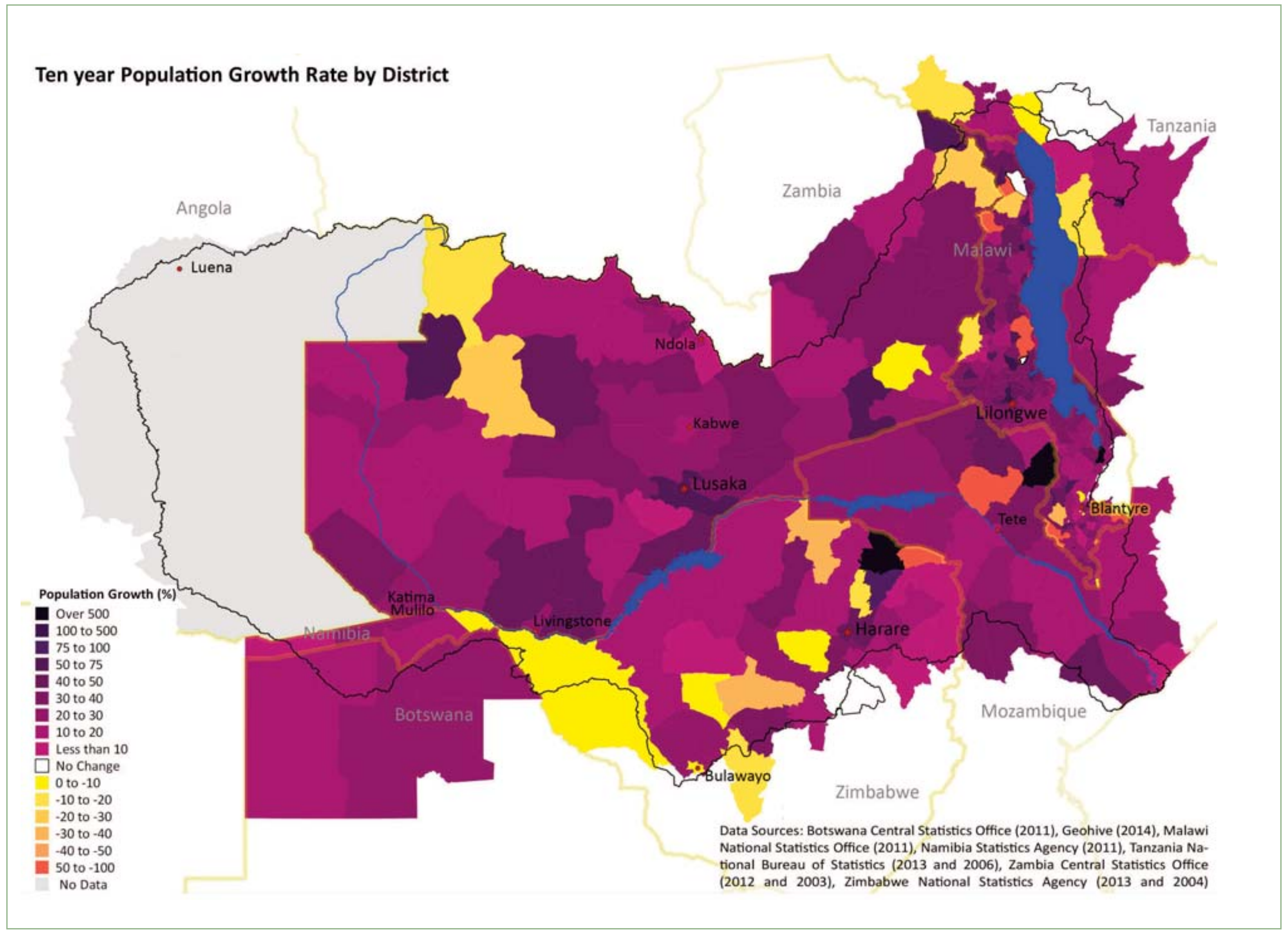
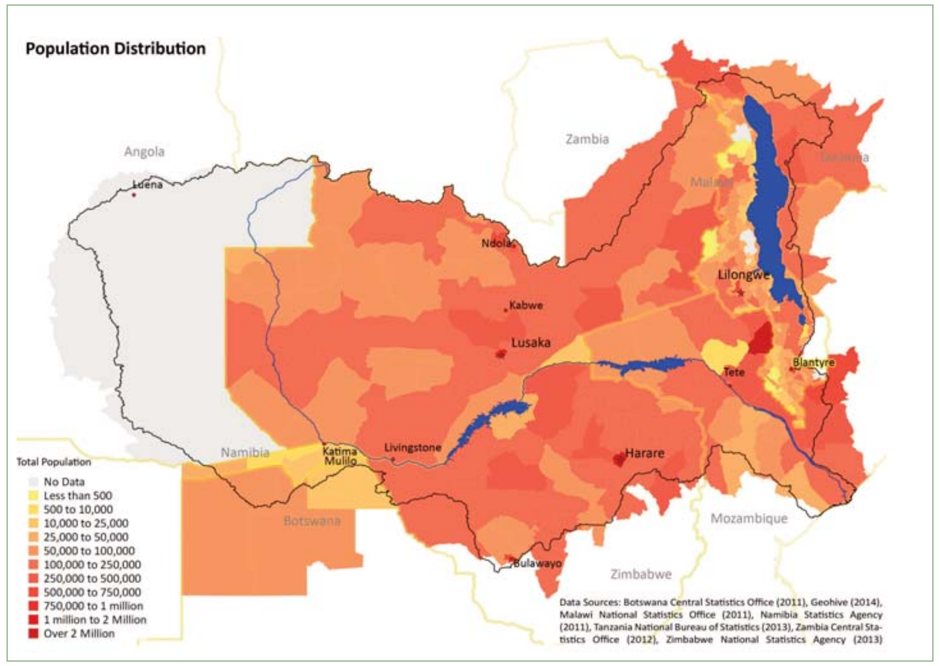
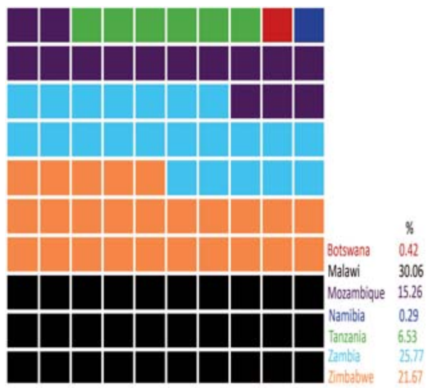


Figure 3. 2 Total Population per District Administrative Area





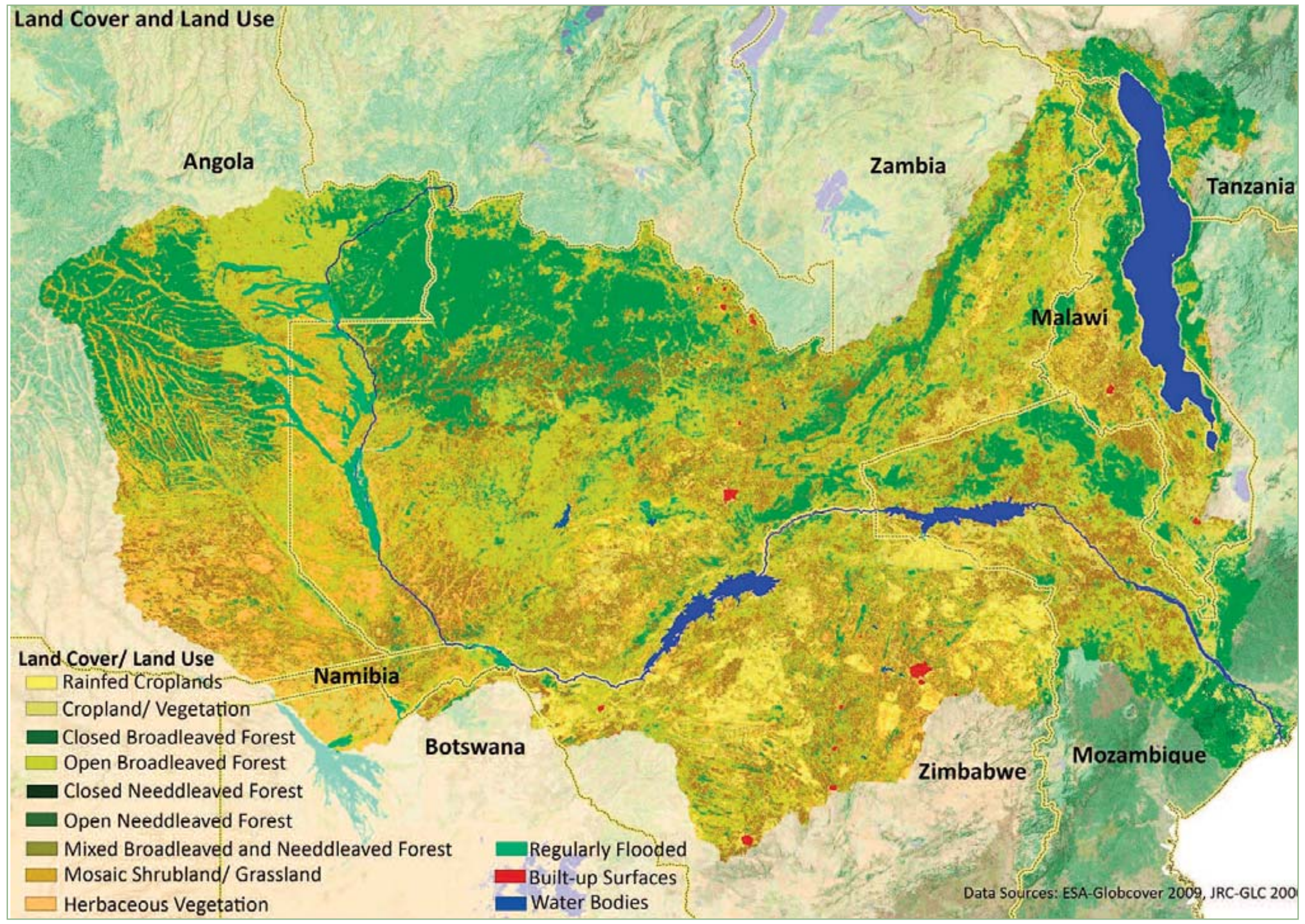
Population share of basin sates as a percentage of the total number of people in the basin based on latest census numbers. (Note that there is no data for Angola)

3.2 Land Cover and Land Use

Land cover/use has a great impact on water resources – it affects how precipitation that falls on the ground eventually translates into runoff, infiltration, evaporation, and the quality of the water (SADC & ZRA 2007). Large tracts of land within the basin have been classified as croplands, majority of which are rain-fed indicating the susceptibility of the basin's food security to climate variations. In southern Africa women are the direct managers of environmental resources as they are the food producers, water collectors and fuel wood gatherers (Chenje and Johnson 1996). Undesirable land cover changes or land-uses will firstly impact women and their contribution to livelihoods. Rainfall patterns that alter availability of natural resources will greatly affect the role of women.

Human changes in land-use significantly alter environmental flows and ecosystem function. The clearing of forests for agriculture and the destruction of large quantities of biomass reduces the environments capacity to absorb CO2 and changes rainfall and subsequent run-off patterns (Tumbare 2010). Destruction of wetlands such as the Barotse floodplains that regulates flows and floods downstream will result in completely different flow regime of the Zambezi River (Tumbare 2010).

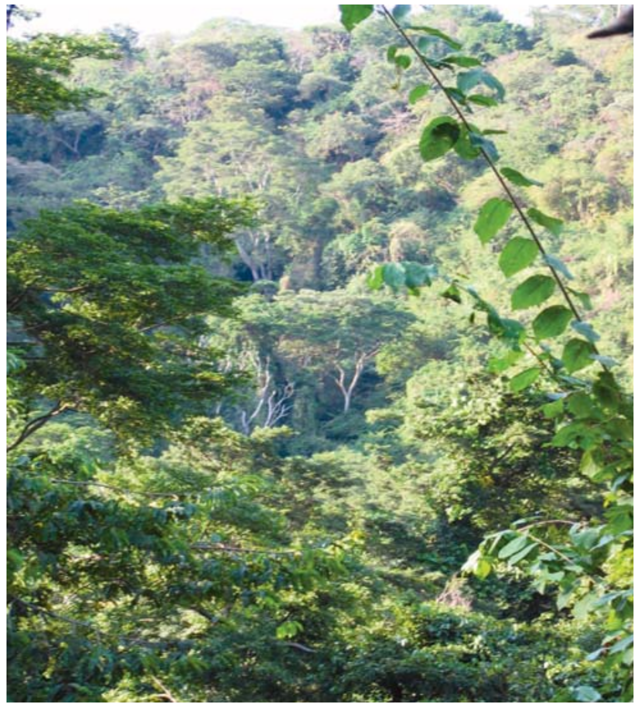
Figure 3. 4 Land Cover and Land Use in the Zambezi basin



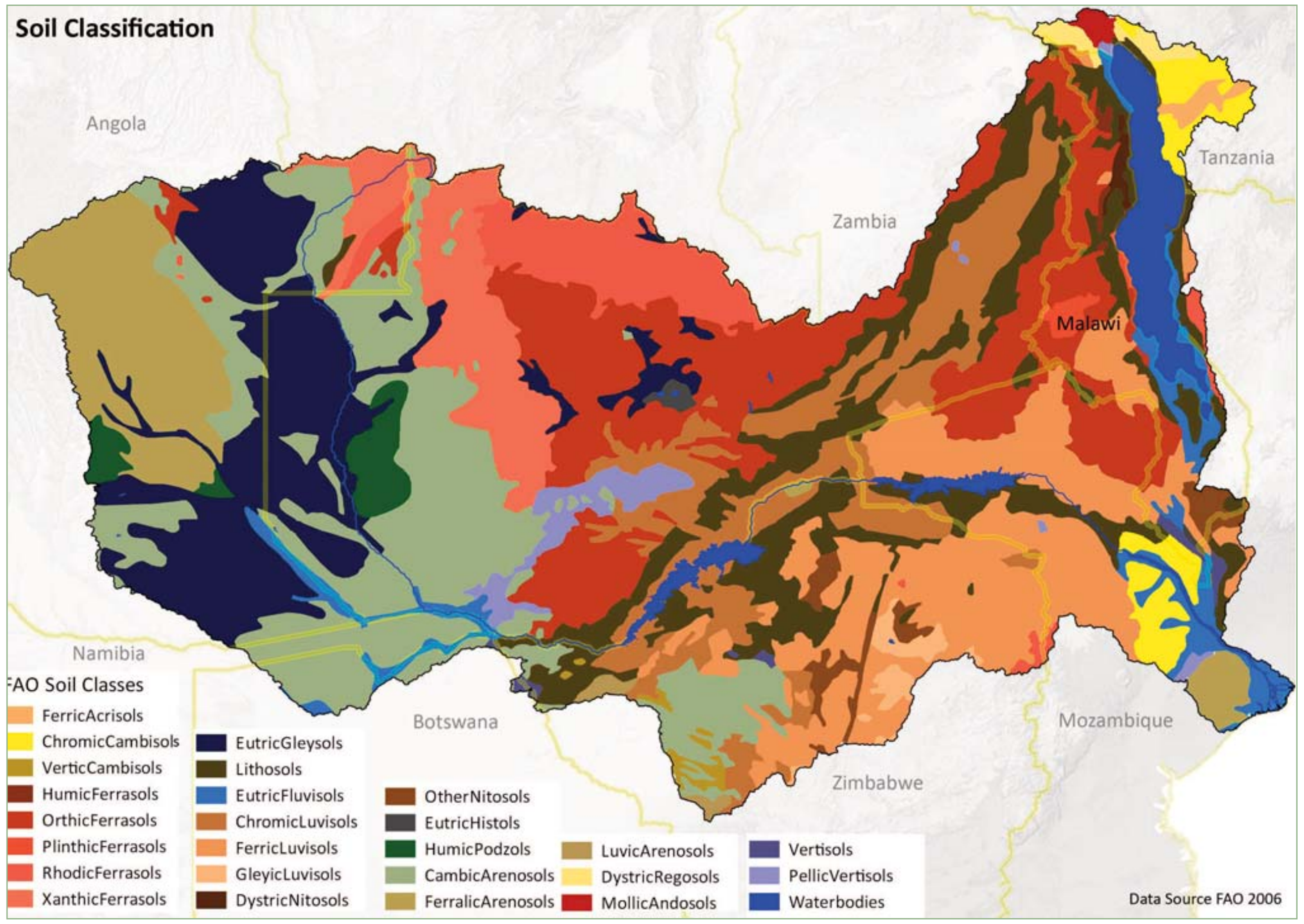

Wetlands


Grassland


Cropland and Vegetation Mosaic


Closed Forests

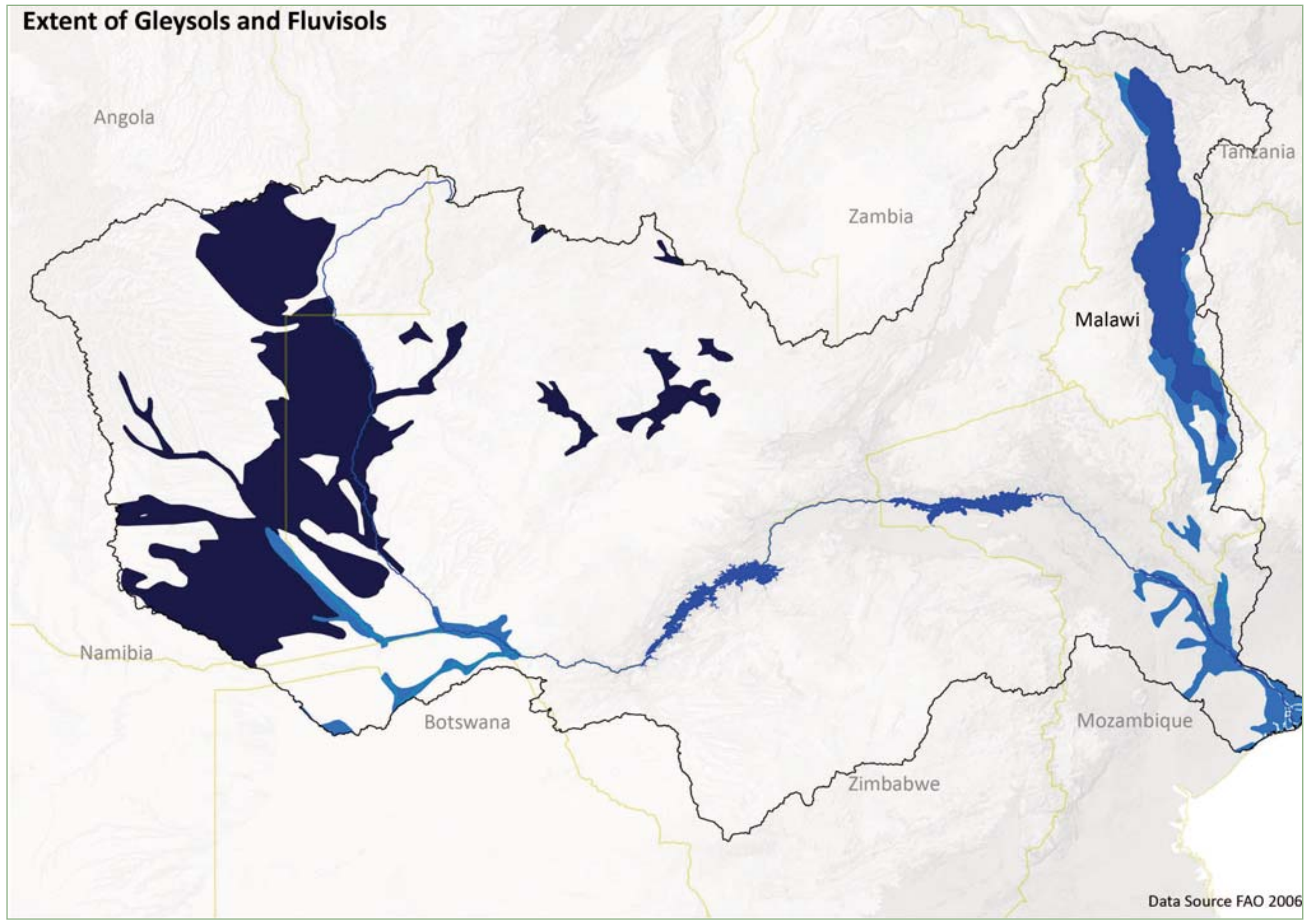
3.3 Soils



A change in the soil structure will affect run off in the watershed area. Changes that reduce infiltration or soil erosion that cause siltation of channels can exacerbate flooding as rivers break their banks (Tumbare 2010). Soil formation is determined by the parent rock material, climate and biological activity. The dominant soil types in the basin are the tropical red soils, generally classified as ferrasols (Chenje 2000). A typical watershed comprises of interconnected elements such as the slope of the landscape, vegetation, weathered rock (including soil) and channels; in which soil is a key element (Mazvimavi 2002).

The different soil properties and soil types play a role in the land-use and land cover which impacts environmental processes. The most dominant soils Ferrasols found in the basin are part of fersiallitic soils which are critical for agriculture in countries such as Zimbabwe (Chenje 2000). Figure 3.6 shows the large expanse of Gleysols in the Upper Zambezi basin which denotes the swampy wetlands of the great Zambezi Floodplains (Barotse Floodplains) on the borders of Angola and Zambia (Jones and others 2013). This extensive network of wetlands, dambos and swamplands plays a vital role regulating the flow of the Zambezi River, serving as a form of natural flood management and control in the basin (Beilfuss and Dos Santos 2001).

Figure 3.6 a The extent of Gleysols (dark blue) and Fuvisols (light blue).



Gleysols and Fuvisols coincide with major floodplains and wetlands that influence flooding patterns in the Zambezi River Basin

Changes in land terrain and soil strcuture that result in accelerated erosion, salt accumulation, surface crusting and soil compaction among others increase the impact of drought and dryness which can contribute to the begginng of a vicious cycle of desertification and more drought (SARDC and UNEP 2009). Through various programmes coummunties throughout the basin have been involved in various soil conservation and management practices that include terracing, soil bunding, gully reclamation and conservation agriculture. In the mountanious region of the Iringa region (southern Tanzania) on the northern tip of the basin, a pitting technique locally known as *ngoro* or *ingolu* has been used for cultivating crops for almost 200 years (Temu and Bisanda 1996). This technique was developed to control soil erosion on the steep slopes and improve soil fertility. They also help retain water and improve soil moisture, which is crucial during the dry periods (Kayombo, Ellis-Jones and Martin 1999). Such soil conservation techniques can be considered as being part of a wider strategy to reduce the effects of prolonged dryness and maintain food productivity as climate becomes more variable.

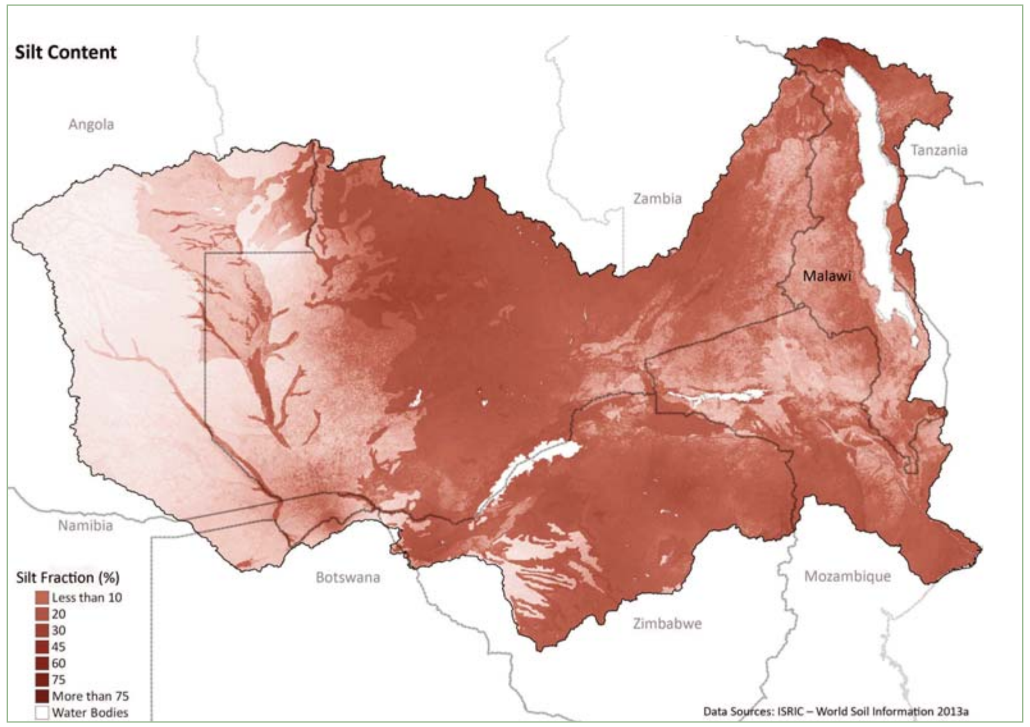
Figure 3.6 b Satellite image of the "swollen" Zambezi Floodplains under flooding

The underlying Gleysols attribute to the floodplain's existence (NASA-EO 2011, acquired April 2010).

Soil Properties

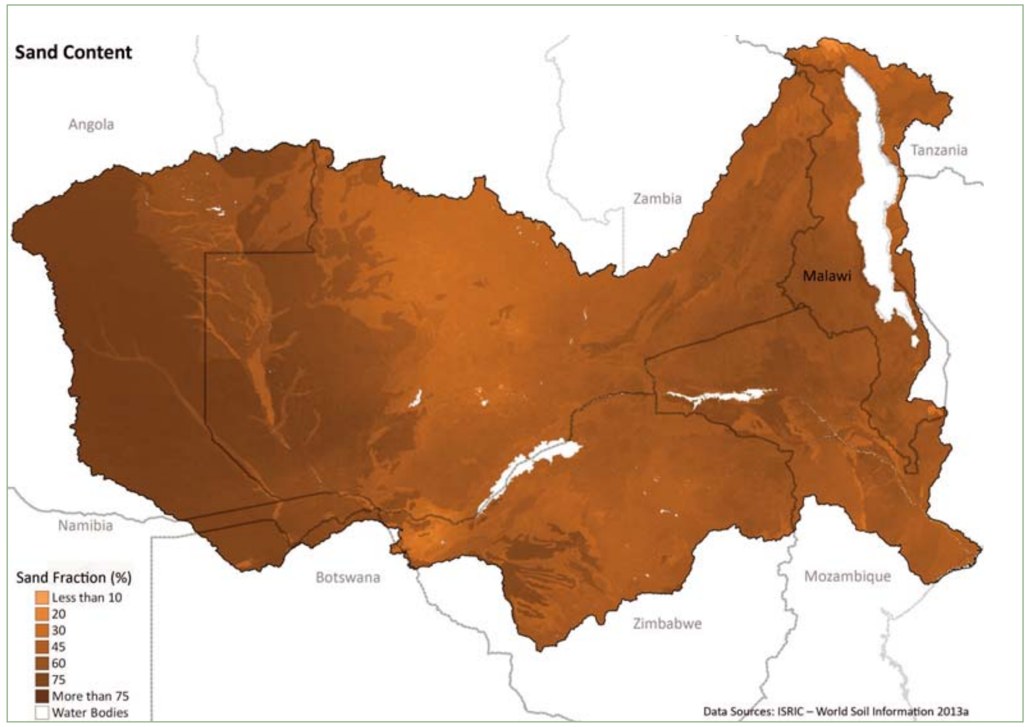
Soil properties such as bulk density, determine important charteristics such "as" soil permability, suitability for cultivation and other important land-uses (Figures 3.7a to 3.7c). Soil moisture, an important charcteristic that determines the severity of droughts or run-off, is a function of soil texture and available water at the surface (Beilfuss 2005a). Bulk density of the soil indicates soil compation which influences aeration and suitability for crops (Figure 3.9). For example high bulk density in clay dominated soils may result in poor yields of certain crops but assist retain water during drier periods. These properties influence land use and the ability of people to adapt to floods and droughts.

Figure 3.7 a Silt Content



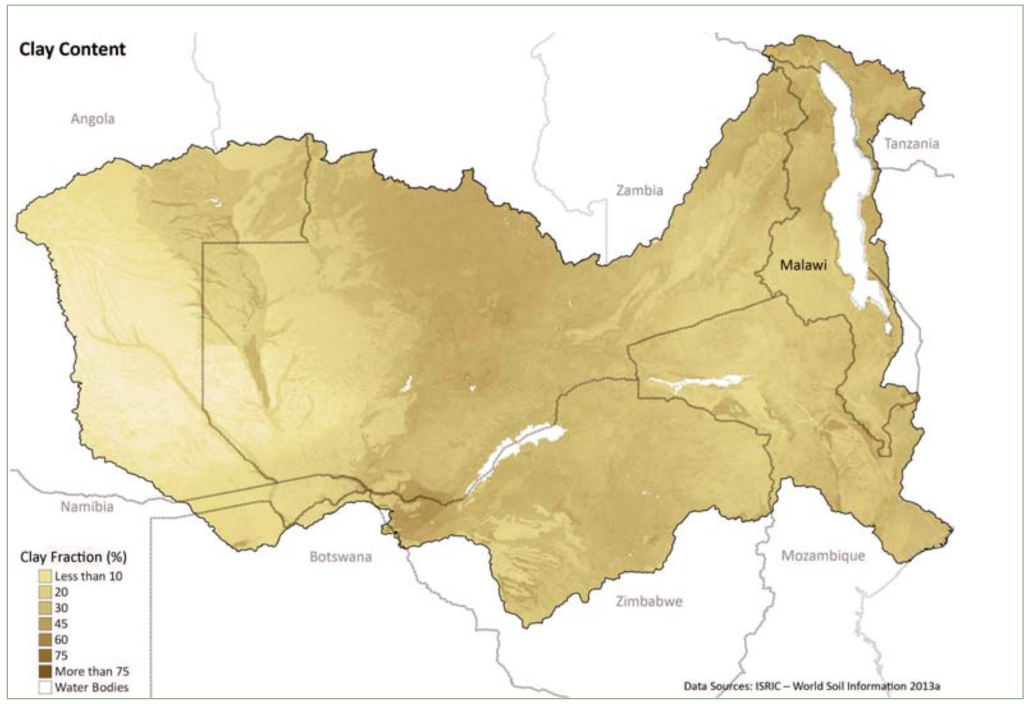
The average proportion of silt partcles (2 to 50 µm)in the first 100cm of the soil

Figure 3.7 c Sand Content



The average proportion of sand particles (less than 50 to 2000 µm)in the first 100cm of the soil

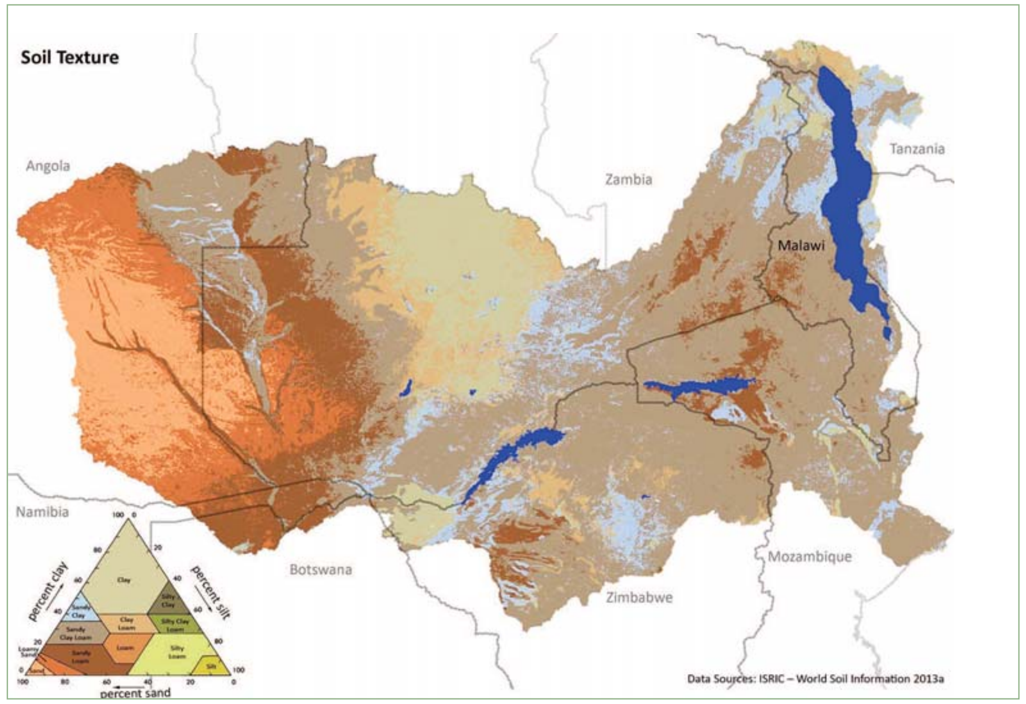
Figure 3.7 b Clay Content



The average proportion of clay particles (less than 2 µm)in the first 100cm of the soil.

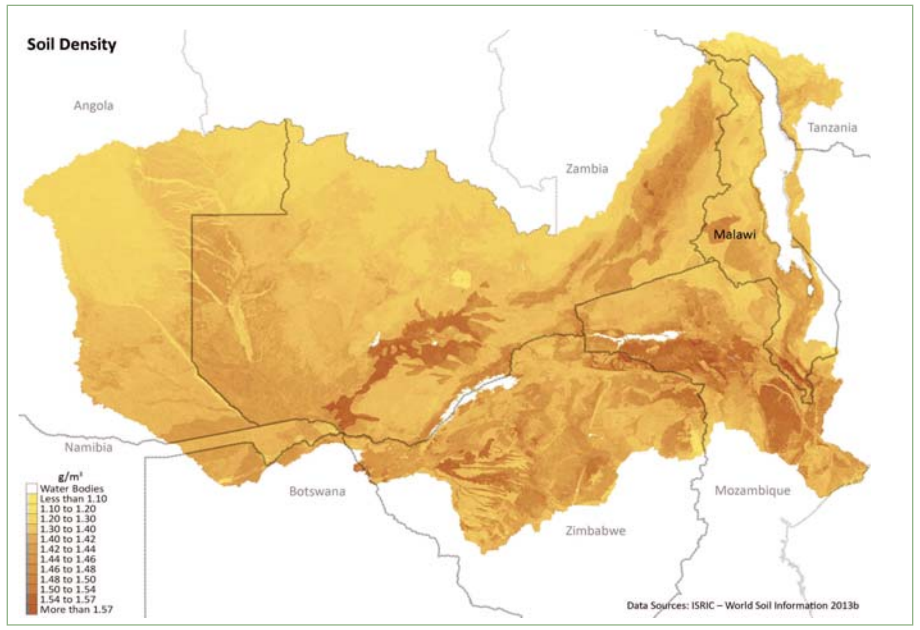
At the regional level, the broad soil classes for large portions of the basin can be described as Sandy Clay Loam soils (Figure 3.8). This regional outlook is helpful to create an overall picture but does not fully describe important features that determine environmental flows in local watershed areas. Historically the fine-grained soils of the Zambezi Delta maintained a highwater table during the dry season, but the water table levels have been steadily declining due to persistent drought and the failure of the annual floods (Beilfuss 2005a).

Figure 3. 8 General soil texture for the first 100cm soil depth



The average proportion of clay particles (less than 2 µm)in the first 100cm of the soil.

Figure 3. 9 Soil Bulk Density



The average proportion of clay particles (less than 2 μm)in the first 100cm of the soil.

The Zambezi Delta
The Zambezi Delta formed from the accumulation of sediments and alluvium transported downstream by the Zambezi River over several thousand years. It is characterised by a mosaics of various clays, clay loams, organic silts and gleyed soils. The soils in the delta swell during the rainy season and form a hard crust during the dry season, encouraging extensive flooding when the first rains arrive.
Over the past century, flooding patterns in the delta have been affected by the operation of Kariba and especially Cahora Bassa Dam, the construction of embankments along the main stem Zambezi, upper delta floodplains, and coastal plains, and the down-cutting of the main Zambezi channel. (NASA-EO 2013a; Beilfuss 2005b)

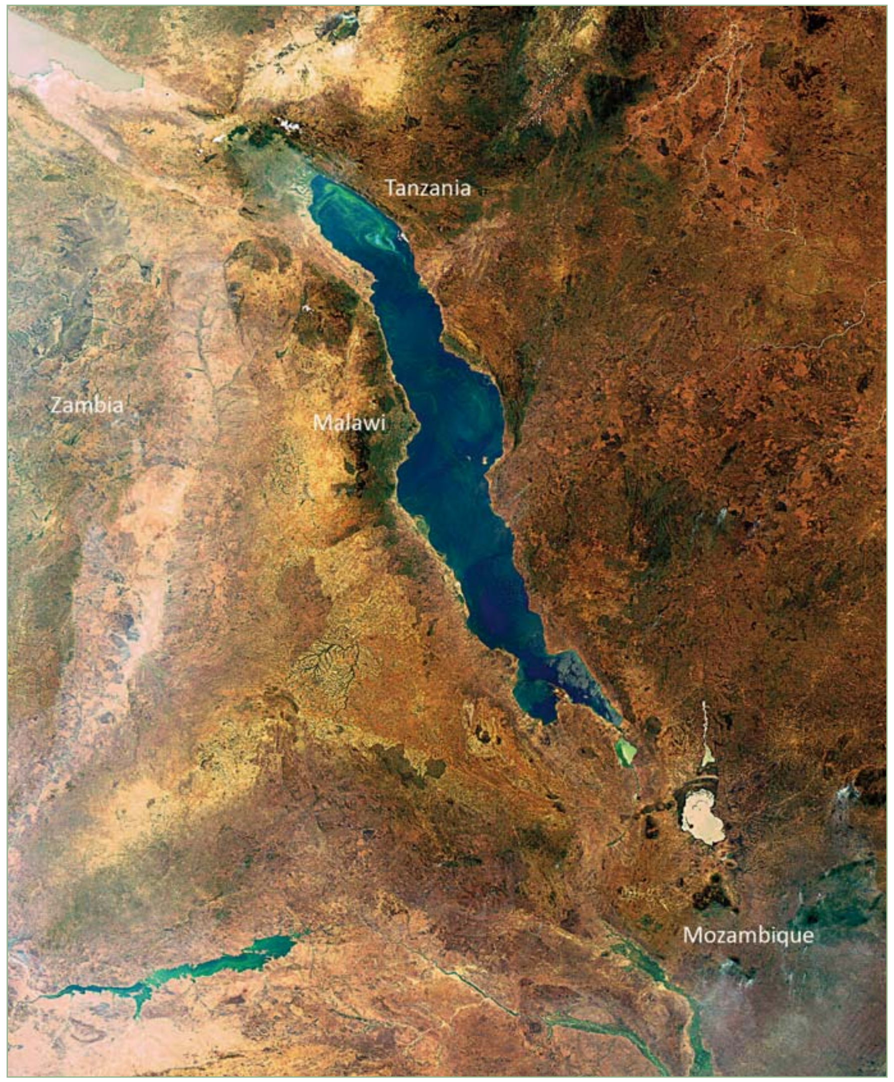
3.4 Topography and Hydrology

Topography determines the direction of environmental flows and therefore is essential to consider when mapping flood prone areas. Large portions of the Zambezi River Basin's landforms in existence today are a result of historical geological processes (SADC and ZRA 2007). Few areas within the basin lie below 800m amsl or above 1500m amsl as shown in Table 3.2 (SADC and ZRA 2007).

Country	Physical Feature	Altitude (m)
Malawi	Mt Mulanje	3002
Mozambique	Zambezi River Delta	At sea level
Zambia	Kalene Hills	1585
Zimbabwe	Mt. Inyangani	2592
	Muzarabani	400

Table 3. 1 Topographical features in the Zambezi River Basin

The basin's varying physical features impact environmental processes and human-nature interactions (Chenje 2000). People living in low lying flat areas such as Muzarabani area in northern Zimbabwe or in the Caprivi Strip of eastern Namibia tend to migrate to neighbouring higher altitude areas during the flooding periods. After the floods recede these flatland floodplains become key for survival during dry spells.



Lake Malawi/Niassa/Nyasa
The geomorphology of the Lower Zambezi Basin is dominated by the Great East African Rift Valley with Lake Malawi/Niassa/Nyasa occupying the greater part of the rift valley trough. It is the only and largest natural lake in the basin. With a surface area of 29,950okm2 and a volume of 7,775km3 the water stored in the reservoir is important for many social, economic and environmental activities in the Lower Zambezi. (Bootmsa and Jorgensen 2006; Chenje 2000)

Figure 3. 10 Topography and Water in the Zambezi River Basin

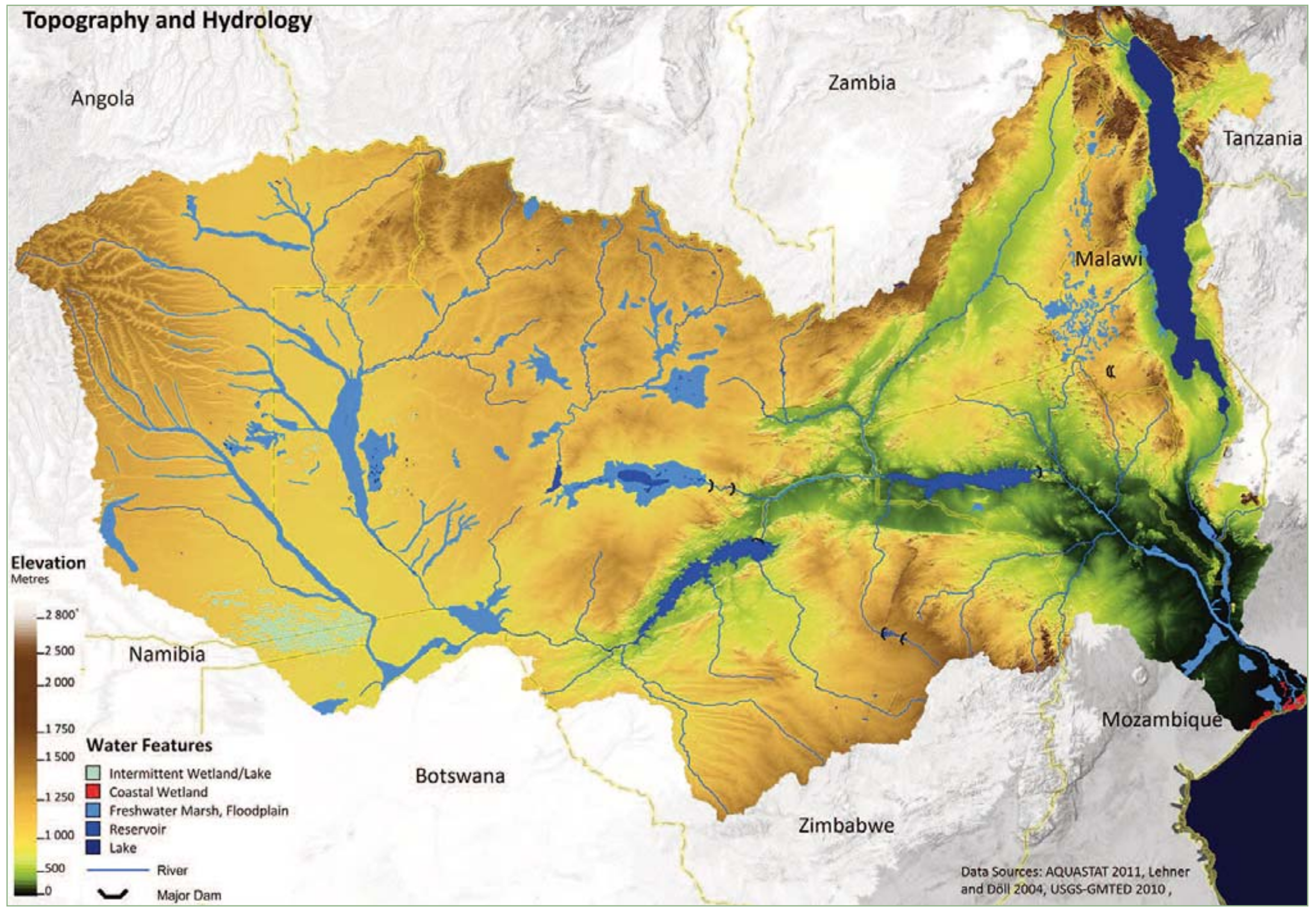
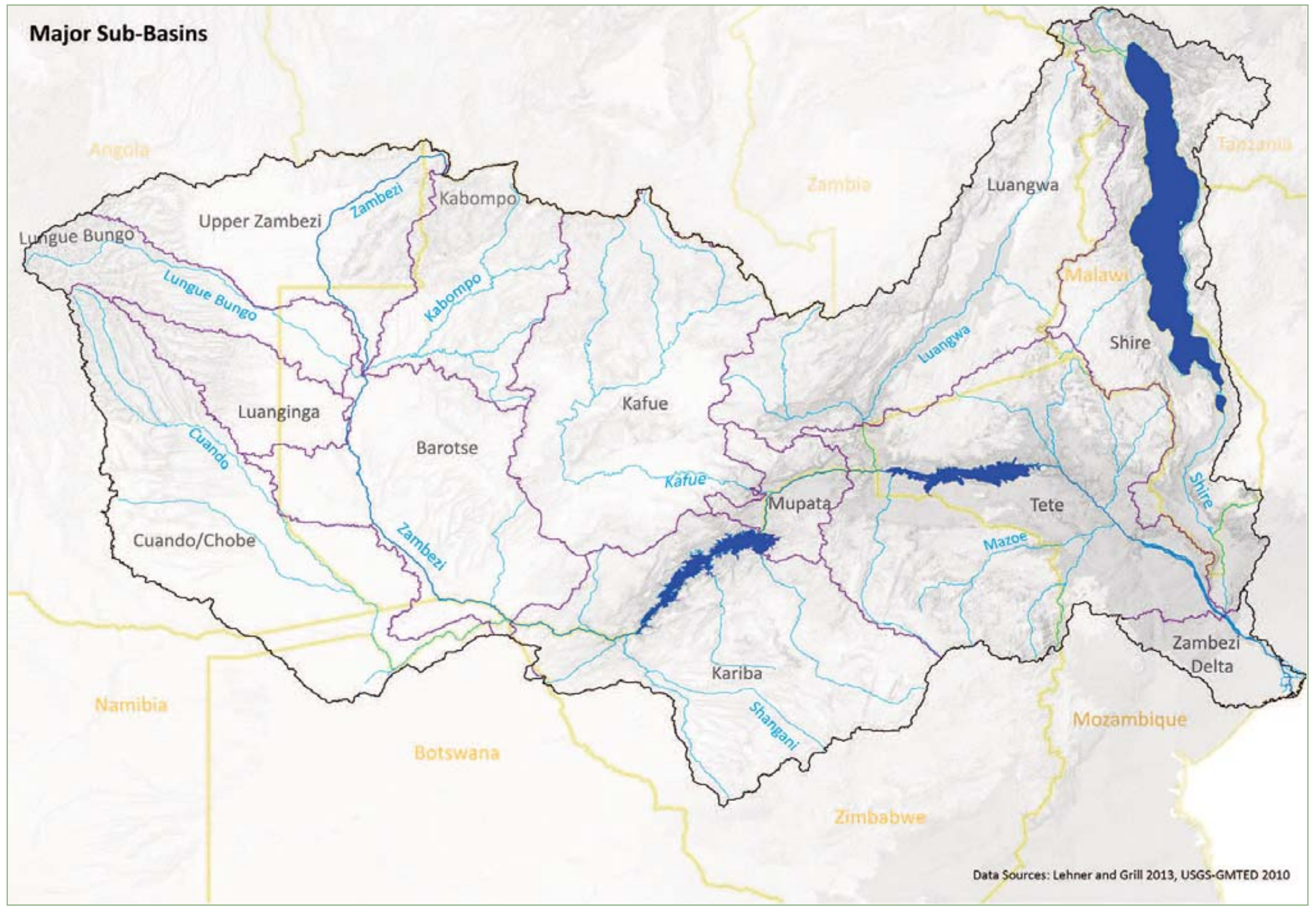


Figure 3. 11 Major sub-Basins of the Zambezi River Basin



Hydrology

The hydrology of the basin is a critical factor which determines the nature of environmental flows.Draining an area of 1.385 million square kilometres (sq km), the Zambezi flows eastward for 3000km from the Kalene Hills of Zambia to the Indian Ocean by central Mozambique making it the largest African river to flow into the ocean (Chenje 2000; ZAMCOM/SADC and SARDC 2014). The Zambezi hydrological system can be divided into three segments; the upper, middle and lower Zambezi, each with its on varying characteristics that define the diversity of the river basin at large.

Sub-basin	Area (km2)	%
Kabompo	69301	5.03
Upper Zambezi	90359	6.55
Lungue Bungo	46482	3.37
Luanginga	33931	2.46
Barotse	118994	8.63
Cuando / Chobe	151465	10.99
Kafue	157629	11.43
Kariba	163202	11.84
Luangwa	148286	10.76
Mupata	19552	1.42
Tete	197816	14.35
Shire River / Lake Malawi	158043	11.46
Zambezi Delta	23653	1.72
	1378713	100.00

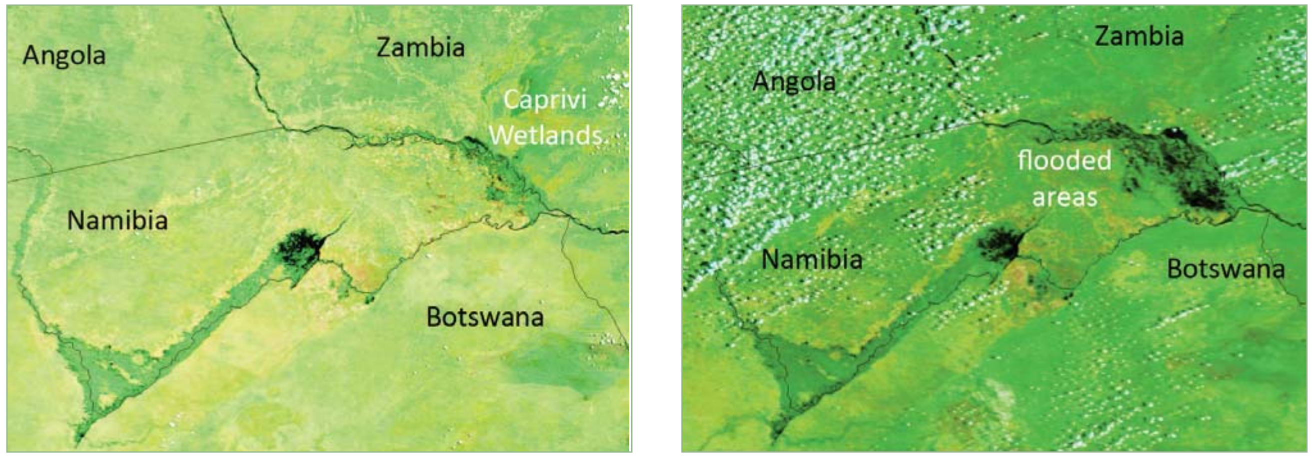
Upper Zambezi/ Headwaters

The source of the Zambezi River is found at the Kalene hills region in Zambia from where the river flows through east central Angola and back into western Zambia capturing run-off from the Kabompo River and Lungue Bungo Rivers. These headwater systems are in areas that receive high annual rainfalls making this region a vital "water tower" for the whole basin (Beilfuss 2012). The rest of the Upper Basin is dominated by vast areas of interspersed flood plains, dambos and wetlands of the the Zambezi Floodplains (Barotse Floodplains) (SADC/SARDC and others 2012). These floodplains are home to the Lozi who use their traditional knowledge of the flooding regime to adapt to annual floods. The *Kuomboka* ceremony, in which the Lozi King leads the people in an annual migration out of the plain at the height of the flood is the cue for local people to follow the king in escaping the rising waters (SARDC and HBS 2010).

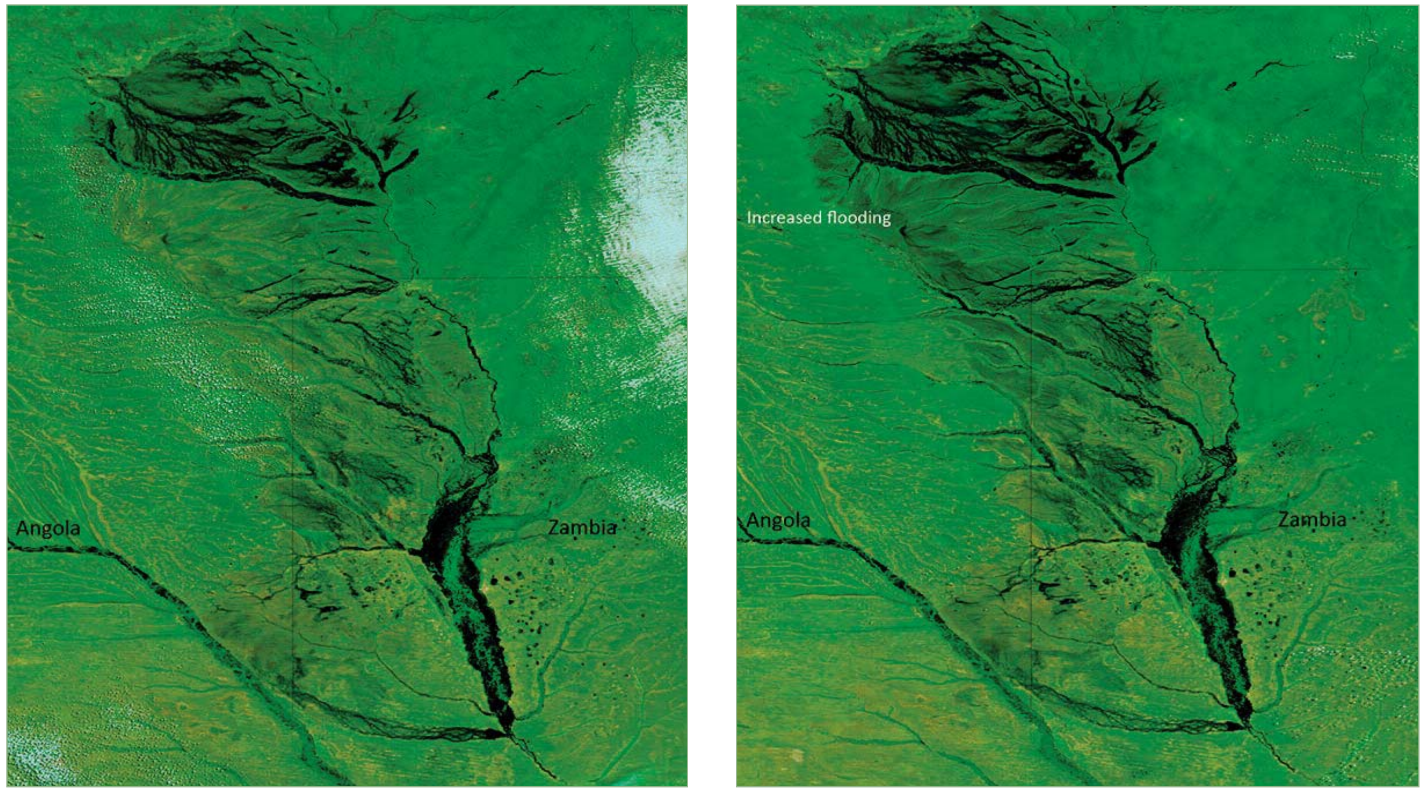
Kuomboka, meaning “moving out of the water” is an annual ceremony where thousands gather to dance, feast and watch the royal barge rowed by dozens of oarsmen beneath a giant replica elephant signifying the start of the flooding season (SARDC and HBS 2010).

The Zambezi River flows further downstream where it is met by the Cuando River at the extensive floodplain system of the eastern Caprivi Strip. These wetlands are used for various economic activities such as ecotourism, fishing, cultivation and the use of reeds for handcrafts that support locals, further emphasising the importance of rainfall and subsequent run-off as major water sources within the basin and throughout the region as a whole (SADC/SARDC and others 2012). The Caprivi Strip wetlands have a long history of settlement because of the regular fertile alluvial deposits that support cultivation, livestock rearing and allow for activities such as fishing, all of which greatly contribute to meeting household nutritional needs (Masundire and Mackay 2002). According to a report by the Directorate of Rural Water Supply, Namibia (DRWS), fish are an important protein source in the eastern Caprivi and at times inadequate flooding has been met with declining fisheries, which is often exacerbated by overfishing (2000).

Fish captured from the Chobe River by two men in a rural community in Salambala Conservancy, Caprivi Strip, Namibia.



Flooding in the Eastern Caprivi Floodplains
Heavy rains upstream resulted in near-record breaking flooding in the Eastern Caprivi Region. It was reported that authorities evacuated more than 1000 residents late January 2011. The bottom image shows the extent of inundation in February 2011 compared to the previous flood season at the same time in 2010. (NASA-EO 2011a)



Flooding in Zambezi Floodplains (Angola/Zambia)
Flooding in the Zambezi Floodplain area generally occurs in the immediate aftermath of the annual rain season. People living in the Zambezi floodplain area have long relied on nutrient-rich silt brought in by the floods.
The bottom Image shows increased inundated areas in April 2011, the top image shows the same area in April 2010 taken from Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Terra satellite. This flood plain is generally flooded from late December into June. Inundation is prevalent in both years, but more prominent in 2011. (SARDC and HBS 2010; NASA-EO 2011b)

The Middle Zambezi Catchment

The middle Zambezi Basin, between Victoria Falls and the Zambezi-Luangwa River confluence is characterised by river flows running through a combination of narrow gorges and broad fault-derived valleys (Timberlake 1998). The river flow is regulated by two major dams in the basin; Kariba Dam and the Cahora Bassa Dam (which demarcates the beginning of the lower Zambezi Catchment) and other dams constructed for hydropower generation (Table 3.2). These developments have greatly altered hydrological conditions in the flow of the river (Beilfuss 2012). Although Kariba was primarily commissioned for hydropower generation, other major uses include tourism, support to national parks and wildlife, aquaculture, urban water supply, lake transportation and mining activities (Tumbare 2008). Drought periods that reduce water levels tend to increase competition between uses and disrupt the delivery of much needed services. This was exhibited when periodical droughts between 1981 and 1992 saw the water level Kariba Dam drop by 11.6 m , severely impacting the dam's capacity to generate hydropower (SADC and SARDC 2008). At it's maximum the Cahora Bassa Dam, the second largest artificial reservoir in the basin after Kariba, can inundate an area up to 3,000 km2.

Table 3. 2 Major Dams and water reservoirs in the Middle Zambezi Catchment

Dam	River	Live Storage (km3)
Cahora Bassa	Zambezi	51.7
Itezhi Tezhi	Kafue	5
Kafue Gorge	Kafue	0.9
Kariba	Zambezi	64.8

(Source: SADC 2011)

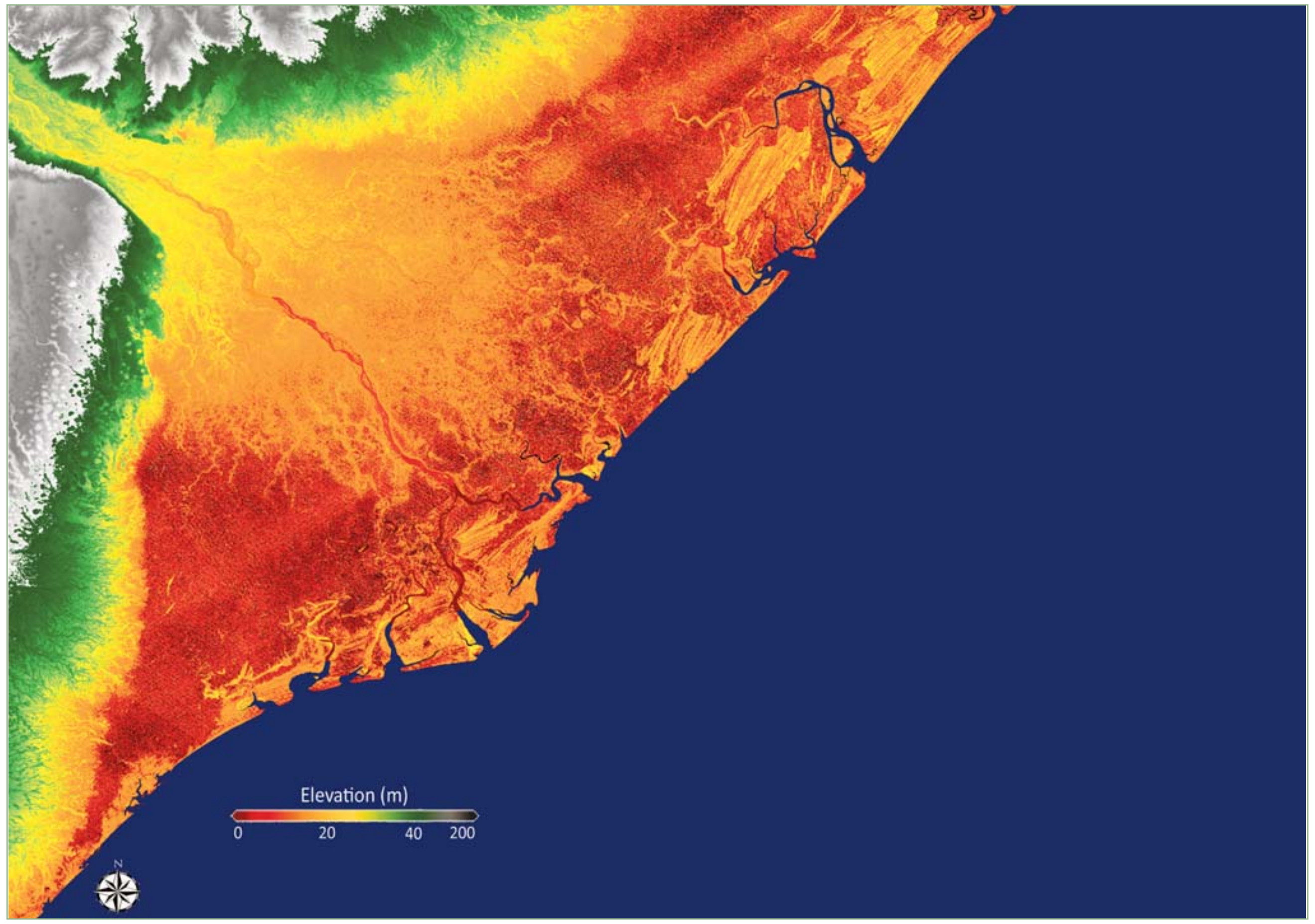
Major tributaries in the middle basin include the Gwayi, Sengwa, and Sanyati Rivers and runoff from these sub-catchments generates the characteristic early flood known locally as *Gumbora* (Beilfuss & dos Santos 2001). The Luangwa River rises from the west bank of Lake Malawi/Nyassa/Niassa and its river basin is a typical from other sub-basins in the Zambezi River Basin because the river flows through an incised channel with no bordering floodplains or major hydrological constructions for most of its length. Therefore the Luangwa River's mean annual runoff is nearly double that of the similarly sized Kafue catchment (Beilfuss & dos Santos 2001).

Luangwa River Floods
Following short intense heavy rains in January 2007 the Zambezi spilled its banks in many locations leading to flooding exacerbated by the filling Cahora Bassa. Backflows reached as far back as Luangwa River (marked increased flooding) by February 2007. On February 8, 2007, the government of Mozambique ordered the evacuation of 2,500 people as water levels rose (NASA-EO 2007). Images were taken from MODIS on NASA's

The Lower Zambezi Catchment and Zambezi Delta

River flow in the Lower Zambezi is influenced by the Cahora Bassa Dam, Lake Malawi/Nyassa/Niassa and eventually the extensive network of levees and channels of the Zambezi Delta that empty into the Indian Ocean. Below Cahora Bassa the Zambezi catches run-off from the upper Luenha channel, which rises in the Inyanga Mountains of the Manica Plateau (1000-1500 amsl) and the Mazowe River rises from highland areas near Harare, Zimbabwe (Beilfuss & Dos Santos 2001). Further downstream the river recieves run-off from the The Shire River originates as an outflow from Lake Malawi/Nyassa/Niassa (Lake MNN), which can be considered as being a major and important sub-system in the Lower Zambezi. Lake MNN is the only large natural lake in the Zambezi basin with a catchment area of 126,550 km2 (Beilfuss & Dos Santos 2001). This sub-system supports fishing and water transport, agriculture, tourism industries and the hydropower plants located in the Lower Shire produce about 95percent of Malawi's electricity requirements (SADC 2011). Low water levels hinder important social and economic activies including viability of hydropower generation which requires constant and sufficiently high river flows (SADC 2011). Serious flooding is experienced in the Lower Shire sub-catchment has the Shire River flows from Lake MNN to the Zambezi River and Shire River confluence.

Below the Shire confluence, Zambezi River branches giving way to a network of levees and channels of the Zambezi Delta that empty into the Indian Ocean. The delta is a broad, flat alluvial plain, 0-100m above sea level supporting a vast mosaic of grassland, palm, thicket, woodland, and mangrove communities (Beilfuss & Dos Santos 2001; Chenje 2000). The delta can be described as triangular in shape, covering an area of approximately 1.2 million hectares (Beilfuss and Brown 2006). Infrastructure developments within the delta region of roads and embankments affect the surrounding geomorphology exacerbating flooding during extremely high run-off periods (Beilfuss & Dos Santos 2001). Prior to the construction of large dams upstream on the Zambezi River, the original flooding pattern of the delta consisted of high waters in January to April and low waters in October-November. This has been eradicated by upstream dams that now regulate 70 percent of the basin (SADC 2011).



The Topography of the Zambezi Delta
The topography of the delta depicts the triangular shape with higher elevations occurring in north west and north east directions. Leveés along the Zambezi River and its minor tributaries and old channels together with derelict beaches have created elevated areas. Near the coast are higher lying dunes, which are most prominent in the Northern part of the delta (indicated in shades of yellows and oranges).
(Chenje 2000) [data source: NASA SRTM]

4. Climate Change and Variability

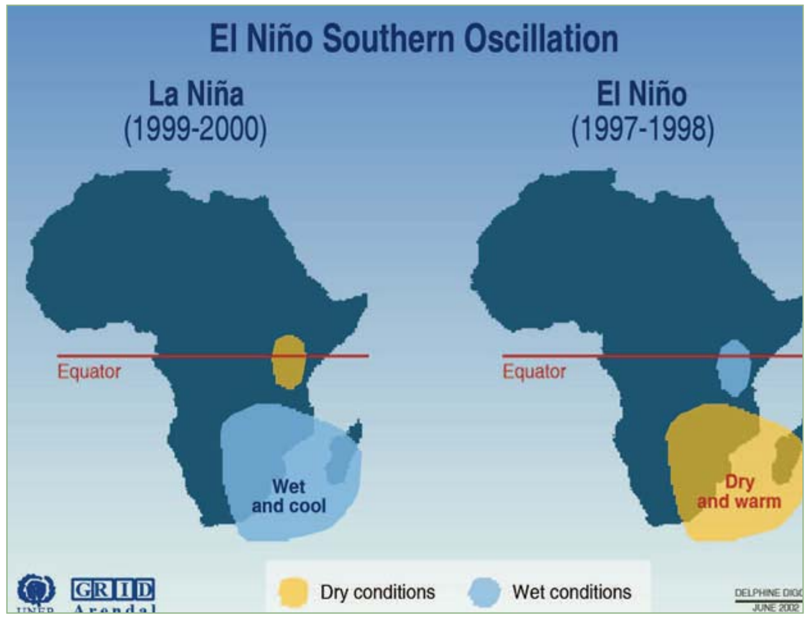
According to the Intergovernmental Panel on Climate Change Assessment Reports (5th IPCC 2014), floods and droughts are expected to be more frequent and more intense as the climate changes. Increase in temperature is already being felt in the Zambezi Basin and the rest of sothern Africa. Temperatures in southern Africa have risen by more than 0.5°C over the past 100 years and the 1990s were the warmest and driest ever. (SADC and SARDC 2008)

The Zambezi Basin's climate is much influenced by wind systems such as the Inter-Tropical Convergence Zone (ITCZ) and the presence of large water bodies such as Lake Malawi/Nyasa/Niassa (SADC/SARDC and others 2012). The emergence of tropical cyclones in the Indian Ocean has at times influenced severe rain storms within the basin (Chenje 2000). The Basin as the rest of Southern Africa is characterised by a hot and wet season from October to March with a short inter-seasonal dry spell; and a dry season from April to September with relatively colder spells from May to August. Climate in southern Africa is also subject to the El Niño Southern Oscillation. Southern Africa experiences unusually dry conditions during the December-February period in some El Niño events as opposed to wet and cool conditions in La Niña events as shown in Figure 4.1 (GRID-Arendal and UNEP 2014).

Temperature

Temperature across the basin varies according to elevation with the highest and lowest temperatures experienced at the end of October into early November and July respectively (Chenje 2000). Cooler temperatures are generally experienced in the south-central portions of the basin and the highest mean daily temperatures generally occur in low-lying areas such as in the lower Zambezi valleys in northern Zimbabwe and Mozambique as shown in Figure 4.2 (SADC/SARDC and others 2012; Chenje 2000).

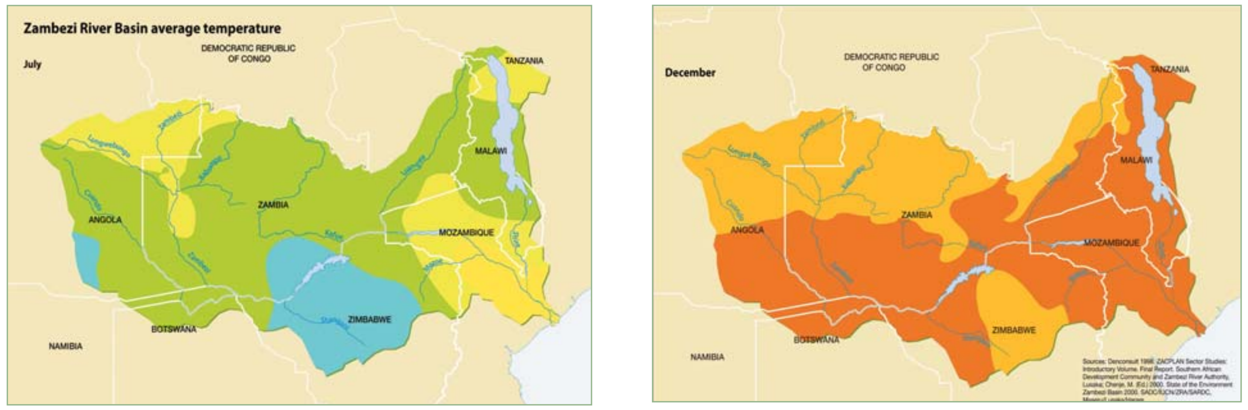
Figure 4. 1 El Nino and La Nina effects in Southern Africa



(Source: GRID-Arendal and UNEP 2014)

Temperature inversions frequently develop in valleys and lower areas of the basin, these micro-climatic changes can potentially impact livelihoods of locals especially during the growing and harvesting season (October to March) (Chenje 2000). Little cloud cover results in bright sunshine for eight hours or more in a day throughout the dry season (Chenje 2000), thereby limiting agricultural activities. The basin experiences high daily temperature ranges which can be as high as 20°C in the dry season, as a result about 65 percent of all rainfall evaporates as soon as it falls with another 20 percent lost through evapotranspiration (SADC/SARDC and others 2012).

Figure 4. 2 Average Temperature for July and December

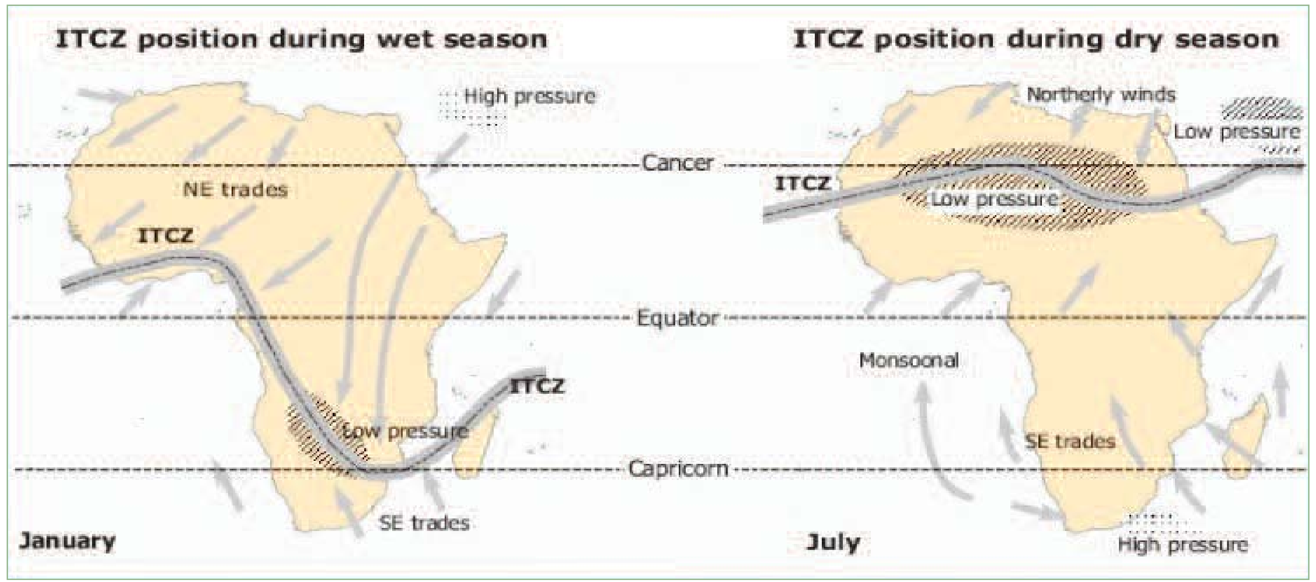


(Source: SADC/SARDC and others 2012)

Rainfall

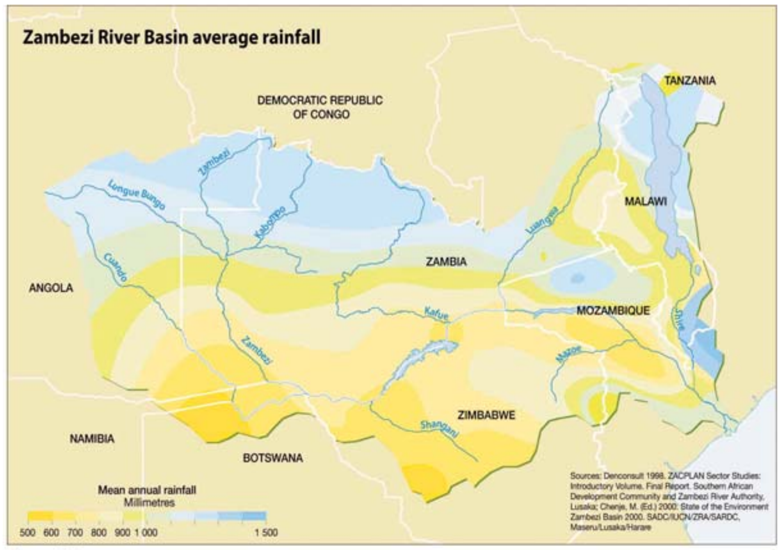
Rainfall in Southern Africa is greatly influenced by the ITCZ and the Botswana Upper High wind systems. Rain-fed agriculture continues to be the mainstay for many livelihoods throughout the basin. As a result, changes in rainfall patterns have a huge bearing on livelihood sustinence throughout the region. The ITCZ tends to bring good rains in the region while the Botswana Upper High tends to create unfavourable conditions for widespread heavy rainfall and its frequent occurrence results in drought in some countries (UNEP and SARDC 2009). The ITCZ is a zone of intense rain-cloud development created when the southeast Trade Winds collide with the northeast Monsoons (SADC and SARDC 2008). Its movement southwards from the equator marks the start of the main rainy season over southern Africa and the rainy season tends to peak in January and February when the ITCZ is above Zambia as shown in Figure 4.3 (SADC and SARDC 2008; Chenje 2000). The Botswana High is a high-pressure cell usually centred over Botswana between three and six kilometres above sea level (SADC and SARDC 2008).

Figure 4. 3 ITCZ and Rain in Africa



(Source: INGC, UEM and FEWS NET-MIND 2003).

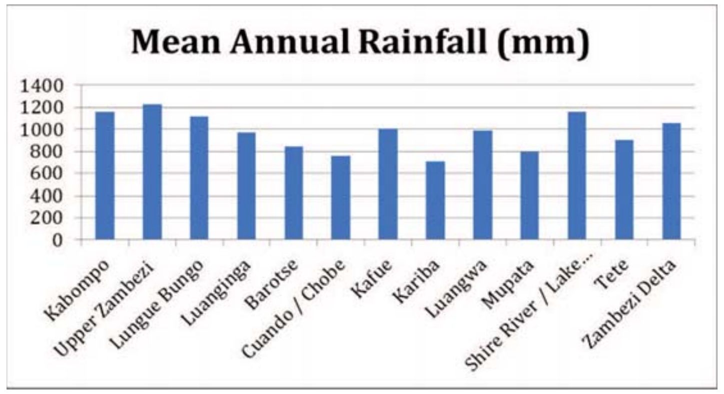
Figure 4. 4 Average rainfall pattern



(Source: SADC/SARDC and others 2012)

Average annual rainfall across the river basin varies from 500mm in the extreme south and southwest part of the basin to more than 1400mm in the Upper Zambezi and Kabompo sub-basins, in the north-eastern shores of Lake Malawi/Nyasa/Niassa in Tanzania and in the southern border area between Malawi and Mozambique (Chenje 2000). The Northern part of the basin generally receives high amounts of average annual rainfall. This tends to decrease going south as shown in Figure 4.5 (SADC/SARDC and others 2012).

Figure 4.5 Average rainfall pattern for Major sub-basins



(Source: ZRA & SADC 2007)

Rain plays a major role in the socio-economic welfare of the basin. The scarcity of water is a major challenge to development throughout the region. The basin's environment is quick to respond to wet or dry periods in many basin states countries potential evapotranspiration exceedes average rainfall (Table 4.1). It is important to note that very short spells of dryness of even a couple of days during the rainy season (October to March) is enough to negatively impact agricultural production by wilting crops. Intense short rains can lead to flash floods and high run-off in some areas of the basin (Chenje 2000).

Table 4. 1 Rainfall and evaporation for basin states

	Rainfall Range (mm)	Average Rainfall (mm)	PET range (mm)	Total Surface run-off (mm)
Angola	25-1600	800	1300-2600	104
Botswana	250-650	400	2600-3700	0.6
Malawi	700-2800	1000	1800-2000	60
Mozambique	350-2000	1100	1100-2000	275
Namibia	10-700	250	2600-3700	1.5
Zambia	700-1200	800	2000-2500	133
Zimbabwe	350-1000	700	2000-2600	34

(Source: Hirji and others 2002).

Seasonal transformation in the Caprivi Strip

Rainfall and subsequent run-off in the Caprivi wetlands area on the Namibia/Zambia border during the 2013 rainy season transformed the Zambezi River and its surrounding floodplain area. The top image shows the area before the rains during the dry season and the bottom image shows the same location after the rains during the wet season. Images were taken from the Advanced Land Imager (ALI) on NASA's Earth Observing-1 (EO-1) satellite (NASA-EO 2013b).

5. Determining Drought Prone Areas

It is important to note that droughts are temporary and they have to last long enough to cause damage, whereas permanent climatic dryness denotes aridity (SADC and SARDC 1994). Table 5.1 highlights some of the most prominent drought spells in southern Africa. Rainfall will be used as the main indicator to determine drought prone areas in the basin.

Considering the Southern African region is characterized by inter-annual variability in rainfall this study will look at the months where agricultural activity is most crucial for wide-spread food security. In southern Africa the main agricultural activities take place from October to March as shown in Figure 5.1. Land preparations and planting traditionally takes place during October, November, December (OND). The rainy season begins in October going all the way through to March. Rainfall and climatic conditions during the January, February, March (JFM) period determines the type of harvest that begins end of March. It is important to note that most of agricultural activity is rain dependent and cropping during the dry winter period of May to September is limited to those who have irrigation or access to perennial water sources such as wetlands, springs and various types of water reservoirs. The agricultural calendar presented in Figure 3.2 gives a good outline on activities based on long term observations although it is important to note that local conditions may vary by a week or two. This has an impact on how risk prone an area is to variable climatic conditions. (Source SADC/SARDC and others 2012; SADC-FANR 2013)

Table 5. 1 Occurrence of extensive dry periods in Southern Africa

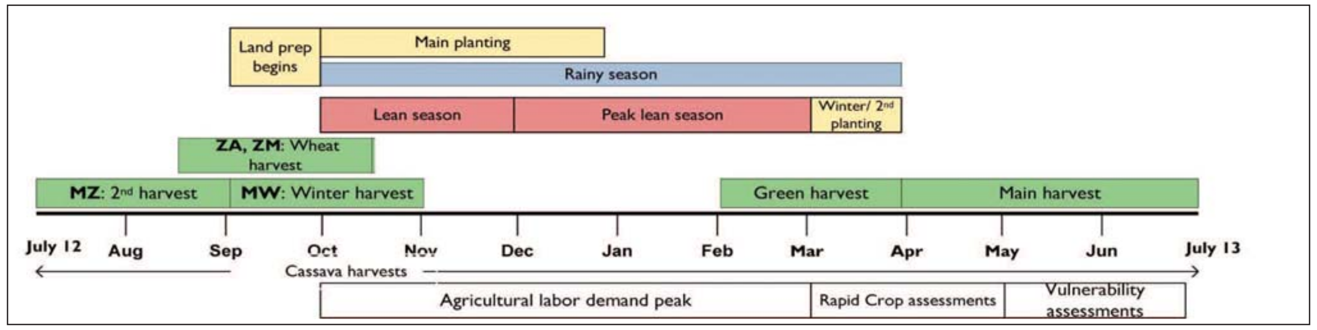
2012-2013	Following poor performance in November, good rains were received in the first 10 days of December but dry conditions resumed late January throughout to May in the southern parts of the basin.
2004-2005	Many parts of the basin experience below normal rainfall during agricultural season. Several riparian declared state of natural disasters
2001-2003	Severe Drought in the SADC Region
1994 – 1995	Many countries in the SADC were hit by a severe drought, surpassing the impact of the 1991 – 1992 droughts.
1991 – 1992	Worst drought in living memory at the time experienced in southern Africa, excluding Namibia.
1986 – 1987	Drought conditions returned to the region.
1983	This year saw a particularly severe drought for the entire African continent.
1982	Most of sub-tropical Africa experienced drought.
1981 – 1982	Severe drought occurred in most parts of southern Africa.
1967 – 1973	This six-year period was dry across the entire region. Some records show a severe drought

Drought Prone Areas

Monitoring rainfall trends is commonly used to denote periods of dryness. Using rainfall as determinent is in line with the defintions of meterological and agricultural droughts. A prolonged departure of precipitation from the normal conditions can be desrcibed as a meterological drought, the moisture deficiency is associated with low agricultural outputs which are sensitive even to the slightest decrease in rainfall amounts (Tirivarombo and Hughes 2011).

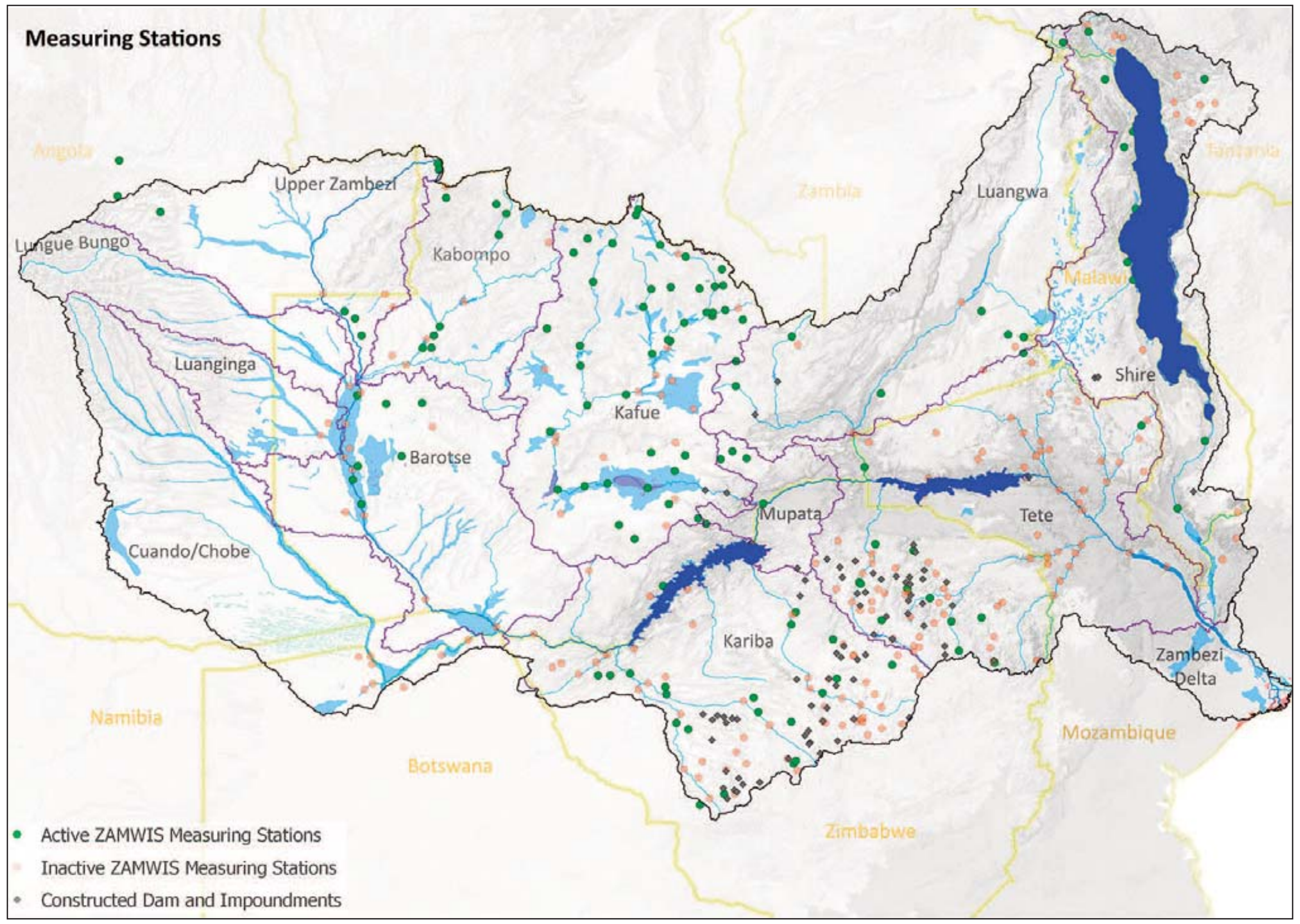
Regular spatial and temporal rainfall data is sparse across the basin because of the sparse and irregular distribution of guage stations within the basin (Figure 5.2). This study will use rainfall data derived from the African Rainfall Estimation Algorithm Version 2 (RFE 2.0). This rainfall algorithim is derived by using data from available gauaging stations and various satellite rainfall data (Xie and Arkin 1997). Combining satellite estimates with guaging data increases the effectiveness of RFE data although it does not incorporate orographic features well (NOAA CPC).

Figure 5. 1 Agricultural calendar in a typical year in Southern Africa



(Source: FEWS NET 2012).

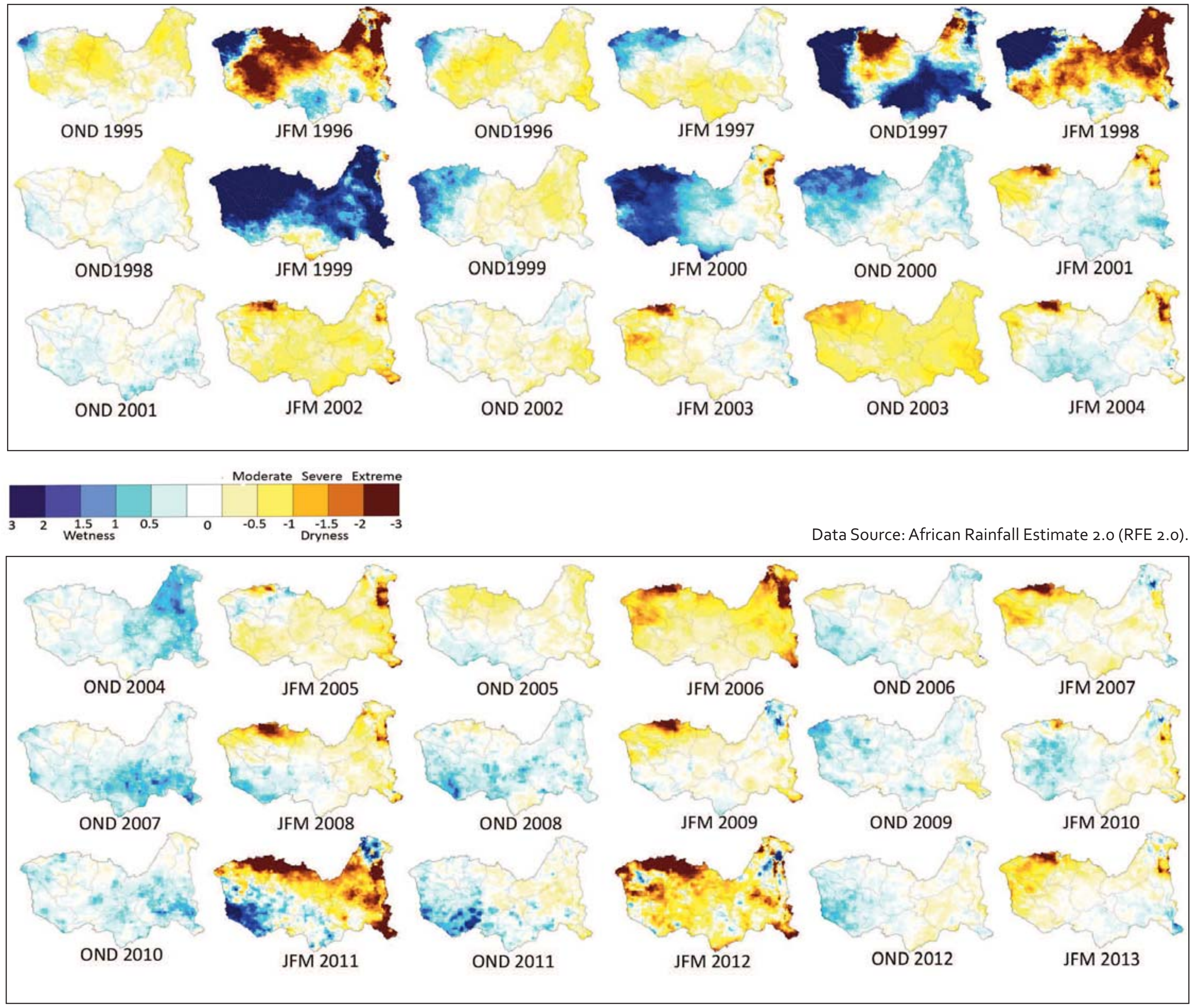
Figure 5. 2 Gauging Stations in the Zambezi River Basins



Data source: Adopted from ZAMWIS (2007).

The frequency of dry periods between 1995 and 2013 classified as being severe to moderate (SPI score less than

Figure 5. 3 Drought Index (1995 to 2013).



Data Source: African Rainfall Estimate 2.0 (RFE 2.0).

The Drought Index is a Standardised Precipitation Index (SPI) which is calculated as:
([3-Month Mean] - [Long-Term Mean])/ [Long Term Mean Standard Deviation].
This equation measures how much the mean deviates away from the long term mean and gives it a score between -3 and +3. This departure from 0 is a probability indication of the intensity of wetness or dryness (Guttman 1998). Scores ranging from -0.9 to +0.9 indicate the condition is near normal, values less than -1.5 values or greater than +1.5 denoting extremely dry or wet periods (Tirivarombo and Hughes 2011). The Long term mean data is derived from interpolated gauge recordings from 1920 to 1980, which is collated and disseminated by FEWS NET.

Figure 5.4 a Occurrence of Severe dry periods during the OND period over 18 years (1995 to 2013).

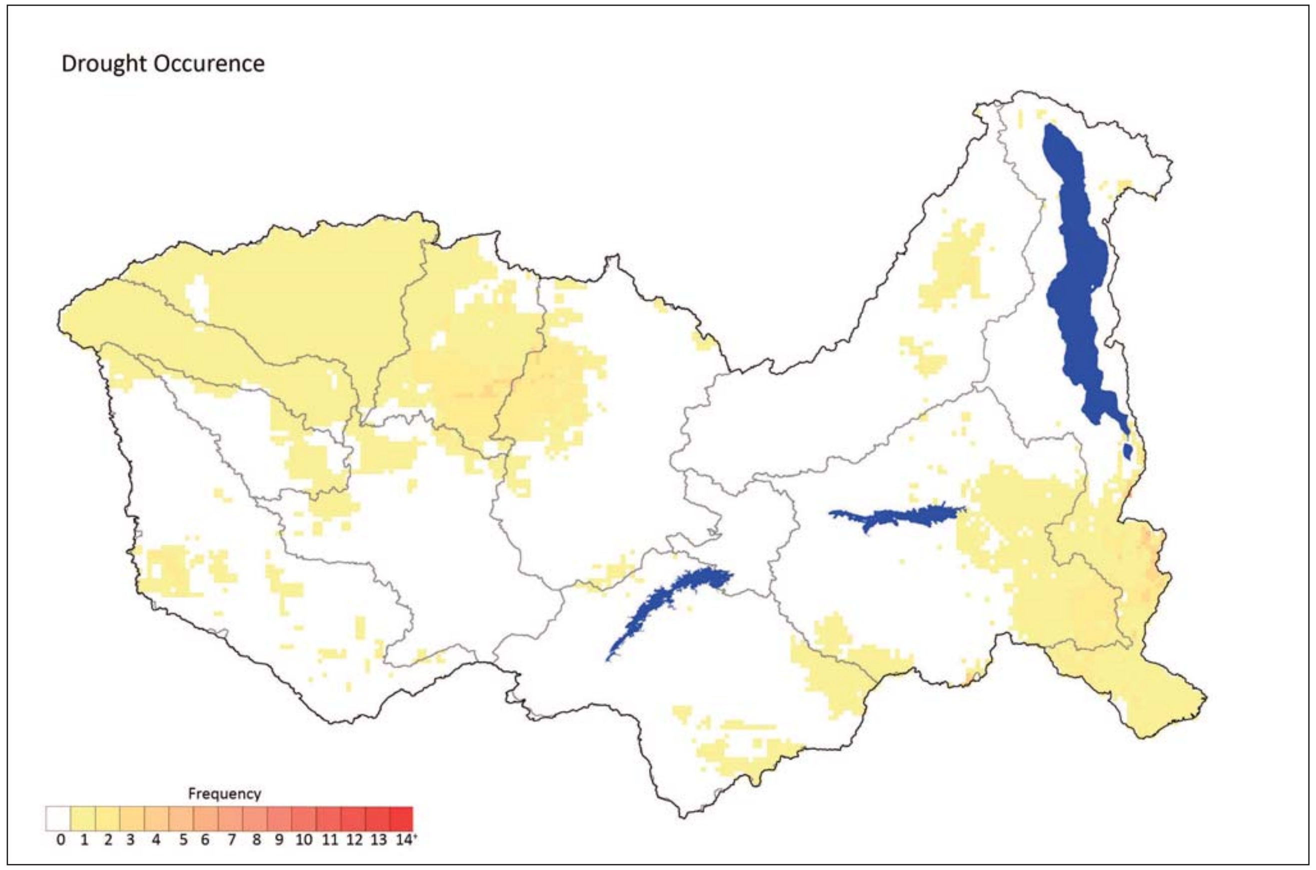
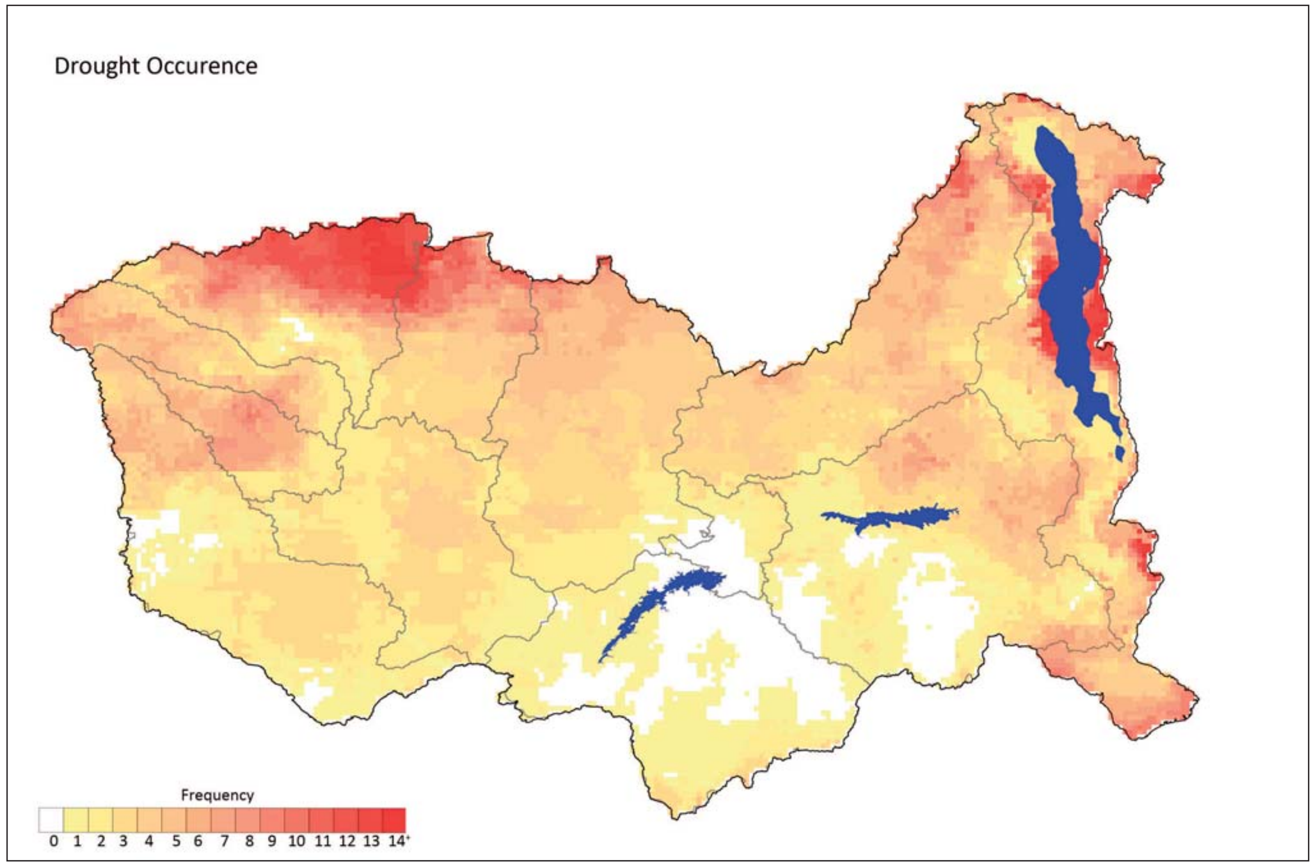


Figure 5.4 b Occurrence of Severe dry periods during the JFM period over 18 years (1995 to 2013).

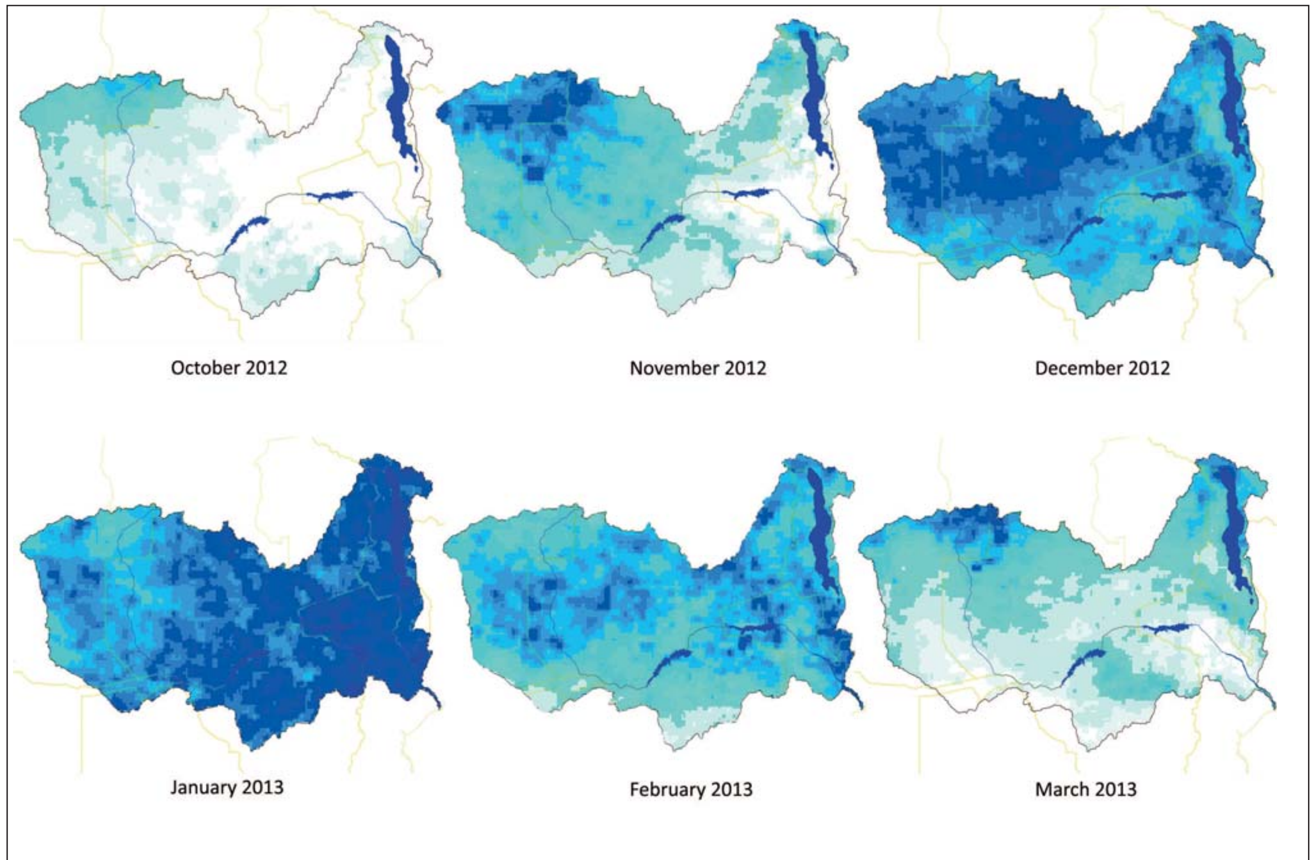


-1) tend to be experiecened in the upper and lower portions of the basin during the growing and early rainfall season (OND) based on the drought index used (Figure 5.3). However it is important to note that the index indicates how far rainfall is from the long term average. Long term records and observations show that the upper portion of the basin tends to be wet therefore this could be an indication of the RFE 2.0 inability to fully capture orographic effects which are important in the hills of the Upper Basin. It is important to note that for the past 18 years majority of the basin has witnessed below average rainfall at least once for the JFM periods (Figure 5.4b). Figure 5.3 shows us the SPI responding to observations of drought widely reported for the 2001-2003, 2005 and 2012 years.

The 2012-2013 agricultural season

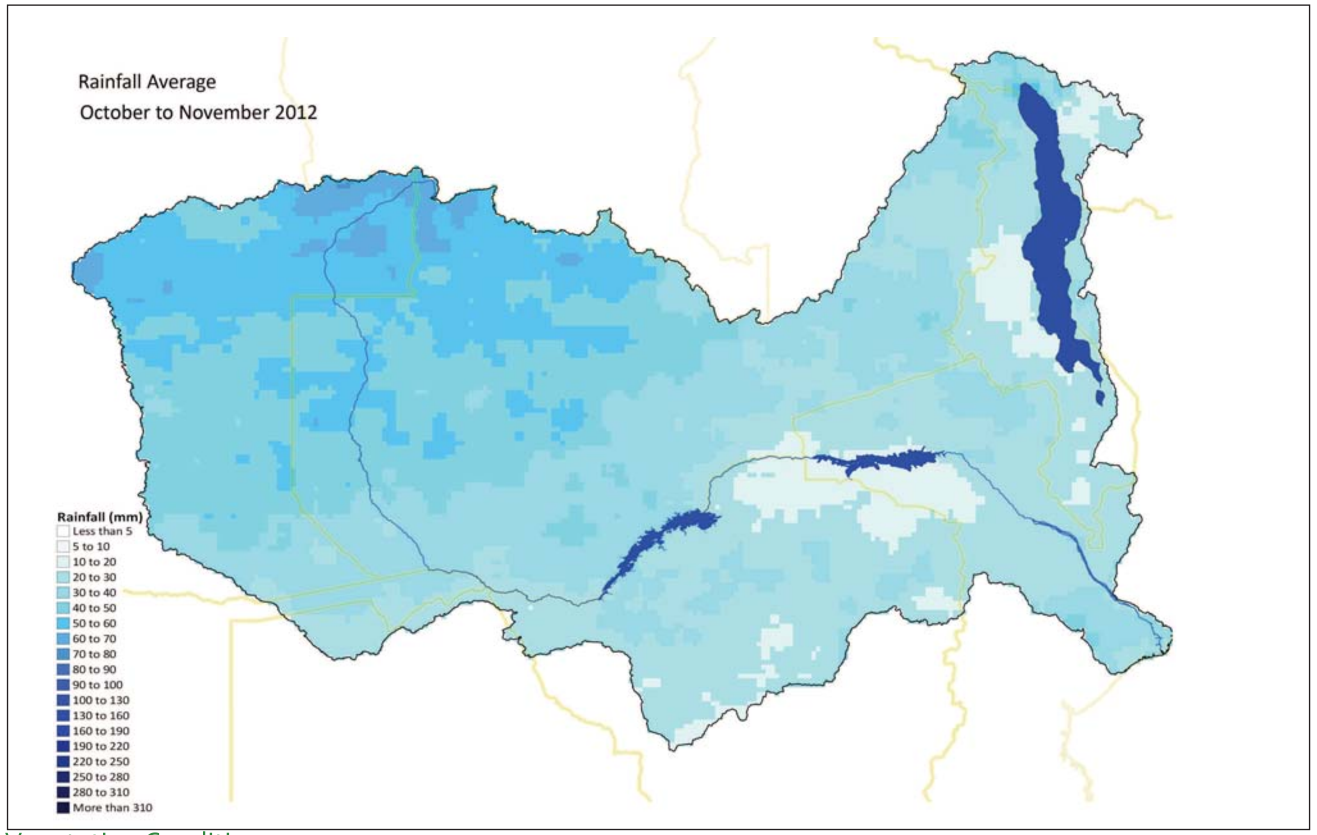
The 2012-2013 agricultural season started on the backdrop of poor 2011/2012 rains and entered into November with low rainfall. This is highlighted in the diagrams below showing widespread vegetation stress across the basin based on vegetation condition index derived from satellite images. Below average vegetation conditions during the main-planting periods are enough to affect household food security. Late rains in December eased pressure on the vegetation as reported in the FEWS NET Seasonal Monitor but for some communities in the basin it was too late to prevent food insecurity.

Figure 5. 5 Rainfall average per month for 2012/2013 Agricultural Season



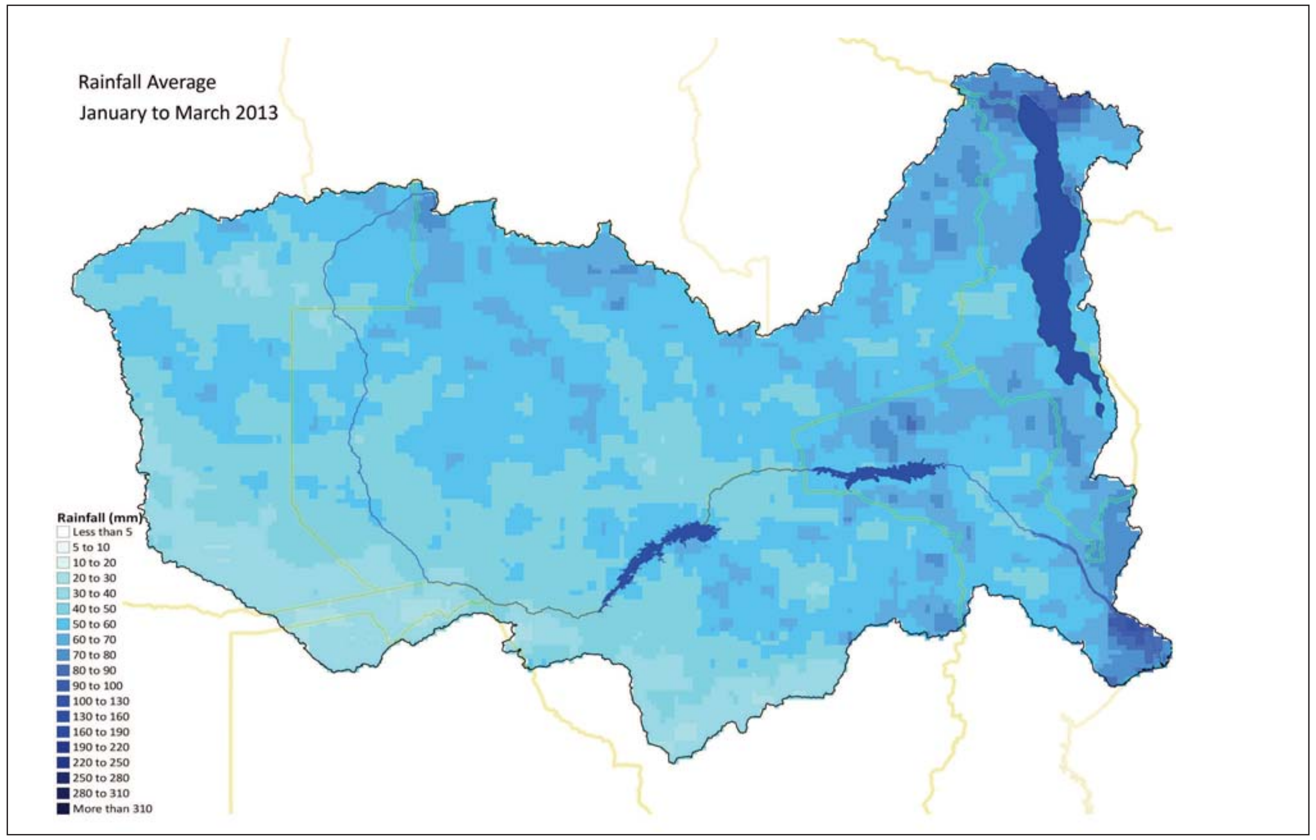
Data source: RFE 2.0

Figure 5.6 a Rainfall average October to November 2012



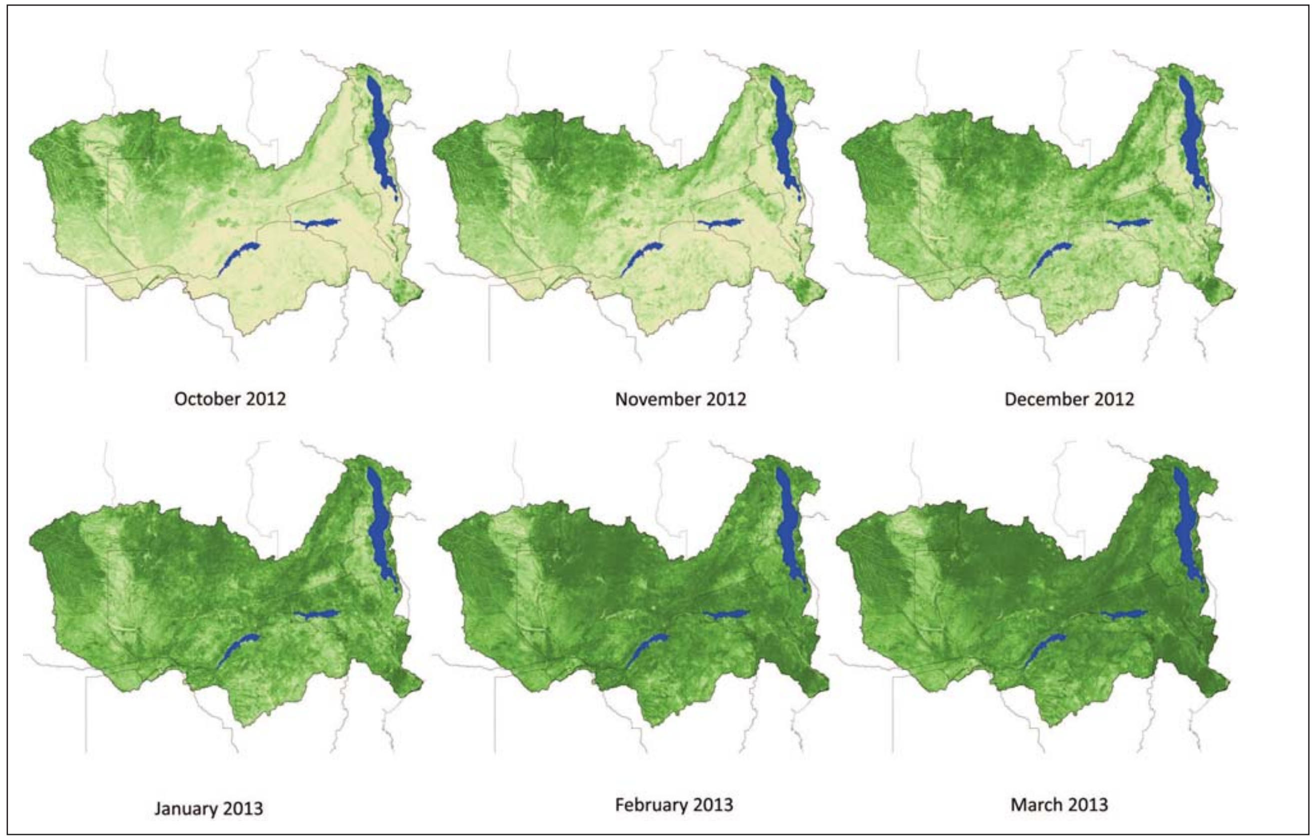
Vegetation Condition

Figure 5.6 b Rainfall average January to March 2013



Vegetation condition is a useful indicator used to denote dryness and identify drought conditions. Vegetation condition is dependent on water availability. Lack of rainfall and dropping water tables put stress on the vegetation, this can be devastating during the main planting agriculture season (between the months of October and December).

Figure 5. 7 Vegetation Condition per month for 2012/2013 Agricultural Season



Date source: eMODIS NDVI

The vegetation condition is determined by the Normalised Difference Vegetation Index (NDVI). NDVI uses spectral bands from satellite images that detect photosynthesis activity. The higher the NDVI the healthier the vegetation (shown in dark green), stressed vegetation is showed by lighter greens to dark browns.
NDVI was calculated from images taken from the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite and compiled into the eMODIS NDVI dataset and disseminated by FEWS NET. The MODIS images used are at a 250km spatial resolution and are compiled into 10 day averages (dekads) per month (FEWS NET 2013)

The NDVI gives an accuarate representation of the vegetation on the ground over large areas but can be susceptible to local ecological and climatic conditions (Unganai and Kogan 1998). For heterogenous land cover, NDVI, is normally higher in the areas with more favorable climate, soil, and more productive ecosystems (such as forest) compared to the areas with less favorable environmental conditions (dry steppe) which can lead to misinterpretations of drought (Unganai and Kogan 1998). In order to overcome this a Vegetation Condition Index was created that compares the current NDVI with the long term NDVI values.

Figure 5.8 a Vegetation condition for OND 2012 compared to long term average

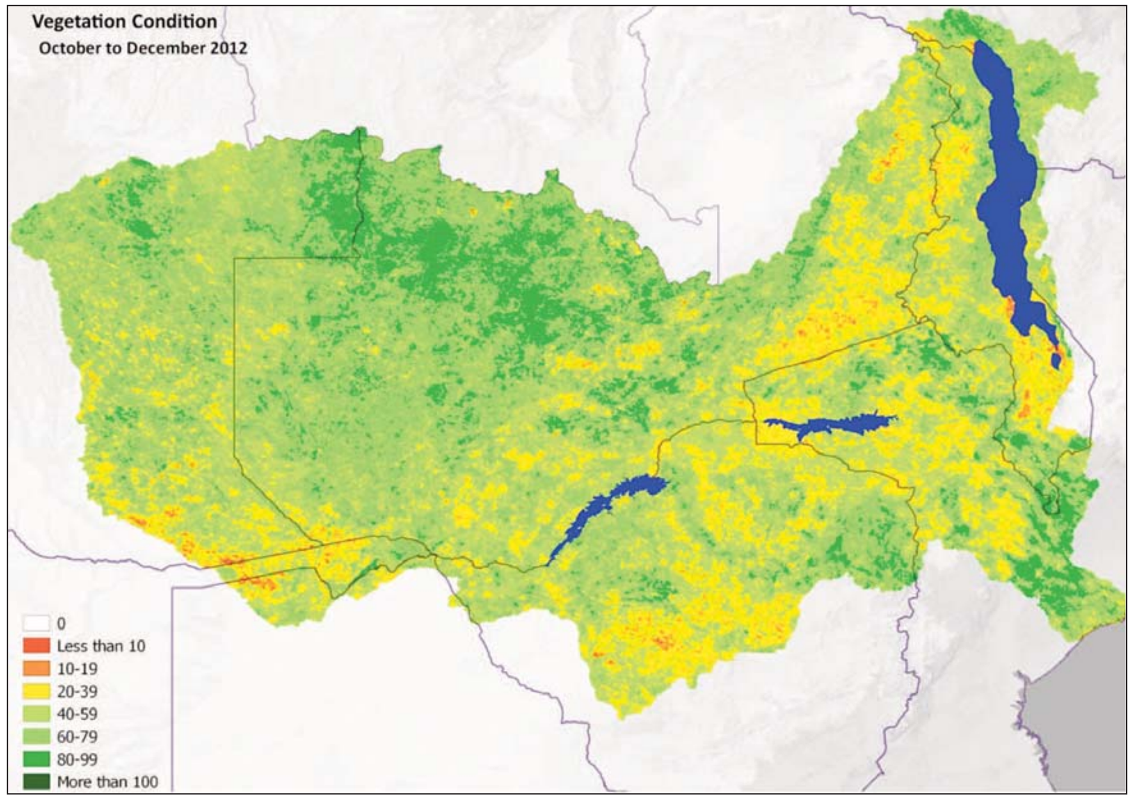
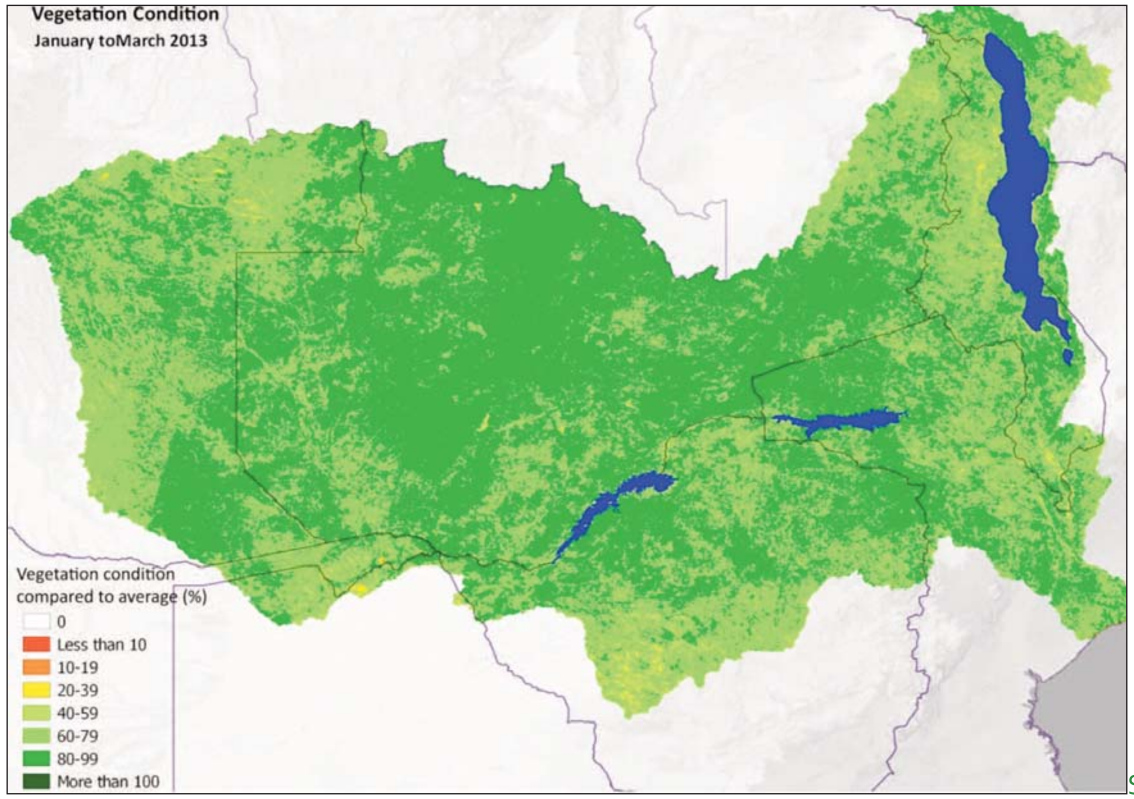


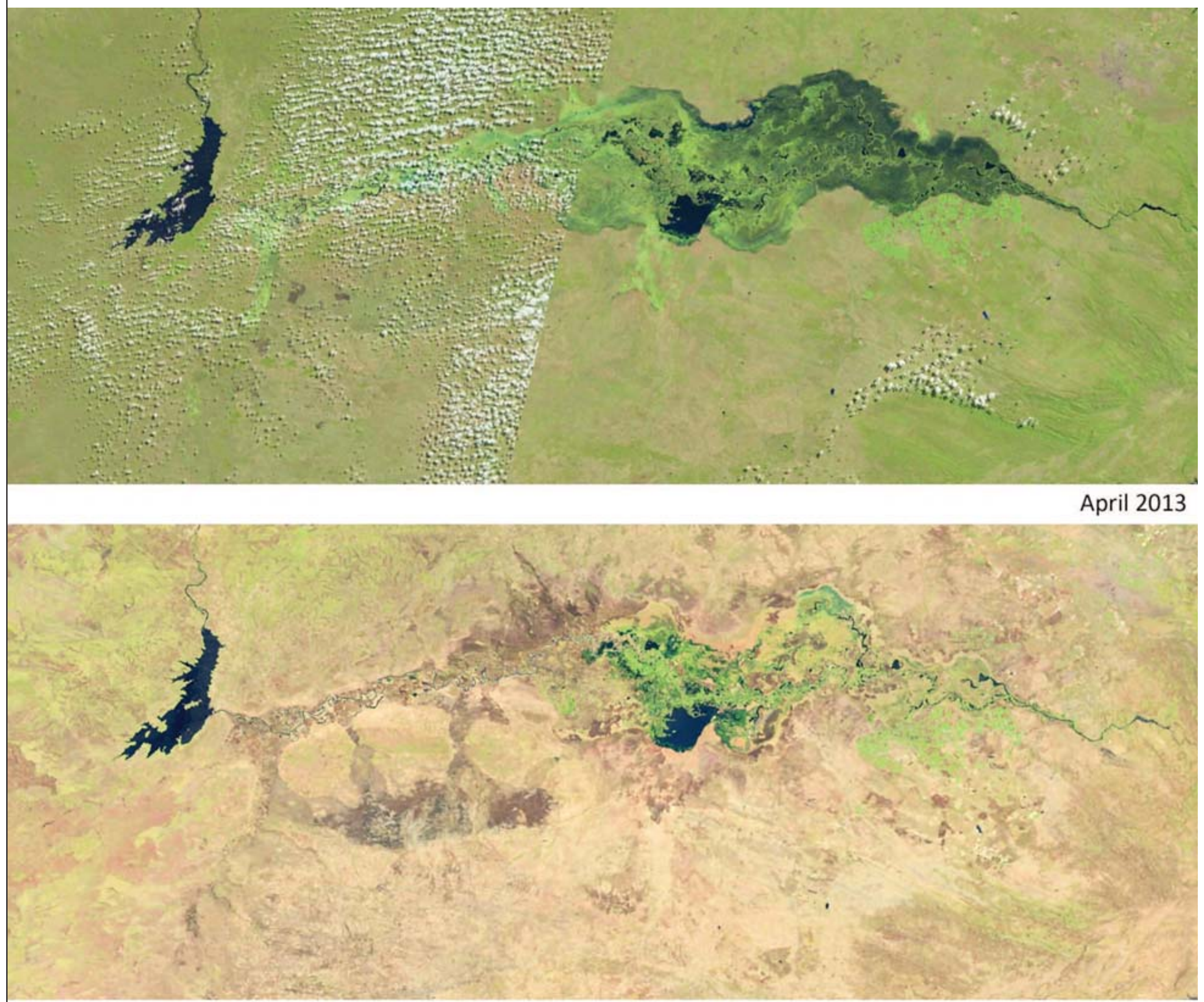
Figure 5.8 b Vegetation condition for JFM 2013 compared to long term average.



Soil Moisture

Date source: AMESD SADC THEMA (a)

Soil moisture is an important determinant for successful planting and germination of the crops seeds. Prolonged dryness because of late rains during the critical OND season results in a late start of planting thereby increasing household vulnerability (Tirivarombo and Hughes 2011). Wetlands and floodplain agriculture is important because of the presiding wet conditions that can ensure sufficient soil moisture for germination before the first rains



Dryness in the Eastern Kafue floodplain, during the October planting season
The Kafue Flats are a broad alluvial plain extending for a distance of about 250 km, 60 km wide and covers about 650 000 hectares. This wetland area is a source of potable water for 40% of Zambia and a major water source for its capital city of Lusaka. It supports livelihoods as it used for fishing, tourism, grazing and is important maintaining the diverse ecosystem in the region which promotes biodiversity.

The Ila, Tonga and the Twa have populated the Kafue Flats area for centuries relying on the floodplain for fishing and agriculture. Participation of locals in recent developments has helped secure the integrity of the floodplain. However long periods of dryness caused by late onset of the rains puts more pressure on the water resource while delaying planting due to little soil moisture. The top 2-week mosaic image shows the floodplain after the rains in April 2013 and the bottom 2-week mosaic shows dry conditions in the mid October 2013. (source: NASA-Landsat8; SADC/SARDC (2012); Mujwahuzi (2002))

Figure 5.9 a Soil Moisture average OND for every 10 days (dekad).

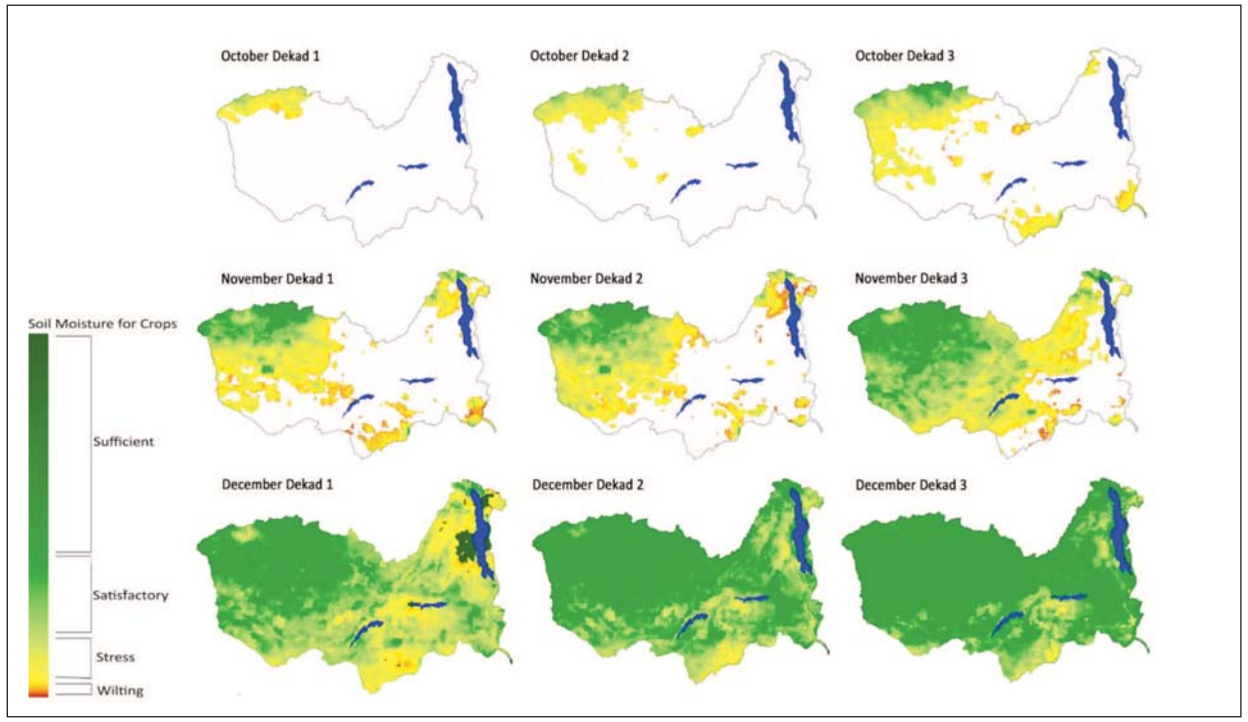
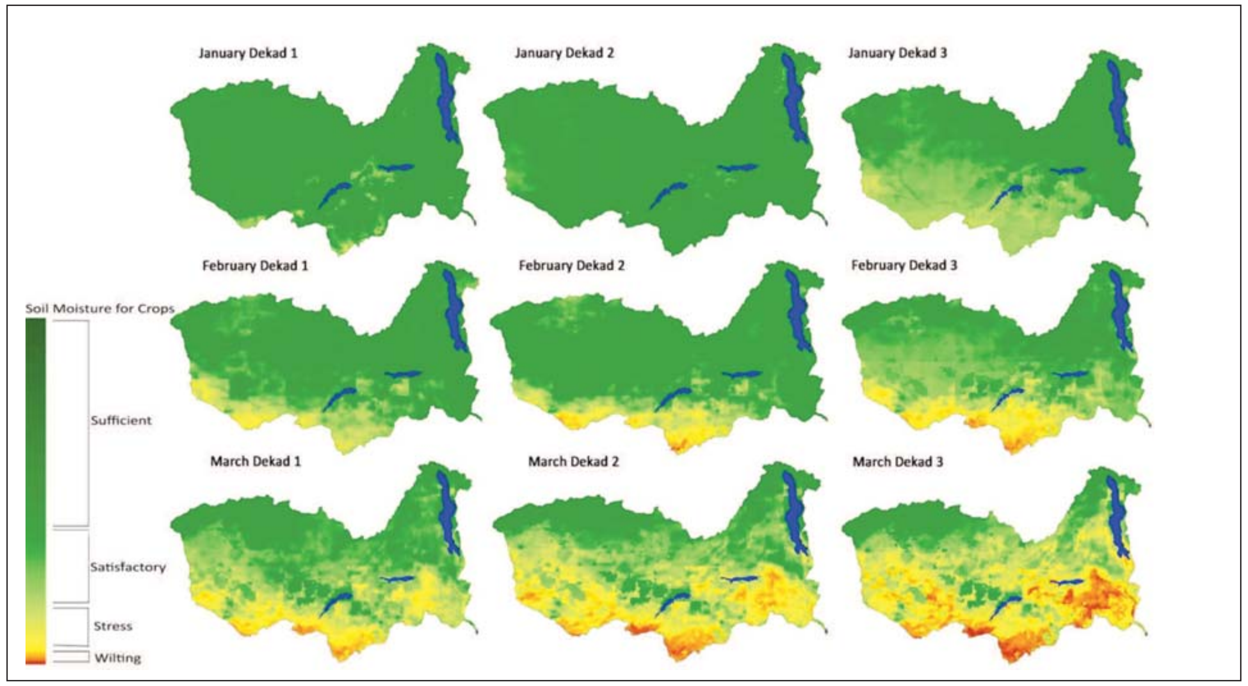


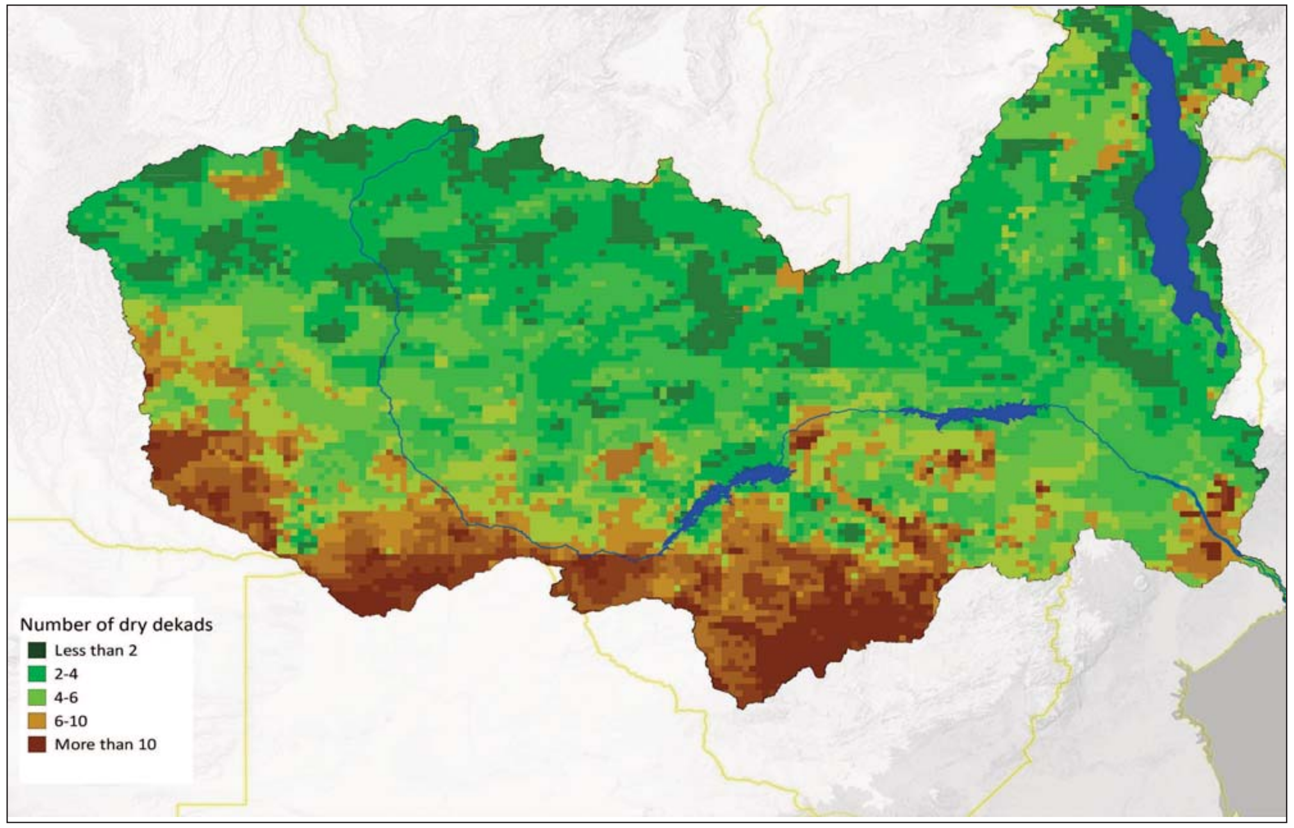
Figure 5.9 b Soil Moisture average JFM for every 10 days (dekad)



Data source AMESD SADC THEMA (b)

Soil Moisture is determined by the Soil Moisture Index (SMI). SMI was developed to assess suitability for cropping therefore it based on a simple supply/demand ratio, which is calculated as:
([Precipitation + Available Soil Water]/Potential Evapotranspiration) * 100
SMI relies on rainfall to determine the available soil water therefore does not fully capture those areas that are constantly wet before the rains. This makes it more useful to determine moisture for cropping than determining soil moisture in general, therefore SMI is more suited to show agricultural drought. (AMESD SADC 2014)

Figure 5. 10 Occurrence of Dry dekads from November to March



Data source: AMESD SADC THEMA (b)

Dry dekads are 10 day averages where conditions indicated crop stress or wilting.

The dominant crop throughout the basin is maize although in areas of higher rainfall such us northern Zambia cassava tends to have more prominence and small grains such as millet and sorghum tend to be cultivated in drier areas (Chenje 2000). Each crop needs a certain number of satisfactory soil moisture days in order to develop. The early onset of rains during October allows for planting to begin in areas that rely on rainfall for cropping, but Figure 5.10 show that large portions experienced a late onset of rains thereby delaying planting of food crops. During the JFM period of the agricultural season, soil moisture is important to ensure the development of germinated crops but the delayed harvests caused by late planting can put many familes at risk.

Signifcant portions in the southern parts of the upper and middle basin experienced at least 100 days (10 dekads) where soil moisture conditions denote crop stress or wilting. It is important to note that in areas such as the Caprivi strip this agriculutrual drought is offset by the prevelance of the wetlands and floodplains although, those who do not have access to water sources will still feel the effects of poor crop yields.

6. Flooding Hazard Areas

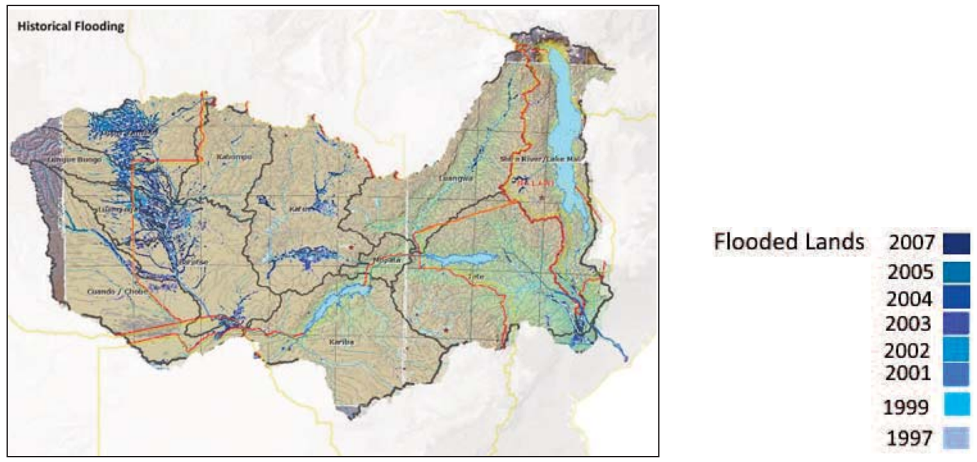
The majority of the population in rural areas across the Zambezi River basin practice subsistence agriculture along the flood plains, swamps, wetlands and margins of large water bodies. For large parts of the river basin the threats related to flooding are limited, the situation is different in some sections of the upper, middle and lower Zambezi where floods inundate extensive areas and result in serious infrastructure damage, people and property loss as shown in Table 6.1 (SADC and ZRA 2007). The existing flood prone areas (Figure 6.1) are located inareas with little river regulation.

Table 6. 1 Flooding Trends in the Zambezi River basin

	Location	Description	Socio-Economic Impacts
1997	Lower Shire River Valley	Flash floods	Extensive damage to roads, bridges, houses as well as crops and livestock. 4 people drowned. 400,000 people affected
2000	Most of the Zambezi Basin	Prolonged and exceptionally heavy rains compounded by cyclone Eline caused flooding throughout Southern Africa. Mozambique was the most affected.	Loss of lives, extensive damage to roads, bridges, crops, and communication lines. Outbreak of diseases. More than 200,000 people affected.
2001 to 2002	Provinces in Zambia, Zimbabwe, Malawi and Mozambique located in the Middle to Lower Zambezi basin	Southern Africa experiences abnormally high rainfall and disastrous floods causing damage to infrastucture and loss of lives and property	
2003	Villages near Lake Malawi	Rising water levels in Lake Malawi submerged nearby villages	Houses collapsed. 107 families displaced
2006	Lower Shire valley	Heavy rains caused flooding	Destruction of houses and outbreak of diseases (cholera). 37,431 households were affected. 1,794 houses destroyed
2007	Mozambique and parts of Zimbabwe.	Cyclone Favio-induced floods from torrential rains	Destruction of villages and many residents forced to moved
2008 – 2009	Angola, Botswana, Malawi, Namibia and Zambia	Heavy rains caused flooding	The basin experienced flooding, affecting and displacing thousands of people

Source: SADC 2011; SARDC and HBS 2010

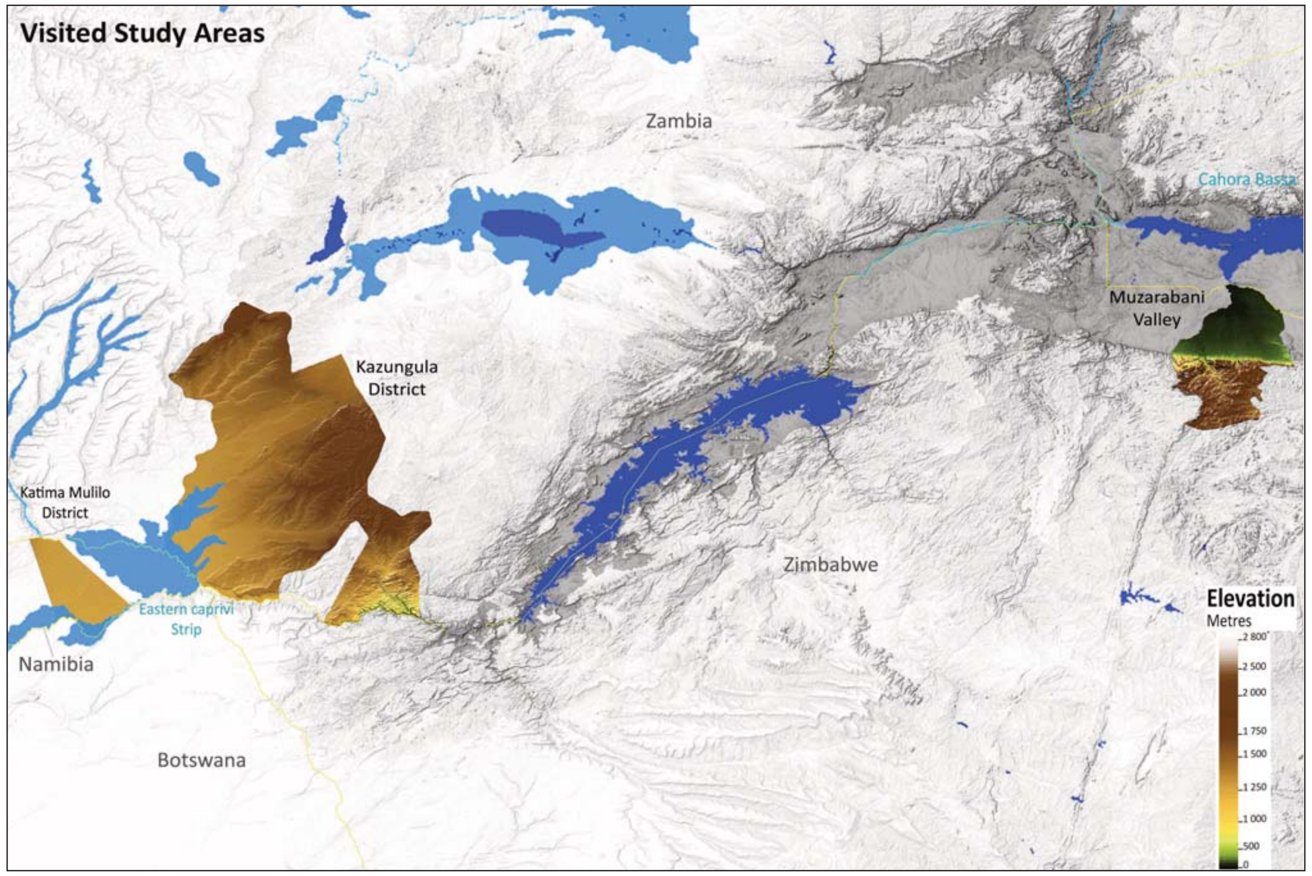
Figure 6. 1 Historical Flooding Events



(Source: SADC and ZRA 2007)

7. Community Views

Figure 7. 1 Study Sites Visited in the Zambezi Basin



Introduction

The study identified three areas within the basin that have been historically shaped by droughts and floods that were visited in order to get community perspectives and information on floods and droughts. Various settlements and villages in Kazungula area along Zambia-Botswana border, Katima Mulilo District in the Caprivi Strip, Namibia and the Muzarabani area North of Zimbabwe along the Zimbabwe -Mozambique border were visited. At all sites the researchers met locals and discussed the impacts and responses to the natural hazards in their communities.

The three areas are similar in their topography because they are located in low lying areas and have generally flat terrain. Muzarabani is unique because the south of the district is divided from the northern part by a mountain range that creats a sharp decrease in elevation. The northern communities are affected differently than the southern communities. The Kazungula and Katima Mulilo are influenced by the natural flow of rivers that create the extensive floodplain areas, whereas Muzarabani floodplain is heavily influenced by the Cahora Bassa and Kariba Dam reservoirs.

Eastern Caprivi Strip, Namibia

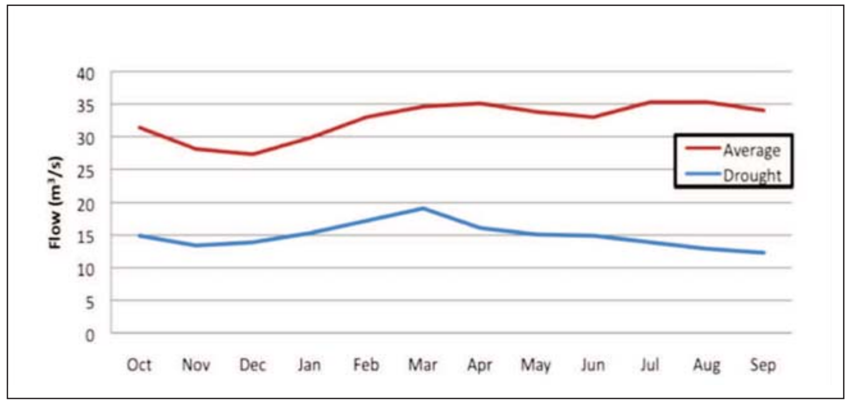
The Eastern Caprivi region is situated in the eastern most part of North-East Namibia. The entire region is exceptionally flat making it susceptible to flooding because of the very little drainage that the flat terrain allows for (DRWS 2000). A huge area of the Eastern Caprivi is made up of floodplains that have been a crucial resource for the surrounding settlers for several centuries (Hirji and others 2002).

Located in the Cuando-Chobe Sub-River Basin, area surrounding the flooding is regulated by the Chobe, Cuando and the Zambezi Rivers. During the early part of the flood season, the Chobe River conveys this runoff to the Zambezi River, and may contribute substantial runoff in some years. As Zambezi levels rise, however, the Chobe River reverses direction and flows back to the northwest where it discharges into Lake Liambezi (Beilfuss 2012).

Ngoma Settlement Area in Eastern Caprivi

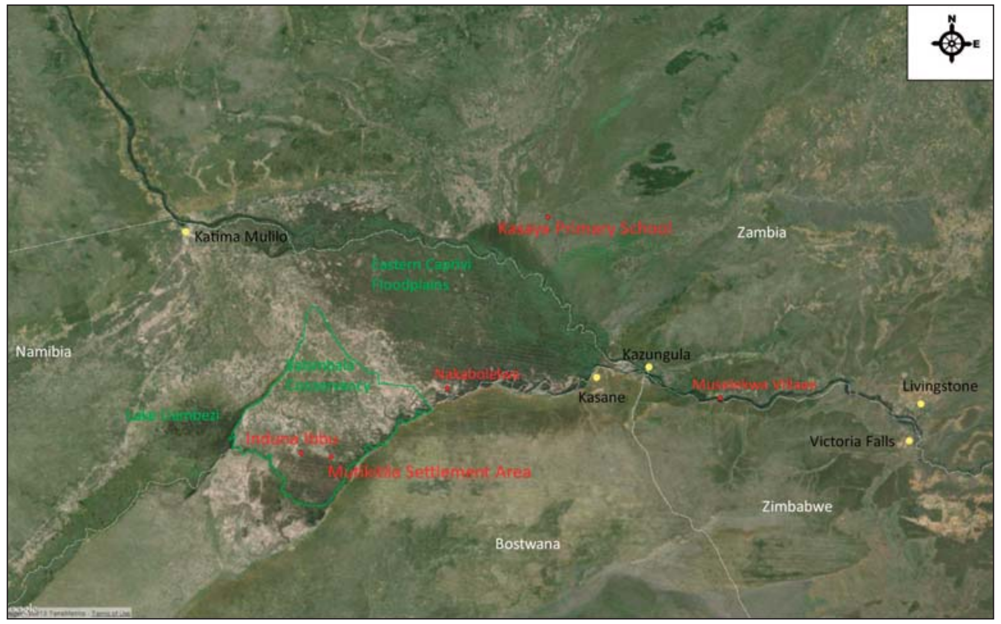
Experiencing frequent flooding the Eastern Caprivi is also prone to dry periods that negatively affect socio-economic activities. The 2012/ 2013 agricultural season was generally perceived as being normal season with prolonged dry spells. Discussions with representatives from the Ngoma Village District Council based in Salambala Conservancy revealed that the 2012/2013 season was characterised by dry periods. Rain started in November but was erratic throughout the season. Some of the elders noted that the climate pattern over the years has changed into more desert like conditions in areas that are historically not considered to be desert. Elders observed that the flow level of Zambezi River has been getting lower in the area. They also mentioned that several boreholes in the area that provide safe water are drying up quicker than usual

Figure 7. 2 Mean monthly flows in the Cuando/Chobe sub-basin



Source: Beilfuss 2012

Figure 7. 3 Communities visited in Kazungula and Katima Mulilo



Source: Beilfuss 2012

Nakabolelwa Settlement

Residents in the isolated Nakabolelwa settlement area reported that they are greatly affected by the erratic rainfall season compounded with the regular flooding in the area. Most of the activities that the women pursue in that area are negatively affected. Initiatives by government and other organisations introduced rearing of small livestock projects but these were difficult to pursue owing to lack of regular water sources. During the dry season majority of the women collect water from unsafe water sources such as dug-out wells because the school borehole is nonfunctional

A dug-out well that provides household water use

Small plots of crops scattered around the household. These are planted behind the tall grass reeds that are used to fence off homesteads.

Women in this area tend to deal with the prolonged dry periods by pursuing small scale projects such as baking scones, creating mats using water reeds, small plots of crops planted in the shade of the household complex. In the past they used to have floodplain gardens. However floodplain gardening has become less favourable because of the longer distances needed to be travelled to reach the wetter areas. A previous incident involving an attack of a local by a crocodile has discouraged women from going to floodplain areas because they do not feel safe.

One of the many boreholes and water tanks located throughout the Eastern Caprivi that provide safe water

Women reported that they felt left out as most of the relief coming from the government was geared towards provision of crops such as maize with less support for crops such as leafy vegetables and pumpkins that are more common amongst the women. Several respondents expressed the need for government to supply seeds for those crops.

When travelling through Salambala Conservancy, researchers observed that the secure boreholes that provide safe water tend to be located within the very immediate proximity of an Induna (headman) if not on the Induna's property. While targeting Indunas is an effective strategy to assure widespread water availability, most of them are men, no women have authority of the safest water source even if they have readily access.

Recommendations from Communities in Eastern Caprivi

The general feeling towards the droughts and floods within the visited areas of Eastern Caprivi Strip was that there is very little human activity that can be done to address the hazards although many ideas came out from the various discussions.

In terms of dealing with droughts, many respondents suggested the need to install pipes to draw water from the surrounding rivers. Water collection storage through the creation of reservoirs was also seen as a way to increase water supply during the dry periods. Respondents indicated that the floods bring much needed water but highlighted the need to capture it effectively. Another interesting suggestion was the need for governments to diversify drought relief by supplying drought-resistant variants of crops and different kinds of seeds so that the variety will improve household nutrition. For instance, mixing or intercropping maize with other crops such as beans to promote not only efficient labour utilization but also lessening the risk of total crop failure since chances were that if one of the crops succumbed to environmental stress others would survive. Mixed cropping or intercropping stabilizes yields, preserve the soil and make it possible to harvest different crops at the same time.

Kazungula, Zambia

Kazungula District is located in the southern part of Zambia with the southern most part of the district separated from Botswana and Namibia by the Zambezi River. The sites visited in Sikaunzwe community are prone to droughts and floods that have had devastating effect on communities in those areas. The area visited is a low lying area and receive flooding from the Ngwezi and Zambezi Rivers.

The 2012/2013 season was characterised by general dryness due to late onset of rains. Many of the respondents practiced agriculture and communicated reaping poor harvests compared to the previous season. In Kasaya community many relied on the local earth-field dam located at the Kasaya primary school. The water from this source is used for multiple purposes ranging from cooking, washing gardening. Although used by locals many elders were not comfortable of its safety. Yet women in the area heavily rely on the dam for their household use

A common strategy within the area to cope with the dry period amongst women was the cultivation of small gardens near the dam to produce crops for sale. Through government initiative a borehole was drilled next to Kasaya School. However communities raised concerns that the water was salty and not potable, despite efforts to drill deeper. Currently studies are being done to investigate these phenomena

Recommendations from Communities in Kazungula

Government and supporting organisations have provided communities with drought relief although the general feeling amongst the people was that these organisations should improve early warning systems for droughts and floods so they are better informed and prepared. Communities also felt that there is need to reinforce the local dam so that it can collect more water. Other construction that could be useful will be the installation of canals or water pipes to bring water closer to households so that women and children in the areas do not have to travel long distances to collect water.

Muzarabani, Zimbabwe

Muzarabani is in Mashonaland Central province of Zimbabwe, about 260 km North of Harare. The term Mzarabani in the local language means flood plain or an area that is frequently flooded (Madamombe 2004). It lies in the floodplains of the Zambezi River with Lake Kariba upstream and Lake Cahora Bassa downstream at the confluence of Musengezi and Zambezi Rivers. The first and most frequent type of floods is the seasonal flood. This occurs in most years normally in January or February and these extreme floods tend to affect the day to day activities of women and children because of the traditionally assigned roles. Due to its geographical position, the district is affected by Cahora Bassa Dam backflow, resulting in weak points along the tributaries bursting and flooding the low lying areas of Muzarabani district where people are settled (Tauya 2014).

Group discussion with Chief Chadereka and his household revealed that over the years Muzarabani has been experiencing more extreme climatic events. The dry seasons tend to be longer and there are more floods that come from the tributary backflows. During the 2012 season the rains came late in December and lasted for only few weeks. They however reported that the annual flooding tends to bring some relief.

In many cases families lost their valuable livestock because of the lack of water. Livestock hold a very important place in household economics for many families in Muzarabani. In the valley area of the northern district, families tend to exchange their livestock for grain or sell to communities in the southern part of district as a form of survival. The droughts and floods that affect livestock greatly impact livelihoods.

Birds as indicators of rain or floods occurrence

Some informants interviewed during the site visits mentioned that when a bird known as *dzvotsvotsvo* (rain bird) starts to sing, it warns them that heavy rains will fall in the next hour or two. Those herding cattle would start going back home and those who had crossed the rivers would start crossing back before floods may occur. One informant reported that when swallows (*nyenganyenga*) lay eggs on raised patches in the river valley that is a sign of floods approaching. Farmers then would avoid planting in the flood plains. The opposite is true when the swallows breed on the ground under cover of grasses and reeds, signifying low rainfall to drought conditions. Farmers would then do early planting in river valleys and wetlands as well as growing drought tolerant crops such as sorghum, rapoko and pearl millet on the greater part of the field. Another informant mentioned that if chickens wonder around during the rains it means the rain is not going to stop soon. It will be what they call *mubvumbi* (drizzle) which can last for two to three days. In such cases floods are likely to occur in the low lying areas. They will then prepare moving to high grounds.

Another coping strategy is the use of wild fruits such as *muchakata (Parinari curatellifolia), muzhanje (Uapaca kirkiana or wild loquat), musekesa (Piliostigma thonningii)* and *Parinari curatellifolia* fruits. Some of these wild fruits are used to bake cakes, their residue was mixed with boiled water to make a tea substitute, and the pulp was crushed to make porridge and *mahewu* – a common sweet brew. In several of the households visited, women had sacks full of the popular *masau (Ziziphus mauritiana)* which is dried and crushed to be used as an equivalent or supplement for crushed grain.

Some communities reported the need to revive the traditional way of forecasting for early warning preparations. They mentioned the use of animals, birds, insect and atmospheric elements such as observing the moon, wind and sun. They were concerned that this knowledge is disappearing and very little is being done to make use of it. The box below provides an example of how birds were used to predict climate events.

Recommendations from Communities

Locals expressed support for the timely Kariba flood gate opening warnings coming from the ZRA which has improved their ability to prepare for the floods. Locals have also benefitted from housing initiatives and the creation of safe-havens in the upper land areas. However many areas still remain inaccessible after previous floods damaged transport infrastructure. Locals recommended the refurbishment of those structures and development of new roads. Locals raised the issue of having food exchange programmes with the government which will involve government support in the way of agricultural supplies, infrastructure and transport to encourage cultivation of selected small grains that can be sold to the Grain Marketing Board.

Communities reported the need to improve in preserving the wetlands in their communities. Wetlands have been regarded as source of food in times of famine. They used them for growing rice, and yams, thus keeping the, moisture in the soil. The vegetation would control erosion as the roots hold the soil and trap sediments. The wetlands were kept in such a way that they would continue to act as sponges during the rainy season sucking the water which will then be released during the dry periods. Wetlands would therefore play an important role in flood control and erosion prevention.

Communities recommended the need to revive IKS on early warning systems in schools. They were concerned that elders are no longer passing on this important knowledge to the new generations. As such the best way to preserve the IKS is to document it in different materials such as fact sheets, newsletters, special reports, posters and brochures, as well as making IKS part of school curriculum

Indigenous Knowledge Systems

Indigenous Knowledge Systems (IKS) is the local knowledge unique to a given culture or society, and can be described as the sum of facts that are known or learned from experience or acquired through observation and study which are handed down from generation to generation (Manyatsi 2011; UNEP 2008). This knowledge is originated locally and naturally as a result of the intertwining relationships among people, animals and the earth (Mapara 2009).

IKS has been critical in natural resource management, sustainable livelihoods and community responses to natural hazards. Families across the region have adopted techniques such as drying foodstuffs, building granaries to stock grain (Chenje 2000). Communities in the Zambezi River Basin have used IKS to develop systems of gathering, predicting, interpreting, and decision-making in relation to weather (SARDC and HBS 2010). A study in Malawi and Zimbabwe, for example, showed that farmers were able to forecast weather by observing various changes. Farmers would note the timing of fruiting by certain local trees, the water level in streams and ponds, the nesting behaviour of small quail-like birds, and insect behaviour as indicators to predict the weather (SARDC and HBS 2010).

Incorporating indigenous knowledge into the climate change policies can lead to the development of effective adaptation strategies that are cost-effective, participatory and sustainable (Robinson and Herbert 2001).

Zunde raMambo Concept

Incorporating IKS strategies will involve reviving traditional safety nets such as The Zunde raMambo Concept in Zimbabwe. This is a traditional concept meant to boost the chief's grain reserves which will be used to help those in need, and also feed the guests whenever the chief hosts a function at the compound (Tauya 2014). The concept of having mazunde in each village and where possible household zundes will encourage families to sustainably manage their harvests so that they will not have to depend on food hand-outs for survival in drought seasons (Tauya 2014).

8.Conclusions

Key findings from the study

Key findings from conducting the research for this study are;

1. SADC conducts extensive research and monitoring of climate conditions through its various climate initiatives. However information linked to floods and droughts collected from national and regional institutions in not readily available.
2. The Zambezi basin has been predicted to face some of the worst potential effects from climate change amongst other African River Basins.
3. Short dry spells during the October to November and late onset of rainfall in previous seasons has negatively affected household food security and livelihoods.
4. Indigenous knowledge and local observations have noted long-term-changes in the environment and the climate. Yet there is little integration of such knowledge with current scientific disaster management strategies. Most national disaster management strategies are silent on integrating IKS.Community initiatives tend to leave women on the periphery. Most disaster management strategies in the basin are not gender sensitive.
5. There is still limited information on rise in sea level for the Zambezi Delta at local level such that data is based on global sources. See level rise could affect the delta through backwash flooding.
6. Until recently most strategies in southern Africa focused on disaster relief and not prevention. The basic goal was to alleviate the immediate suffering of victim as the way of thinking was that dealing with disasters was a logical exercise involving the supply of emergency relief, with the result that the people affected were seen as helpless, needy victims and were treated as passive recipients of external aid. With this approach the root causes of people's vulnerability are overlooked.

7. Due to focussing on the responsive approach (needs- based approach) many communities have developed a dependence syndrome for survival even after the disaster. This approach has led some communities to define themselves as having only deficiencies to the point where they can no longer identify anything of value around them. They have come to believe that only a state of degradation will enable them to attract resources. The net result of the needs-based approach is that vulnerable citizens are left even more vulnerable when the next crisis arrives because they have traded self.

Policy options in relation to floods and drought

1. **Incorporating IKS in strategies**
   From where IKS is incorporated into disaster management plans, it has proved very useful and effective in improving the strategies. Incorporating IKS into policy strategies provides for good local solutions which come from and are understood by communities. It gives more opportunity for community participation and positive organisation in disaster preparedness and response. It empowers people particularly marginalised groups such as older people and women as well as lowering dependence on outside help. IKS online programmes such as that by UNEP could be developed for the Zambezi basin. The programme contributes to information on IKS in reducing vulnerability to floods and drought, increase community and public awareness of the risks associated with natural, technological and environmental hazards

2. **Strengthen existing institutional arrangements for dealing with floods and droughts by including women at all levels**
   Existing Early Warning Systems (EWS) can be strengthened by integrating IKS concepts. Communities throughout the basin have often relied on observing flora and fora to forecast weather. Visits to the study sites showed that information tends to go through men as the head of households especially warning forecasts. EWS can be improved by including women at all levels of information dissemination especially within local structures where women are most affected by the different hazards. Further improvements should include strengthening dissemination of information to communities through tools such as the community radios in Zambia known as the RANET system.

3. National Climate Change Responses Strategies being developed at the National level, such as in Zimbabwe, should be guided by and speak to the SADC Climate Change Strategy that is currently being finalised.

4. Cultivating various drought resistant crops such as finger millet rukweza, sorghum mapfunde and pearl millet mhunga helps reduce vulnerability. The use of traditional methods to preserve grain such as use of Mopani leaves, twigs of mutsambe tree ashes of muchinarota tree and a lot of grain hundi residues to protect the grain storage from termites**.**

5. **An integrated infrastructure and non-structural approach should be initiated.**
   Structural strategies could include the installation of canals and water pipes in order to transport water to drought prone areas. Construction of temporary houses located in higher grounds should be part of the strategy. Many locals are willing to engage in food exchange programmes which involve the cultivation of certain crops in exchange for food crops during the drought periods

6. **Relief agencies and governments should give equal prominence to prevention as is given to response**
   DRR are the measures, policies, frameworks or strategies taken to prevent, mitigate, manage or reduce impacts of disasters which often take a multi-disciplinary approach. Governments and relevant agencies such as the International Committee of the Red Cross (ICRC) should incorporate DRR concepts into their operations furthermore governments where possible should work across borders to coordinate and align DRR policies.

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