

# Overview Report pertaining to the Okavango Basin and the Upper Zambezi Basin



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## Executive Summary

Demands for water and land for cultivation is increasing in Africa, with concomitant degradation of river and other aquatic ecosystems. Management of scarce water sources, especially in developing countries with data-poor arid regions, poses significant challenges. The Kavango, Cuito, Cuando (Kwando) and Zambezi Rivers arise in the Angolan highlands or in northern Zambia, and display a variety of spectacular ecosystems such as floodplains, dambos, swamps and forests. The Okavango River is one of the most pristine systems in southern Africa, while the Upper Zambezi River remains relatively free from dam construction. Biggest future threats come from hydropower initiatives in the upper reaches of the Okavango and Zambezi Rivers in the Angolan, Namibian and Zambian head streams due to predicted future water shortages in Namibia, Botswana and Zambia. Altered flow could result in localised species extinctions coupled with changed community function and consequent bush encroachment, as well as reduced food security for communities depending on food provisioning services of the rivers and their tributaries.

More research is needed for the two rivers and their tributaries. Scant information exists regarding the Upper Zambezi (and its tributaries), the Cuito and the Cuando Rivers in terms of hydrology, biodiversity, ecosystem health, and socio-economic circumstances of people dependent on them. Cuando-Cubango Province in Angola has been excluded from recent economic development largely due to landmines and the remoteness of the region. This resulted in the area being largely inaccessible for not only research purposes, but for irrigation and hydropower schemes.

The potential for conflict is great, with increasing pressure on riparian governments to develop the relatively pristine rivers in order to address socio-economic needs in the basin. Angola – with four times as much rainfall as Botswana – has few challenges in terms of water supply but many in terms of reerecting a decimated infrastructure for a disenfranchised population. Angola's focus is thus on economic development, especially in the agricultural sector. Namibia on the other hand is the driest country in Sub-Saharan Africa, and has great need of the water that flows in the Okavango and Zambezi Rivers. Botswana derives the most economic benefit from Angolan waters, however its mining and agricultural sectors are heavily dependent on water and the country is facing water shortages in future. Water abstraction in the upper reaches of the Okavango as well as in the Upper Zambezi, would have significant impacts on the fauna, flora and rural communities that depend on the rivers' resources for survival. It is encouraging to note that riparian States are working together with research institutions and NGOs in designing and implementing Integrated Management Plans for their shared water resources.

## List of Acronyms

CBNRM	Community Based Natural resource Management
DEA	Department of Environmental Affairs
ER	Ecoregion
ERHIP	Every River has its people
EU	European Union
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GMA	Game Management Area
HOORC	Harry Oppenheimer Okavango Research Centre
IFA	Integrated Flow Assessment
ITCZ	Intertropical Convergence Zone
IWRM	Integrated Water Resource Management
NP	National Park
ODMP	Okavango Delta Management Plan
ODIS	Okavango Delta Information System
OKACOM	The permanent Okavango River Basin Commission
RAMSAR	Wetlands of International Importance
SADC	Southern African Development Community
SafMA	Southern African Millennium Ecosystem Assessment
TDA	Technical Diagnostic Analysis
UNCBD	United Nations Convention on Biological Diversity
UNEP	United Nations Environment Programme
WERRD	Water and Ecosystem Resource Development – Balancing Societal needs and Wants and Natural Resource Systems Sustainability in International River Basin Systems
ZACPLAN	Zambezi River Basin Action Plan
ZAR	Zambian River Authority
ZBWCRUP	Zambezi Basin Wetlands Resource Conservation and Utilization Project

## General Introduction

In a rapidly developing world, the wise management of ecosystems is of global importance (King & Brown, 2009, 2006). Developing countries especially face having to support international conservation goals, while meeting food security and developmental needs of large rural populations. The Millennium Ecosystem Assessment (2005) hoped to tackle the rapid degradation of the world's ecosystems by evaluating not only ecosystem integrity, but the goods and services provided by them.

Mittermeier *et al.* (2003) state that the miombo-mopane woodlands are one of five ecozones (together with Amazonia, Congo, New Guinea and the North American deserts) which needs to be prioritized for biodiversity conservation due to high species endemism. Miombo woodlands occur to a significant extent (2.4 million km<sup>2</sup>) in southern Africa, in countries such as Zambia, Zimbabwe, Malawi, Angola, Mozambique and Tanzania. More than half of the Zambezi Basin is covered by Miombo woodland. The woodland is typified by the presence of species such as *Brachystegia*, *Julbernardia* or *Isoberlinia*, *Colophospermum mopane* and *Baikiaea plurijuga*. The Zambezian biome (95% of Zambezi basin) comprises woodland, grassland, swamps and lakes – with miombo-mopane or Acacia woodland predominating. Miombo woodland is not particularly species-rich, but it is of major economic importance to those dependent on its natural resources. However, pockets of vegetation types with restricted distribution and high *conservation* interest occur, and include the dry forests of Barotseland on Kalahari Sands (Timberlake, 2000).

Two of the most significant River Basins in Southern Africa are found within this Miombo-Mopane region: the Okavango and Zambezi Rivers, and their tributaries, are lifelines in an otherwise semi-arid region. These rivers provide fisheries, floodplain agriculture, natural services and products, aquifer replenishment, water quality improvement in polluted sites, and high biodiversity to rural and global communities alike. According to Skelton (1994), the Okavango and Zambezi Rivers were once connected - the early tertiary drainage of the confluent Cunene, Okavango, Upper Zambezi and Kafue Rivers flowed in a south westerly direction until draining into the ocean near the current Orange River mouth. This accounts for many of the faunal similarities. The Okavango Delta is a Wetland of International Importance in Botswana, while the Zambezi Basin contains ten wetlands, of which the Barotse Floodplain, among others, is listed ([www.ramsar.org](http://www.ramsar.org)).

Wetlands are not only associated with the people that depend directly on them to sustain their livelihoods, but they also have global benefits – for example in their role in climate regulation. In spite of their importance, wetlands have been under increasing pressure from economic perspectives – developments in agriculture, hydropower and irrigation schemes threaten to disturb and irreversibly alter these fragile ecosystems. Wetlands have been undervalued by decision makers, and it is for this reason that wetland loss was until very recently seen as a minor cost when compared to future benefits from developmental activities (Seyam *et al.*, 2001). Reasons for wetland loss included lack of financial

incentive for wetland preservation, individual preference for cultivation of land and inconsistencies in governmental policies regarding wetland conservation. Yet ecosystem services provided by rivers and floodplains sustain life in Africa's rural communities through the provisioning of goods and services.

The Millenium Ecosystem Assessment lists freshwater services provided by rivers and wetlands as follows:

*1. Provisioning services*

- consumptive use including drinking, domestic, agricultural and industrial use
- non-consumptive use including power generation, transport
- aquatic organisms for food and water

*2. Regulatory Services*

- Maintenance of water quality
- Buffering of floods and erosion

*3. Cultural Services*

- Recreation
- Tourism
- Existence Values

*4. Supporting Services*

- Role in nutrient cycling and primary production
- Predator/prey relationships
- Ecosystem resilience

The Southern African Millenium Ecosystem Assessment (SAfMA) evaluated trends in ecosystem services such as food, fresh water, fuel-wood, cultural and biodiversity in the Southern African Development Community (SADC) region. It reports that freshwater resources across the region appear strained (van Jaarsveld *et al.*, 2005). The provision of fresh water is a critical ecosystem service which is vital for human sanitation and survival. Other important economic sectors depend on freshwater (agriculture, industry, tourism), while ecosystem processes depend on river health for proper functioning (flooding events regulate fish recruitment, which in turn affects the subsistence fishing sector). The "goods and services" provided by the Okavango and Zambezi Basins, such as water purification and supply of food and timber are inextricably linked to the well-being of rural communities, whose livelihoods depend on River health. Polluted water (from mining, fertilizer and other industrial activities) further affects ecosystem health, while water-borne pathogens/illnesses such as diarrhoea, helminths, cholera, trachoma and bilharzia are a major cause of debilitation among rural children. The degradation of freshwater ecosystems through siltation, pollution and land clearance contributes to a decline in fish stocks - already reports are being made of fish stocks declining in the Zambezi Basin, which significantly impacts rural communities dependent on fish for protein as well as income. The risk of episodic flooding, and water storage capacity and thus seasonal water availability are further concerns.

Sub-Saharan Africa is considered by the Food and Agriculture Organisation (FAO, 2002) to be the most food-insecure region in the world (Table 1), and many rural communities are subsistence farmers vulnerable to fluctuating food security. SAfMA found that food



insecurity was multi-dimensional, listing social, health and economic challenges such as Aids, access to markets and distribution challenges as some of the factors compounding the issue (Biggs *et al.*, 2004). Climate variability also impacts livelihoods, with cattle and plant products directly dependent on water access, available land and soil fertility.

81% of protein consumption in rural households comes from plant sources such as cereals, with domestic animals constituting 14%, and fishes 4%. Wild plants and animals play an underreported role in food security, due to the absence of reliable records. This is exacerbated by the illegal bushmeat trade, which is said to be increasing in the region due to policy constraints and lacking support for programmes aimed at sustainable resource management (Scholes & Biggs, 2004). Biggs *et al.* (2004) state that future threats to water availability include growing human populations, increased water abstraction for individual households and industry, climate change and water policy.

The SafMA report revealed that ecosystem services such as recreational, spiritual and aesthetic values were highly valued by all populations at multiple scales. While the ability to measure these less tangible ecosystem services is still inadequate, nature-based tourism is increasingly quantifiable. Southern Africa has a wealth of biodiversity, which is not only an ecosystem service in its own right, but also underpins other important services such as tourism, traditional medicine and rural food security. Biodiversity is also integral to regulating ecosystem processes such as nutrient cycling and carbon sequestration.

Tourism to the wilderness areas of the Basin States has an important role to play economically, as well as environmentally: tourism to Botswana's wilderness areas is the second largest contributor to the country's GDP after diamonds. The Zambezi and Okavango Basins contain some of the World's most exciting wilderness areas, including one of the seven World Wonders – The Victoria Falls, as well as Wetlands of International Importance, National Parks of incredible wildlife such as Chobe NP, Luangwa NP, Kafue NP, Liuwa NP, which is witness to the second largest wildebeest migration in Africa after the Serengeti/Mara. Angola's wilderness (and thus resource extraction) potential is massive, but due to a lack of infrastructure and post-war minefields, remains largely inaccessible.

The incentive to protect and sustainably manage the health of the River Basins is of global as well as national interest, directly impacting human wellbeing at multiple scales.

The main purpose of this overview report is to collate information regarding Freshwater Services, Food Security, Natural Resource Management and Governance, as well as Payments for Ecosystem Services (PES) for the Okavango and Upper Zambezi River Basins, with specific attention given to the Cuito River sub-system, the Kwando River sub-system, and the Zambezi River northwards of Katima Mulilo/Sesheke. The Terms of Reference and Key Deliverables are set out in Annex 1.

However, it must be noted that there is a serious paucity of information regarding water quality, biodiversity, hydrology and socio-economics of numerous sub-catchments, including the Cuito and Kwando (Cuando) Rivers (Table 1). Thieme *et al.* (2005) note that in the following ecoregions, data quality is: low for the Zambezian Headwaters (ER 76) and medium for the Upper Zambezi Floodplain (ER 16), while it is high for the

Okavango Floodplains (ER 12). This is particularly the case for Angola, and Zambia. For the entire region, information regarding economic assessments of ecosystem services is based on the only available, and comprehensive, reports, both conducted by Turpie *et al.* (1999, 2006), while a biodiversity assessment of the Zambezi Basin by Timberlake (2000) proved most useful.

It is in the interest of the global conservation community as well as those tasked to manage ecosystem health to evaluate the good and services provided by wetlands and the extent to which they satisfy human need, in order to present a conservation case to relevant decision makers. Information gaps such as those regarding the Okavango and Zambezi catchment area in Angola and northern Zambia should be addressed as a matter of urgency, especially with regard to the impacts global warming will have on food security, and inevitably on the conservation of rangeland for wildlife.

**Table 1:** People living in southern Africa suffer from high poverty levels (Source: [www.unep.org](http://www.unep.org))

<b>Country</b>	<b>HDI* Rank (177)</b>	<b>HPI**Rank (102)</b>
Botswana	131	90
Mozambique	168	94
Namibia	125	57
Zimbabwe	151	88
South Africa	121	53

Notes \* Human Development Index, \*\* Human Poverty Index



# Okavango Basin





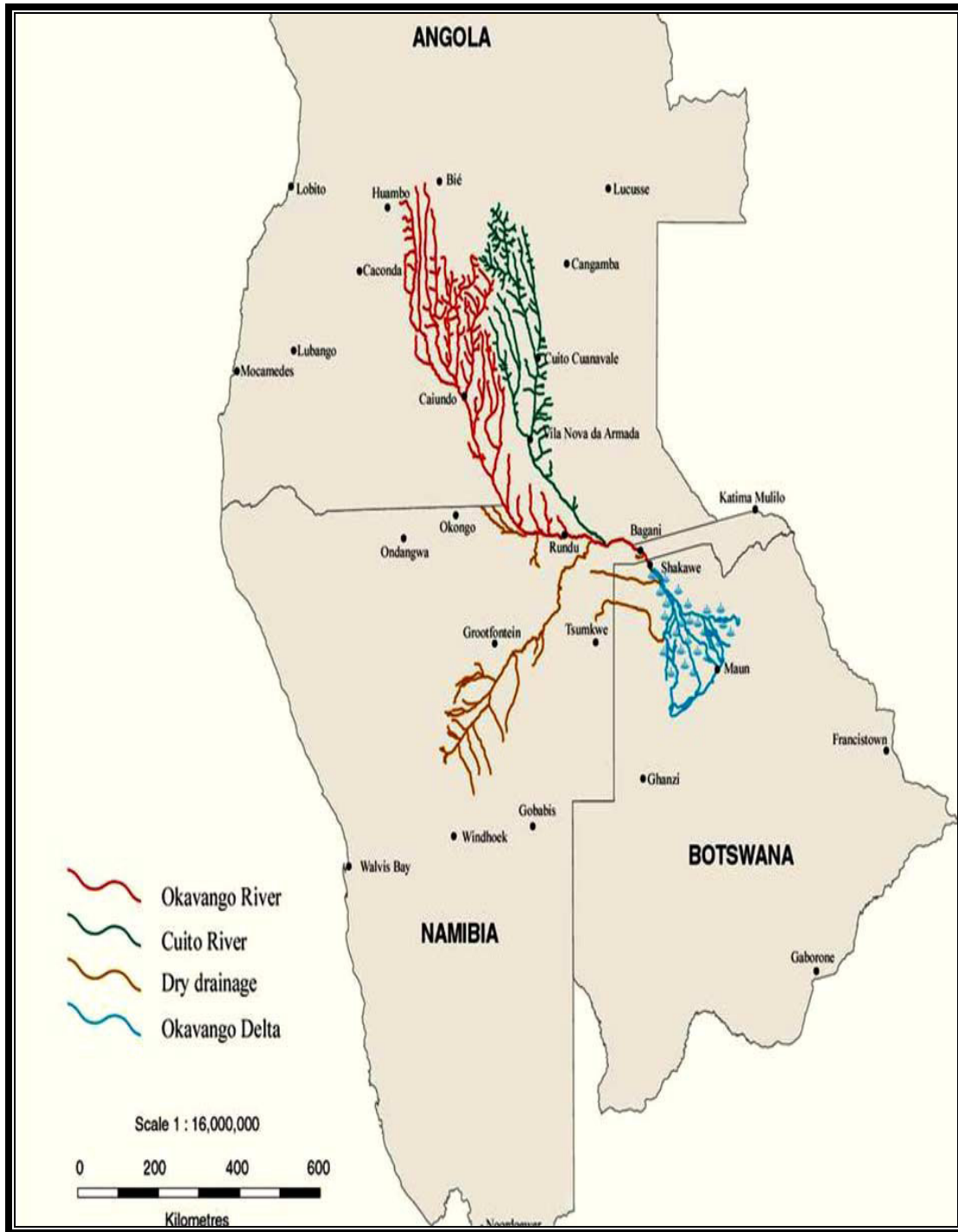
### 1.1 Location and extent:

The Okavango Basin is one of the least impacted freshwater ecosystems in Africa. It covers an area of 192 500 km<sup>2</sup>, discharging about 9.4 cubic kilometres of water into the Okavango Delta each year. The Okavango Basin contains the largest expanse of wetlands in southern Africa (Thieme *et al.*, 2005). It comprises the Cuito and Cubango active catchments (110 000km<sup>2</sup>) in the Cuando-Cubango Province Angola, and the non-active Kavango-Okavango catchments in Namibia and Botswana. In Angola, the western Cubango sub-Basin consists of the following rivers, which join to form the Cubango/Okavango River: Cubango, Cutato, Cuchi, Cacuchi, Cuelei, Cueba, Cueio and Cuatir. The Cuito sub-Basin consists of the Luassinga, Longa, Cuiriri, Cuito and Cuanavale Rivers, which merge and become the Cuito River before its confluence with the Okavango River (Mendelsohn & el Obeid, 2004). The active catchments of the Cubango and Cuito cover 66 300 and 44 950 km<sup>2</sup> respectively.

The Cubango (Okavango/Kavango) River's headwaters arise on the Benguela Plateau in the central highlands of Angola. Sandy terraces and floodplains are typical of the Cubango River, where little subsistence agriculture practised. The Cuando Cubango Province covers an area of 200 000 km<sup>2</sup> (Porter & Clover, 2003). The area supports low numbers of people in its lower reaches, although the upper reaches particularly around the headstreams are densely populated (Kgathi *et al.*, 2006). The Cuito also arises in the Angolan Highlands, and is a system comprised of extensive areas of linear swamps, with its drainage area largely unpopulated due to the war and its remoteness (Kgathi *et al.*, 2006). The Cuito nearly doubles the annual flow of the Okavango River, and plays a major role in the downstream fish populations. In dry years, flows in the Cuito are unreliable and drop to very low levels.

The Cubango and Cuito rivers converge at Katere 100km from Rundu, and flow south easterly, entering Namibia at Kitwitwi, becoming the Kavango River before flowing into Botswana (Figure 1). Here the Okavango River drains 5-16 Mm<sup>3</sup> (million cubic metres) of water per annum into the riverine floodplains (known as the panhandle), before fanning out into the numerous channels of the Okavango Delta in Ngamiland District, north western Botswana (Turpie *et al.*, 2006). 45% of water flowing into the Delta comes from the Cuito River, 55% from the Cubango/Okavango River (Mendelsohn & el Obeid, 2004). The permanent swamp covers 6000-8000 km<sup>2</sup>, and with the arrival of the annual flood waters from Angola, the inundated areas expand to 12000-15000km<sup>2</sup> (Thieme *et al.*, 2005).

The largest Ramsar site in the world, the Okavango Delta occupies 4 per cent of the basin. It is a renowned natural wonder – ecotourism is the second biggest contributor to the countries GDP after diamond mining. The delta is drained by the seasonal Thamalkwane River. This flows in south westerly direction from the north-east, passing through the town of Maun. During high rainfall events, the river can flow as far as Lake Ngami and into the Boteti River. Some outflow may occur via the Selinda Spillway and the Linyanti Swamps. The extent of flooding depends on rainfall in Angola, evaporation rates and degree of flooding from the previous year.



**Figure 1:** The Okavango Basin. Most tributaries in Namibia and Botswana are either totally dry or infrequently ephemeral (Source: Mbaiwa, 2004).

## 1.2 The Physical environment

**Table 2:** Area statistics of the countries comprising the Okavango Basin (Source: Ashton & Neal, 2003).

<b>Basin Country</b>	<b>Component catchment area (km<sup>2</sup>)</b>
Angola	151 200
Botswana	
River only	58350
Direct Rainfall onto Delta only	15 844
Namibia	123 560

### 1.2.1 Topography

The Okavango River System has an average altitude of 940-1700m above sea level. The Cuito headwaters lie at over 1500m, whereas the confluence of the Cuito and Okavango lies at 1000m above sea level. Gradients are steepest in the northern part of Angola, and shallowest in the Okavango Delta in the south. The wetlands of the Basin are divided into six forms, with Valleys, Floodplain Valleys and Valley marshlands found mostly in Angola and Namibia, and the Panhandle, Permanent swamps and Seasonal Swamps in Botswana (Mendelsohn & el Obeid, 2004). Sand predominates in the catchment with the result that river water is clear and clean, with low mineral and mud content. 170 000 tonnes of sand are transported from the headwaters in Angola to the Delta each year. Due to the low nutrient levels of the water and water retention properties, much of the basin is not considered good for crop cultivation. Some areas in the Delta however are the exception, and have good quality soils.

Soil erosion is not considered a major threat in the Delta due to the flat topography. The low topographic gradient in the Delta causes low flow velocities. Peak flow from the upper basin reaches northern Botswana by April and the lower limits of the Delta by August.

### 1.2.2 Climate

The Okavango Basin straddles sub-humid climactic zones in Cuando Cubango Province in Angola, and arid climatic zones in Namibia and Botswana, with a rainfall gradient that decreases from the high altitudes of Angola to the lower altitudes of the Delta in Botswana.

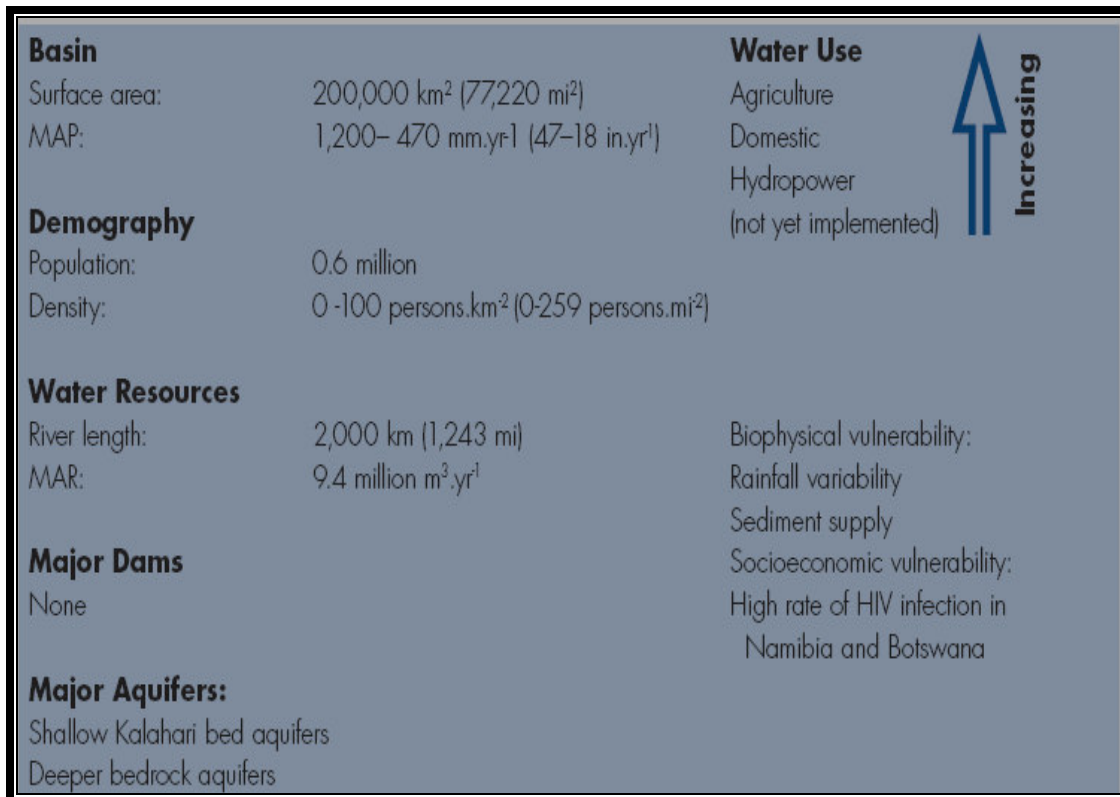
The Inter-Tropical Convergence Zone (ITCZ) affects the Basin's climate by transferring moist air from the north, bringing rain to the northern regions of the Basin earlier. High pressure anticyclone cells in the south interact with the ITCZ, bringing dry air to southern Africa.

The semi-arid region experiences hot, wet summers and cold dry winters. Rain falls between November and March, with an average of 500mm per annum. Rainfall is sporadic and there is a high risk of draught conditions (Turpie *et al.*, 2006). The annual average rainfall in the highest areas of the catchment is over 1,200 mm, whereas it is only 450 mm (18 in) in Maun. Rainfall peaks in the north in November and December, and in March and April. Humidity is highest during the rainy season, particularly between January and March. Rainfall becomes more variable and unpredictable in the southern regions of the basin, limiting crop growth.

Depending on rainfall in Angola, floods in Namibia start during December, reaching their peak in March/April, and subsiding by May.

Evaporation is about 5-6 times higher than rainfall in the Delta due to its position in the semi-arid Kalahari Desert, with 96% of water entering the Delta lost to evaporation (Mendelsohn & el Obeid, 2004). Rainfall from the Angolan catchment (600km away) reaches the panhandle by about April.

Warm conditions prevail in the Basin throughout the year, with annual temperatures averaging around 20 degrees Celsius, increasing towards the south.



**Figure 2:** Okavango Basin Statistics (Source: Mendelsohn & el Obeid, 2004, OKACOM, 1999)

### 1.2.3 Natural Environment

Dense stands of Miombo woodlands occur in the Angolan part of the Basin, decreasing in density with aridity gradients towards the south. The wetter, northern regions of the Cuando Cubango are covered by grassland (*Loudetia simplex*) and are interspersed with thousands of small streams surrounded by swampy marshes. Further south in the drier regions of the province, *Burkea-Brachystegia* woodland predominates (Mendelsohn & el Obeid, 2004). The eastern sections of the Cuito and the western sections of the Cubango are dominated by floodplain vegetation, with mixed woodland, grassland and floodplain grasses being more common to the Cubango (Kgathi *et al.*, 2006). Due to population densities being very low, the area is relatively pristine, much like the Okavango Delta. However most wildlife in Cuando Cubango was eradicated during the war and National Parks have been abandoned. Satellite data however is suggesting that elephants are slowly returning to Luiana Partial Reserve in the south east.

Hocutt *et al.* (1994) divided the River into 4 zones: From Katwitwi to Kasivi, shallow water and rocky substrates dominate, while from Kasivi to Mbambi, floodplains, oxbow lakes and backwater habitats are dominant. From Mbambi to Popa Falls, rapids on a substratum of sand and gravel, with large boulders typify the landscape, while the zone from Popa Falls to the Namibia/Botswana border forms the beginning of the Panhandle, featuring large floodplains.

In Namibia, the Kavango River forms the northern border of the Kavango District. The southern Bank of the Kavango, as it becomes known here, is densely populated and heavy, traditional cultivation as well as large scale, irrigated agriculture is practised. Riverine forest survives in pockets in less populated areas (Kgathi *et al.*, 2006). Birdviewing has been noted as a significant tourism activity in Kavango – specifically around Popa Falls and Mahango Game Reserve. Due to a lack of infrastructure and Community-based Natural Resource Management (CBNRM) initiatives, this potential remains to be exploited (Kgathi *et al.*, 2006).

In Botswana the Okavango flows through the 100km long Panhandle before fanning out in the Delta proper. During high flow years, water is carried by the Boteti River and to the Makgadikgadi Pans. To the south east, the river forms a permanent swamp before branching out into numerous channels. The Okvango Floodplains are listed as a vulnerable ecoregion (Thieme *et al.*, 2005) as it contains the largest expanse of floodplains in southern Africa, with the Delta being one of the largest endorheic deltas in the world. The Delta consists of three ecotypes: permanent swamps (channels and lagoons), seasonally inundated areas and drier, higher land masses, with papyrus (*Cyperus papyrus*) dominating the deepest waters

The Okavango is an exceptionally nutrient-poor wetland as the Kalahari sands that underlie both the delta and most of the catchment area have low nutrient levels. Grasslands, savannah and shrubland cover 91 per cent of the basin, with forests covering just 2%. Woodland, including *Brachystegia*, *Mopane* and *Acacia*, cover the rest of the basin (WRI 2003).

Tourism is focussed around the drier landmasses, or “sandveld tongues” - Chief’s Island is the biggest of these, and is located centrally. Strictly controlled hunting quotas have kept wildlife numbers stable in Botswana. Protected areas in the Okavango Basin include Moremi Game Reserve in Botswana, and the Mahango Game Reserve in Namibia.

The Okavango floods seasonally. Flooding is one of the most important ecological processes of the Okavango, determining fish distribution and recruitment, with spawning occurring in the floodplains in the oxygen-and nutrient laden floodwaters.

Fish populations in the Basin are small due to the low nutrient levels. However, over 80 species of fish have been recorded. Bream (*Oreochromis andersoni*, *O. macrochir*, *Tilapia redanlii*, *Serranochromis* spp), cat fish (*Clarias* spp) and tiger fish (*Hydrocynus vittatus*) dominate, while three fish species (ocellated spiny-eel, largemouth squeaker and broad-headed catfish) with restricted distribution in scarce rocky habitats have been recorded (Skelton, 1993). Fish density is highest in the panhandle, decreasing towards the delta edges, while the floodplains and seasonally inundated areas provide important fish breeding habitat. Flooding provides fish larvae with important nutrients. When flood waters recede trapped fish provide an important food resource for people and animals. (Mendelsohn & el Obeid, 2004). Skelton (1994) has noted that a high proportion (55%) of the fish species recorded in the Cunene and the Okavango are common to both rivers. The Delta supports about 1300 plant species and 115 mammal species, with high numbers of elephant and buffalo contributing 73% of herbivore biomass. The Delta is an important dry season refuge for large numbers of elephant – in 1999 for example numbers doubled from 12847 in the wet to 30971 in the dry). Lechwe is the most abundant mammal in the delta – estimated at between 50-60000 by Mendelsohn and el Obeid (2004). Considerable numbers of buffalo, hippopotamus, giraffe and tsessebe are also found. Mammals are restricted to the Delta by a veterinary fence. The Okavango supports a rich bird fauna, with more than 500 species recorded in the Delta (Mendelsohn & el Obeid, 2004), including the rare Wattled Crane (*Grus carunculatus*) and Pels’ Fishing Owl. The region is also a breeding site for the vulnerable slaty egret (*Egretta vinaceigula*).

### 1.3 Socio-economic conditions

Poverty levels in the Basin are high, and many people rely on the Basin’s resources to support their livelihoods (Kgathi *et al.*, 2006). Arable farming, livestock, fishing, tourism and craft making constitute the major sources of income in the Okavango Basin. Approximately 52 per cent of the Basin is not populated, with 30 per cent of the population residing in the 4 main towns of Menongue, Cuito Cuanavale, Rundu and Maun (Mendelsohn & el Obeid 2004). Urban areas in Botswana are the most densely populated, while urban settlement density remains low in Angola. Only 3% of Angolans, 7% of Namibians and 5% of Botswana’s population live within the Basin area.

Many people from the Namibian component of the basin are Angolan immigrants, or of Angolan descent. 58% of people in the Basin live in Angola, 27% in Kavango and 15%



in Ngamiland (Kgathi *et al.*, 2006), with highest densities in the town of northern Cuando Cubango and along the length of the river.

The total population of the Angolan catchment and near the River in Kavango and Ngamiland consists of over and above 600,000 people, with an estimated 14 ethnic groups with different cultural backgrounds (Mendelsohn & el Obeid, 2004).

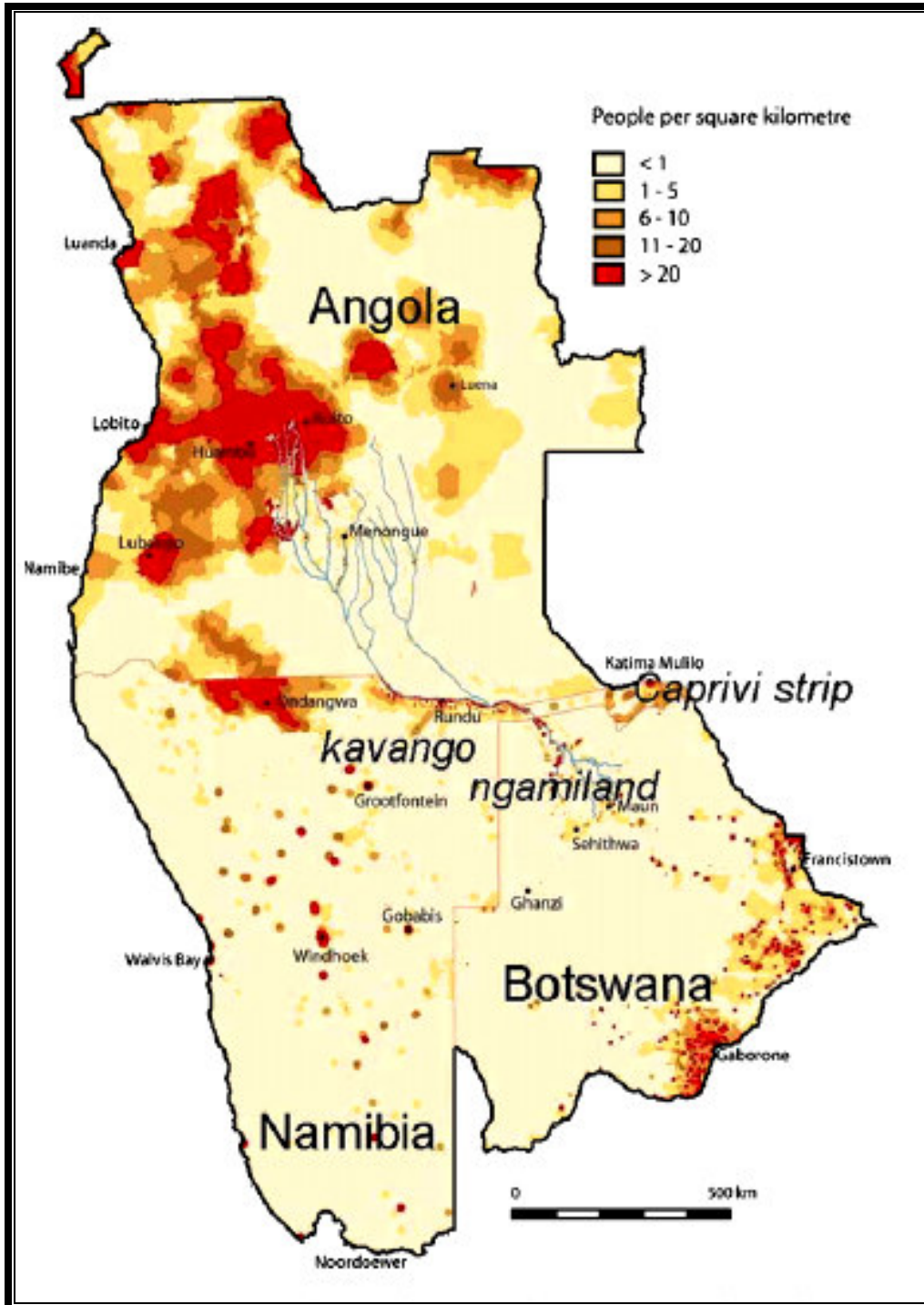
Population numbers in Namibia and Botswana have increased - Kavango's population (136 000 people) grew 5.2 percent between 1961 and 2001, largely due to the immigration of people fleeing the civil war in Angola and seeking economic opportunities in areas where Namibia's infrastructure and services are superior (Mendelsohn & Obeid 2004). As a result, the densely-populated south bank of the river in Namibia has been cleared of much of its natural vegetation and wildlife, except for protected areas (e.g. Muhango National Park).

Mendelsohn & el Obeid (2004) estimated population density for the Kavango region to be 11->20 people per km<sup>2</sup>, with average household size higher than elsewhere (Figure 3). Approximately 90% of the population live within 10km of the river, 80% within 5km. Fishing is integral to rural livelihoods, with over 50% of population being comprised of fishers (Hay *et al.*, 2000).

Due to landmines and isolation of the area, people living in the southern parts of Angola in Cuando-Cubango are cut off from the rest of world, with no recent developments or investments in the region (Porter & Clover, 2003). A staggering 50% of children in Angola have stunted growth and are seriously malnourished. Half of Angola's populations is comprised of children less than 15 years of age, 20% of children are under 5. More than one million children are believed to have no access to education and medical facilities (Porter & Clover, 2003). Few functional clinics, hospitals and educational facilities exist in Angola, whereas people in the other two countries enjoy access to health facilities and schools. The Cuando-Cubango Province in Angola is poorly studied, yet it is estimated that its 140 000 inhabitants mostly practise subsistence agriculture, with maize, cassava, millet and vegetables being the preferred staple crops. Unlike their Botswanan and Namibian counterparts, Angolan farmers are desperately poor and have little or no access to cash incomes. People keep livestock (cattle, goats, sheep). Water use of rivers is restricted to small regional centres (Porto & Clover, 2003). Resettlement is taking place along the demined transport routes in the Cubango and Cuito sub-basins.

Most people in the Okavango Delta are also rural and poor (Turpie *et al.*, 2006). Main activities include dryland recession flooding farming, livestock, wage labour, fishing, gathering and hunting. Subsistence agriculture is practised with cattle kept in cattle posts and around settlement areas. The main livelihood activities differ between the ethnic groups, with the WaYei and HaMbukushu very active in fishing, while the Baherero and Batawana are pastoral farmers. Malapo farming is mostly practised by the WaYei. In the Delta, people are concentrated at the edges of the Delta and along major roads. The total Population of the Okavango Delta is estimated at 120 000 people, with a 4.1% growth rate. Children constitute 53% of the population (Turpie *et al.*, 2006). Tourism is the biggest employer in the area – men are employed as polers, drivers, guides, camp builders and security guards whereas the women work as maids, receptionists, and in cleaning, washing and catering.

Malaria, Aids, Tb, malnutrition, bilharzia and diarrhoea are the most important health problems in the Basin.



**Figure 3:** Estimated population densities in the Okavango Catchment (after Mendelsohn & el Obeid, 2004).

## 1.4 Food Security

Small-scale farming is practised by most rural households in all three Basin States, with Angola enjoying more predictable rainfall and better soil quality than Botswana and Namibia. Income from farming in Kavango is lower than from other cash-earning activities due to erratic rainfall, and farmers prefer to use goats and cattle as security and investments (Mendelsohn & el Obeid, 2004). In Botswana and Namibia, social welfare benefits, drought relief, formal employment and rural trade contribute to rural livelihoods. The poorest subsistence farmers live in Angola. Mendelsohn & el Obeid (2004) note that in Angola, an expected 60 000 people depend on farming, as opposed to 18 000 and 8500 in Kavango and Ngamiland respectively. Due to the moister climate and improved soil quality, maize, cassava and vegetables are planted in Angola whereas millet is more common in the drier south. Cattle rearing is a significant contributor to livelihoods, with 5% of Angolans and 50% of people in Botswana and Namibia enjoying access to cattle.

More than 136 000 people live in the Okavango region, with an annual growth rate of 3%. Population estimates along the Okavango region range from 38 people per square kilometre at Musese to 1937 people per square kilometre at Rundu (Hay *et al.*, 2000). Most economic and social activities in Kavango in Namibia are centred on the river. For more than 90% of households, fish provides a source of subsistence and cash income (45% of households). Traditional and more modern methods such as gill nets are used, with mosquito nets also utilised widely (Hay *et al.*, 2000).

Botswana enjoys the highest tourism levels, with the Delta being a significant contributor to tourism (5% of GDP). The Delta is home to significant concentrations of wildlife – especially for large mammals such as elephant, buffalo and lechwe. Kgathi *et al.* (2006) suggest however that tourism tends to marginalise the poor, despite the fact that 60% of the total labour force in Ngamiland is in the employ in tourism-related sectors. Tourism to the delta and Kavango has increased rapidly. Sadly there is only one hotel in the Angolan section of the Basin at Menongue, whereas there are 19 facilities in Kavango and 50 in the Delta (Mendelsohn & el Obeid, 2004). It is expected that over one million refugees are to return and settle on the Okavango River in Angola (Andersson *et al.*, 2003), adding to the increasing pressure on the environment.

In the Delta, 21%-34% of adults are formally employed. According to Arntzen (2005), households derive their livelihoods from gathering, hunting and fishing; livestock, arable farming, crafts and the formal sector. The multisectoral approach to livelihoods allows households to spread risk in low rainfall or high draught years.

Large numbers of fish are harvested in Kavango and Ngamiland, but no data is available for the Angolan part of the Basin. Fish numbers are at their peak when river flow is lowest between September and December. Mendelsohn and el Obeid (2004) estimate that in Kavango, each person living near the river consumes an average of 10-20kg of fish per year. Small scale fishermen also occur in the Panhandle of the Delta, and commercialisation of the fishery includes the sale of salted fish, as well as tourism (tiger

fish are especially popular). Fish stocks are considered stable in the Delta, whereas Kavango has seen a drop in fish populations probably due to fishing methods (gill and mosquito nets).

Due to erratic rainfall in the south, pasture for livestock is variable. Plant products are used for domestic purposes and construction, with some used by local communities for cash income from basket-making, weaving, wood craft, firewood and thatching grass.

### 1.5 Ecosystem services in the Okavango Basin, using the Okavango Delta as a case study:

Indirect use values or ecosystem services in the form of carbon sequestration, groundwater recharge, water purification, wildlife refuge functions and provision of scientific and educational value, are provided by the Ramsar site. Turpie *et al.* (2006) conducted a recent economic evaluation of the Okavango Delta, which is used as a basis in this report to give a broad overview for ecosystem services, including direct and indirect values associated with the Okavango Delta<sup>1</sup>. Although the results from the Turpie report could be applied in broader terms to the greater region, there is an urgent need for such economic evaluations for the Namibian and Angolan sector of the Okavango River, as well as for the Cuito River in Angola.

*Direct Use Values* (Table 3, Source: Turpie *et al.* 2006)

#### Key points

- The delta contributes about 37% of natural resource value to households.
- Almost half of the cash income is generated from natural resources.
- Agriculture and natural resource use generates over Pula (P) 95 million to households.
- Crops and livestock typically provide at least half of the overall value.
- Households in the Panhandle and Central zones derive a much greater proportion of value from natural resources, with wetland resources playing a major role.

**Cattle:** Cattle are more important to household revenue than crops, and provide households with milk, milk, and social status.

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<sup>1</sup> Wetland Total Economic value consist of Direct use values (physical products used for consumption and sale), indirect use values (ecological functions that maintain and protect natural and human systems), option values (premium placed on maintaining a pool of genetic resources for future use) and existence values (intrinsic value of wetland ecosystems).

**Crop cultivation:**

75% of households in the Delta cultivated crops, with 47% practicing dryland farming and 28% molapo farming. The main crops grown include maize, millet and sorghum, which are cultivated with groundnuts and beans. Millet and maize are staple foods, whereas sorghum is grown mainly for brewing beer.

**Grasses and reeds:**

Grasses were used for thatching purposes and for the construction of fences, whereas reeds (*Phragmites australis*) were used for the build of traditional houses. Reeds have been depleted in some areas, particularly where flooding no longer occurs in the lower delta, and are reportedly increasingly scarce (Kgathi *et al.* 2006).

Baskets, handbags and crafts are made from the leaves of the Mokolo palm (*Hyphaenae ventricosa*), which grows in the floodplains.

**Timber:**

Timber is collected for fuel wood, construction material and makoros. Most households depend on timber for cooking. It is estimated that almost 1.8 million bundles are harvested per annum, of which less than 10% is traded.

**Fishery:**

Although the Delta is considered nutrient-poor, it supports the largest fishery in Botswana. Presently, the Botswana fishery is unregulated with conflict between various stakeholders revolving around access rather than stock declines. With a lack of a national fisheries policy, management continues to be a challenge (Mosepele, 2001). Mosepele (2001) estimates that there are 3289 fishers in the Delta, with 65% in northern Ngamiland dependent on the fisheries sector. Fishing gear used include baskets, gillnets, spears and traps. Total gillnet production was estimated at 114 tons per annum. Main species targeted include three-spot tilapia *Oreochromis andersonii*, green-head tilapia *O. macrochir*, large-mouth speckle-face tilapia *Serranochromis angusticeps*, red-breast tilapia *Tilapia rendalli*, sharp-tooth catfish *Clarias gariepinus*, blunt-tooth catfish *C. ngamensis* and tigerfish *Hydrocynus vittatus* (Mosepele 2005).

According to Turpie *et al.* (2006), declining fish stocks are blamed on gillnet fishing methods by recreational fishers but other explanations have been put forward for the decline, including drought in the 1980s, spraying against tsetse fly, and burning or other ecological factors (Skelton *et al.*, 1985)

**Wildlife use:**

Much like gathering of natural products for medicinal and household consumption purposes, hunting is a traditional way of life for many tribes of the Delta. Turpie *et al.* (2006) estimate that 36 – 61% of households in the different areas have members who engage in hunting, with approximately 60 000 birds hunted per year, of which 12 000 are wetland birds.

**Indirect Use Values:** (Source: Turpie *et al.* 2006)

**Key points:**

- The wetland is estimated to have an indirect use value of P199 million, while the entire Ramsar site is estimated to be worth to P230 million.
- Carbon sequestration accounts for the largest component, followed by wildlife refuge, scientific and educational value, groundwater recharge and water purification.
- With tourism excluded, the indirect use values were higher than the direct use value.
- For the Zambezi however (Turpie *et al.*, 1999), the direct use values were valued higher than indirect use values. The difference can be attributed to the pristine status of the Okavango Delta, which is the result of low levels of direct use and low population density.

**Groundwater recharge:**

Approximately 5.8 Mm<sup>3</sup> of groundwater is extracted with an estimated worth of P16 million. The Okavango Delta provides a conduit for the recharge of groundwater aquifers, which are utilised around the perimeter of the wetland.

**Carbon sequestration:**

The valuation study estimated that the carbon sequestration function is worth about P86 million in the delta, and P158 million for the entire Ramsar site.

**Wildlife refuge:**

The Delta provides refuge to numerous wildlife species. Its value is estimated to be P77 million.

**Water purification:**

Wetlands have the capacity to absorb or dilute wastewater, thus saving on treatment costs. Water purification in the Delta is estimated at P2.2 million as wastewater flow into the Delta is minimal.

**Scientific and educational value:**

The scientific and educational value of the region is estimated to be P24 million for the Ramsar site, of which P18 million is attributed to the wetland area.

**Option and non-use value:**

No studies have been conducted to estimate the option and existence value of the study area or the Okavango Delta. Further research is needed in order to highlight the full trade-offs made in policy decisions.

<b>Aggregate values (Pula)</b>	<b>Gross private value</b>	<b>Net private value</b>	<b>Cash income</b>	<b>Gross economic output</b>	<b>Gross value added</b>
Clay pots	151 416	149 492	-	158 987	157 833
Upland grass	1 636 657	1 600 496	45 406	1 718 489	1 702 171
Wetland grass	1 541 534	1 487 264	119 193	1 618 611	1 593 054
Grass brooms	118 952	117 064	86 380	124 900	124 333
Reeds	2 346 010	2 252 361	433 723	2 463 311	2 326 969
Reed mats	6 999	6 776	3 181	7 349	7 290
Reed fish gear	18 703	3 300	-	19 638	4 235
Papyrus	24 851	16 658	-	26 094	22 407
Papyrus mats	106 154	105 531	46 626	111 461	111 297
Palm leaves	1 792 090	1 787 837	5 331	1 881 695	1 878 505
Palm products	1 518 759	1 513 640	1 345 705	1 594 697	1 593 344
Wetland veg	43 579	43 579	12 756	45 758	45 758
Wetland fruits	55 628	55 628	1 466	58 409	58 409
Upland veg	1 084 129	1 084 129	117 700	1 138 335	1 138 335
Upland fruits	221 755	221 755	77 372	232 842	232 842
Fruit-based drinks	2 406 624	2 406 624	2 225 709	2 526 955	2 526 955
Medicinal plants	281 882	277 730	55 322	295 976	291 616
Firewood	8 822 904	8 581 022	787 548	9 264 049	8 911 897
Poles and withies	1 794 388	1 681 222	21 329	1 884 108	1 727 193
Timber	572 008	568 697	174 545	600 608	596 230
Wood products	277 822	190 569	267 715	291 713	223 981
Traditional fishing	726 079	657 883	70 661	762 382	759 349
Modern fishing	2 315 803	2 007 637	1 310 092	2 431 593	2 399 054
Honey	1 264	1 031	-	1 327	1 083
Wild animals	357 843	283 209	-	375 735	167 677
Upland birds	707 014	650 687	23 602	742 364	573 384
Wetland birds	168 763	112 436	58 685	177 201	8 220
<b>Total Upland</b>	<b>14 139 727</b>	<b>13 664 647</b>	<b>2 226 125</b>	<b>14 846 713</b>	<b>14 131 124</b>
<b>Total Wetland</b>	<b>14 959 880</b>	<b>14 199 610</b>	<b>5 063 923</b>	<b>15 707 874</b>	<b>15 052 296</b>
<b>TOTAL</b>	<b>29 099 607</b>	<b>27 864 257</b>	<b>7 290 048</b>	<b>30 554 587</b>	<b>29 183 420</b>
<b>% from wetland</b>	<b>51%</b>	<b>51%</b>	<b>69%</b>	<b>51%</b>	<b>52%</b>

**Table 3:** Summary of direct use values from natural resource in the Okavango Delta (Source: Turpie *et al.*, 2006).

## 1.6 Natural Resource Management & Governance

The Okavango Basin includes three Basin States: Angola, Namibia and Botswana. For Angola, the Okavango presents hydropower possibility and an irrigation source for post-conflict reconstruction, for Namibia, it is the second most important river basin after the Cunene in terms of water supply and for Botswana, the River is a substantial resource for rural food security and tourism contribution to GDP (Turton, 2005). Potential for conflict is thus great.



Water sector reforms in all 3 riparian countries have recently resulted in the review and revision of national water policies and legislation. The opportunity was taken in all 3 countries to incorporate international water management concepts (e.g., Integrated Water Resources Management; Water Demand Management; Polluter-Pays- Principle; Environmental Flow Requirements; basin-wide approach to water resources management. All 3 countries are signatories of the Ramsar Conventions, and both Namibia and Botswana have recently drafted their National Wetland Policies

The Okavango Delta Management Plan (ODMP) was developed by the Department of Environmental Affairs (DEA) in Botswana, and is supported by the World Conservation Union (IUCN). Its aim is to promote conservation, sustainable resource use and integrated resource management in the Okavango Delta. The overall implementing authority of the ODMP is the Ministry of Environment, Wildlife and Tourism, with government departments such as Forestry, Water Affairs, Tourism, Wildlife and Lands allocated responsibility for their sectors. The development of the Okavango Delta Management Plan is expected to provide input into the overall management of the Okavango River basin through the Permanent Okavango River Basin Water Commission (OKACOM) – the highest-level institutional umbrella of the Basin. OKACOM was established in 1994, and is the umbrella institutional body for the Okavango. Three OKACOM commissioners are appointed by cabinet, and are assisted by three senior technical staff from each country that serves on the Okavango Basin Steering Committee (OBSC). However, Angola's lack of capacity has limited its contributions to riparian dialogues despite the fact that it is the most prominent in terms of water contribution to the Zambezi, Cunene and Okavango Rivers. The World Bank and the Norwegian Energy and Water Resource Administration have been asked to assist Angola in the development of cross-sectoral policy with Angola's National Directorate for Water (Porter & Clover, 2003).

Water development in the region occurs in conjunction with the Southern African Development Community's (SADC) Protocol on Shared Watercourses. Botswana and Namibia are signatories to the Protocol, which aims to ensure profit-sharing as well as environmental protection of shared watercourses.

All 3 countries are signatories of the United Nations Convention on Biological Diversity (UNCBD, 1992) and The Ramsar Convention on Wetlands of International Importance (RAMSAR). Both Botswana and Namibia have ratified the Ramsar convention, while Angola is still considering its position (Table 4).

Donor funded activities include Every River has its people (ERHIP) Project based in Namibia. Water and Ecosystem Resource Development – Balancing Societal needs and Wants and Natural Resource Systems Sustainability in International River Basin Systems (WERRD) ([www.okavangochallenge.com](http://www.okavangochallenge.com)) is a European Union (EU) funded project, developed to foster understating of key hydrological and ecosystem variables underpinning Basin functioning.

Country	Ratification Date				
	Ramsar*	UNCBD*	UNCCD*	UNCSW*	UNFCCC*
Angola	n/p	1/4/1998	30/6/1997	n/p**	17/5/2000
Botswana	9/12/1996	12/10/1995	11/9/1996	n/p	27//1995
Nambia	23/8/1995	16/5/1997	16/5/1997	n/p***	19/5/1995

**Notes:**

\*

Ramsar - Ramsar Convention on Wetlands of International Importance

UNCBD - United Nations Convention on Biological Diversity

UNCCD - United Nations Convention to Combat Desertification

UNCSW - United Nations Convention on the Non-Navigational Use of International Watercourses

UNFCCC - United Nations Framework Convention on Climate Change

\*\*

n/p - not yet party to Convention (based on available information)

\*\*\* Namibia has signed the UNCSW, but has not ratified it.

**Table 4:** Ratification dates of key international conventions by Angola, Namibia and Botswana. (Source: from Ashton & Neal, 2003)

A key research institution is the University of Botswana's Harry Oppenheimer Okavango Research Centre (HOORC) in Maun, which has a variety of research projects (including hydrological monitoring) focused on the Delta. Little is known of the Angolan catchment, due to the civil war occurring there, and the difficulties associated with working in this region. A relatively large body of information has been synthesized for the Namibia Kavango region between the Angolan catchment and the delta (McCarthy 1992). Two major GIS and statistical databases (RAISON; Okavango Delta Information System (ODIS) have been developed. Little effort has been made, however, to standardize data collection techniques and parameters across the basin. The Departments of Water Affairs in Namibia and Botswana maintain several river flow-gauging stations.

## 1.7 Current and projected threats and challenges

Thieme *et al.* (2005) state that the Delta is in good condition, yet the Okavango Floodplain ecoregion, excluding the upper reaches, is listed as 'vulnerable'. Overfishing is not listed as a serious concern, although it may occur locally. The Delta edge is cause for concern due to the encroachment of people and cattle. Furthermore, the highly invasive Kariba weed (*Salvinia molesta*) occurs in sections of the delta. The effects of spraying insecticides on local fauna and flora may be harmful to people, fauna and flora alike. The assessment further lists overgrazing and clear-cutting of trees for agriculture as

future threats, with little or no forest occurring along the Okavango River. Siltation of rivers through erosion is cause for concern. The veterinary fences that contain cattle and spread of disease restrict movements of the larger mammals.

In Kavango, reeds and thatching grass are said to be decreasing, with fish stocks also declining due to unsustainable fishing methods (Kgathi *et al.*, 2006). The same trend is witnessed in Ngamiland, with reeds becoming scarce due to over-exploitation from lack of appropriate conservation measures (Kgathi *et al.*, 2006).

The Provincial government in Cuando Cubango in Angola has identified the following as priorities in an emergency plan of action to address serious malnourishment and poverty: Land distribution and agricultural inputs and technical support, improved access to water and sanitation, resettlement of high numbers of internally displaced people, reduction of child mortality from malaria (Porter & Clover, 2003). The development of the headstreams is looming, with potentially huge consequences for downstream communities.

Demand for water from the river is expected to increase to accommodate agricultural activities and expanding urban centres, some even outside the basin. Botswana's Tourism industry focus around the Okavango Delta may be threatened by upstream water extraction from the Okavango and its tributaries by Botswana, Namibia and Angola, with Namibia currently negotiating extraction from the Okavango River of 20 million m<sup>3</sup> per annum (Thieme *et al.*, 2005). The biggest threat comes from the proposed Popa Falls Hydroelectric Power Scheme, which, if established, would change the hydrological functioning of the Delta, with potential negative affects on the entire system Kgathi *et al.*, 2006). Reduced flow would affect a host of wildlife species (particularly lechwe and elephant) as well as people relying on the Delta's natural food resources (fish etc). This concern is echoed by Turpie *et al.* (2006), while Andersson *et al.* (2003) make mention of a revived plans for hydropower generation in the Cuito and Cubango Rivers. Conflict between the riparian states for water abstraction is an ongoing concern (Mbaiwa, 2004) and the active engagement of Angola must be ensured if adequate flows for the future are to be secured.

### **Future threats**

Climate change is expected to exacerbate rainfall variability and water availability. The duration and quantity of River flow can be affected by increased exploitation of ecosystem resources - Deforestation, overgrazing, erosion, and cultivation in marginal soils all contribute to habitat destruction, thereby increasing desertification along the Okavango River, particularly in Namibia and the panhandle section of the river in Botswana (McCarthy, 1992), while interfering with sediment deposition in the Delta will detrimentally affect the entire ecosystem. The annual sediment load carried into the delta is 420,000 tonnes of dissolved material (mostly silica, calcium and magnesium bicarbonate) and 200,000 tonnes of particulate matter.

# Upper Zambezi/ Lyambai Basin



## 2.1 Location and extent:

The Zambezi River Basin is approximately 1.33million km<sup>2</sup> in extent, and is one of the largest river basins in southern Africa. It lies across eight countries, with much of the basin occurring in Angola, Zambia, Zimbabwe, Malawi and Mozambique, and to a lesser extent in Namibia, Botswana and Tanzania (Table 5). The Zambezi River is the fourth largest River in Africa after the Congo, Nile and Niger, and is the largest river system in terms of both area and flow volume. The Victoria Falls – one of the seven wonders of the world, are found on the Zambezi. Over 30 large dams in the Zambezi River Basin serve domestic, industrial and mining water supply, irrigation and power generation.

The Zambezi River arises from the Kalene Hills in Zambia, and flows south until it spills into the Indian Ocean some 2650km to the east in Mozambique. Its numerous tributaries include the Kafue, Kwando (Cuando), Luangwa, Shire, Gwayi, Manyame and the Mazoe Rivers. The Luangwa is one of the few unregulated river systems, whereas the middle Zambezi has been dammed – with altered downstream environments. Yet the Zambezi River, its tributaries and associated ecosystems are considered the most important natural ecosystem in southern Africa (Ashton *et al.*, 2001). Ten major wetlands are found in the Zambezi Basin (Table 6). Due to the diversity of ecosystems, the basin is considered a regional centre of endemism, with the Zambian portion one of the richest in Africa with 6000 species of plants, 650 species of birds and 200 species of mammals recorded (Chenje, 2000). Many of Africa's most renowned National Parks are found here, including Chobe National Park in Botswana, Kafue and Luangwa National Parks in Zambia, Hwange National Park in Zimbabwe, Liwonde National Park in Malawi and Gorongosa National Park in Mozambique. Its river systems support large numbers of people and encompass important conservation areas. Rivers also supply most of the Southern African Development Community (SADC) countries with hydropower: two of the largest dams in Africa are constructed across the Middle Zambezi - Kariba and Cahora Bassa.

The headwaters of the Zambezi share a watershed with the Congo River Basin and the Cuanza River. The major tributaries are the Lungwebungu, Luanginga, Cuando (catchment size equals 57 000km<sup>2</sup>), Luena, Dongwe and Kapombo Rivers (Thieme *et al.*, 2005). The Upper Zambezi runs from the source, 25km south east of Kalene Hill in Mwinilunga District in north west Zambia, through Cazombo in Angola down to Barotseland and Victoria Falls, where it plunges into the Batoka Gorge. In Zambia, Liuwa- and West Lunga National Parks are traversed by the mostly pristine Luanginga, Kapombo and Lunga Rivers. Various rapids occur between Nangweshi and Katima Mulilo. The Ngonye Waterfalls (21m) lie 300 km upstream from Victoria Falls. The Barotse floodplain is 240 km long and 34 km wide, extending from Lukulu in the north to Nangweshi in the south. When flooded, the Barotse Floodplain covers an area of 7500 km<sup>2</sup> (Thieme *et al.*, 2005). The floodplains of the Upper Zambezi are comparable in size to the Okavango Delta, Kafue Flats and the Bangweleu Swamps.

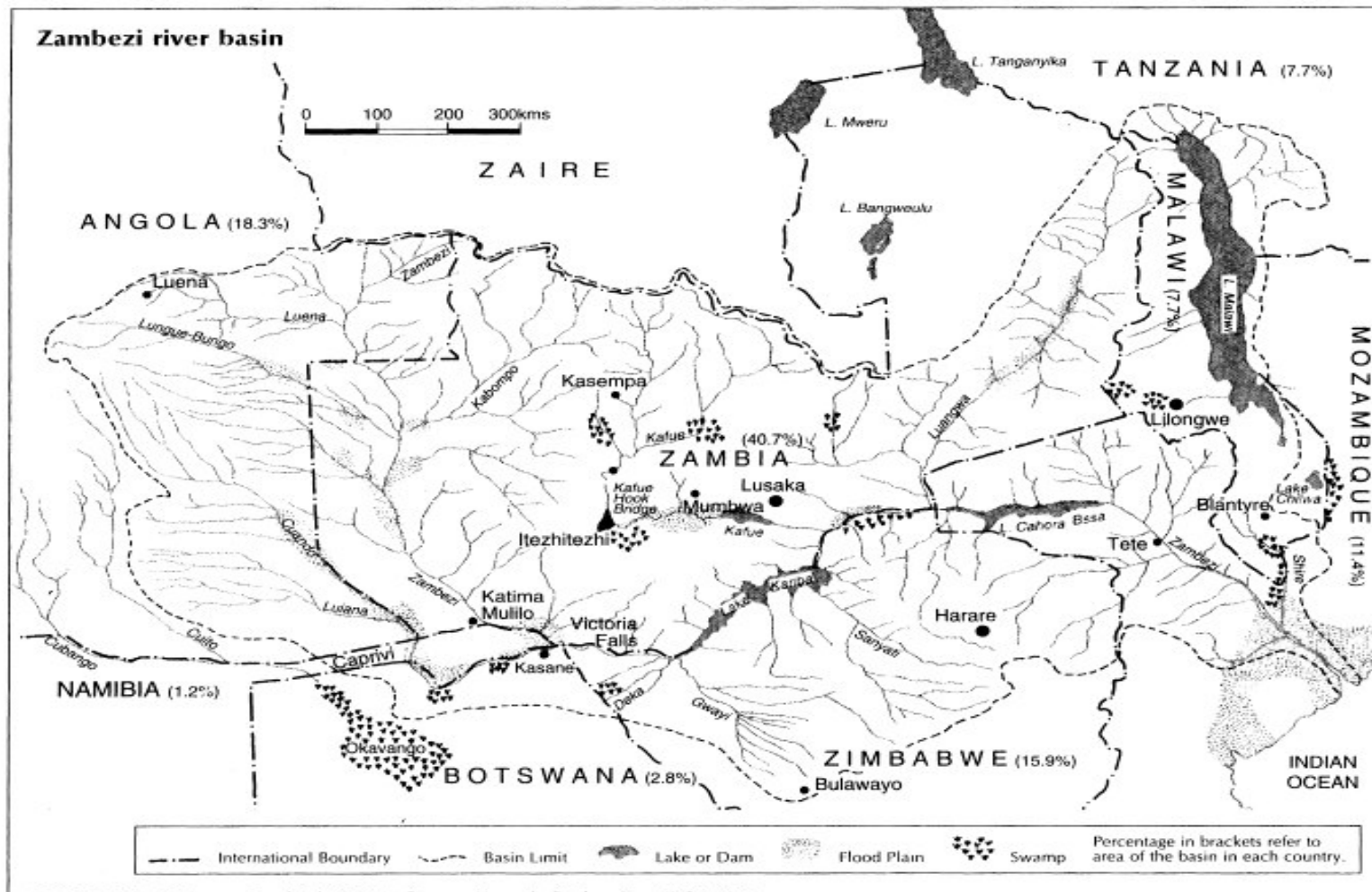
The TORs specifically note the upper Zambezi River, northwards of Katima Mulilo and Sesheke. The Upper Zambezi for the purposes of this report includes the sections northwards of Katima Mulilo and Sesheke, including the Kwando and Upper Zambezi Rivers. According to Hoekstra *et al.* (2000), the Kafue, Luangwa and Lake Malawi-Shire basins drain into the Lower Zambezi basin, while the Cuando-Chobe basin connects to the Middle Zambezi basin, just upstream of the Victoria Falls. The Chobe/Linyanti, Kafue and Luangwa River systems were excluded from this report as they are considered to be part of the Middle Zambezi, and because the scope of this report did not allow for their inclusion. Serious lack of data regarding the upper Zambezi and its tributaries is a knowledge gap that requires urgent filling (Table 7, adapted from Ashton *et al.*, 2001). For descriptions of sub-catchments, please refer to the Appendix.

**Table 5:** Area statistics for the 8 SADC countries comprising the Zambezi Basin. (Source: Ashton *et al.*, 2001).

Country	Total Area of Country (km <sup>2</sup> )	Country Area in Basin (km <sup>2</sup> )	Proportion of Country Area (%)	Proportion of Basin Area (%)
Angola	1 246 700	145 000	11.6	11.3
Botswana	600 370	34 000	5.7	2.7
Malawi	118 484	110 390	93.2	8.6
Mozambique	801 590	140 000	17.5	10.9
Namibia	825 418	24 000	2.9	1.9
Tanzania	945 087	37 000	3.9	2.9
Zambia	752 614	540 000	71.7	42.1
Zimbabwe	390 759	251 410	64.4	19.6
Totals:	5 680 843	1 281 800	22.6	100

**Table 6:** Major freshwater wetlands in the Zambezi Basin (Source: Seyam *et al.*, 2001)

Wetland	Area (1000 ha)	Utilisation	Conservation Status
Kafue flats	650	Fishery, grazing, wildlife limited agriculture	Partially protected
Lukanga	250	Fishery, grazing, transport	Unprotected
Barotse	900	Fishery, grazing, wildlife limited agriculture	Partially protected
Liuwa Plain	350	*	*
Linyanti-Chobe	20	Fishery, tourism	Protected
Quando	200	*	*
Elephant Marsh	52	Fishery, grazing, agriculture	Unprotected
Luangwa	250	*	*
Busanga	200	Unexploited wildlife refuge	Protected
Luena	110	*	*



**Figure 4:** Zambezi River Basin, its tributaries, lakes, and riparian states (Source: Shela, 2000).



**Table 7:** Data availability in sub-catchments in the Zambezi Basin (Source: Ashton *et al.*, 2001)

<b>Sub-catchment</b>	<b>Water Monitoring systems</b>	<b>Water quality data</b>	<b>Water management systems</b>
<b>Kazungula</b>	none	none	Botswana Department of Minerals, Energy and Water.
<b>Luiana</b>	none	none	Angolan Department of Water Affairs.
<b>Cuando</b>	none	none	Angolan Department of Water Affairs.
<b>Luanginga</b>	none	none	Angolan Department of Water Affairs, Barotseland Mongu Office (Zambia)
<b>Lungue Bungo</b>	none	none	Angolan Department of Water Affairs, Barotslenad Kalabo Office (Zambia)
<b>Luena and Zambezi Headwaters</b>	none	none	Angolan Department of Water Affairs.
<b>Kabompo</b>	Sporadic water quality monitoring at Kalabo.	none	Zambian Department of Water Affairs.
<b>Middle Zambezi</b>	Sporadic water quality monitoring at Mongu and Sesheke.	none	Zambian Department of Water Affairs.
<b>Lunga</b>	Sporadic water quality monitoring is carried out at Solwezi.	none	Zambian Department of Water Affairs, Copperbelt office.
<b>Upper Kafue</b>	Regular water quality monitoring carried out near major tailings dams and effluent discharge points on the Kafue River.	Petterson & Ingri (1993, 2000a, 2000b)	Zambian Department of Water Affairs, Copperbelt office.
<b>Lower Kafue</b>	Regular monitoring at Kafue and at the two hydroelectric dam sites.	none	Zambian Department of Water Affairs.
<b>Kariba (Zambia)</b>	Occasional sampling of water near the mamba Colliery to check the extent of acid mine drainage.	none	Zambian Department of Water Affairs.

## 2.2 The Physical environment

### 2.2.1. Topography

The topography of the Zambezi Basin is varied. Elevation in western Angola's catchment is 1000m, reaching over 3000m in the east in Malawi, and sea-level at the mouth of the Zambezi in Mozambique. Of note are the Muchinga Escarpment on the west of the Luangwa Rift Valley, the Nyika and Viphya Plateaus between Malawi and Zambia, and the Livingstone mountains on the border with Tanzania (Chenje, 2000).

Along its upper reaches, the Zambezi flows along a moderate gradient until it reaches Victoria Falls. The land surface of Zambia's Western Province, and Liuwa Plains National Park and Barotseland, has an average elevation of 1000m, with a gradual slope of 1200m in the north to 900m in the south. The southern end of the Upper Zambezi is trapped by basalt, which prevents the Zambezi from fanning out, giving rise to the vast floodplains of the Zambezi and its tributaries. Acidic soils predominate, with soil fertility considered low (Chenje, 2000). High quality vertisols (black cotton soils) are however found in some areas, including the floodplains of the Kafue Flats and Barotseland. The soils of the middle Zambezi are alluvial and support extensive agriculture.

### 2.2.2. Climate

Prevailing wind systems affect the climate of the Basin, notably the rain-bearing Inter-tropical Convergence Zone (ITCZ) which moves seasonally from the north to the south. Temperature varies with seasonality, with highest temperatures occurring in the austral summer months and the lowest during the cool, dry winter months. The area experiences three seasons: wet, cool season, a dry season and a hot dry season. Temperatures range from 27 degrees Celsius in summer to 15 degrees Celsius in winter. Rainfall is also seasonal, with 450 mm per annum in the lower Zambezi valley to over 2000 mm per annum in Mulanje Plateau in Malawi. Evaporation rates are consequently variable, ranging from 2.4metres per annum in south western Botswana, Namibia and Zimbabwe to 1.65 metres in the cooler regions of northern Malawi (Ashton *et al.*, 2001). Evapotranspiration is estimated at 870 mm per annum, ranging from 1,000 mm in the Luangwa, Shire and lower parts of the basin, to 500 mm in the south western parts of the basin.

The Upper Zambezi experiences seasonal rainfall, with most rain falling between October and April. River flow is consequently lowest in October and peaks in April. Precipitation is approximately 1000 mm per year.

### 2.2.3. Natural Environment

World Heritage sites such as Lake Malawi National Park, Victoria Falls and Mana Pools on the Zambezi River in Zimbabwe and Zambia attract significant numbers of tourists who bring foreign currency to the riparian countries, and are also valuable natural heritage monuments for present and future generations (Shela, 2000). The Zambezi Basin further holds many important wetlands which absorb and attenuate flows from upstream catchments. This trapped water is released slowly, and provides an important source of water in dry season months. The most significant wetlands include the Zambezi

Floodplain in Barotseland, the Busanga swamps on the Lunga River (Kafue Tributary), the Chobe-Linyanti Swamps in north-eastern Namibia and Botswana and the Lukanga Swamps and Kafue Floodplain on the Kafue River. Headwater wetlands known as dambos (waterlogged depressions) are important areas of also smallholder cultivation in the upper Zambezi basin. Subsistence agriculture is however mainly focused around the riparian wetlands. Extraction of water from the Zambezi River to urban demand centres are under investigation, as Basin states are experiencing growing water shortages, with global climate change adding to the problem (Ashton 2005). Water quality along the length of the Zambezi is considered very good, although Ashton (2005) notes that Victoria Falls and Livingstone were still discharging partially treated effluent into the River.

Between 6-7000 species of plants have been estimated to occur in the Basin (Timberlake, 2000). More than half of the Basin is covered by Miombo woodland. Four biomes have been identified by Timberlake (2000). Relevant to this report is the Zambezian biome (95% of basin), which comprises woodland, grassland, swamps and lakes – with miombo-mopane or Acacia woodland predominating. Woodland typically consists of *Brachystegia*, *Julbernardia*, *Isoberlinia*, *Colophospermum mopane* and *Baikiaea plurijuga*. Miombo woodland is not particularly species-rich, but it is of major economic importance to those dependent on its natural resources. However pockets of vegetation types with restricted distribution and high conservation interest occur, and include the dry forests of Barotseland on Kalahari Sands. The Congolian biome is associated with the headwaters of the Zambezi in north western Zambia and north eastern Angola, where a moister and warmer climate predominates, and species are a mix of those associated with the forested Congo Basin and the less tropical Zambezi Basin.

The Zambezi Basin and its tributaries provide critical habitat for freshwater fishes – out of 239 species recorded in the Basin, 122 make use of the Zambezi River itself (Skelton, 2001). Shela (2000) records that 200,000 tonnes of fish are harvested per annum within the basin, of which 70,000 and 50,000 tonnes come from Lake Malawi and the Zambia part of the Zambezi River basin, respectively.

### **The Upper Zambezi**

The Zambezi Floodplain is a wetland of International Importance under the Ramsar Convention. Its floodplain is home to Red Lechwe, hippos, crocodiles, Sitatunga and Tsessebe, all species listed on the CITES index. Wattled crane and lion, listed by the IUCN as vulnerable, are also found here. Economically important tree and plant species are found in the region, notably *Baikiaea plurijuga*, *Pterocarpus angolensis*, as well as reeds and sedges (*Phragmites* sp and *Papyrus* sp). The Upper Zambezi Floodplain is considered relatively intact (Thieme *et al.*, 2005) as no major developments have taken place. The region contains a range of habitats that are not found in the Middle and Lower Zambezi. The wetlands hold the world population of three species of lechwe antelope, and are home to significant populations of globally threatened birds. Many of the reptile, amphibian, fish, invertebrate and pant species of the Upper Zambezi remain to be identified. The reaches of the Upper Zambezi appear to be of great antiquity, and are considered a centre of species radiation and endemism (Timberlake, 2000), while Darwell *et al.* (2009) note the upper Zambezi at the confluence of the upper Zambezi,

Kwando and Chobe Rivers above Victoria Falls as one of three key centres of species diversity.

The Zambezi headwaters contain species that are found nowhere else in the Basin – these include the tree pangolin (*Manis tricuspis*), the otter shrew (*Potomogale velox*) and a species of horseshoe bat (*Rhinolophus sp.*). Timberlake (2000) urges that areas of conservation priority need to be identified and secured. Five endemic fish species, and two rare dragonflies occur in the upper reaches (Thieme *et al.*, 2005), with stable populations of Nile crocodile occurring. Miombo woodland (*Brachystegia, Julbernardia* spp) interspersed with grassy dambos characterises the upper reaches of the Upper Zambezi, with swamp and riverine forests common to the area (Timberlake, 2000). Mopane (*Colophospermum mopane*) and Acacia woodlands are also found to the south west, including woodland savanna and semi-arid grasslands. Near Mongu, a number of nutrient-enriched springs contain unusual plant species such as ground orchids (Timberlake, 2000).

Much of the wildlife of the Upper Zambezi, especially large mammals, occurs in Liuwa Plains National Park with some on the Luena Flats, while the wildlife of Barotseland has all but disappeared, in part due to poaching facilitated by semi-automatic weapons obtained during various liberation wars in the region. A high population of blue wildebeest migrates between Angola and Zambia, the second biggest migration in Africa – involving some 35 000 animals, which arrive in Liuwa NP in November. Liuwa Plain National Park is particularly important to populations of black-winged pratincoles (*Glareola nordmanii*).

In Barotseland, the Zambezi becomes wider. Expansive floodplains, dambos and grasslands (*Acroceras macrum*, *Brachiaria arrecta*, *Digitaria sp.*, *Echinochloa pyramidalis* among others) occur in the region. In deeper channels, *Phragmites mauritanicus* is the most abundant reed. Floodplains and dambos have higher biodiversity than swamps and contain more species of restricted distribution. The dambos of the Central African Plateau are biodiverse with many species not found elsewhere (Timberlake, 2000). These dambos are threatened by pollution, drainage and overgrazing. The floodplain is also an important site for breeding birds, including the vulnerable wattled crane and vulnerable slaty egret. It hosts more than 20 000 ruff (*Philomachus pugnax*) and 10 000 cattle egrets (*Bubulcus ibis*).

The Barotse Floodplain has the richest herpetofauna in the basin, with 89 species recorded. One frog (*Ptychadena mapacha*) is endemic to the region. Flooding regulates fish migration, which is species specific. 80 fish species have been recorded. Cyprinids, cichlids and mochokid catfishes (with a species radiation of *Synodontis* catfish) dominate the fish fauna of the area. *Clariallabes platyprospos* with its limited range is found in two localities near Katima Mulilo and Impalila. A fishing survey of the Upper Zambezi, the West Lunga and Kapombo Rivers, the Barotse Floodplain, the Zambezi River above Victoria Falls and the Luangwa River of the Middle Zambezi ([www.awf.org](http://www.awf.org)) revealed that fishing pressure near Senanga and Mongu was intense, with all fish species being harvested, while poor recruitment was recorded in the Luangwa River (Thieme *et al.*, 2005).

South of Senanga, the wetland area decreases. Dambo-type grasslands are common, while extensive woodlands on Kalahari Sand are dominated by *Baikiaea plurijuga* and *Pterocarpus angolensis*. At Katima Mulilo, the river turns east before reaching the 98m high Victoria Falls.

The Cuando however flows south into the Caprivi Strip in Namibia, 100 km west of Katima Mulilo. It is bordered by floodplain riparian woodland. To the south, it then forms a series of swamps (the Linyanti Swamps) along the border of Botswana. The Kwando/Linyanti then join the Chobe River further east, connecting at the dried up Lake Liambezi (Timberlake, 2000). Scattered settlements occur on the eastern banks of the Kwando River in southern Zambia in Sioma Ngwezi National Park, whereas approximately 11 000 people live on the densely settled eastern banks of the Kwando River in Namibia in Kwando-, Mayuni- and Mashi Conservancies ([www.irdnc.org](http://www.irdnc.org)). National Parks provide important dry season habitat for elephants, which are increasingly moving from Chobe National Park into Luiana Partial Reserve in Angola via Namibia. In Angola, Luiana Partial Reserve, Kameia National Park and Mavinga Partial Reserve afford wildlife little protection due to post-war restrictions on infrastructure and administrative costs.

### 1.3 Socio-economic conditions

The Basin is home to an estimated 40 million people with Zambia, Zimbabwe, Malawi and Mozambique having the highest proportion of the basin population. All Zambezi Basin states experience migration from rural areas to urban towns. Zambezi Basin states carry the economic and environmental burden of several million refugees, notably from Angola, Rwanda, Mozambique, Burundi and DRC (Ashton *et al.*, 2001). 20 per cent of the basin is under crop cultivation. The basin has 10 large urban centres, with the present growth rate of urban centres estimated to be 5 per cent. The Zambezi River Basin has a wealth of natural resources yet economies of the riparian countries are generally characterized by low levels of industrial development and economic growth. The region is therefore largely underdeveloped, with high unemployment and widespread poverty. People in the basin rely on the Zambezi River for drinking water, irrigation, hydropower, mining and ecosystem maintenance (Kirchhoff & Bulkley, 2008). Main agricultural products include maize, sorghum and rice, with fisheries, cattle rearing and forestry playing a significant role in sustaining local livelihoods.

Western Province (Barotseland) is one of the nine provinces of Zambia. The Barotse Kingdom was established as far back as 1600 when the first King (Litunga) settled in the Barotse Plain. The Litunga rules through chiefs, called Indunas. In addition, the traditional Prime Minister or Ngambela, who is not part of the royal family, oversees traditional administration. The population of Zambia's Western Province is estimated to be 782 509, with an annual population growth of 2.8% (Turpie *et al.*, 1999). 84-90% of people live adjacent to the floodplain. Mean household size of Barotseland is 8.1 people (Turpie *et al.*, 1999), with 43% of population being under the age of 15 years. Less than 5% of the productive age group are in formal employment, with 76% of the rural population of Western Province living in poverty (Simwinji, 1997).

In Barotseland, agriculture, fishing and livestock are the primary activities in terms of subsistence food production, with maize the preferred staple crop. Other cash-earning activities include beer-brewing, arts and crafts, sale of fuelwood, fish and agricultural products at local markets.

#### 1.4 Food security

The region is largely underdeveloped, with 70% of the population of the Zambezi Basin rural and poor. Causes of poverty include poor economic government policies, poor governance, corruption, inadequate access to land and capital, poor prioritisation of use of available resources by governments and occurrence of natural disasters such as droughts and floods (Tumbare, 1999).

The ecosystems of the Zambezi River offer a wide range of natural resources (including fisheries and forestry) that support local communities. The rural economy of the basin countries is principally subsistence agriculture, with main agricultural products including maize, sorghum and rice. Poor agricultural practices are prevalent and result in land degradation, which accelerates soil erosion, siltation and pollution of water sources.

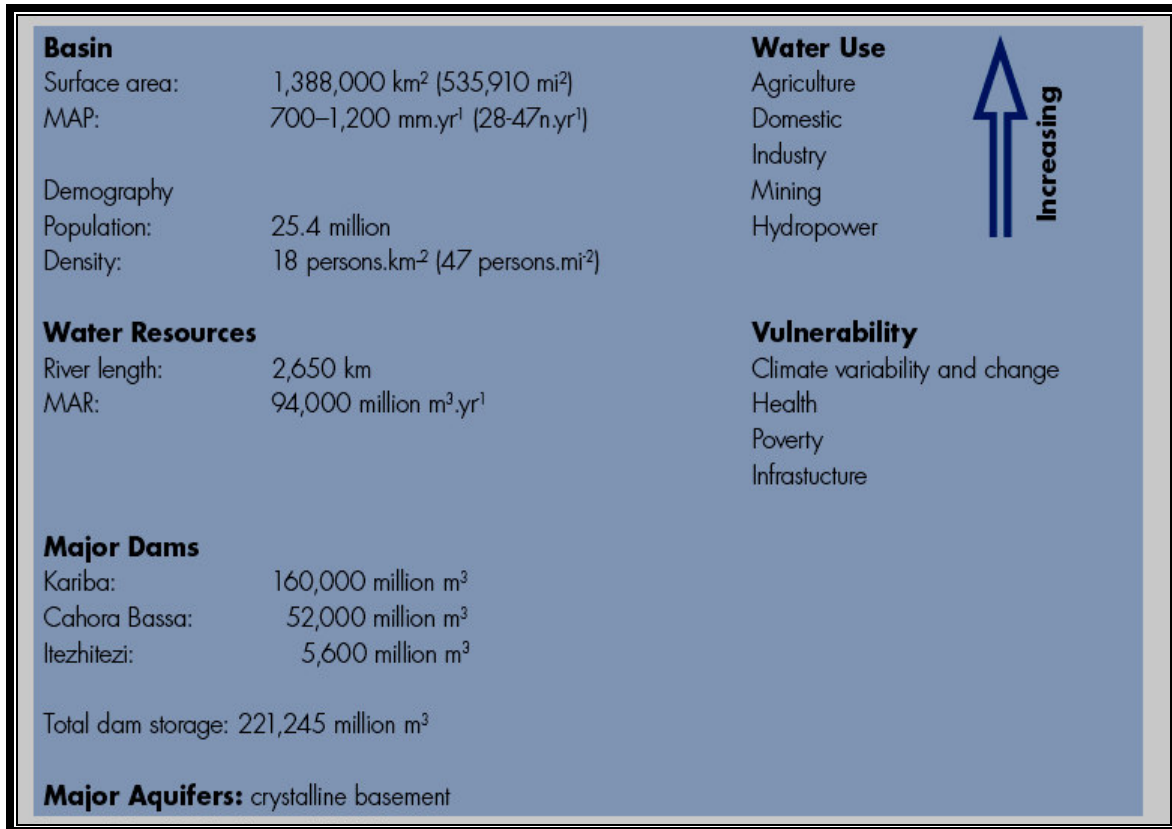
The demand for fuelwood by the rural poor for cooking, lighting and heating purposes is increasing. This sector has no access to alternative energy sources. According to Tumbare (2004), forests are being cleared daily to meet this demand, resulting in greenhouse gases emissions, deforestation and land degradation.

Large areas of the Barotse Floodplain are being cleared for agriculture owing to increased human populations, improved technology, increased government and donor involvement and reduced tsetse fly occurrence (Timberlake, 2000). Chenje (2000) recorded that between 1972 and 1990, Malawi's total forest cover declined by 41%. 71% of land in Barotseland is "open land", where chitemene (shifting agriculture) is practised. Land is a critical resource to subsistence farmers in the Basin states. Much of the land is under communal tenure. Chenje (2000) notes that land ownership is one of the most salient factors constraining effective land use and conservation, with overcrowding contributing to land degradation - large areas of natural vegetation have been cleared for cultivation and for fuel wood production. Subsistence fishing occurs along the entire length of the Zambezi from the Upper reaches down to the Delta.

It is important to note that fish is the main source of animal protein for the majority of rural communities of the Zambezi Basin riparian states. The Barotseland fishery between Likulu and Senanga is important to livelihoods in the region both as a traditional staple food and as a source of income. A combination of traditional and gill and seine net fishing is used. Fish stocks are still stable (Thieme *et al.*, 2005) although fishing pressure is intense. The Zambian fisheries sector contributes around 1 percent on average to GDP (US\$109 million in 2007). Fishery's contributions to food security have been mostly undervalued. Fish and fish products account for more than 20 percent of animal protein

intake and provide essential micronutrients to the majority of Zambia's population who are highly vulnerable to malnutrition.

Finally, all socio-economic and cultural activity in the region is mediated by the climate. The Zambezi River Basin is vulnerable to climate variability, manifested by frequent floods and droughts. Activities that depend on rainfall and regular flooding include cultivation, livestock rearing, fishing, reed products and other crafts, and reproduction of culture (for example, through the annual Kuomboka festival).



**Figure 5:** Zambezi Basin characteristics (Source: Pallet, 1997; Hirji *et al.*, 2002)

### 1.5 Ecosystem Services provided by Zambezi Basin, using the Barotse Floodplain as a case study

Two economic valuation studies have been carried out on the Zambezi Basin wetlands: the larger study was conducted by Turpie *et al.* (1999) and the smaller study by Seyam *et al.* (2001). Turpie' study was initiated by the IUCN as part of the Zambezi Basin Wetlands Resource Conservation and Utilization Project (ZBWCRUP). Four study areas were selected: the Barotse Floodplain in western Zambia, the Chobe-Capriwi wetlands in



Namibia and Zambia, the Lower Shire wetlands in Malawi and the Zambezi Delta in Mozambique. Direct use values for the Barotse wetland are presented in Table 8, and Indirect use values in Table 9. Although the results from the Turpie report could be applied in broader terms to the greater region, there is an urgent need for such economic evaluations for the Zambian and Angolan sector of the Zambezi River, as well as for its tributaries, including the Cuando, Lungwebungu, Luanginga, Luena, Dongwe and Kapombo Rivers, not to mention the ecologically significant Kafue and Luangwa Rivers.

The aim of the study by Seyam *et al.* (2001) was to develop a rapid wetland valuation system with limited data availability, and summarizes the most frequently reported products and services of the Zambezi basin wetlands for the local population. Results are presented in Table 10. Of note is that wildlife services and goods were given negative values, suggesting that costs of managing wildlife exceed income from ecotourism. Products provided by wetlands include flood recession agriculture, fish production, wildlife resources, cattle grazing, forest resources, natural products and medicine, ecotourism, biodiversity, water supply, transport and scientific information services. Although based largely on the Kafue Flats (Seyam *et al.*, 2001), results indicated that fish production and floodplain recession agriculture account for most of the total use value of the wetland. Marginal values were mostly low, indicating that subsistence utilisation of wetland products is associated with low efficiency, and that there is much room for improving wetland productivity and total use values. Although values were crude, Seyam *et al.* (2001) state that these values still fall far below the full total values as many values (such as forest resources, conservation value etc) were excluded. Lack of data also contributed to the underestimation.

**Direct use values** (Source: Turpie *et al.* 1999)

**Key points:**

- Products provided by wetlands include flood recession agriculture, fish production, wildlife resources, cattle grazing, forest resources, natural products and medicine, ecotourism, biodiversity, water supply, transport and scientific information services.
- Households perceived crops to be by far their most important source of income (including non-cash income). Crops contribute a net financial value of between US\$89 per household in Barotse
- The Barotse floodplain is one of the most productive cattle areas in Zambia and is of significant economic importance to the economy of the Western Province.
- The fisheries sector is one of the most important sectors in the Western Province, and is mainly concentrated on the floodplains of the upper Zambezi, with local consumption being five times the national average.
- Most wildlife is confined to protected areas.
- Tourism value in Barotse is low.
- Men tend to make decisions which affect the resources collected by all members of the household, and this has implications for the sustainability of many resources.

Non-use values for Barotse wetland biodiversity was measured using the Contingent Valuation method (CVM) and was estimated at \$ 4, 229,309 .

**Table 8:** Summary of current consumptive use values of Barotseland (from Turpie *et al.*, 1999)

BAROTSE	Cattle	Crops	Fish	Animals	Reeds and papyrus	Palms	Grass	Clay	TOTAL
<b>Average wetland hh (US\$/y)</b>									
Gross financial value	120.4	90.8	179.6	5.83	15.12	0.43	8.25	2.39	417
Net financial value	120.4	88.7	174.1	0.41	10.72	0.27	8.07	2.33	405
Gross cash income	11.5	6.1	52.6	0.01	1.61	0.04	0.3	0.02	72
Gross home value	109	84.8	127	0.42	13.51	0.39	7.95	2.37	345
<b>Total wetland (US\$ '000s/y)</b>									
Gross economic value	3,988	1,447	5,947	12	501	12	272	66	12,244
Net economic value	3,908	-75	4,258	10	271	3	221	52	8,647
Gross financial value	3,323	2,507	4,956	12	417	12	228	66	11,52
Net financial value	3,323	2,447	4,803	11	296	7	223	64	11,174
Cash income	316	167	1,452	0.3	44	1	8	0.5	1,989
Gross home value	3,007	2,34	3,504	12	373	11	219	65	9,531

### Livestock:

Cattle herding in Barotseland was estimated to have a net economic value of \$ 4 million per annum in 1997. Cattle constitute wealth, and area a source of milk, meat, manure, income and bridal dowry. Natural pastures constitute the main feed for cattle, while crop residues account for 5% of their intake. Turpie *et al.* (1999) report that cattle owners sell 5.1% of their cattle per year, and slaughter another 1.4% for own use.

### Crops:

Simwinji (1997) estimates total agricultural land in Western Province at 279 000 ha, with 90 % of the population involved in subsistence agriculture. Maize is the most planted crop, closely followed by sorghum, millet and cassava. Rice constitutes an important cash crop. Crops are planted by October, with harvesting season between March and May. Different types of fields occur in the area including dryland fields, raised gardens, village gardens, seepage gardens lagoon and river bank gardens.

### Fishery:

Fish is central to life on the Barotse Floodplains, with fish providing an important source of protein and income. Bream, tilapia, minnows and barbell constitute most of the catch. Highest catches occur in June/July after flood waters recede in April, with fish productivity determined by flood levels. Gill nets are mostly used, while mosquito nets are now considered a threat to local fishery. Although a license system was put in place by government, and traditional authorities supposedly control fishing at local levels, the fisheries sector in Barotseland lacks defined "fishing rights" and is considered by

Simjwinji to be “open-access” (1997). Catches are declining with number of big fishes decreasing, and fishers from other countries such as Angola dominating the fishery. Lists of the fish of the Zambezi Basin are found in Skelton (1994).

**Wildlife:**

The only formally protected area in Barotseland is the Liuwa Plains National Park. Outside of protected areas in the Game Management areas, wildlife has been decimated by poaching and land clearance for agriculture. Bags of maize are given to inhabitants of the floodplains by poachers in turn for their cooperation – species targeted by poachers include birds (caged bird trade), red lechwe and reedbuck. Poaching of elephants is on the rise. Species that are consumed by rural inhabitants include geese, egrets, storks and cormorants. Fires are also a threat to birds nesting in grass. Importantly, villagers did not demonstrate an awareness of the positive values of hippopotami in keeping floodplain water channels open.

**Natural products:**

Wild Plants included reeds (*Phragmites* spp) are central to rural living, and is used for construction of courtyard fences, mats, fishing baskets and rods. Papyrus (*Cyperus papyrus*) is used to make sleeping mats, and for tying in construction. Grass was mostly used for thatching and weaving, while palms (*Borassus* and *Rappphia* spp) were used to make ropes and baskets. Fuel needs are met by the harvesting of weeds, cow dung and crop residues. Trees are scarce, although villagers prefer firewood and charcoal, which was sold at ZK 400 a bundle of 5 pieces in Mongu markets at the time of the survey (1999).

**Clay:**

This is collected in the early rainy season, and is important to house construction. Women also use clay for pottery.

**Tourism:**

Liuwa NP offers limited Tourism facilities, with access in the rainy season (Nov-Mar) problematic due to flooding of roads.

**Indirect Use Values** (Source: Turpie *et al.* 1999)

**Key points:**

- The Zambezi River Basin study estimated the value of five indirect uses: flood attenuation, groundwater recharge, sediment retention, water purification and shore line protection.
- Total indirect use value of Zambezi River basin is US\$ 64 million with the Kafue and Barotse wetlands constituting 55% of total use values.
- The Barotse wetland is estimated to have an indirect use value (Net Present Value) of \$ 43.9 million.
- Carbon sequestration accounts for the largest component, followed by groundwater recharge and sediment retention.

- Direct use values were valued higher than the indirect use values due to high dependence on natural resources by people of the Barotse Floodplain and high population density.
- Net Present Value of existence and option value was estimated at 4 229309

**Table 9:** Estimated Net Present Value (NPV) of indirect uses, or ecosystem functions, for the four wetland areas

<b>Ecosystem function</b>	<b>Barotse</b>	<b>Chobe-Caprivi</b>	<b>Lower Shire</b>	<b>Delta</b>
1. Flood attenuation	0.4	Low	2.7	Medium
2. Groundwater recharge and water supply	5.2	0.5	7.5	3.2
3. Sediment retention	Medium	8.9	Low	Medium
4. Water purification	11.3	1.6	18.4	12.7
5. Shoreline protection	-	-	-	Low
6. Carbon sequestration	27	11	8	64
Minimum estimate of total (US\$ millions)	43.9	22	36.6	79.9

### **Flood attenuation**

The Barotse floodplains have a storage capacity of  $8.6 \times 10^9 \text{ m}^3$  at normal flood levels, and as much as  $27 \times 10^9 \text{ m}^3$  at high floods with a retention time of at least one month, which benefits the downstream lower lying areas such as the Chobe-Caprivi.

### **Groundwater recharge**

Turpie *et al.* (1999) concluded that the Barotse floodplain does not contribute significantly to the groundwater supplies of the broader region

### **Sediment Retention**

The sediment load of the Zambezi River around Mongu is very low and water clarity is consequently high. There is thus no real value assigned to the reservoir protection function for the Barotse wetlands in this study. 435 000 cattle rely on wetland vegetation on the Barotse Floodplain. Vegetation vigour depends on soil nutrient status, which is aided by sediment retention levels.

### **Water purification**

The Barotse floodplain acts as a sink for wastewater from major towns and large rural populations, and performs a water purification function to some degree. Few of the communities living around the study site wetlands, either urban or rural, have access either to piped sewage supplies, or to treated water.

### Carbon sequestration

Based on an average of two tons of carbon removed per hectare per year, the Barotse Floodplain was estimated to have a Net Present Value of \$ 27 million.

**Table 10:** Total use values of the Zambezi wetlands (Source: Seyam *et al.*, 2001)

Wetland service or product	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
<b>Marginal value (USD/ha/year)</b>	<b>128.4</b>	<b>51.2</b>	<b>-1.88</b>	<b>46</b>	<b>0.66</b>	<b>0.11</b>	<b>6.5</b>	
<b>Area contribution to the service %</b>	<b>10%</b>	<b>40%</b>	<b>*</b>	<b>40%</b>	<b>30%</b>	<b>*</b>	<b>10%</b>	
Wetland	Area (10 <sup>3</sup> )	Total use value of the wetland in million USD/year						
<b>Kafue</b>	650	8.3	13.3	-0.12	12	0.129	0.007	0.4
<b>Lukanga</b>	250	3.2	5.1	0	4.6	0.05	0	0.2
<b>Barotse Plain</b>	900	11.6	18.4	-0.17	16.6	0.178	0.01	0.6
<b>Liuwa Plain</b>	350	4.5	7.2	-0.07	6.4	0.069	0.004	0.2
<b>Linyati-Chobe</b>	20	0.3	0.4	-0.03	0.4	0.004	0.002	0
<b>Cuando</b>	200	2.6	4.1	-0.04	3.7	0.04	0.002	0.1
<b>Elephant marsh</b>	52	0.7	1.1	0	1	0.01	0	0
<b>Luangwa</b>	250	3.2	5.1	-0.05	4.6	0.05	0.003	0.2
<b>Busanga</b>	200	0	0	-0.34	0	0.04	0.02	0.1
<b>Luena</b>	110	1.4	2.3	-0.02	2	0.022	0.001	0.1
<b>Total</b>	<b>2982</b>	<b>36</b>	<b>57</b>	<b>-0.83</b>	<b>51.2</b>	<b>0.59</b>	<b>0.049</b>	<b>1.9</b>

(1): Floodplain recession agriculture

(2): Fish production

(3): Wildlife services and goods

(4): Livestock grazing

(5): Eco-tourism

(6): Biodiversity

(7): Natural products and medicine

\* Fraction of area protected is determined in light of Table 1 where completely protected wetlands

are assigned a fraction of 90 percent, partly protected areas 10 percent and not protected areas

are assigned a fraction of 0 percent

## 1.6 Natural Resource Management & Governance

Governance remains a key constraint to sustainable water resource management in the Zambezi Basin, with competing water demands, and institutional capacity challenges (Kirchoff & Bulkley, 2008). Eight countries share the Zambezi Basin watershed, making it one of the most complex freshwater resources to manage. Basin states segment their respective territories into Water management Units, which are usually sub-catchments (Ashton *et al.*, 2001). Water management is the responsibility of central government and or provincial departments. SADC Protocol on Shared Watercourse Systems provides

legislation for cooperative governance of shared water resources yet a lack of institutional and professional capacity a problem (Ashton *et al.*, 2001).

Zambia and Zimbabwe formed the Zambezi River Authority (ZRA) in 1987. ZRA focuses its activities on sections of the Zambezi shared by the two countries. Yet the exclusion of the 6 remaining countries precludes effective management of the entire system.

With the assistance of UNEP, the Zambezi River Basin Action Plan (ZACPLAN) was adopted by riparian states in the mid-1980s with the aim to establish mechanisms for common management of the Zambezi River. Of 19 envisaged projects, only 4 have been implemented, and none have been completed (Shela, 1998). The 'Development of a United Water Resources Quantity and Quality Monitoring System for Zambezi River' was pursued under ZACPRO 5 and ZACPRO 6, yet no joint monitoring programmes are in place (Shela, 1998).

Barotseland, although governed in principle by central government, seems to operate somewhat independently due to the ancient and traditional Barotse Royal Establishment, which is the custodian of the traditional laws and court systems. The Lozi people are conservationists by nature, and monitoring of wetlands and wetlands natural resources is conducted by the court (Liwanka, 2000). The Litunga (currently Chief Inyambo Yetha II), in consultation with the Ngambela, appoints an Induna to be in-charge of specific natural resources.

## 1.7 Current and projected threats and challenges

A number of inter-basin water transfers from the Zambezi River to the southern regions of SADC, that include irrigation requirements, are being contemplated, with riparian zones in the Kafue Flats, Gwembe and Lusito valleys near Lake Kariba, and the lower Zambezi and Shire Flood plains listed as potential land for agriculture by Shela (2000).

Main threats to biodiversity have been listed by Timberlake (2000) as follows:

- Encroachment by humans in the Upper Zambezi.
- Overexploitation- hunting, poaching and overfishing (elephant, rhino
- Deforestation - timber such as mukwa, African Ebony and Zambezi Teak). Deforestation in Barotseland has resulted in the opening of the tree canopy, with concomitant increase of fire risk as well as loss of nutrients to the system due to soil erosion.
- Land clearance (specifically in the Middle Zambezi Valley) – for agricultural purposes with the financial support of government and donor agencies.
- Increase in grazing pressure by domestic cattle
- dams and modification of hydrology (flood regimes regulated by dams are responsible for the drying up of some of the Zambezi wetlands e.g. Marromeu, which supported herds of grazers such as buffalo).

- Introduction of exotic species – Kariba weed in the Chobe System, as well as exotic fish species such as Nile Tilapia and Lake Tanganyika Sardine outcompeting local species.
- Fire – uncontrolled burning. Burning occurs regularly in order to prepare soils for agriculture. Erosion increase, as well as reduction of birds and animals that cannot escape.
- Pollution, particularly from agrochemicals (agriculture) and urban and industrial wastes, remains a major concern.

Timberlake (2000) suggests that there are 4 areas of biodiversity conservation significance: Lake Malawi, the swamps, plains and woodlands of the upper Zambezi in Zambia and Northern Botswana, the Middle Zambezi Valley (in northern Zimbabwe and the Luangwa Valley in eastern Zambia), and the Gorongosa/Cheringoma/Zambezi Delta area of central Mozambique. Poaching in GMAs, road construction, poor agricultural practises and riverbank cultivation are some of the threats listed to the Barotse Floodplain (Ramsar, 2008). Improved management and protection is recommended for Liuwa Plains National Park (3660 km<sup>2</sup>), Sioma Ngwezi NP (5276km<sup>2</sup>) and the West Zambezi Game Management Area as poaching is a serious concern (Thieme *et al.*, 2005).

Thieme *et al.* (2005) list overfishing, overgrazing, alien invasives and the removal of riparian vegetation as future threats.

Lack of data is a problem: data are lacking on the Angola portion of the basin. Botswana and Namibia have satisfactory data. Monitoring, however, is not uniform throughout the basin. Zimbabwe and Zambia have information on surface water resources, and limited information on groundwater resources. The other riparian countries have very limited monitoring programmes and, consequently, limited data availability.

The Zambezi River Authority lists the following as threats (Tumbare, 2004):

- Climate Change (floods and droughts) as rainfall variability will affect the functionality of the basin ecosystems
- Poverty with urban population growth having a profound effects on water demands and supply and
- Water pollution
- Deforestation
- HIV/Aids

## Conclusions

Both Basins are considered Basins at Risk (Turton, 2005), based on indicators of basins that had the potential for conflict. This is made poignant by the fact that three of the basin states are approaching water scarcity (Namibia, Botswana, Zimbabwe), which may affect economic growth potential in the future. Of the Zambezi Basin, Shela (1998) states that there is a 'lack of awareness of international water management issues, their importance and required capacity in the joint and integrated monitoring, assessment, planning, development, conservation and protection of water resources in the Zambezi River basin. Although there is likelihood of water related conflicts, there are currently no mechanisms for their settlement or management within the Zambezi River basin.'

In Africa, 114 new major dams are considered for development – in many cases, developing countries across the continent face the challenge of developing their rivers within the ethos of sustainable development.

Failure to do so would not only degrade rivers, but would erode socio-economic structures among especially rural communities. Loss of land, decline of fisheries, increase in pest species, decreased water quality are some of the factors listed by King & Brown (2009), with flood and drought events expected to become more severe in future.

King & Brown (2009) propose the development of Environmental Flow Assessments for rivers that address the cost-benefit balance for all stakeholders, in the hope of achieving an optimum trade-off between the two (Table 11). This assessment then could lead to the development of an Integrated Water Resource Management (IWRM) plan. Beilfuss & Brown (2006) conducted such an assessment using the DRIFT type model (King *et al.*, 2003) for the Zambezi Delta, where the construction of Cahora Bassa in 1974 and of Kariba dams in 1959 led to vast ecological and socio-economic changes. Cross-sectoral stakeholders were consulted in order to address stakeholder needs across the system, and to adapt the pattern and magnitude of flow accordingly in future.

The importance of such analyses is clearly demonstrated by the following assessment of the Okavango Basin by King (2010):

'A Technical Diagnostic Analysis (TDA) of the Okavango River Basin was recently completed for OKACOM. One part of it was an Integrated Flow Assessment (IFA), co-funded by Biokavango, which used an holistic approach to provide predictions of the ecological, social and resource-economic implications of development of the basin's water resources. The TDA was funded by the UN-FAO via a project named Environmental Protection and Sustainable Management of the Okavango. Major findings from the TDA were:

1. The Okavango is a flood-pulse driven system. Massive riverine floodplains, particularly in the Cuito River and the lower Okavango, store floodwaters upon which the lower part of the ecosystem and associated social structures depend.



2. Significant changes in the flow regime would occur with water-resource development. Dry-season flows, for instance, could begin up to 11 weeks earlier and last 18 weeks longer than present in different parts of the basin under the most extreme scenario. The flood season could shorten by two months or more and lose one-third of its volume, impacting the floodplains.

3. The flow changes would result in a progressive decline in condition of the river ecosystem from the Low to the High Scenario, with the High Scenario rendering large parts of the system unable to sustain present beneficial uses and causing significant terrestrialisation within the Delta.

4. Run-of-river abstractions could severely impact smaller headwater tributaries in the dry season, but the effects would be localised. An accumulation of such developments in the upper and middle reaches would trigger a widespread decline in the middle and lower reaches with increasing transboundary impacts.

5. Climate change is likely to provide more water for the upper basin but exacerbate drying of the Delta. Sustainable use of the river system could be promoted by adopting a new perspective on water-resource development.’

Such assessments of especially the upper reaches of the Okavango and Upper Zambezi are highly recommended, as they would not only provide much needed data for the region, but would also prevent potentially irreversible damage – ecologically and socio-economically – in the not so distant future.

**Table 11:** Hypothetical example of the matrix of information that could be developed for each part of a river basin (Source: King & Brown, 2009).

Indicators	Scenarios of increasing levels of water-resource development					
	PD	A	B	C	D	E
<b>Man-made benefits</b>						
Hydropower generation	x	x	x	xx	xxx	xxx
Crop production	x	x	xx	xxx	xxxx	xxxx
Water security	x	xx	xxx	xxx	xxxx	xxxx
National economy	x	x	xxx	xxxx	xxxx	xxxx
Aquaculture	x	xx	xxx	xxx	xxx	xxx
<b>Ecosystem attributes</b>						
Wild fisheries	xxxx	xxx	xxx	xx	xx	x
Water quality	xxx	xxx	xx	xx	x	x
Floodplain functions	xxxx	xxxx	xxx	xx	x	x
Cultural, religious values	xxxx	xxx	xxx	xxx	xx	xx
Ecosystem buffer against need for compensation of subsistence users	xxxx	xxx	xx	xx	x	x

The indicators would be more numerous than shown and could differ from river to river. The crosses illustrate possible trends in the level of beneficial use under each scenario, and would normally be replaced by quantitative or qualitative details from supporting research. PD, Present Day – not necessarily pristine.

## Appendix 1:

### Catchment

#### **Kazungula sub-catchment**

Comprises “headwater zone” of the Chamabonda Stream, a series of small, ephemeral streams with episodic flows that flow into Zimbabwe and enter the Zambezi River above and below Victoria Falls. In the northern part, a few small ephemeral streams flow into the Zambezi River at Kazungula.

#### **Luiana sub-catchment**

A major tributary of the Cuando River in Angola. Flows are seasonal though there is no information as to the size of the flows.

#### **Cuando sub-catchment**

Drains the southeastern portion of the Bié Highlands in central Angola. Flows are seasonal though there is no information as to the size of the flows.

#### **Luanginga sub-catchment**

Drains the southeastern portion of the Bié Highlands in central Angola. Flows are seasonal though there is no information as to the size of the flows.

#### **Lungue Bungo sub-catchment**

Drains the eastern portion of the Bié Highlands in central Angola. Flows are seasonal though there is no information as to the size of the flows.

### Surface water users

- Settlements at the Botswana border post of Kazungula.
- Small villages scattered throughout the sub-catchment
- Anecdotal evidence for the presence of UNITA army camps in the headwaters region of the sub-catchment.
- Small villages scattered throughout the sub-catchment
- Anecdotal evidence for the presence of UNITA army camps in the headwaters region of the sub-catchment.
- Small villages scattered throughout the sub-catchment.
- Prospecting teams in the subcatchment uses small volumes of water.
- Small villages scattered throughout the sub-catchment.
- Prospecting teams in the subcatchment uses small volumes of water.
- Small administrative centres are located near the town of Kalabo in Zambia.

### Human impacts on water resources

- Minor non-point impact from sparse, subsistence agriculture located close to Kazungula and the veterinary fence control points
- Disposal of domestic and commercial solid waste at Kazungula
- Minor non-point impact from subsistence agriculture and garbage disposal at the Mpandamatenga border
- Disposal of domestic and solid waste and UNITA army camps in the headwaters; and
- Minor non-point impact from sparse, subsistence agriculture throughout the sub-catchment.
- Disposal of domestic and solid waste and UNITA army camps in the headwaters
- Minor non-point impact from sparse, subsistence agriculture throughout the sub-catchment.
- Prospecting teams in the sub-catchment uses small volumes of water.
- Disposal of domestic and solid waste from small communities;
- Minor non-point impact from sparse, subsistence agriculture throughout the sub-catchment.
- Disposal of domestic and solid waste from small communities
- Minor non-point impact from sparse, subsistence agriculture throughout the sub-catchment.

### **Luena and Zambezi Headwaters sub-catchments**

The Luena River drains the eastern portion of the Bié Highlands in central Angola, and joins the Zambezi River in its headwater zone. Flows are seasonal though there is no information as to the size of the flows.

- Small villages scattered throughout the sub-catchment.
- Prospecting teams in the subcatchments use small volumes of water. Small administrative centres are located near the town of Luena in Angola.
- Disposal of domestic and solid waste from small communities
- Minor non-point impact from sparse, subsistence agriculture throughout the sub-catchment.

### **Kabompo sub-catchment**

Drains the northwestern portion of the watershed between Northern Zambia and the Democratic republic of Congo, joins the Zambezi River after it flows out of Angola. Flows are seasonal though there is no information as to the size of the flows.

- Small villages scattered throughout the sub-catchment.
- Prospecting teams in the subcatchment uses small volumes of water.
- Disposal of domestic and solid waste from small communities.
- Disposal of domestic and solid waste from prospecting camps.
- Minor non-point impact from sparse, subsistence agriculture throughout the sub-catchment.

### **Middle Zambezi sub-catchment**

Covers the Zambezi Floodplain in Barotseland. During the seasonal floods, the Zambezi spills its banks, often reaching 48-50 kilometres in width. Several large tributaries arising in the Angolan sector of the basin join the Zambezi in this sub-catchment.

- Small towns and villages scattered throughout the sub-catchment.
- The Provincial capital, Mongu, is located on the banks of the Zambezi River
- The smaller town of Sesheke is also located on the banks of the Zambezi River, opposite the town of Katima Mulilo in Caprivi.
- Prospecting teams also use water from the river
- Disposal of domestic and solid waste from small towns and communities
- Disposal of domestic and solid waste from prospecting camps;
- Minor non-point impact from sparse, subsistence agriculture throughout the sub-catchment.

### **Lunga sub-catchment**

Most important tributary of the Kafue River and drains the central portion of the watershed between Northern Zambia and the Democratic Republic of Congo. Flows are seasonal though there is no information as to the size of the flows.

- The major settlement is the town of Solwezi.
- Several small villages scattered throughout the sub-catchment.
- Prospecting teams in the sub-catchment uses small volumes of water.
- Disposal of domestic and solid waste from town, small communities
- Prospecting camps
- Increased quantities of suspended solids washed into the rivers from cleared and eroded areas
- Minor non-point impact from sparse, subsistence agriculture throughout the sub-catchment.

### Upper Kafue sub-catchment

Most important river in Zambia as it drains the mineral and economic heartland of the country. Flows south-westwards, draining the eastern portion of the watershed between Northern Zambia and the Democratic Republic of Congo, before swinging southwards to join the Lunga River and enter the Kafue Floodplain. Flows are highly seasonal though there is no information available as to the size of the flows.

### Lower Kafue sub-catchment

Covers the Kafue River Floodplain in the Central province of Zambia. During seasonal floods, the Kafue spills its banks, often reaching 15-20 kilometres in width across the floodplain. Several small tributaries join the Kafue in this sub-catchment. The Kafue River is dammed at the ItzHITEZHI gap and at the Kafue Gorge; both dams are designed for hydroelectric power generation and supplement the power gained from the Kariba North hydroelectric power station at the Kariba Dam.

### Kariba (Zambia) sub-catchment

Comprises a series of small sub-catchments, whose rivers flow from the surrounding plateau down steeply inclined riverbeds into Lake Kariba. None of these rivers are perennial, though continual seepage from Maamba Colliery gives the appearance of perennial flow in a nearby stream.

- All of the towns use substantial quantities of water for domestic and industrial purposes.
- Mining operations use considerable volumes of water.
- The numerous small “informal” settlements around periphery of the Copperbelt towns rely on shallow hand-dug wells in dambos, or draw water directly from nearby rivers and streams.
- Disposal of domestic and solid waste from towns, industries and small communities.
- Disposal of domestic and solid waste from peripheral industries (e.g. cement factories)
- Increased quantities of suspended solids washed into the rivers from cleared, cultivated and eroded areas
- Seepage of oils, fuels and industrial chemicals from roadways and industrial sites into the local ground water and nearby streams
- The Provincial capital, Mumbwa, is located north of the Kafue River.
- Smaller towns of Chilanga and Kafue are located near to the downstream end of this sub-catchment.
- Considerable quantities of water are used for sugar cane irrigation as well as for livestock rearing.
- Disposal of domestic and solid waste from small towns and communities.
- Salinized return flows from extensive irrigation schemes
- Discharge and seepage of water from livestock farms
- Minor non-point impact from sparse, subsistence agriculture throughout the sub-catchment.
- There is some consumption of water for small-scale agriculture in the communal lands along the escarpment
- Most of the water used for domestic purposes in the towns is obtained either from the Kafue River or from local boreholes.
- Some water is used at the Maamba Colliery.
- Disposal of solid waste at Maamba Colliery and local towns;
- Disposal of liquid effluent at local towns;
- Urban run off from towns
- Non-point sources of domestic effluent in the rural areas
- Litter and garbage on the main road between Livingstone and Lusaka.

**Chamabonda sub-catchment**

Located in the extreme northwest of Zimbabwe. The catchment zone comprises a series of small ephemeral rivers that flow into the Zambezi shortly above or shortly below Victoria Falls. The largest river is the Chamabonda Vlei.

- The only settlements of any size are the resort town of Victoria Falls and the border post of Kazangula.
- The other main use of water is tourist use of the Zambezi River: boating, canoe safaris, white water rafting, scenic value, fishing and game viewing.
- The Zambezi River, along with a few boreholes, is the only source of water for wild animals in the Parks & Wildlife Land in the dry season.
- Disposal of domestic and commercial solid waste, Victoria Falls and Kazangula; Disposal of domestic and commercial liquid effluent, Victoria Falls and Kazangula; Fuel loss and litter on the main roads and the railway.
- Run off from Victoria Falls International Airport;
- Minor non-point impact from sparse, subsistence agriculture in Hwange Communal lands.
- Non-point impact from minefield in northeast.

**Organisations of Interest:**

- Juventude Ecologica Angolana (JEA) in Luanda, Angola
- Association of Preserving the Environment of Integrated and Rural Development (ACADIR) from Cuando-Cubango Province
- Harry Oppenheimer Okavango Research Centre (HOORC) in Botswana
- Research and Information Services of Namibia (RAISON)
- African Water Issues Research Unit (AWIRU) in South Africa
- Counsel for Scientific and Industrial Research (CSIR) in South Africa
- Zambezi River Authority (ZRA)
- The Permanent Okavango River Basin Commission (OKACOM)

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