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The Hydrology of the Okavango Basin and Delta in a development perspective

Guest editors:

Dominic Kniveton, and Martin Todd

Paper 1. The Okavango; a river supporting its people, environment and economic development.

By: D. L.Kgathi[1], D. Kniveton[2], S. Ringrose[1], A. R. Turton[3]; C. H. M. Vanderpost[1]; J. Lundqvist[4], M. Seely[5]

[1]Harry Oppenheimer Okavango Research Centre, University of Botswana, Private Bag 285, Maun, Botswana

e-mail: kgathi@mopipi.ub.bw; sringrose@orc.ub.bw; cvanderpost@orc.ub.bw.

[2]University of Sussex, Falmer, Brighton, UK.

e-mail : D.R.kniveton@sussex.ac.uk

[3] C S I R Environmentek, P.O. Box 395, Pretoria 0001, South Africa

e-mail: csir.co.za

[4]Linkoping University, 581 83 Linkoping, Sweden

e-mail: janlu@tema.liu.se

[5]Desert Research Foundation of Namibia (DRFN), P.O Box 2022, Windhoek, Namibia

e-mail: mseely@drfn.org.na

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Abstract

The Okavango basin comprises the Cuito and Cubango active catchment areas in Angola, in addition to the Kavango-Okavango non-active catchment in northern Namibia and Botswana. The Okavango River water and its ecosystem resources are critically important sources of livelihoods for people in the basin. Pressures from livelihoods and development are already impacting on the environment. These pressures may increase in the future due to the rapid increase in population, the peace process and associated resettlement activities in Angola, and major development initiatives in Botswana and Namibia. For instance, possible future increase in water abstraction from the Okavango River may affect the long-term environmental sustainability of the Okavango Delta by minimizing channel shifting and thereby reducing spatial biodiversity. The paper argues that while conservation of the natural environment is critical, the pressing development needs must be recognized. The reduction of poverty within the basin should be addressed in order to alleviate adverse effects on the environment. The paper recommends that the development of sustainable tourism and community-based natural resource management initiatives may be appropriate strategies for reaching the Millennium Development Goals of poverty alleviation and achievement of environmental sustainability in the Okavango Basin. These initiatives have a comparative advantage in this area as demonstrated by the performance of the existing projects.

Keywords: Okavango River, Livelihoods, economic development, natural environment, Botswana, Namibia, Angola.

1. Introduction

The Okavango River basin is relatively underdeveloped and is only recently coming under pressure as a result of economic change in the basin states of Angola, Namibia, and Botswana. Famous worldwide for it's large terminating inland Delta (which is geomorphologically speaking, an alluvial fan) the river is one of the largest in southern Africa spanning over 1000 km (Fig. 1). Fourteen major ethnic groups with different cultural backgrounds occupy the Okavango River basin. These groups include the San people, who are among the most marginalized people in southern Africa, not only in terms of limited access to education, health, and economic benefits, but also in terms of their cultural identity (Kgathi et al., 2004). A substantial proportion of the population in the countries of Angola, Botswana and Namibia still live below the poverty datum line, particularly in Angola (Matlosa, et al 2002; Werner, 2002). Due to the high incidence of poverty in the basin, the majority of people depend on natural resources freely available from the river and surrounding areas to support their livelihoods (Werner, 2002; Kgathi et al., 2004).

While poverty is most acute in the Angolan part of the basin, its sub-tropical climate ensures potential for rainfed agriculture, development of tourism, and hydropower generation in the upper catchment (Matlosa et al., 2002;UNDP, 2005;Pinheiro et al., 2003). In semi-arid Botswana and Namibia, there is currently dependence on the water *per se* for irrigated agriculture and tourism related activities, which in turn requires the sustainability of wildlife habitats. It is expected that the pressure on the river and its natural resources will increase in the future, primarily because of demographic changes and the increase in socio-economic needs in the basin, the peace process in Angola and the various development initiatives taking place in the basin states (Pinheiro, et al., 2003). Hence, the sustainable use of the Okavango River water and its resources is critical for the social, economic, and environmental sustainability of the basin in the future. It will play a crucial role in the attainment of the Millennium Development Goals of poverty reduction and environmental sustainability (UNDP, 2003) in the Okavango Basin.

This paper examines the natural background of the Okavango River basin, and its potentials particularly with regard to the extent to which people have access to river-based livelihood activities and opportunities and their interaction with the riparian environment. The paper provides an overview of the physical background of the Okavango River system in terms of the availability and use of soils, natural vegetation and water. It describes the background and diversity of peoples living along the river and provides an analysis of the past and future economic potential of the basin area. In this way this paper serves as an introduction and context setting for the companion papers, which set out in detail the hydrology of the river basin (Wilk et al., this issue) . The papers model the hydrology of the system (Hughes et al, Wolski et al., both this issue), using a model-based exploration of the influence of development and climate scenarios on the hydrology and ecosystems of the basin (Andersson et al., Murray-Hudson et al., both this issue.

2. Physical human interface

2.1 Geological background

Geological evidence suggests that the Okavango River, along with the parallel Kwando and upper Zambezi Rivers flowed southeastward in late Pliocene-early Pleistocene time into the Limpopo catchment (Moore and Larkin, 2001). The lower Zambezi River forming the Zambezi system, which subsequently captured the Kwando along the Okavango fault lines, has since captured the upper Zambezi. The faults are seismically active and the southernmost faults appear to be extending at the rate of approximately 2 mm/year (Hartnady, 2004). Topographic evidence suggests that the capture of the Okavango River, immediately south of the Panhandle is geologically imminent (e.g. Gumbricht et al., 2000), and could result from possible future earthquake activity in the Makgadikgadi, Okavango, and Zambezi (MOZ) rift depression (Kampunzu et al., 1998; Ringrose et al., 2005). Outcrops of Archaean rocks only occur in the extreme north-western margin of the Okavango Basin in the Angolan upper headstream area with varying thicknesses of Kalahari sediments occurring downstream in northern Namibia and Botswana (Haddon, 2000). The sediment is of mixed aeolian-fluvial origin (Ballieul, 1979, Lancaster 2000) and has been extensively reworked (McCarthy and Ellery, 1995; 2002, Ringrose et al., 2002, 2005). Recent work has pointed to the source rocks of the Okavango Delta sediments as mainly Proterozoic granitoids, gabbros and related volcanic and orthometamorphic rocks (such as those) exposed in the catchment area in Angola, northern Namibia and northern Botswana (Huntsman-Mapila et al., 2005)

At the present time, sediment derived from the catchment and deposited in the Delta is estimated at up to 170 000 t/a clastic bed load with a c. 39 000 tons suspended load component (McCarthy and Ellery, 1998). This contrasts with a chemical influx of 350 000 t/a in solution and about 250 000 t/a as atmospherically derived aerosols (Garstang et al., 1998). Clastic deposition at present mainly takes place in the Panhandle and upper Delta while most sedimentary processes ongoing in the lower (seasonal-intermittently flooded) distal Delta involve chemical accumulation as the dominant aggradational process (McCarthy and Metcalfe, 1990). The chemical processes reflect the geo-chemistry of surface waters which due to high evapotranspiration (potential evapotranspiration is 1580 mm/yr or 3 times the precipitation) rates show increasing concentrations of river-borne cations and anions downstream (Cronberg et al., 1996). While the relatively nutrient poor sands with their low moisture retention capacity support minimal cultivation peripheral to the Okavango River, the catchment produces potable water such that the oligothrophic system generally ensures good water quality to people who live along the banks of both the River and Delta (Anderson et al; 2003).

2.2 Climate

The climate of southern Africa is primarily semi-arid and typically has a marked seasonal cycle with 80% of the rainfall falling in the summer, from October to March (Tyson and Preston-Whyte, 1998). The summer climate of the region results from the complex interplay of the converging airstreams of the north-east airflow from the East African monsoon which crosses the equator and moves into eastern Africa and southwards; tropical easterlies from the Indian Ocean and low level recurved westerlies that enter southern Africa from the Atlantic Ocean at about 12°S (Hudson and Jones, 2002). The dynamic convergence zones generated by the confluence of these airstreams are characterised by vertical motion and the daily formation of tropical lows and troughs (Hudson and Jones 2002). These converging airstreams control the climate systems of the Inter Tropical Convergence Zone over the east and the Zaire Air Boundary over western parts of the subcontinent. In turn these climate systems result in two rainfall gradients (from high to low) from the north to the south and east to west of the subcontinent.

Within southern Africa the Okavango River basin sits astride the two subcontinent scale rainfall gradients, with rainfall decreasing from the higher altitude northern part of the catchment over Angola to the lower altitude Delta in Botswana. The region as a whole is characterised by a higher degree of interannual variability of rainfall. In contrast to rainfall, evaporation is highest in the winter months and in the southern parts of the catchment decreasing towards the north and into summer. Annual temperatures over the basin average about 20°C increasing towards the south with decreasing cloud cover (Mendelson and El Obeid, 2004).

Unfortunately the region has a low density of meteorological stations with no observations in recent years in the north of the catchment. Despite increasing observations in the south of the catchment there is still a lack of observations over the Delta leaving open the question of how much water is recycled in the region. In Figures 2 and 3 the spatial distribution of averaged hourly rainfall is shown from satellite based estimates of rainfall for the summer months of December through to March and also for March through to April. These rainfall estimates were derived over the period 1996-2002 using combined satellite data from different sensors (Layberry et al., 2006).

These figures clearly show the north to south and east to west rainfall gradients and also suggest that rainfall is being recycled over the Delta during peak flooding of the Delta in March to May.

The lack of surface observations, high interannual variability and steep climatic gradients make the region particularly difficult to model atmospherically and thus present difficulties in simulating present and future climates. For example simulations of current climate over southern Africa by a high resolution Global Circulation Model, HadAM3H show a large negative rainfall bias over the northern part and a large positive bias over the southern part of the catchment during summer with magnitudes of –50% to 100% (Hudson and Jones 2002). It is thus that climate change scenarios of the future should be viewed with a large degree of caution. However currently regional simulations from a number of climate models show a consistent 'greater than global average' warming of the southern African region in this century and a less consistent 'small decrease' in precipitation in the south of the basin and small increase in the north (Giorgi et al., 2001). The potential impact of these climate changes on the rivers hydrology is assessed in Anderson et al (2005).

2.3 Water and land patterns

The Okavango River is comprised of the Cuito, Cubango and Okavango catchments. While in Angola the Cubango and Cuito rivers and related tributaries occur in a country with relatively high rainfall, this contrasts with the situation in Namibia, where the mid-Okavango forms a unique narrow wetland strip in one of the driest countries in the region. In Botswana, the lower Okavango River and subsequent Delta contrast sharply with the surrounding land where rainfall is low and erratic, evaporation rates are high and surface water is lacking for most of the year (Dincer et al., 1979; Wolski et al., 2005) (Table 1).

Currently, the active part of the catchment that supplies almost all water to the river is wholly located in south central Angola and comprises about 112 000 square km (Mendelsson and El Obeid, 2004). The many tributaries flow approximately 1000 km through valleys which vary in width from 0.25 to 1.5 km. The valleys also vary considerably in physiography although most sustain relatively unused fluvisol type soils. The Cuito system comprises extensive areas of linear swamps, which are peat filled fluvisols, which retain water much longer than the predominantly sand rich Cubango River. The Cubango is also wide in places but extensive sandy terraces and floodplains have formed within the valley. The Cuito drainage area is largely unpopulated partly because of the war (discussed in detail in the next section) and partly because the area is quite remote. The Cubango also presently supports relatively few people in its lower reaches, although the number of settlements increases upstream to the headstreams, which are densely populated. In either case, neither the swamps nor the sandy terraces are currently extensively used for agriculture. Evidence from satellite imagery suggests that most agricultural clearing has taken place in the adjacent hillslopes (ferrasols) and intervening dambos (luvisols) although overall such agricultural activity appears limited. A major feature of the Angolan part of the Okavango basin on sequential satellite imagery is that relatively large areas appeared cleared in the 1970s and 1980s, and that large portions of these areas have now revegetated due to the out-migration of people during the war. Present day clearing is slow, and is taking place often cautiously around larger more permanent towns and villages as more widespread resettlement is restricted by the presence of landmines.

Predominantly the vegetation cover in the Angolan section forms part of the Miombo woodlands, which become increasingly less dense with distance south along the aridity gradient (Frost, 1996). However, the high rainfall, high elevation portion of the northern Cubango sub-basin is typically covered by "planalto" grassland (Mendelsson and El Obeid, 2004), which comprise extensive upland grasslands (e.g. *Loudetia simplex*) interspersed with thousands of small streams surrounded by swampy, grassy peat marshes that feed water into the headwater streams. Further south, the zone of open *Brachystegia* savanna is interspersed with swampy areas. This zone has been intermittently cleared for cultivation. Locally around permanent towns and villages, the clearing has been relatively extensive, especially in the western section (Fig. 4). The eastern portion of the northern catchment is mostly covered by dense evergreen *Brachystegia* woodland (e.g. *Julbernadia paniculata, Pteleopsis anisoptera, Cryptosepalum pseudotaxu* (Mendelson and el Obeid, 2004). Further south again, the species composition changes to form *Burkea-Brachystegia* woodland, a transition zone to deciduous *Burkea* woodland in the inactive portion of the basin in dryer southern Angola and Namibia and northern Botswana (e.g. *Burkea africana, Pterocarpus angolensis, Baikiaea plurijuga, Terminalia sericea*). The valleys tend to have specific aquatic vegetation associations, but true riverine forest is rare. The eastern valleys of the Cuito are dominated by floodplain vegetation with central reed-beds, bordered by wide-open seasonally flooded grasslands. Sections of the western Cubango valleys also support floodplain vegetation but valley woodland and grasslands are much more common here, being a mix of woodlands, grasslands and floodplain grasses, sedges and reeds. Interestingly, in Angola much of the natural vegetation is preserved because the human population density is low. This is due (since 1974) to out-migrations from the Okavango basin area. However, the population density in the basin was always relatively low due to the widespread occurrence of tsetse fly (*Glossina spp*), and the high occurrence of tropical diseases. Because of the largely intact flora and river networks the area can potentially support moderate wildlife populations, although evidence suggests that most of these were annihilated during the war because of food shortages (Huntley and Matos, 1992). As a result the major national parks in area have been largely abandoned.

After Angola the 250 km long mid Okavango River forms the northern margin of the Kavango District of northern Namibia and the adjacent Caprivi Strip. In Namibia the southern bank of the river is densely populated throughout due to the overall scarcity of water in the country. The river valley forms a series of sand terraces (arenosols and anthrosols) most of which have been cleared, and are presently being cultivated. Richer soils occur in interdune areas (calcisols) and along the margins of ephemeral tributaries (luvisols) (Table 2). Mostly the agriculture is traditional in nature occurring adjacent to villages from which the people use oxen to plough their fields and grow millet and maize. Interspersed with the smaller fields are extensively irrigated areas. Approximately 22 x 10^{6} m^3 of water are extracted each year of which 74% is for irrigation schemes 15% for watering livestock and 11% for the town of Rundu. In Namibia along the southern banks of the mid-Okavango, in sharp contrast to the northern Angolan bank, much vegetation has been cleared for small-scale and large-scale (irrigated) cultivation, although riverine forest survives on islands and at less populated locations (Fig. 5).

In Botswana, the lower Okavango River flows initially through the 100 km long Panhandle before dispersing across the alluvial fan (the Delta) that varies in size and shape and is currently active over an area of about 9,000 km^2 (Jellema et al., 2002). The outflow of the Delta is about 2% of the inflow such that the southernmost Lake Ngami or the Boteti River only receives substantial water during higher flow years. The Boteti River, which is now mostly dry, ultimately connects to the Makgadikgadi saltpan to the southeast of the Delta. The Panhandle comprises a linear depression with a 3-4 km wide floodplain upon which terraces (fluvisols) have developed. These terraces are not used for agriculture (except seasonal cattle grazing) because of annual inundation. Further southeast, the river forms an extensive permanent swamp prior to branching into several channels (e.g. Nqoga, Jao-Boro), which flow as distributaries through seasonally or intermittently flooded floodplains supporting phaeozems and luvisols (Fig. 6). The distributaries are interspersed with sandy islands and tongues of dry land, which comprise mainly arenosols. During recent decades outflow from the Delta has declined and the patterns of flow have continued to change. The Khwai River has experienced increased (out) flow during recent years, while very recently (2004) outflow into Lake Ngami through the Matsibe-Kunyere system reached a size it had not attained for several decades (Fig. 6). By contrast, recent outflow through the Gomoti, Santantadibe, and Thamalakane Rivers was below levels experienced earlier. The variations in the flow are due to a number of factors, summarized in Ringrose et al., (2003) and include tectonics, rainfall inputs and hippopotamus movements but recent flow variations such as the decline of the Thoage are also related to channel blockages by vegetation (Ellery et al., 1995). Such variations are critical to support the biodiversity of the Delta as annual flow variability ensures that nutrients sustaining the various ecological units are dispersed in place and time (Ramberg et al., 2005). However, this variation has severe adverse impacts on the people whose livelihoods depend on water availability as rivers may dry for decades causing villages to become moribund. Flow variability and the low levels of population are historically related to the prevalence of tsetse fly, which has ensured the survival of extensive wildlife populations, which in turn currently attract thousands of tourists annually worldwide. Tourist activities take place mainly in the Delta core area, while most agricultural activity takes place peripheral to the Panhandle and along the western and southern margin of the Delta. Here mostly traditional maize and millet crops are grown on lower lying land including inter-dune depressions and flood recession cultivation, which utilizes both rainfall and seasonal drainage. The Delta core and peripheral agricultural areas are separated by veterinary cordon fences to help prevent foot and mouth disease from spreading into the local cattle population (Fig. 6). The fence (erected in 1982) has had the beneficial effect of minimizing cattle incursions into the Delta core, as tsetse fly are now all but eradicated (Ringrose et al., 1997).

In the Delta aquatic vegetation is associated with surface water and surrounding valleys, while terrestrial vegetation communities are more independent of the river (Ringrose and Matheson, 2001). Typically, tall reeds and *Cyperus papyrus* are found in deeper water with grasses and sedges (e.g. *Phragmites australis*) in the shallower flooded fringes (Ringrose et al., 1988). Their growth depends on the details of flow and flooding and on access to nutrients (Ellery et al., 2000). Terrestrial plants and trees are mainly influenced by soil characteristics and rainfall conditions (Ringrose et al., 2001, 2003). In terms of the spatial distribution of different vegetation types, the Delta vegetation is divided into permanent swamp vegetation dominated by *Cyperus papyrus* with reed beds of *Phragmites australis* and Typha bulrushes. More variation exists in the seasonal swamps depending on depth of water and duration and level of flooding. Grasses and sedges dominate with Riverine forest on islands and along channels (Ellery and Ellery, 1997). The Delta core is flanked by Mopane (*Colophospermum mopane*) woodland on the east/north-east and Acacia woodlands (*Acacia erioloba, Acacia tortilis*) to the southwest /west. Plant usage in the Okavango Delta and the basin is shown on Table 3.

3 Socio-political climate

The socio-political climate of the Okavango Basin has been adversely affected by the civil war in Angola which lasted for about three decades (Porter and Clover, 2003). The war had adverse impacts on the economy of

Angola, and also made cooperation of the riparian states in the management of the basin very difficult. In the post war period, the basin states are working together to promote integrated water resource management in the Okavango Basin. The establishment of the Permanent Okavango River Basin Water Commission (OKACOM) in 1994 preceded the signing of the SADC Water Protocol (Pinheiro *et al.,* 2003). The 1995 SADC Protocol on Shared Watercourse Systems and its 2000 revision developed a set of basic principles that apply to the management of all international rivers in southern Africa (Ashton and Neal, 2003). These principles are legally binding even if they are not specifically mentioned in the treaty establishing the River Basin Commission. In the case of OKACOM the signatory countries have agreed to bind themselves to key principles. The principles are in essence those that were developed in the *Helsinki Rules* and the *United Nations Convention on the Non-Navigable Use of International Watercourses* (Ashton and Neal, 2003). Currently relations between the three riparian States are healthy, and OKACOM is starting to function well with a proposed Secretariat in Maun, Botswana.

4. People of the Okavango River Basin[1]

4.1 Current population distribution

About 600 000 people live in the Okavango Basin (Mendelson and el Obeid 2004), 58% living in the basin area in Angola, 27% in Kavango in Namibia and 15% in Ngamiland in Botswana (Fig. 7). As the number of people living decreases from north to south, the proportion of those living in towns increases from 14% in Angola, 26% in Kavango to 50% in Ngamiland. In the Angolan part of the basin, there are two large towns and 55 smaller towns. The large towns are Menongue with about 30 000 people and Cuito Cuanavale with about 20 000 people. In Namibia, the town of Rundu has a population of about 42 000 while Maun in Botswana has about 44 000 people. Some of these town dwellers are not entirely dependent on natural resources, particularly in Namibia and Botswana. People in the smaller settlements along the river are almost all basin inhabitants indirectly dependent on water from the Okavango River.

The highest densities of rural people are located are found in the upper Cubango catchment in Angola, and along the river throughout its course to the border and traversing Namibia to the Delta in Botswana. A majority of the basin area, in Angola and in Botswana, supports less than 1 person per square kilometer while in Namibia it is generally higher. People living in the basin area of Angola represent less than 3% of the total population of

[1] This section is largely based on material published in Mendelson and el Obeid (2004).

Angola, whereas those in Namibia represent less than 7%, and those in Botswana less than 5%. The population of Kavango District in Namibia has rapidly increased during the past century as this has become a major food producing area (Fig. 8). Immigration into Kavango, has accounted for the high population growth rates, leading to a population growth of approximately double that expected from natural growth. Young people dominate the populations of Kavango and Ngamiland and females outnumber males (Fig. 9). If the trend of the rapid population growth continues, the environmental sustainability of the Okavango River water and its resources is likely to be adversely affected, and this may in turn affect social sustainability. As Sachs (1999:27) puts it, "social sustainability and environmental sustainability condition each other". Botswana and Namibia have a high incidence of HIV/AIDS, which has increasingly had an adverse impact on livelihoods of people in basin. Its prevalence for the age group 15 to 49 is estimated at 37.3% for Botswana and 21.3% for Namibia (UNDP, 2005). In the Botswana part of the basin, the percentages of the total population who were HIV/AIDS positive were 16% and 13% in Ngamiland South and Ngamiland North respectively, as compared to the national figure of 17% (CSO, 2004).

5 **Livelihoods and natural resources pressure**

5.1 An overview of economic development

The economy of the Okavango Basin forms part of the larger mineral-led economies of the countries of Angola, Namibia, and Botswana. In 2003, the purchasing power parity (PPP) per capita incomes for these countries ranged from USA $1,890 (Angola) to 6,620 (Namibia) and 7,960 (Botswana) (World Bank, 2005). These average figures mask the high variation of incomes among the basin regions and different categories of households. The rapid economic growth in Botswana, for example, has not led to a substantial reduction in poverty as 50% of the population lives below USA $2 a day (World Bank, 2005). The 1996 human poverty index of the North West district (Ngamiland and Chobe) also reveals that most people still live in poverty in the Botswana part of the basin. This index (at 40.6) shows that more than a third of the population still lives in "human poverty" (circumscribed by life expectancy, poor health, illiteracy and social exclusion) in this region (UNDP, 2000). The index is more than twice the indices for Francistown, Lobatse, and Selibe Phikwe of 14.5, 18.8 and 16.6, respectively (UNDP, 2000). In Namibia, 66% of the population still lives below USA $2 a day (World Bank, 2005). According to Werner (2002), the Kavango region is the third poorest in Namibia (after

Ohangwena and Caprivi regions), and more than 50% of the households are living in abject poverty (DRFN, 2004). As a result of the civil war, the Angolan part of the basin (like in most parts of Angola) is characterized by poor infrastructure, inadequate social services, and limited access to some of the assets needed for the generation of livelihood activities (Porto and Clover, 2003). The proportion of the population living in poverty is not known in the Angolan part of the basin, but the national figure is estimated at 67% (Matlosa et al., 2002). In the 2005 Human Development Report, which has indices for 177 countries, Angola was ranked 160 th out of 177 countries in terms of human development, and had a human development index of 0.445, whereas Botswana and Namibia were ranked 131st and 125 th, respectively and had indices of 0.565 and 0.625, respectively (UNDP, 2005). The development gains achieved in Botswana before the 1990's are being reversed as a result of a decrease in life expectancy resulting from the impact of the HIV/AIDS pandemic. For instance, Botswana's ranking for the human development index (HDI) has fallen by 21 places between 1990 and 2003 to the 131st position. Botswana is among the 12 countries in sub-Saharan Africa whose human development is lower than it was in 1990 (UNDP, 2005).

All the basin countries see the Okavango Basin as a potential source of development opportunities. It is, however, important to recognise that the hydrological regime and water quality of the river as a whole, including the Delta, is to a large extent determined by what is happening upstream in Angola and Namibia. Botswana uses the waters of the Okavango River mainly for tourism development, whereas Namibia uses it mainly for large-scale irrigation. Namibia is also in the last phase of the implementation of the four-phased Eastern National Water Carrier (ENWC) project, which aims at abstracting water from the river in order to supply central and western parts of the country (DRFN, 2004). It is also planning to construct a hydropower plant at Popa Falls upstream from the Panhandle, which is expected to provide a reliable power supply to the towns of Rundu and Katima Mulilo, and make rural electrification in Kavango a possibility (DRFN, 2004). In Angola, the Government is currently more concerned with social recovery and reconstruction of the country, but there are great development opportunities involving the use of the river and its natural resources. A feasibility study undertaken before 1974, revealed a potential for the generation of 350 MW hydropower and irrigation of 54 000 ha (Pinheiro et al., 2003).

5.2. Livelihood activities and opportunities

The main natural resource-based livelihood activities in the Okavango Basin include arable farming, livestock farming, collection of veld products, basket making, fishing, and tourism. Non-natural resource based livelihood activities include social welfare benefits, formal employment, remittances, drought relief initiatives, and rural trade. Important livelihood opportunities for people in the basin are the outcome of a combination of the natural resources available in the area, primarily water, land and living biological resources.

According to Mendelson and el Obeid (2003), more people are dependent on farming in Angola than in other parts of the basin. They estimate that in Angola there are 60 000 farmers involved in small scale arable farming and livestock farming, as compared to 18 000 and 8 500 farmers in Kavango and Ngamiland, respectively. In the Angolan part of the basin, the majority of farmers cultivate their crops on dry lands, but other households practice flood recession agriculture in fields known as *onaka* (*molapo* in Botswana). The common crop planted in these fields is maize (Mendelson and el Obeid, 2004). Arable farming in Ngamiland is also in the form of dryland and flood recession (*molapo*) cultivation. In 1997 and 1998, the proportions of farmers who practiced *molapo* farming accounted for 27% and 16% of the all the farmers in Ngamiland, whereas those who practiced dryland farming accounted for 73% and 84%, respectively. The main crop planted in the *molapo* fields is maize, intercropped with beans, water melons and pumpkins. Cattle rearing is a common livelihood activity throughout the basin. Though the figures for Angola are very scanty, Mendelson and el Obeid (2004) estimate that only 5% of the households have access to cattle in the Angolan basin, as compared to 50% in both Kavango and Ngamiland.

The development of tourism is more advanced in Ngamiland than in Kavango and in the Angolan basin. In Ngamiland, the Okavango Delta is an important attraction for tourism, the second most important economic activity in Botswana after diamonds (Mbaiwa, 2002). Tourism accounts for 5% of the Gross Domestic Product (GDP) or 7% of the non-mining GDP (Department of Tourism, 2000). Currently, 60% of the total labour force in Ngamiland is engaged by the tourism sector and its backward linkage industries and services (Mendelson and Obed, 2003; Mbaiwa, 2002). Some of the tourism activities are in the form of community-based natural resource management (CBNRM) projects. According to Mbaiwa (2005), the tourism sector in Botswana marginalises local companies and investors; repatriates profits, and fails to promote rural development. The UK Department for International Development (DFID) study on wildlife and poverty also asserts that although the tourism sector has the fastest economic growth in developing countries, it tends to marginalize the poor (excluding community based tourism). In the Kavango region, there are limited facilities for tourism, despite the fact that the area is endowed with permanent rivers, wetland systems, and a rich cultural heritage (DRFN, 2004). Bird viewing is becoming an important tourist activity, particularly around Popa Falls and Mahango Game Reserve. This great potential for this region as a tourist attraction has not been fully exploited. The main constraint for the development of tourism is poor infrastructure, which also affects development opportunities for other sectors. There are a total of six lodges and two campsites between Rundu and Divundu, but they contribute little to employment creation and livelihood diversification. In addition, CBNRM initiatives have not been introduced in the Kavango region, as is the case in some parts of Namibia (DRFN, 2004; Water Transfer Consultants, 2003). According to Water Transfer Consultants (2003), these initiatives could be introduced in four protected areas situated near Popa Falls.

Access to rural livelihoods is mediated and affected by institutions, shocks, and demographic and economic trends (Ellis, 2000. Werner, 2002; Kgathi et al., 2006; Mendelson and el Obeid, 2004; DRFN, 2004). In the Okavango Delta, land tenure institutions for the establishment of CBNRM have resulted in reducing access of the local communities to their land and its natural resources (veld products and wildlife resources) (Taylor, 2000). In addition, the introduction of cordon fences by the veterinary department for disease control purposes in Ngamiland also had an adverse effect on livelihoods, as it reduced access of communities to water, pasture, fishing and gathering (Ministry of Agriculture, 2002; Kgathi et al., 2004). There is no information on the impact of changes in land tenure institutions on access to livelihoods on the Angolan and Namibian parts of the basin, but the proposed expansion of irrigation schemes in Kavango may reduce access of the local communities to land and its natural resources.

The common livelihood shocks in the Okavango basin include drought, diseases (animals, crops, and humans), floods, desiccation of river channels (primarily due to natural geographical shifts in the flow of water) and civil unrest (Kgathi et al., 2004; Mendelson and el Obeid, 2004). Desiccation of river channels in Ngamiland has adversely affected access of the local communities to water resources (for humans and livestock), *molapo* farming, fishing, and the harvesting of veld products (Kgathi et al., 2004). The impact of shocks on livelihoods in the Okavango Basin is also demonstrated by the civil unrest of 1999 and 2000 in the Kavango region, which resulted in the closure of many lodges and hotels in this region for a period of one year. The unrest was related to banditry by UNITA troops in Kavango and western Caprivi, which resulted in the Namibian military troops assisting the Angolan Government in combating it. Similarly, the political problems in Zimbabwe in 1999 and 2001 reduced the number of tourists at Moremi Game Reserve (Fig. 6) by 35% (Mendelson and el Obeid, 2004).

5.3 Impacts of the use of natural resources on environmental sustainability

There is an interest to develop and use the natural resources of the Okavango Basin for socio-economic development and a concern to conserve the natural environment. These concerns are significant among various groups inside and outside the basin, which include the general public, policy-makers and the international conservation community (Scudder et al., 1992; Ramberg, 1997; and Jansen and Madzwamuse, 2003). In the basin, these concerns include the environmental sustainability of projects on water transfers, irrigation, hydropower, tourism, and environmental issues in a wider sense (e.g. maintenance of biodiversity, preservation of endangered species and pollution control). There is a perception in Botswana that the abstraction of water from the Okavango River as well as the construction of hydropower at Popa Falls may negatively affect the ecological sustainability of the Okavango Delta in the long run. A recent pre-feasibility study undertaken by a team of consultants to assess the construction of the hydropower plant on the Okavango River at Popa Falls, near Divundu, revealed the importance of sediment transport for the ecological functioning of the Okavango Delta. It revealed, *inter alia*, that the project may reduce the flow of sediments to the Okavango Delta, leading to the following possible impacts: 1) reduction in the rate of switching of channels at the Delta, 2) stabilization of plant communities with the prevention of the renewal of the ecosystem and 3) ultimately a reduction in biological diversity. The study identified a number of key issues that should be investigated such as the magnitude of various impacts, the mitigation measures needed, and a detailed socio-economic study that will weigh the societal costs against the benefits of the project (Water Transfer Consultants, 2003).

The pressure on the river and its resources is increasing, primarily due to demographic and social trends in the three countries, the peace process in Angola (which has seen people returning to the basin), and as a result of various initiatives for development projects. At the moment water abstraction from the river is limited in the basin, but it may not be so in the future. In Ngamiland, natural resources such as raw materials for basket weaving, and river reeds, are increasingly becoming scarce. They are decreasing in availability due to over-exploitation resulting from their commercialization and also because of market failure resulting from their open access nature, lack of appropriate conservation policies, and changes in the distribution of the Okavango River water (Kgathi et al., 2005). In addition, land for *molapo* farming is also perceived to be not readily available. The availability of land for *molapo* arable farming is adversely affected by the desiccation of the

Okavango River channels and the increasing human population (Kgathi et al., 2005). However, the fish resources are not over-exploited because of the good methods used for harvesting them and also because of the low human population density. The maximum sustainable yield (MSY) for the fishery has not been reached and effort can be doubled without any biological exploitation (Mosepele and Kolding, 2003; Kgathi et al., 2005).

In Kavango, natural resources such as reeds, thatching grass, and some wildlife species are reported to be decreasing in availability (Jones, 2001). While fish resources are not over-exploited in the Ngamiland, they are reported to be decreasing in Kavango because of the unsustainable fishing methods (Jones, 2001). According to Hay et al (2003), there is less large fish and lower catch per unit effort in gillnets in the fishing areas of Kavango. The authors further note that the catches are mainly for subsistence purposes, and could drastically be depleted by commercial exploitation.

6.0 Concluding Remarks

The Okavango River is an important source of livelihoods for the basin communities. It is also an important attraction for wildlife-based tourism and a source of water for flood recession cultivation and commercial irrigated agriculture. Namibia has plans to use the Okavango River water to: 1) supply the central and western parts, 2) expand its irrigation farming projects in order to boost production of food and cash crops, and also 3) to construct a hydro-power plant at Popa Falls. Angola may also use the river for various development initiatives once its programme of social recovery and reconstruction has been accomplished. Though the Okavango Basin is endowed with many natural resources, the majority of people still live in poverty and consequently most people still depend on local natural resources (e.g. land, water, wood and wildlife) for their livelihoods.

There is evidence that the exploitation of natural resources in the basin is beginning to exert pressure on the natural environment. This pressure may increase in the future due to the rapid increase in population, the peace process in Angola, and new development initiatives. In Botswana, there is already a scarcity of the land for flood recession agriculture due to the increasing population and changes in flooding patterns of the Okavango Delta (Kgathi et al., 2005). There is also a concern that the possible future abstraction of water from the Okavango River and the use of water for development projects in Angola and Namibia may adversely affect the environmental sustainability of the Okavango Delta, hence some commentators hold the view that the precautionary principle should be adopted in this case, as there are many uncertainties about the possible future impacts on the downstream areas (Pearce and Barbier, 2001; Arntzen and Kgathi, 2005). While there is some wisdom in this suggestion, it is very difficult to implement this idea due to the pressing needs for development, particularly in Angola. There are legitimate and urgent needs in Angola as a result of the humanitarian crises for about half a million war-affected people and the inevitable need to use the river and its resources for livelihood diversification and various development initiatives. Pressing development needs of the poor must, therefore, be recognized and be balanced with the efforts to safeguard the downstream areas, particularly the Okavango Delta. It is necessary to diversify the livelihoods of the basin people in order to alleviate adverse effects on the natural environment as poverty may otherwise result in survival strategies that negatively affect the natural environment. The reduction of poverty may therefore play a significant role in the protection of the environment.

The most appropriate development strategy for alleviating poverty in the basin is to develop tourism and CBNRM initiatives. The potential for these initiatives has not been developed in Angola due to the legacy of the civil war. Mendelson and el Obeid (2004) suggest that the best way to develop tourism in Angola is to allow the tourist operators Botswana to expand into Angola. In this way, there will be a guarantee that investments and activities in Angola may not threaten the downstream interests. According to Pinheiro et al., (2003), it will be necessary to create conservation areas in Angola in order to promote tourism in the future, but in the short term, there is an urgent need is to promote the social recovery and reconstruction programme. Although tourism and CBNRM initiatives have been developed in the Botswana and Namibian part of the basin, it is necessary to improve their contribution to livelihood diversification and poverty alleviation. This can be done by creating incentives that will enable the private sector to promote “pro-poor tourism” (Livestock and Wildlife Advisory Group, 2002). In the Namibian part of the basin, it is also necessary to develop the infrastructure to boost tourism as well as other developments. Development strategies such as the promotion of commercial irrigated agriculture and manufacturing should be discouraged in the basin as they are associated with the use of agro-chemicals and emission of pollutants, respectively, and may thus affect natural ecosystems that are the basis of the tourism industry.

It is also crucial to integrate HIV/AIDS programmes into the development process as this pandemic increases the vulnerability of households to poverty, especially as it results in mortality of “prime-age” adults (Kgathi et al., 2006). The seriousness of this pandemic has adverse consequences for the viability of achieving the Millennium Development Goals, particularly those of poverty eradication, reduction of infant mortality, improvement of maternal health and environmental sustainability (UNDP, 2005), and may therefore ultimately hinder the future sustainable and wise use of the wetland resources of the Okavango River.

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Table 1 Major morphometric and hydrological parameters of the Okavango Delta, Botswana based on satellite imagery and mathematical models (after Dincer *et al*., 1987, Wolski et al., 2003;2005)

Okavango Delta area	20 000 km^2
Mean area of surface water	10 000 km^2
Maximum area of surface water	13 000 km^2
Minimum area of surface water	6000 km^2
Mean active groundwater storage	4×10^9 m^3
Maximum active groundwater storage	7×10^9 m^3
Minimum active groundwater storage	1×10^9 m^3
Inflow from catchment Rivers	10.5×10^9 m^3/yr
Average precipitation	5×10^9 m^3/yr
Evapotranspiration	14.9×10^9 m^3/yr
Outflow (surface)	0.3×10^9 m^3/yr
Outflow (groundwater)	0.3×10^9 m^3/yr?

Table 2. Properties of soils occurring the Okavango basin in sub-surface (after Joshua, 1991)

Soil type	Particle Size (30cm) (fine sand%)	Organic carbon %	Bulk density gm/c	Agric potential
Arenosol /Sandy Fluvisol	62.7	0.08	1.55	Low
Calcisols	37.0	0.33	1.38	Medium-Low
Phaeozems	28.4	0.37	1.5	Medium
Luvisols	36.9	0.66	1.58	Medium-Low
Gleysols	30.7	1.39	1.22	Medium

Table 3 Examples of plant usage in the Okavango basin (partly after Huntley, 1974, Packham, 1993, Frost 1996, Campbell et al., 1996, , Meyer, et al., 2005)

Species	Cover type	Use/Activity	Location
Cyperus papyrus	Reed and Sedge	Thatching-reed fences	Riverine swamps throughout south-central basin
Phragmites australis	Reed and Sedge	Thatching-reed fences	Riverine swamps throughout south-central basin
Loudetia simplex	Tall grassland	Thatching??	Congo interfluve
Julbernardia paniculata,	Tree	Charcoal/fuelwood	Miombo woodland – mainly Angola
Cryptosepalum pseudotaxus	Tree	Charcoal/fuelwood	Miombo woodland – mainly Angola
Burkea africana,	Tree	Charcoal/fuelwood	Miombo transition – Angola/Namibia/Botswana
Pterocarpus angolensis,	Tree	Charcoal/fuelwood Furniture-carvings	Miombo transition – Angola/Namibia/Botswana
Baikiaea plurijuga,	Tree	Charcoal/fuelwood Furniture-carvings	Miombo transition – Angola/Namibia/Botswana
Terminalia sericea	Tree and shrub	Fuelwood-mokoro poles	Kalahari – Namibia/Botswana
Colophospermum mopane	Tree and shrub	Fuelwood-fencing – phane worms	Kalahari – Namibia/Botswana
Acacia erioloba,	Tree	Fuelwood-contruction	Kalahari – Namibia/Botswana
Acacia tortilis	Tree and shrub	Fuelwood-contruction	Kalahari – Namibia/Botswana
Hyphaene petersiana	Tree and shrub	Basket making	Kalahari-riparian fringe Namibia/Botswana
Diospyrous mespiliformis	Tree	Mokoro making Wild fruit	Kalahari – riparian fringe Namibia/Botswana

Figure Captions

Figure 1. The extent of the Okavango basin in southern Africa. The active catchment rises in Angola. Rivers shown in Namibia and Botswana are either totally dry or infrequently ephemeral. (Partly after Mendelson and el Obeid, 2004).

Figure 2. Spatial distribution of the average hourly rain rates for December through to March for 1996-2002 from satellite data

Figure 3. Spatial distribution of the average hourly rain rates for March through to May for 1996-2002 from satellite data

Figure 4. Imagery of settlement patterns in Angola relative to Cutato and Cuchi tributaries of the Cubango River, Angola.

Figure 5. Irrigation and/or traditional farms in the Kavango District, Namibia.

Figure 6. The Okavango Delta, its outflows/distributaries and main population centres

Figure 7. Estimated population densities in the Okavango Catchment (After Mendelson and el Obeid, 2004

Figure 8. Population Growth in Ngamiland and Maun and Kavango and Rundu over the past 90 years (After Mendelson and el Obeid, 2004).

Figure 9. Age structure of population in Ngamiland (Botswana) and Kavango (Namibia) in 2001 (After Mendelson and el Obeid, 2004).

Figure Captions

Figure 1. The extent of the Okavango-Makgadikgadi basin in southern Africa, comprising the perennial catchment in Angola and the ephemeral catchment in Namibia, Botswana and Zimbabwe (Partly after Mendelson and el Obeid, 2004).

Figure 2. Spatial distribution of the average hourly rain rates for December through to March for 1996-2002 from satellite data (geographic dimensions shown in degrees of latitude and longitude).

Figure 3. Spatial distribution of the average hourly rain rates for March through to May for 1996-2002 from satellite data (geographic dimensions shown in degrees of latitude and longitude).

Figure 4. Imagery of settlement patterns in Angola relative to Cutato and Cuchi tributaries of the Cubango River, Angola

Figure 5. Central pivot irrigation in the Kavango District, Namibia.

Figure 6. The Okavango Delta, its outflows/distributaries and main population centres

Figure 7. Estimated population densities in the main Okavango river basin states (After Mendelson and el Obeid, 2004)

Figure 8. Population Growth in Ngamiland and Maun and Kavango and Rundu over the past 90 years (After Mendelson and el Obeid, 2004).

Figure 9. Age structure of population in Ngamiland (Botswana) and Kavango (Namibia) in 2001 (After Mendelson and el Obeid, 2004).

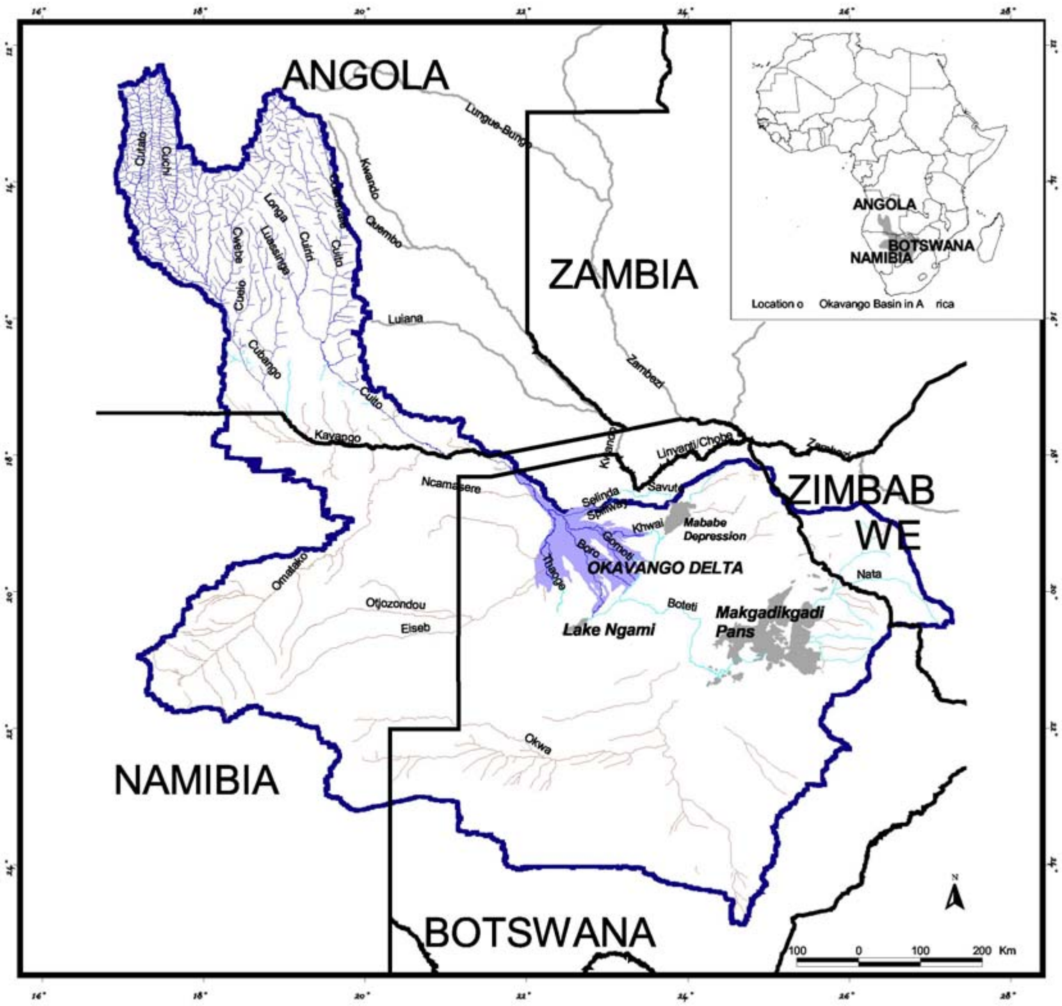

ANGOLA
ZAMBIA
NAMIBIA
BOTSWANA
ZIMBAB WE
Location o Okavango Basin in A rica
OKAVANGO DELTA
Lake Ngami
Makgadikgadi Pans
Mababe Depression
Cutato
Cuchi
Longa
Cuebe
Luassinga
Cuiriri
Cuito
Cuelo
Cubango
Kwando
Quembo
Luiana
Lungue-Bungo
Zambezi
Kavango
Ncamasere
Selinda
Spillway
Savuti
Linyanti/Chobe
Khwai
Gomoti
Boro
Thaoge
Boteti
Nata
Omatako
Otjozondou
Eiseb
Okwa
100 0 100 200 Km

Figure 1

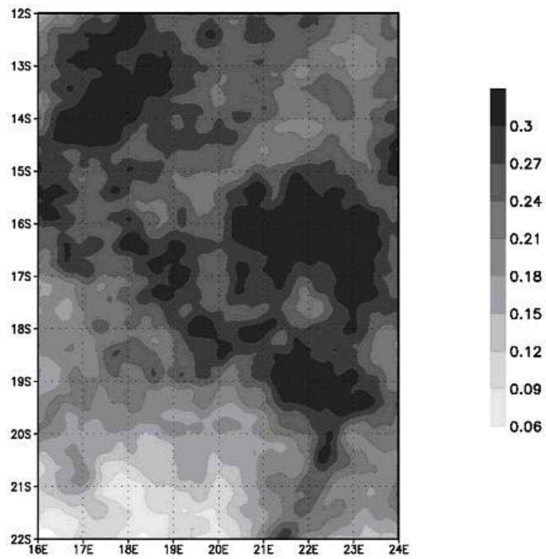

12S
13S
14S
15S
16S
17S
18S
19S
20S
21S
22S
16E
17E
18E
19E
20E
21E
22E
23E
24E
0.3
0.27
0.24
0.21
0.18
0.15
0.12
0.09
0.06

Figure 2

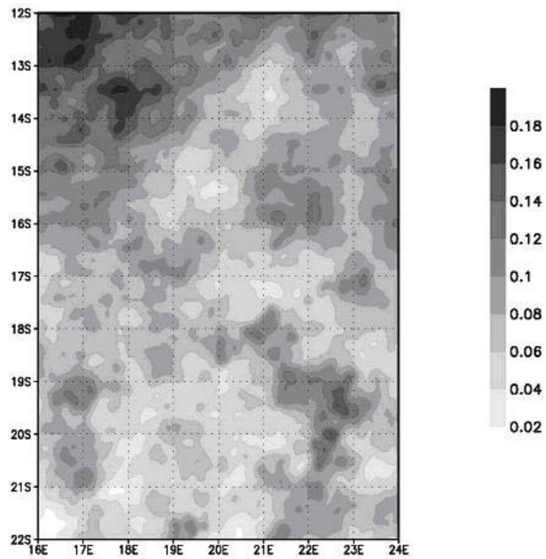

12S
13S
14S
15S
16S
17S
18S
19S
20S
21S
22S
16E
17E
18E
19E
20E
21E
22E
23E
24E
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02

Figure 3

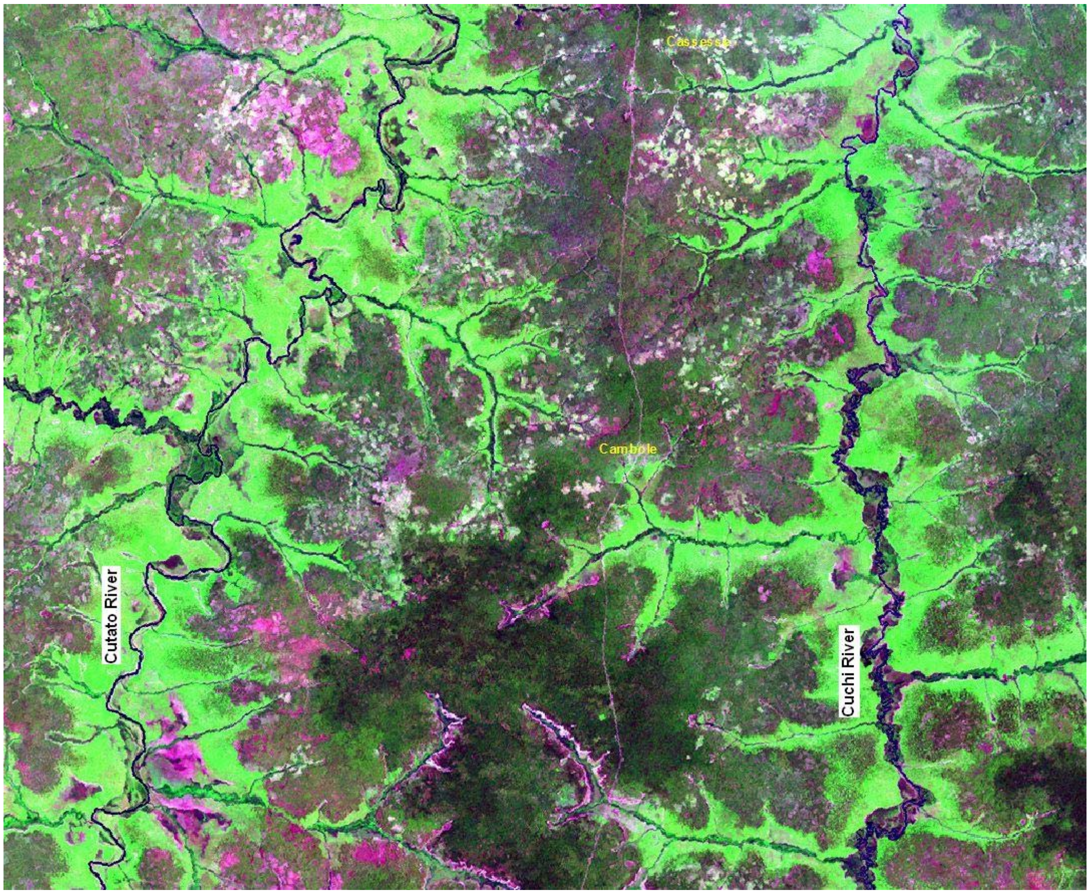


Figure 4

Figure 5

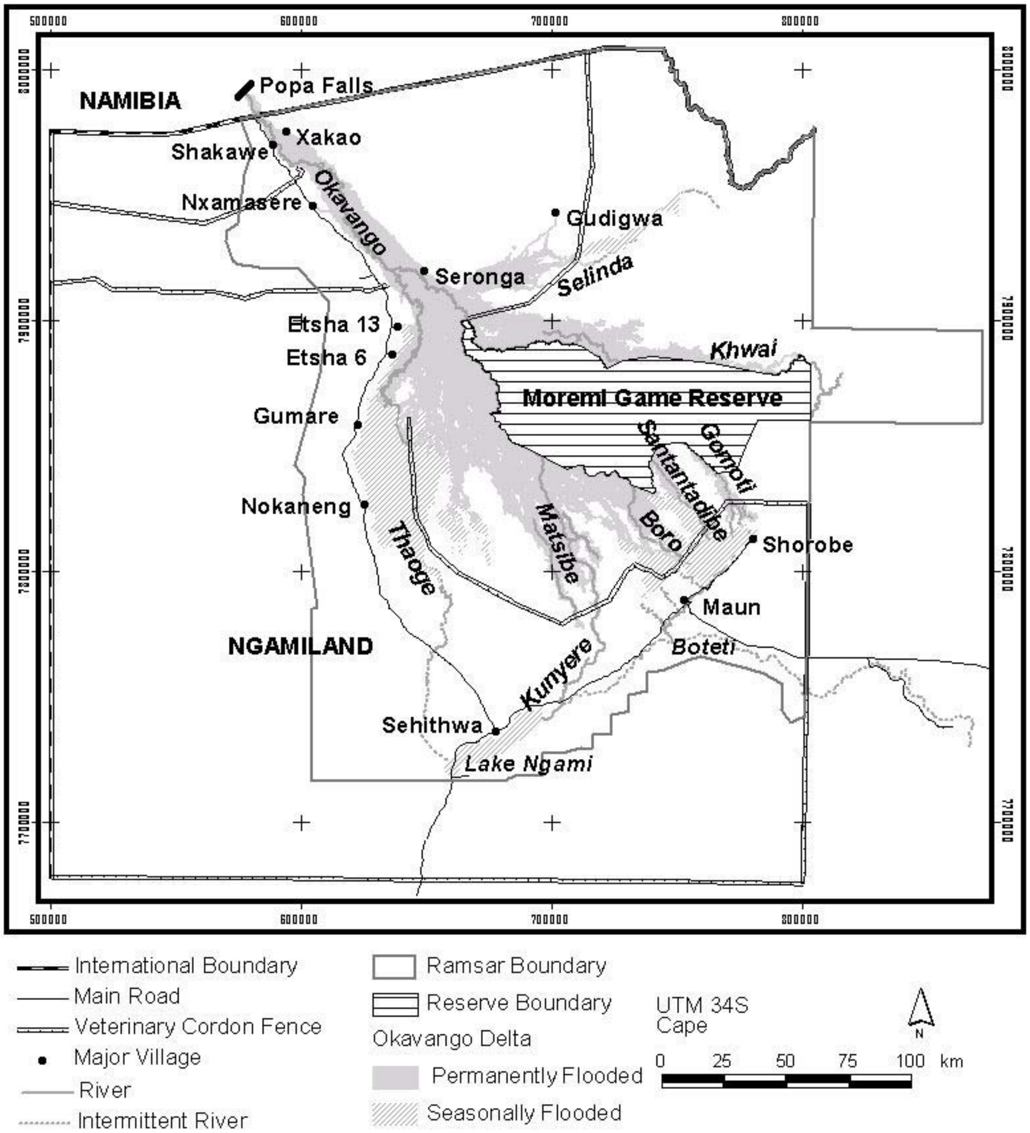

NAMIBIA
Popa Falls
Xakao
Shakawe
Nxamasere
Okavango
Gudigwa
Seronga
Selinda
Etsha 13
Etsha 6
Khwai
Moremi Game Reserve
Gumare
Santantadibe
Gomoti
Nokaneng
Thaoge
Matsibe
Boro
Shorobe
Maun
NGAMILAND
Boteti
Kunyere
Sehithwa
Lake Ngami
500000
600000
700000
800000
7900000
7800000
7700000
International Boundary
Main Road
Veterinary Cordon Fence
Major Village
River
Intermittent River
Ramsar Boundary
Reserve Boundary
Okavango Delta
Permanently Flooded
Seasonally Flooded
UTM 34S
Cape
0 25 50 75 100 km
N

Figure 6

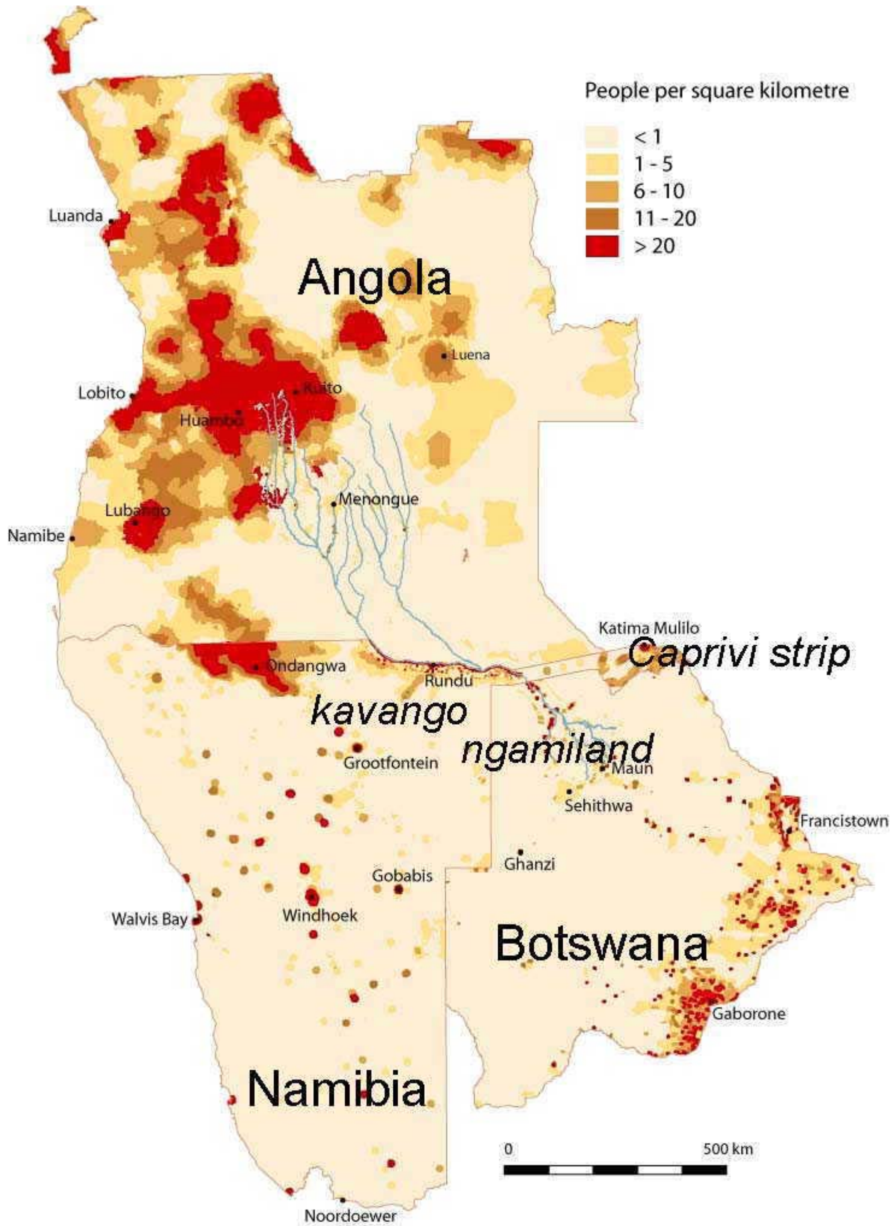

People per square kilometre
< 1
1 - 5
6 - 10
11 - 20
> 20
Angola
Luanda
Luena
Lobito
Kuito
Huambo
Menongue
Lubango
Namibe
Katima Mulilo
Caprivi strip
Ondangwa
Rundu
kavango
ngamiland
Grootfontein
Maun
Sehithwa
Francistown
Ghanzi
Gobabis
Walvis Bay
Windhoek
Botswana
Gaborone
Namibia
0
500 km
Noordoewer

Figure 7

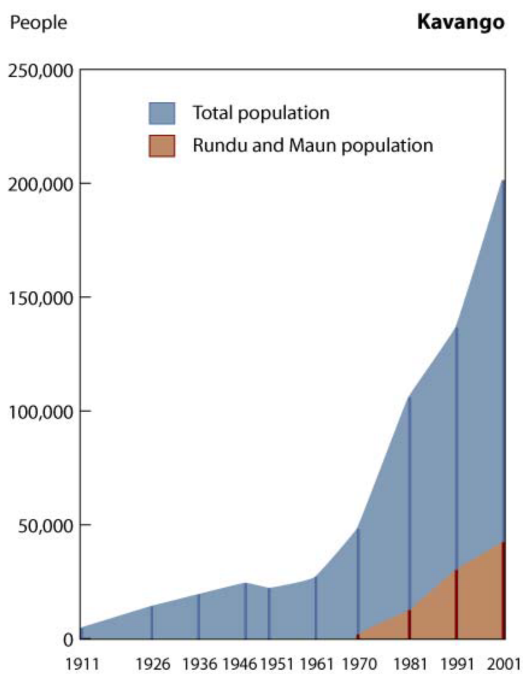
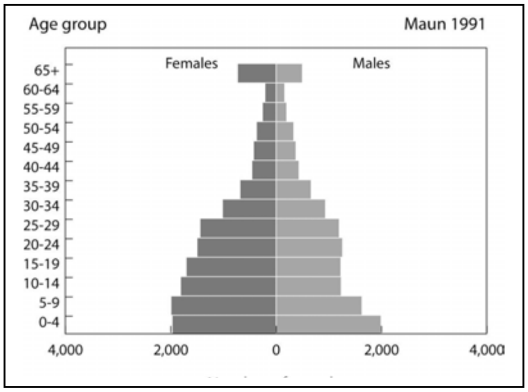

People
Kavango
250,000
200,000
150,000
100,000
50,000
0
Total population
Rundu and Maun population
1911
1926
1936
1946
1951
1961
1970
1981
1991
2001
People
Ngamiland
250,000
200,000
150,000
100,000
50,000
0
1911
1921
1936
1946
1964
1971
1981
1991
2001

Figure 8


Age group
Maun 1991
Females
Males
65+
60-64
55-59
50-54
45-49
40-44
35-39
30-34
25-29
20-24
15-19
10-14
5-9
0-4
4,000
2,000
0
2,000
4,000

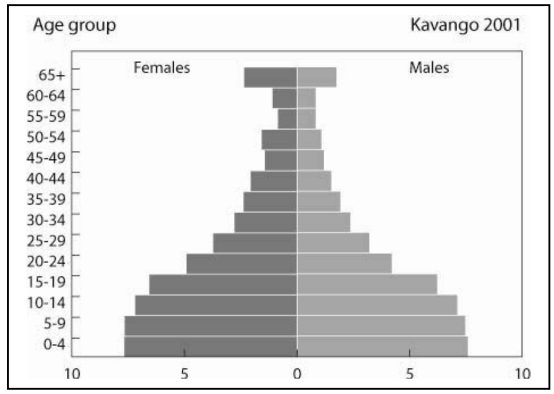

Age group
Kavango 2001
Females
Males
65+
60-64
55-59
50-54
45-49
40-44
35-39
30-34
25-29
20-24
15-19
10-14
5-9
0-4
10
5
0
5
10

Figure 9