Green Water Credits

BASIN IDENTIFICATION

Green Water Credits: Basin Identification

Green Water Credits Report 1

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ISRIC - World Soil Information

Green Water Credits is a mechanism to pay rural people for specified land and soil management activities that determine all fresh water resources at source. These activities are presently unrecognized and un-rewarded. This proof-of-concept program is supported by the International Fund for Agricultural Development (IFAD) and the Swiss Agency for Development and Cooperation (SDC).

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Contents

Tables

Figures

SUMMARY

Green Water Credits (GWC) is a mechanism for payments to land users in return for specified land and soil management activities that determine the supply of fresh water at source. These activities are presently unrecognised and unrewarded. Direct payment will enable better management. At the same time, GWC will provide a reliable diversification of rural incomes, enabling communities to adapt to economic, social and environmental change through asset-building in the shape of stable soils, more reliable local water supply, improved crops and infrastructure.

The proof-of-concept project aims to demonstrate the viability and feasibility of the concept. The criteria for selection of a river basin for the study were:

a) Relevance to water scarcity and poverty issues;
b) Potential for better soil water management to make a difference to downstream water supply;
c) Identifiable downstream water users, able to pay for upstream water management;
d) Upstream benefits in terms of improved food and water security;
e) Political will, necessary legislation or the likelihood that it will be introduced, and effective institutions able to manage the GWC mechanism;
f) Baseline data to assess the upstream and downstream effects of improved soil and water management;
g) The priorities of IFAD and SDC in respect of poverty and the environment, and synergies with existing projects.

IFAD and SDC priorities determined that the basin should be in West, North-Central or East Africa. Four candidate basins were identified during a *Green* and *Blue* Water workshop in Kampala in September 2005 and by consultation with African partners: the Volta in Ghana and Burkina Faso, the Tana in Kenya, the Great Ruaha and Ruvu in Tanzania. Biophysical, socio-economic and institutional information was collected by ISRIC – World Soil Information and the Stockholm Environmental Institute with assistance from national partners. This report presents this information and the ranking of the basins according to the selection criteria:

1: Tana, Kenya

The upper Tana has good rainfall and many farmers, so there is a big potential for downstream water benefits. There are important downstream water users who are in a position to pay for water management services over the long term: hydro-electric power, Nairobi city water supply and irrigators. Water scarcity is an emerging issue in the capital. Current political and economic initiatives in the water sector in Kenya may also be favorable for introduction of *Green Water Credits*: both Nairobi water supply services and KenGen are being opened to private capital.

2: Great Ruaha, Tanzania

The upper basin, around Usangu Plains, has good rainfall and a fair number of upland farmers so there is good potential for downstream water benefits. There are important downstream water users: hydro-electric power, irrigators and natural ecosystems (Usangu Plains and National Park) and water scarcity is a pressing issue.

The Great Ruaha presents a more complex situation for *Green Water Credits* than the Tana: there are small irrigators and wetlands between the main source region and the main water users; big irrigation schemes are in direct competition for water with hydropower schemes further downstream.

3: *White Volta*

The White Volta in Burkina has many upland farmers but a low rainfall. In northern Ghana there is higher rainfall but few farmers. Both situations limit the potential downstream benefits from upstream soil and water management.

In Burkina Faso, downstream water users include hydro-electric power generation, Ouagadougou city water supply, and irrigators. In Ghana, there is a major demand from hydro-electric power generation but a complicating factor is the lack of effective cross-border organisations and the problematic nature of cross-border payment of *Green Water Credits*.

4: Ruvu

The upper Ruvu has good rainfall but few farmers so there is limited potential for downstream benefits of improved soil and water management by the farmers. There is critical demand for improved water supply to Dar-es-Salaam but this might be met more easily in the short term by simple engineering interventions.

1 Introduction: principles and criteria for basin selection

Green water is the water held in soil and available to plants. It is the largest fresh water resource but can only be used *in situ*, by plants.

Blue water is groundwater and stream flow that can be tapped for use elsewhere: for domestic and stock water, irrigation, industrial and urban use and that support aquatic ecosystems (Figure 1:).

Green Water Credits (GWC) is a mechanism for transfer of cash or other benefits to rural people in return for water management activities that determine the supply of green and blue water at source (**Error! Reference source not found.**). These activities are presently unrecognised and unrewarded.

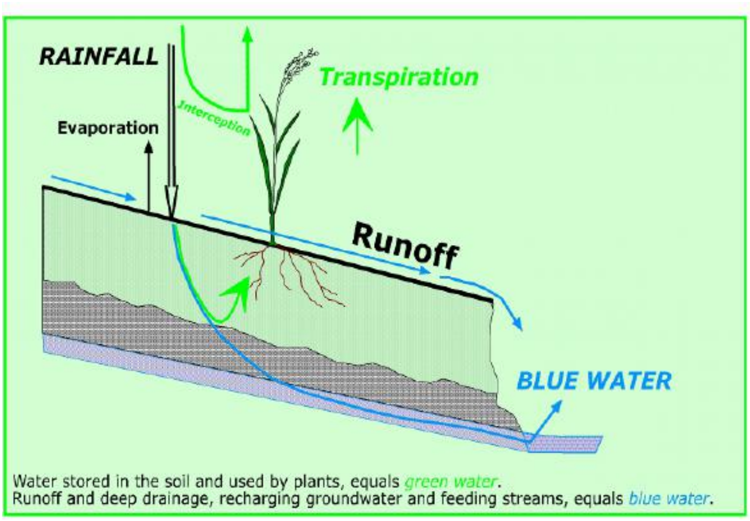

Figure 1: Green and Blue water flows
(after Rockström 1997)

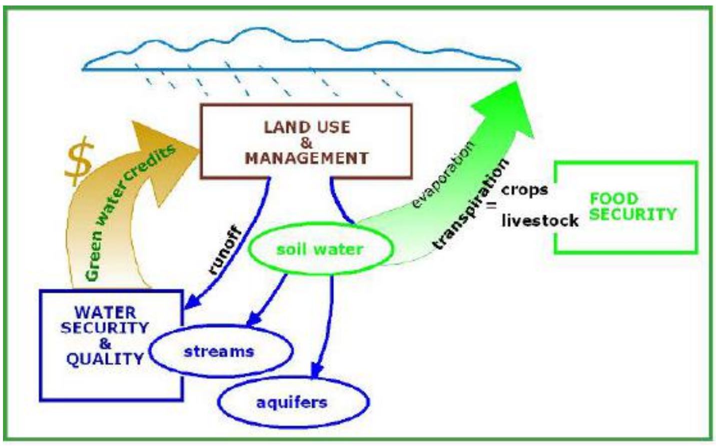

Figure 2: Green Water Credits, principle

The long-term goal of *Green Water Credits* is to enable rural people to better manage land and water resources - to improve food security, water security and public health, and to adapt to environmental changes (including climatic change), economic and social changes.

The GWC proof-of-concept project is supported by the International Fund for Agricultural Development and the Swiss Agency for Development and Cooperation. It aims to demonstrate the viability and feasibility of the offer–and–demand aspects of the GWC concept as a sustainable environmental service mechanism; improve local resilience to external shocks by asset building (*green* water resource, stable soils, shortening the hunger gap, diversified rural incomes); deliver enhanced *blue* water resources, and to reduce the hazards of floods and landslips downstream.

The GWC proof-of-concept will be undertaken in a basin located in the Savannas and Semi-Humid Zones of West and Eastern Africa. Given a favourable outcome to the proof-of-concept, pilot operations of the GWC mechanism will be established.

The criteria for selection of the basin for proof-of-concept studies are:

1. Relevance to water scarcity and poverty issues:
    - Is water scarcity an issue? Is poverty an issue?
    - Is land degradation an issue?
    - Can land use and management make a difference to downstream water supply, water quality, and downstream flood and sedimentation hazard?
2. Identifiable downstream water users, able to pay for upstream water management – such as urban water supplies, irrigation, hydro-power
3. On-site, upstream benefits of improved land and water management in terms of:
    - Environmental services
    - Sustainability of crop and livestock production
    - *Green* water resources
    - Local stream and groundwater (*blue* water) resources
4. Downstream environmental benefits
5. Political will: existence of necessary legislation or likelihood that it will be introduced; existence of effective institutions to manage the GWC mechanism
6. Adequate baseline data for scenario analysis: climate, hydrology, soils, terrain, land use, water use, social and economic data
7. Representativeness: Can the results be extrapolated to significant areas beyond the basin?
8. Synergies with current projects of partners and donor agencies: correspondence with donor priorities in poverty reduction, protection of the environment, water resources, specific countries and regions.

The decision matrix is presented in Annex 1.

2 Study Area

Four basins in Sub-Saharan Africa that might offer potential *Green Water Credit* options have been screened. The basins are shown in Figure 3 and Figure 4:

- White Volta, locally known as the Nakambé in Burkina Faso and Ghana
- Tana in Kenya
- Ruvu in Tanzania
- Great Ruaha in Tanzania

Some country statistics are provided in Table 1.

Figure 3: Location of the potential basins

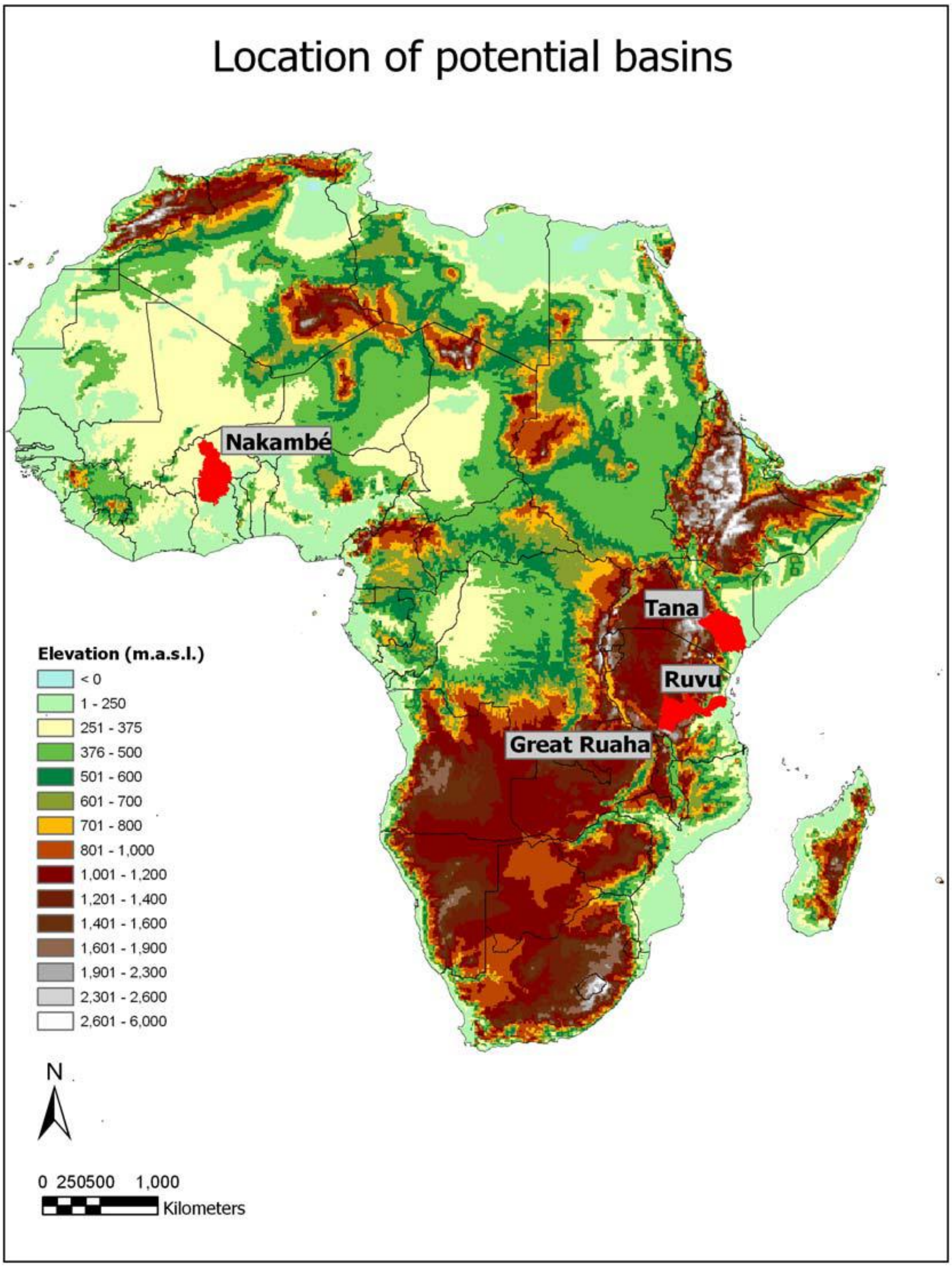

Figure 4: Location of the potential basins

Table 1: Key statistics for the four countries (2005)
Source: Human Development Report 2005 (UNDP)

	Ghana	*Kenya*	*Tanzania*	*Burkina Faso*
Human Development Index	0.52	0.47	0.42	0.32
Life Expectancy (years)	57	47	46	48
GDP (US$ *per caput*)	369	450	287	345
GDP *per caput* annual growth (%)	1.8	-0.6	1.0	1.7
GDP-PPP (purchasing power parity) (US$ *per caput*)	2238	1037	621	1174
Population living below US$1 per day (%)	45	23	20	45
Population living below US$2 per day (%)	79	58	60	81
Total population (millions)	21	33	37	12
Annual Population Growth (%)	1.9	2.5	1.8	2.9
Urban Population (%)	45	39	35	18
Population without access to improved water (%)	21	38	27	49

3 White Volta Basin

3.1 Overview

The Volta River (White Volta and Lower Volta) flows more than 1400 km before reaching the Gulf of Guinea. The basin covers 400 000 km². The mean annual discharge of the river before construction of the Akosombo Dam was approximately 35 km³. The source of White Volta, also known as the Nakambé[1] River, is in Burkina Faso. The Red Volta (referred to as Nazinon in Burkina Faso) and Sissili are tributaries of the White Volta and they too have their source in Burkina Faso. In Ghana, the Black Volta, the White Volta and the Oti join the main Volta at Volta Lake, which was created by the Akosombo Dam.

Water management in this great catchment is not easy and, in the upland areas, rainfall is capricious. People in rural areas are vulnerable to water shortages. Irregular rainfall results in reduced production, wasted seed and inputs, and complicates the farmer's planning. Droughts bring crop failure, livestock losses, malnutrition, and increased health risks.

In Ghana, the Volta River Authority (VRA) is a wholly-owned statutory public institution created by an Act of Parliament in 1961 to develop the Akosombo Hydroelectric Dam and oversee a multi-faceted development of the Volta River Basin. The Akosombo Dam is by far the most important factor in basin water management and central to the economy. Construction began in 1961 and the dam was completed in 1964. The embankment is 119 m high and 640 m long and total embankment volume is 7 962 000 m³. The concrete structures comprise a diversion intake, spillway, and power plant. The initial generating capacity at Akosombo was 512 MW. As of 1982, with completion of the Kpong Dam downstream of Akosombo, the combined generating capacity of the two plants is 1 060 MW (Andreini and others 2000). Forty percent of the generated power is used for industry, mainly aluminium smelting.

Construction of the Akosombo Dam created a reservoir commonly called Volta Lake, with a storage capacity of 148 km³. It has a surface area at Full Supply Level of approximately 8500 km². Its average width is 25 km and the longest arm of the lake reaches approximately 400 km from the dam northwards to Tamale Port at Yapei.

First reports of the declining levels of the Volta Lake appeared in the late 1980s. These were followed by more systematic attempts to document changes in precipitation and stream flows in the basin. By the mid-1990s, three out of four hydro-electric turbines at the Akosombo Dam had been decommissioned. Falling Volta Lake levels have forced VRA to import electricity from Ivory Coast to honour supply agreements with the Kaiser Corporation (USA) for its alumina smelting plant

[1] Nakambé and Nakanbé are used interchangeably for the White Volta. Sometimes Nakambé/Nakanbé is used specifically for the White Volta in Burkina Faso only. The most applied spelling is Nakambé.

(VALCO) and the Governments of the Republics of Togo and Benin, and to meet growing domestic demand (Wardell 2003).

A water allocation study of the White Volta sub-catchment (see red frame Figure 5) in Burkina Faso (not including the Nazinon and Sissili tributaries) shows the need for balancing of water supply to: (i) Ouagadougou, (ii) Bagré dam hydro-electric power (HEP), and (iii) irrigation (Ammentorp 2001). The following issues arise:

- The potential of improved rain water management by dryland farmers (the core element of the *Green Water Credits* project) is not addressed;
- The scenario analyses 1996 - 2020 show that the water flow to Ghana diminishes.

Instead of considering the whole basin, the GWC project might focus on the catchment in Burkina Faso, which potentially has 3 important water users: urban water, hydro-electric power and irrigation. Another decisive factor is the potential for *green* water management, i.e. the proportion of the basin used by dryland farmers. See section on Land Use, Chapter 3.2.4.

Figure 5: White Volta (Nakambé), location

3.2 Physical data

3.2.1 Terrain

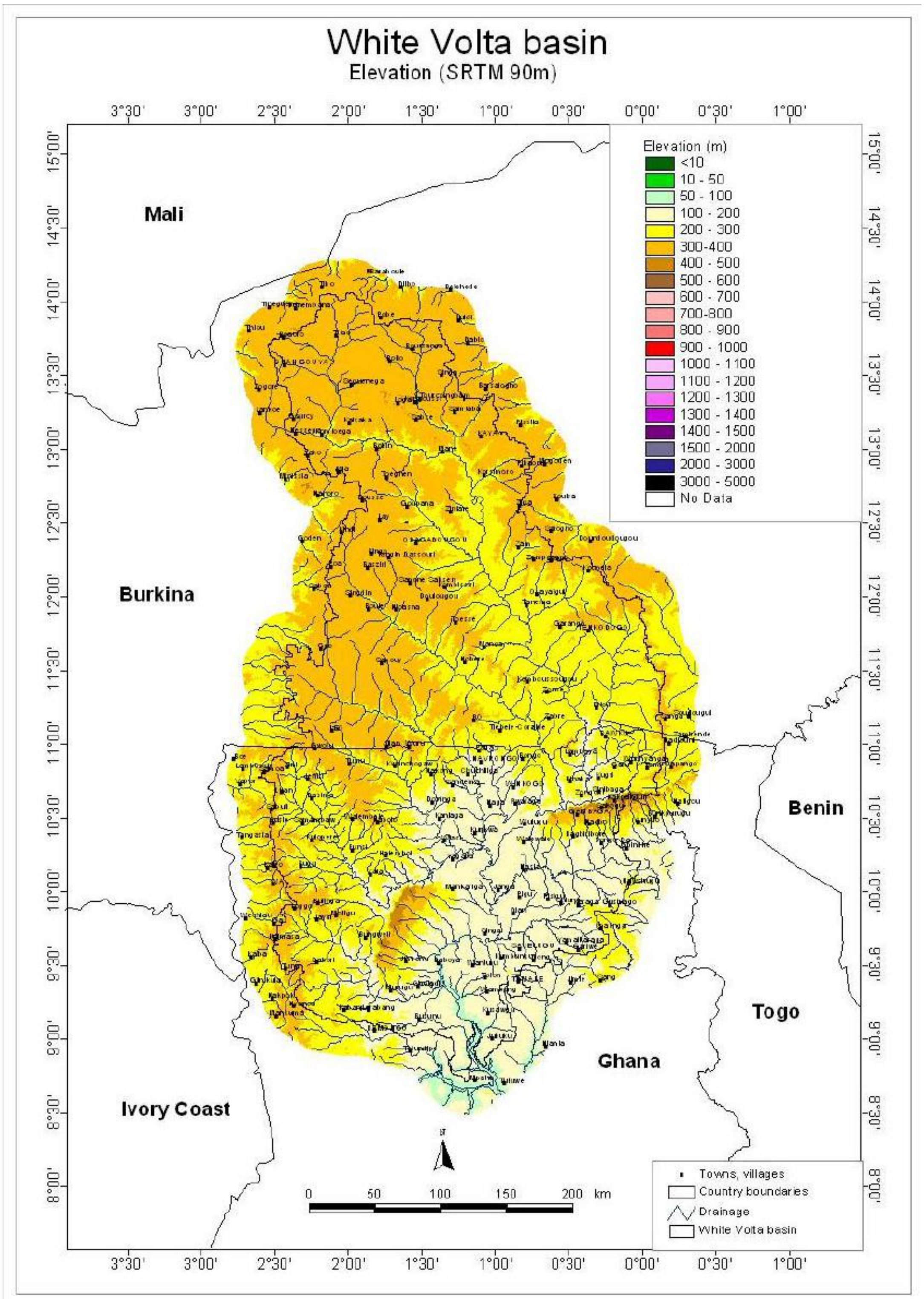

Figure 6: White Volta, elevation
Source:SRTM

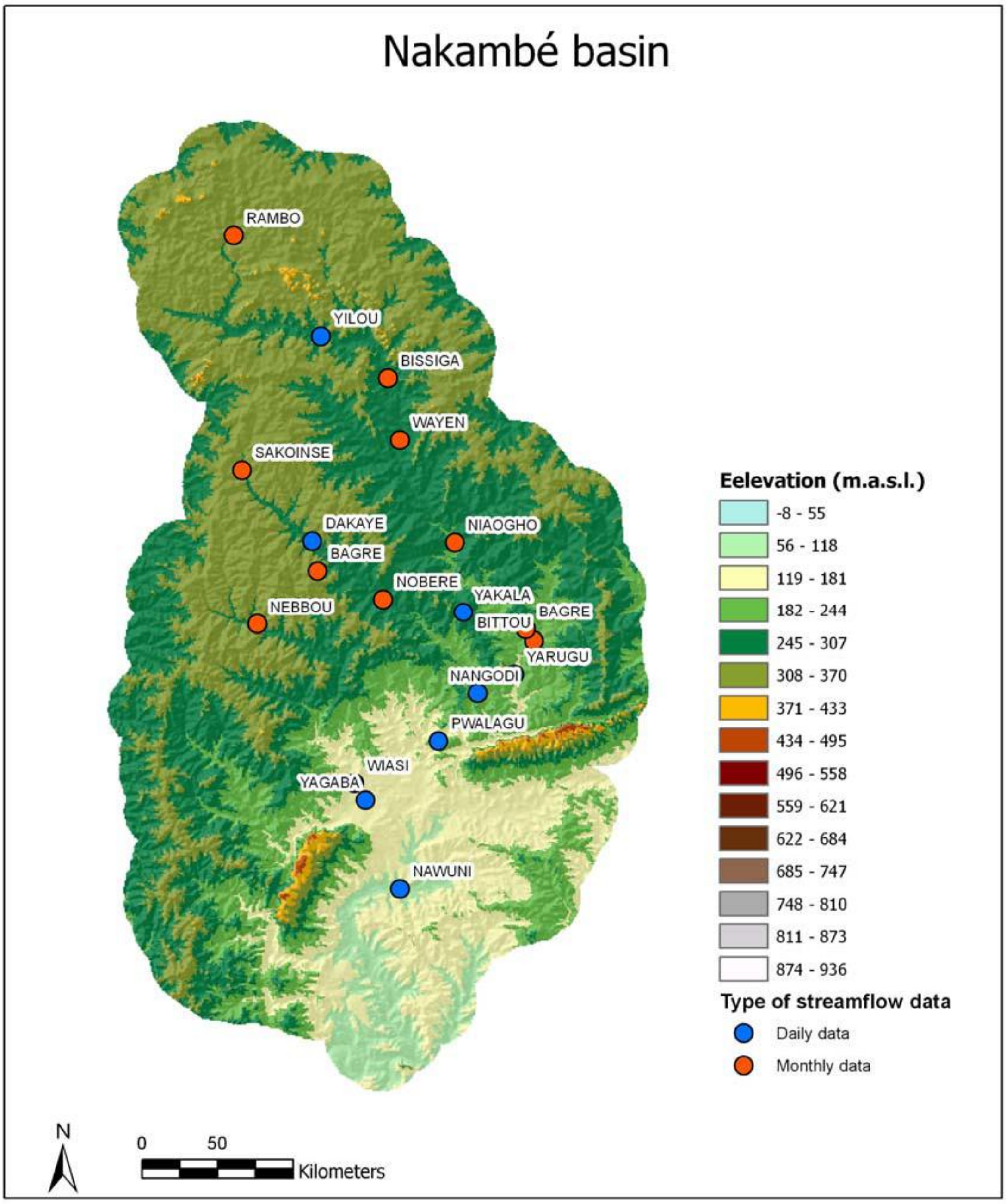

Figure 7: White Volta, location of GRDC stream flow gauges

3.2.2 Meteorological data

In the Sudano-Sahelian Savannah zone, annual rainfall decreases from 700 mm in the south to 400 mm in the north. Maximum monthly rainfall rarely exceeds 100 mm, and drainage is only occasional - between 50 mm and zero (Sedogo 2006).

The best global sources of meteorological data at a relatively high spatial and temporal resolution are available from the Climatic Research Unit of the University of East-Anglia. The CRU TS 2.0 dataset comprises 1200 monthly grids, for the period 1901-2000, and covers the global land surface at 0.5° × 0.5° resolution (Mitchell and others 2003). The dataset comprises: cloud cover, diurnal temperature range, precipitation, temperature and vapour pressure (note that no wind speed data are available in the CRU dataset).

The dataset is based on raw station data. Since data can be scarce in some regions or periods, a method called 'relaxation to the climatology' was used to create continuous grids. This implies that, for some areas or regions, data are less accurate.

For the Volta, three locations were selected, here referred to as South, Central and North. The monthly averages and the annual trends are shown in Figure 8 and Figure 9

A second global dataset, the IWMI World Water and Climate Atlas was used to show the fine-course spatial resolution of precipitation patterns (Figure 10). This dataset has a spatial resolution of 18 km^2, but holds only monthly averages over the period 1961-1990.

A third database, the FAOCLIM database, includes the parameters listed in Annex 1. A shortcoming of the FAOCLIM data is that only monthly averages over the last 30 years are given; whereas the erratic rainfall patterns are considered as the major problem in the area. However, for a limited number of stations, climate time series are given
Regarding meteorological data, the following global datasets can be considered:

- Global Change Master Directory: http://gcmd.gsfc.nasa.gov/
- Climate Change Data: http://ipcc-ddc.cru.uea.ac.uk/ddc_climscen.html
- Tropical Rainfall Measuring Mission (TRMM): http://trmm.gsfc.nasa.gov/

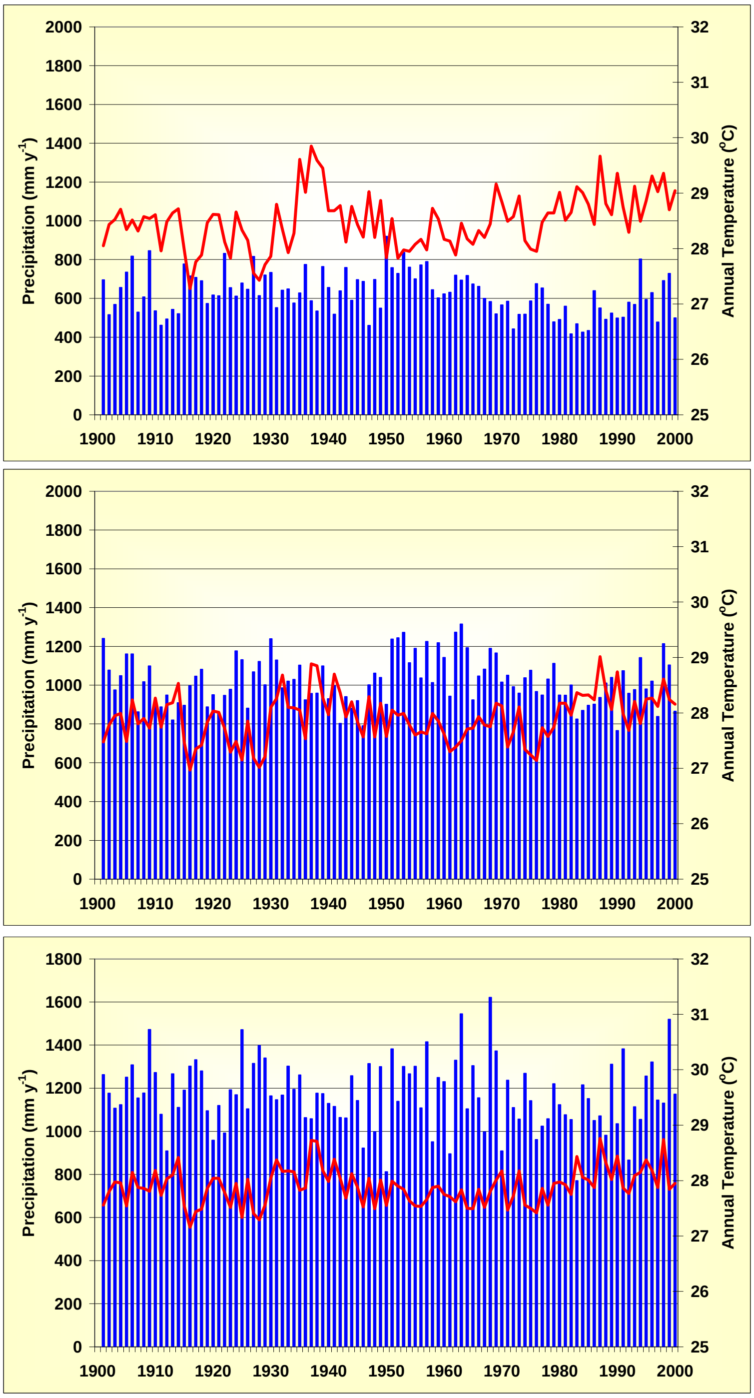

Figure 8: Annual precipitation and temperatures for North (top), Central (middle) and South (bottom) Volta
Source: Mitchell and others 2003

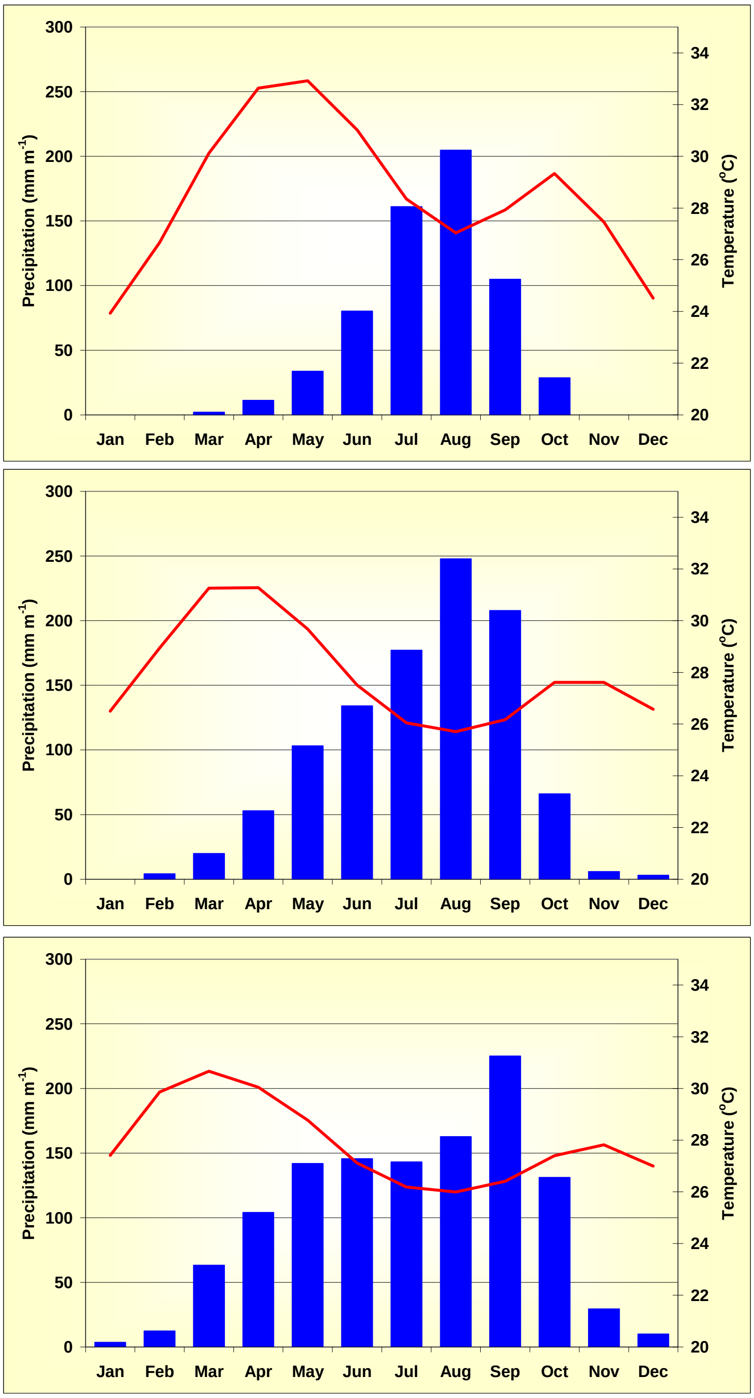

Figure 9: Monthly average precipitation and temperatures for North (top), Central (middle) and South (bottom) Volta
Source: Mitchell and others 2003

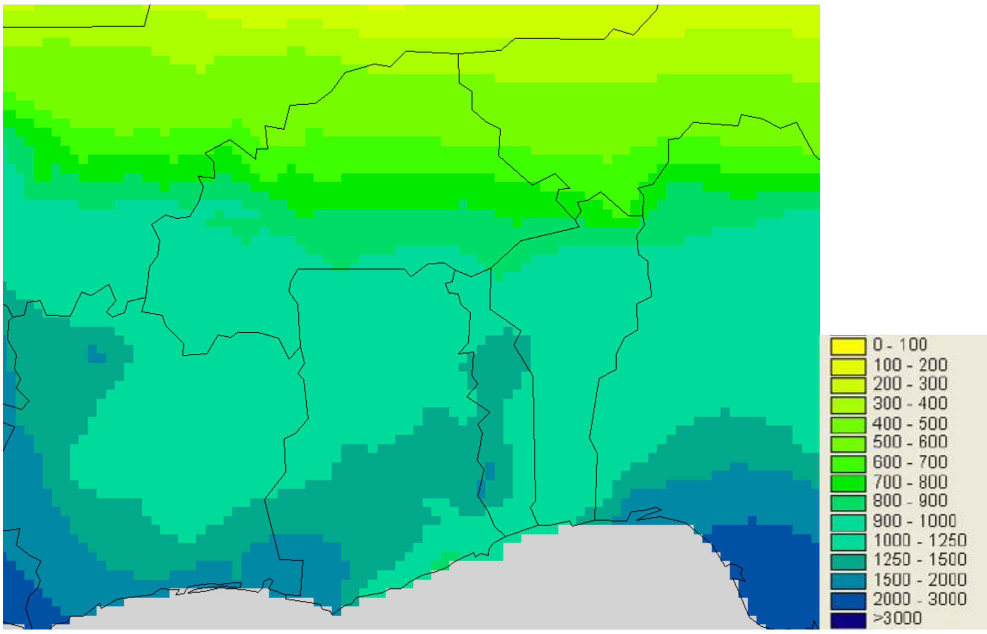

Figure 10: Volta basin, annual precipitation (mm)
Source: IWMI 2000

3.2.3 Hydrological data

The Global Runoff Data Center (GRDC) holds stream flow data for ten stations. Some data are monthly, others daily. Period varies but extends from 1951 to 1995 for some stations. For two stations, Wayen (upstream) and Nawuni (downstream), mean monthly flow data are provided here to show the annual flow characteristics (Figure 11 and Figure 12; for location see Figure 7). Other stream flow data are available from the GLOWA-Volta project, although the exact extent of data is unclear. Most likely, data are available from the last few years only.

The hydrology of the White Volta shows substantial changes during the period 1955 - 1998 with a shift occurring around 1970. From 1970 to the mid-1990s, despite a reduction in rainfall and an increase in the number of dams in the basin, average runoff and maximum daily discharges increased. This counter-intuitive change may be explained by the effects of land use change on runoff and soil water holding capacity: between 1965 and 1995, the extent of natural vegetation declined from 43 to 13 per cent of the total basin area between 1965 and 1995, the cultivated area increased from 53 to 76 per cent, and the area of bare soil nearly tripled from 4 to 11 per cent. Considering that the values for water holding capacity (WHC) given by the FAO represent the situation in 1965 or before, the reduction in WHC is estimated to range from 33 to 62 per cent (Mahe 2005). There is a marked improvement in river flow simulation using the time-varying values of soil WHC (Sedogo 2006).

On the other hand, there are well-described records of reduction in levels of Lake Volta. The main reasons for this is that different parts of the basin react in different ways to changes in land cover and rainfall. Since the 1970s in the southern, more humid part of the White Volta, diminishing rainfall has led to a reduction in runoff.

There has been an increase in runoff in the drier northern part of the basin despite the decrease in rainfall. Also, groundwater plays an important role; the continual reduction in water level in aquifers following nearly 35 years of reduced rainfall adds to the demand upon and vulnerability of the aquifers and has an impact on stream flow (HELP 2005).

Additional stream flow data (about 10 stations) for the White Volta are available from IRD (Figure 13). It is unclear which period the data set includes, but the website provides 2001-2003.

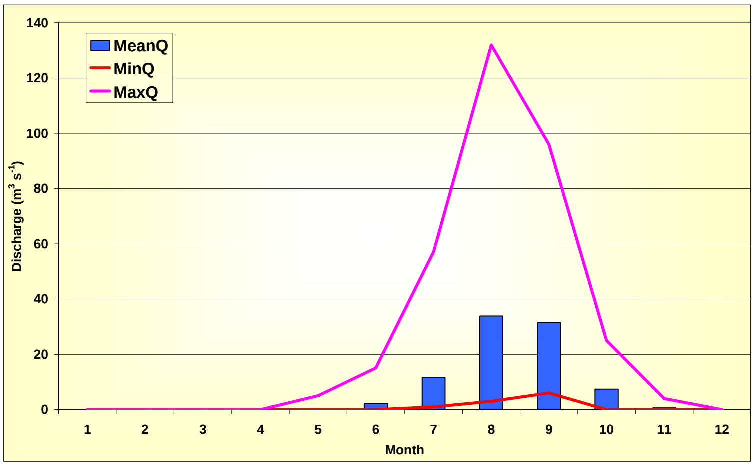

Figure 11: Discharge at Wayen (White Volta)
Source: GRDC

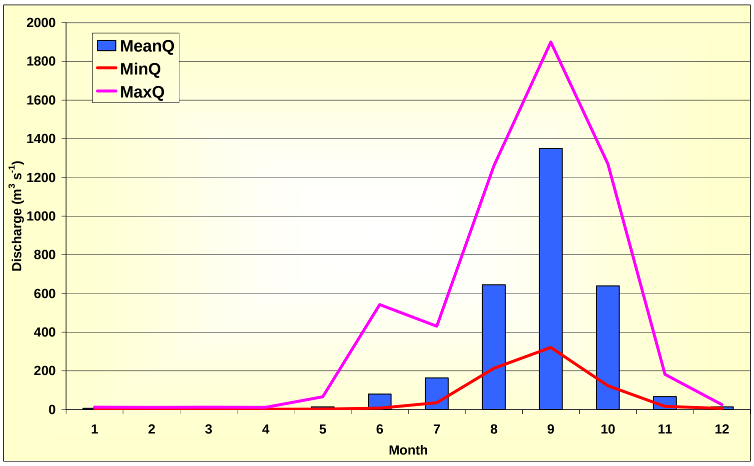

Figure 12: Discharge at Nawuni (White Volta)
Source: GRDC

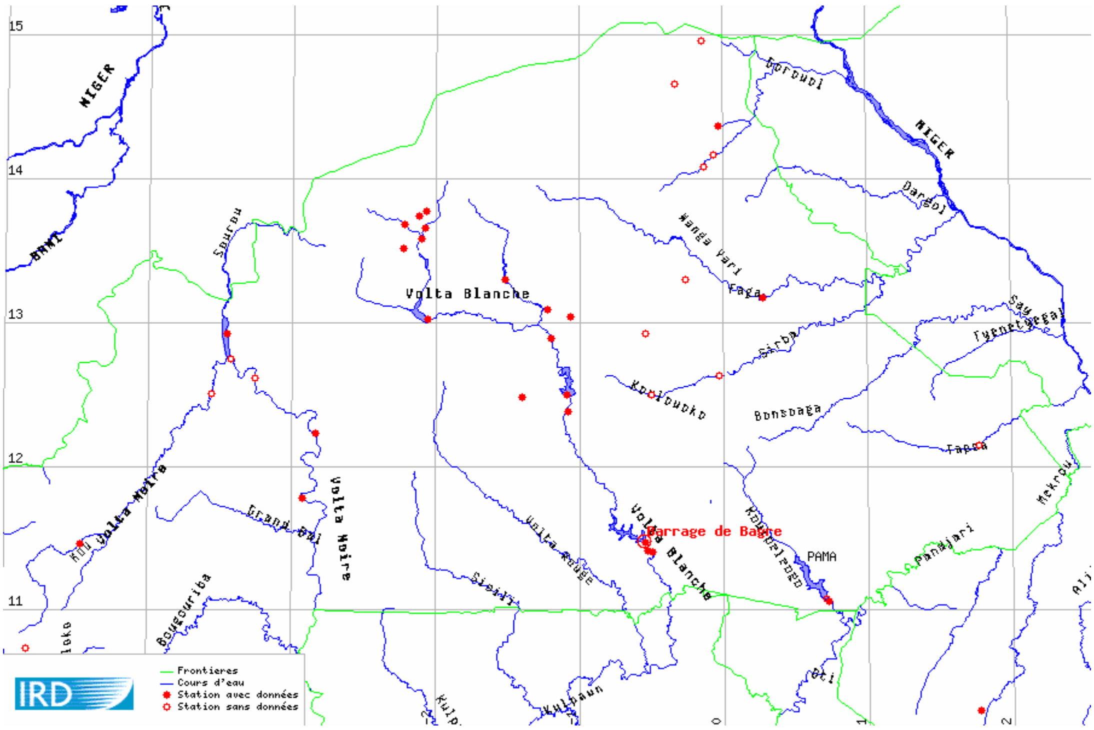

Figure 13: Stream flow stations in Burkina Faso
Source: http://mull.eauburkina.bf/

Further sources:

GLOWA-VOLTA. Discharge Data; these data contain observed daily discharge of several gauging stations from Ghana and Burkina Faso (gerlinde.jung@imk.fzk.de); [http://www.glowa-volta.de/databases/metadata /gvp_meta.htm](http://www.glowa-volta.de/databases/metadata/gvp_meta.htm))

3.2.4 Land use and land cover

Farmers on the Central Plateau of Burkina Faso cope with climatic variability by adapting field locations, crop mixes, and varieties. The water retention capacity of the soils is a primary consideration in deciding what and when to plant: if below-normal rainfall is expected, farmers will plant their staple sorghum in valley bottoms or near watercourses. An increase in frequency of drought over the past several decades has led to increased competition for bottomland fields (Sedogo 2006).

The extent of natural vegetation declined from 43 to 13 per cent of the total basin area in Burkina Faso between 1965 and 1995, whilst the cultivated areas increased from 53 to 76% and the area of bare soil nearly tripled from 4 to 11 per cent (Sedogo 2006). In the north-Sudan savannah, cropping dominates but natural pasture is an important resource (Figure 14). Not all crop residues are reserved for livestock feed; about a third of the total production is available to livestock.

Larger-scale land cover and land use information can be obtained from Landsat images (e.g. Figure 15 and Figure 16) Further examination of images from other periods would be necessary, but the overall picture seems to be of a patchy cropping pattern with most activities along the rivers and streams and below reservoirs.

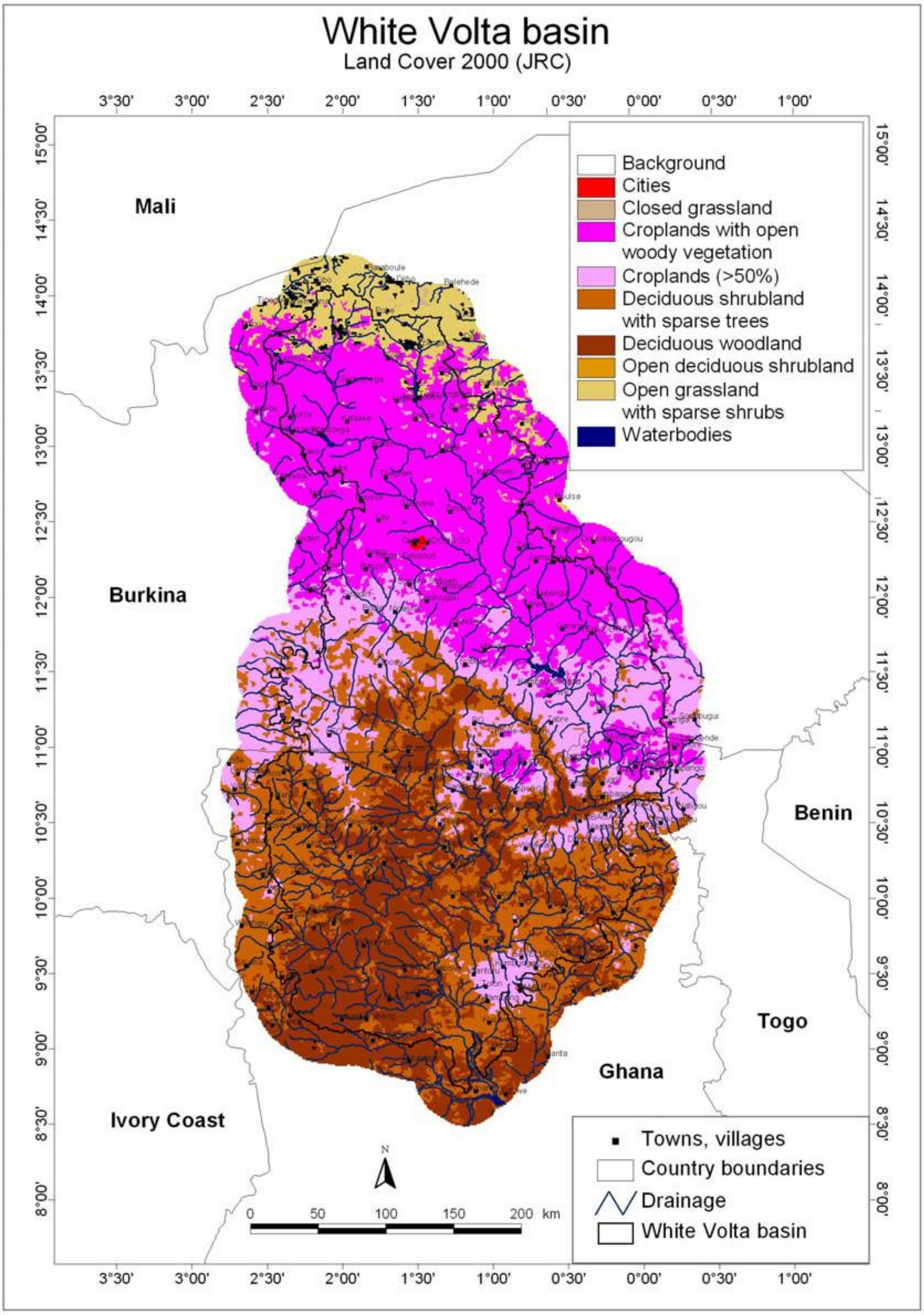

Figure 14: White Volta, land cover
Source: Mayaux and others 2003

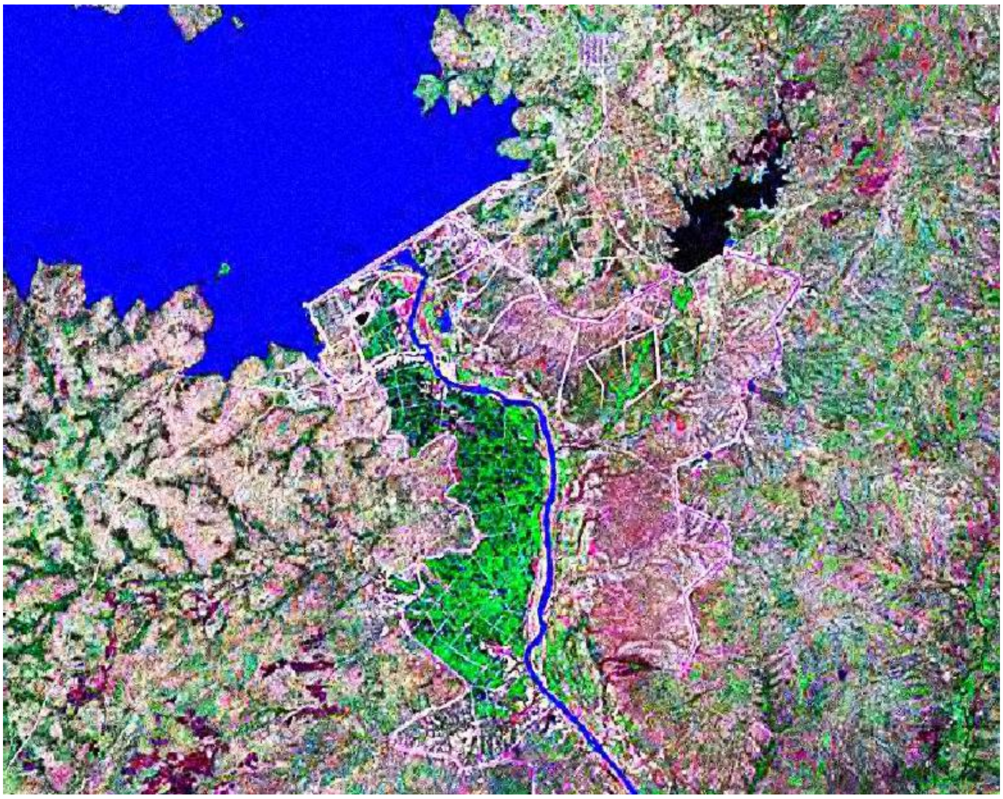

Figure 15: Farmland just below Bagré Dam
(extent about 13 x 11 km)

Figure 16: Farmland along streams 35km north of Ouagadougou
(extent 12 x 9 km)

3.2.5 Soil and water conservation

Surface sealing is common on arable land, bringing a serious problem of high runoff early in the rainy season, when the soil is still bare. Evaporation is also a serious, unproductive water loss.
Many soil and water conservation (SWC) practices are used (Sedogo 2006) by farmers. These include:

- Application of manure
- Microcatchments: earth terraces in the fields in order to slow water runoff and concentrate it in planted areas. Three types are found: contour microcatchment, 'V'-microcatchment and half-moon microcatchment
- Stone lines: rows of stones either around or across the fields, following the contour. Stone lines slow water runoff and allow infiltration
- Mulching: leaving crop residues in the field and bringing in foliage and other organic materials from elsewhere
- Fallow: resting cropland under vegetation re-growth before using it again
- Live hedges: to keep residues in place
- Vegetation strips: preserving strips of vegetation about one metre wide which follow the contour. The interval between strips depends on the slope, but is usually ten metres. Strips of vegetation can be used in combination with stone lines
- Tree planting, particularly on steep slopes.

The White Volta basin straddles two zones of recommended soil and water conservation practices: a zone of stone-line practices and a zone of *zaï* [2]. The various measures to reduce runoff and evaporation often include the use of biomass itself to cover the soil surface. A serious issue is that the production of biomass is not enough, certainly not enough to sacrifice the vital resource as mulch; the demands for fuel, livestock feed and constriction materials are hardly met (Rapidel 2006).

3.2.6 Soils

ISRIC – World Soil Information holds soil maps at scale 1:500 000 for the major part of the basin.

Burkina Faso
For the Burkina Faso part of the Basin, the following information was provided by of the Bureau National des Sols (BUNASOLS):
Soil information is available in digital format for a part of basin and paper format for the rest. BUNASOLS holds more than 100 soil profiles with baseline data (Figure 17). The data include soil classification in the CPCS (1967) and WRB (1999) systems, parent material, landscape element, organic matter content, texture, soil moisture content at pF2.5, 3.0, and 4.2. Bulk density data are lacking so total porosity can only be estimated. ISRIC also holds some 30 profiles with moisture retention values. Verification needed is on (i) method used for the determination of water retention at pF2.5, and (ii) geo-referencing of the profile data (see Annex 3).

[2] The *zaï,* a micro-catchment 20 to 30 cm across and 15 to 20 cm deep, constructed to increase water infiltration.

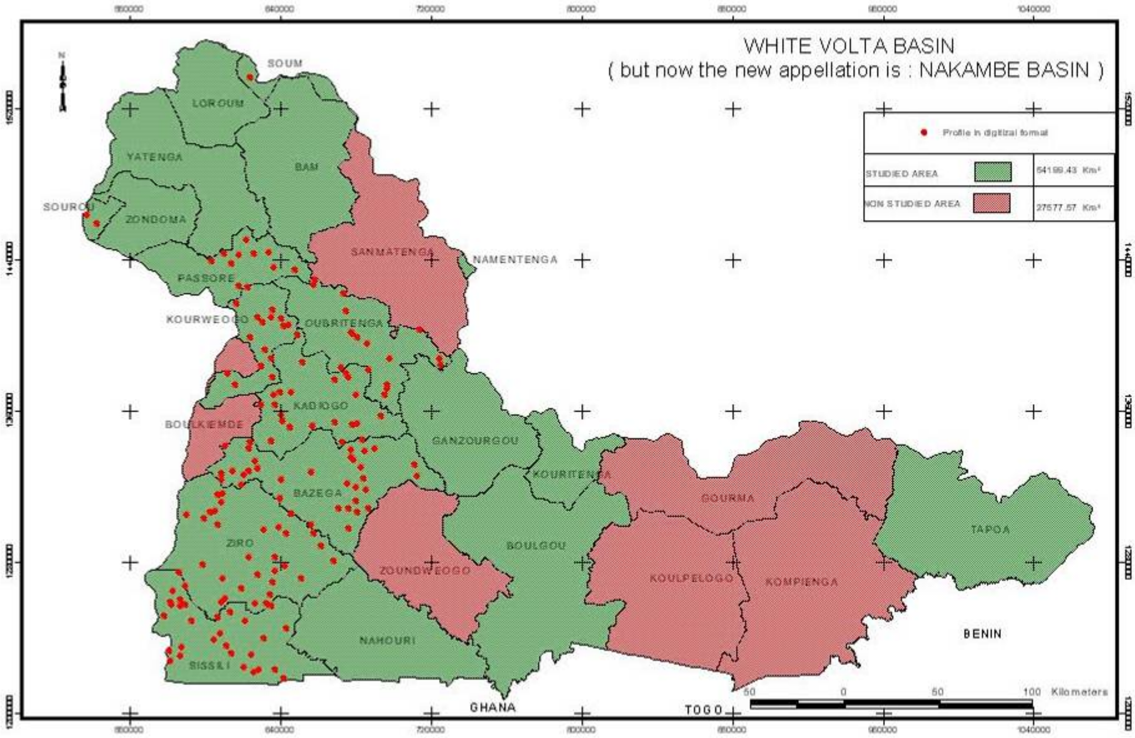

Figure 17: Soil information from BUNASOLS, Burkina Faso

Ghana
ISRIC library holds a few soil survey reports of central and northern Ghana. No physical soil data are found (See annex 3). Additional soil information may be provided by the Soil Research Institute in Kumasi.

3.3 Socio-economic data

3.3.1 Population, Burkina Faso

The White Volta in Burkina Faso has a total population of about 4 million people. Population in the main urban centres are: Ouagadougou (1.13 million), Ouahigouya (52 193), Tenkodogo (31 466) and Kaya (40 000). (HELP 2005) The catchment is the Central Plateau, located in the Sudano-Sahelian Savannah zone, which comprises one quarter of Burkina Faso and holds 43 per cent of its population (Figure 18).

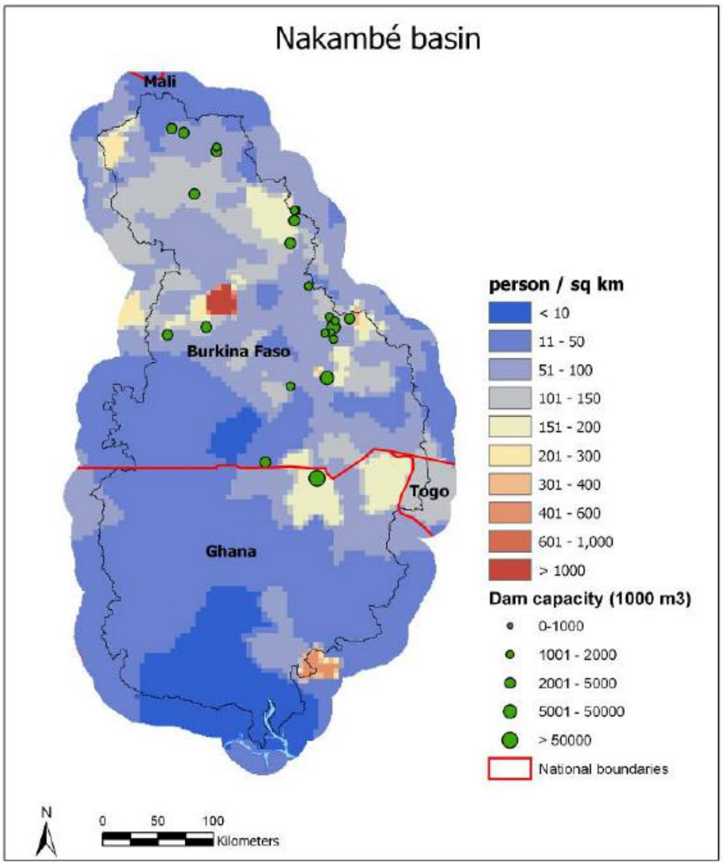

Figure 18: White Volta, population density and location of dams
(CIESIN 2005, FAO 2005)

3.3.2 Economic situation, Burkina Faso

Burkina Faso is a poor country. Based on the current poverty line – approximately CFAF 72 690 in 1998 compared with CFAF 41 099 in 1994 – the proportion of poor inhabitants rose slightly, from 44.5 per cent to 45.3 per cent; the number of poor declined slightly in rural areas but is on the rise in urban areas. Annual *per caput* GDP is US$ 220, lower than in most of Burkina Faso's neighbours (US$ 250 in Mali, US$ 330 in Togo, US$ 380 in Benin, US$ 390 in Ghana and US$ 700 in Ivory Coast). Its Human Development Index is one of the lowest in the World (HDI = 0.304 in 1997). Further socio-economic information is available in *Poverty Reduction Strategy Paper of Burkina Faso* (Ministry of Economy and Finance 2000).

Agriculture supports 92 per cent of the population. The Central Plateau is disadvantaged by its poor soils (exacerbated by serious erosion) yet has a relatively high population density (70-100 inhabitants km^{-2}). The main crops are millet (annual production 217 000 tonnes), sorghum (177 000 t), maize (93 000 t), groundnuts (119 000 t), and cotton (64 000 t). Minor crops include rice (11 000 t), njebe (9 000 t), voandzou (8 000 t), fonio (500 t), sesame (500 t), and soya (500 t) (Sedogo 2006).

3.3.3 *Hydro-power*

Ghana

The Akosombo dam was constructed primarily for the generation of hydropower and produced 912 MW of electricity at its maximum operating capacity. Other positive impacts include fishing, farming, transportation and tourism. Negative impacts, some not foreseen at the outset have emerged on the physical, biological and human subsystems within the immediate project environments and places much more distant.

Lake levels have fallen: comparisons of the runoff from two most important tributaries of the Volta (White Volta and Oti) for 1951–1970 and 1971–1990 showed reductions in mean stream flows of 23 per cent on the White Volta (Figure 20) and 32 per cent on the Oti. A plot of the mean annual temperatures for the Upper Volta basin indicated a 1°C rise in temperature from 1945–1993 (Gyau-Boakye 2001).

Burkina Faso

The Bagré Project is building of a dam on the White Volta River with a power plant and a projected 15 000 ha agricultural development of the Bagré plain (Figure 15 and Figure 19) (Ki-Zerbo and others 2005).

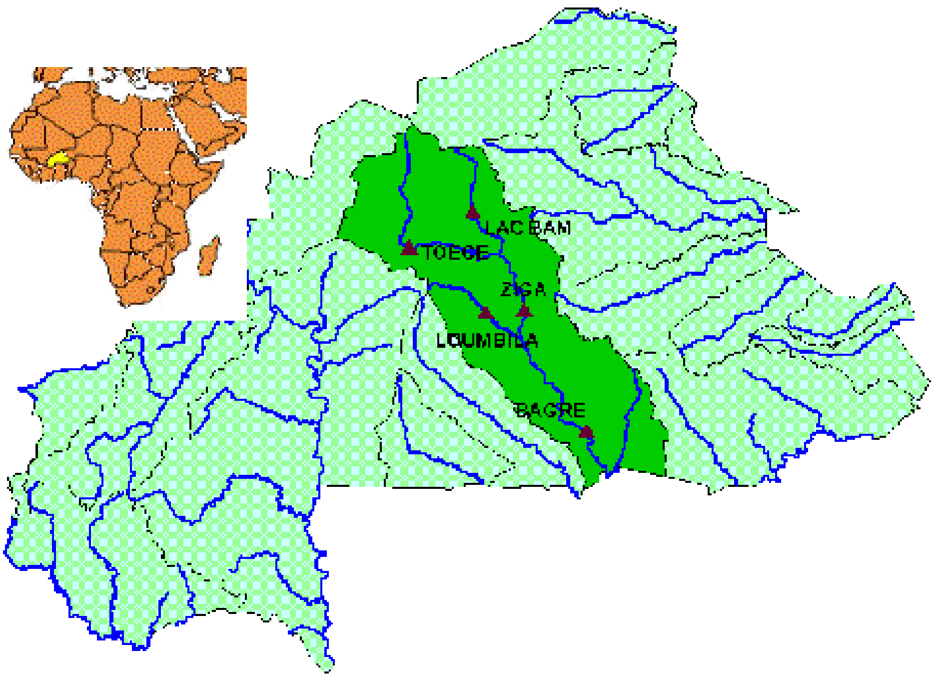

Figure 19: White Volta, location of the main reservoirs

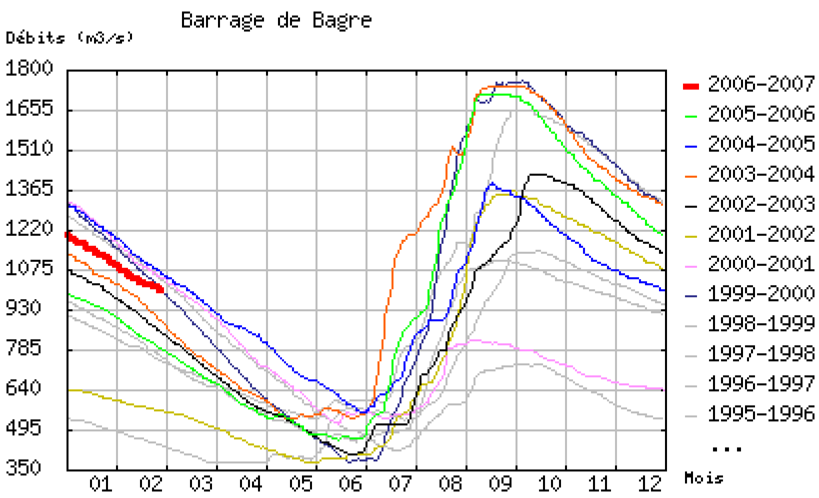

Figure 20: Flows at station Barrage de Bagré
Source: http://mull.eauburkina.bf/

3.3.4 Water Management Organisations

Two institutions and one Ministry are responsible for water management issues in the White Volta basin in Burkina Faso:

- Office National de l'Eau et de l'Assainissement (ONEA): an autonomous public utility, established in 1985, to provide water, sanitation and drainage services to all urban centres.
- The Societe Nationale d 'Electricite du Burkina (SONABEL) is vested with the exclusive right to generate and distribute electric power throughout the country. Hydropower generation by SONABEL is small by comparison with the VRA in Ghana and potential is limited by low and unreliable streamflows.
- La Direction Générale de l'Hydraulique has six divisions, including drinking water and agricultural water, and 10 regional offices.

Regional collaboration and monitoring in trans-boundary issues for the Volta basin are weak. There is no framework for managing the basin on a regional level. National legal and regulatory efforts to manage the basin resources are fragmented and often ineffective (GEF 2003b). There has been occasional, informal cooperation and a Volta Basin Water Resources Management Initiative has been proposed.

3.4 Partnerships / projects

Potential international partners

- IUCN helps set up trans-boundary cooperation on water resources management in White Volta Basin: Improving Water Governance in the Volta Basin (PAGEV). Supported by DGIS among others http://www.iucn.org/en/news/archive/2005/10/white_volta.pdf
- GLOWA – Volta (leader ZDF, Bonn)
- CGIAR Challenge Program on Water and Food (CPWF)
- An IWMI post doctoral scientist will be in ZDF from the end of March 2006 to collect and organize all data available from Glowa-Volta

Potential national/regional partners

- Volta Basin Authority is a Ghanaian statutory institution with the mandate to develop the Akosombo Hydroelectric Dam and promote a multi-faceted development of the Volta River Basin
- BUNASOLS: Research and soils information for Burkina Faso. Contact established with Kissou Roger, Director, who promptly provided information on request and is keen to contribute with a technical input to the GWC project.
- INERA: Mandate for agronomic (including socio-economic aspects) research and dissemination. Contact established with Dr Michel Sedogo, Head of Natural Resources Department, who provided a summary on land and human resources information for the basin. INERA is interested to contribute to the GWC project.
- Soil Research Institute in Ghana

Relevant projects

- GLOWA – Volta
- HELP Basin: Hydrology for the Environment, Life and Policy. http://portal.unesco.org/sc_nat/ev.php?URL_ID=3751&URL_DO=DO_TOPIC&URL_SECTION=201

3.5 Green Water Credits Potential

Management of the water resources of the Basin faces enormous challenges, especially the knowledge gap in terms of hydrological processes, impacts and linkages. Rainfall has diminished over recent decades, resulting in less streamflow for the south parts of the basin, while for the north lower rainfall coincided with higher streamflow. For the GWC feasibility study, this is a reason to focus on a coherent area. Changes in land use, more specifically less natural vegetation in areas where runoff has increased, are most likely the dominant factor.

The main potential buyer of GWC services is the Volta River Authority (VRA). There can be no doubt about their willingness to buy *Green Water Credits*. However, it might be difficult to convince this potential buyer to transfer money to another country.

In the White Volta in Burkina Faso, the potential buyer will be SONABEL which must ensure more regular flows in the Bagré and Kompienga reservoirs to generate electricity. A second important buyer might be ONEA, to improve the reliability of water supply to Ouagadougou; the government of Burkina Faso signed a four-year contract (2002-2006) with Compagnie General des Eaux to help improve the management of ONEA (Obeng-Asiedu 2004).

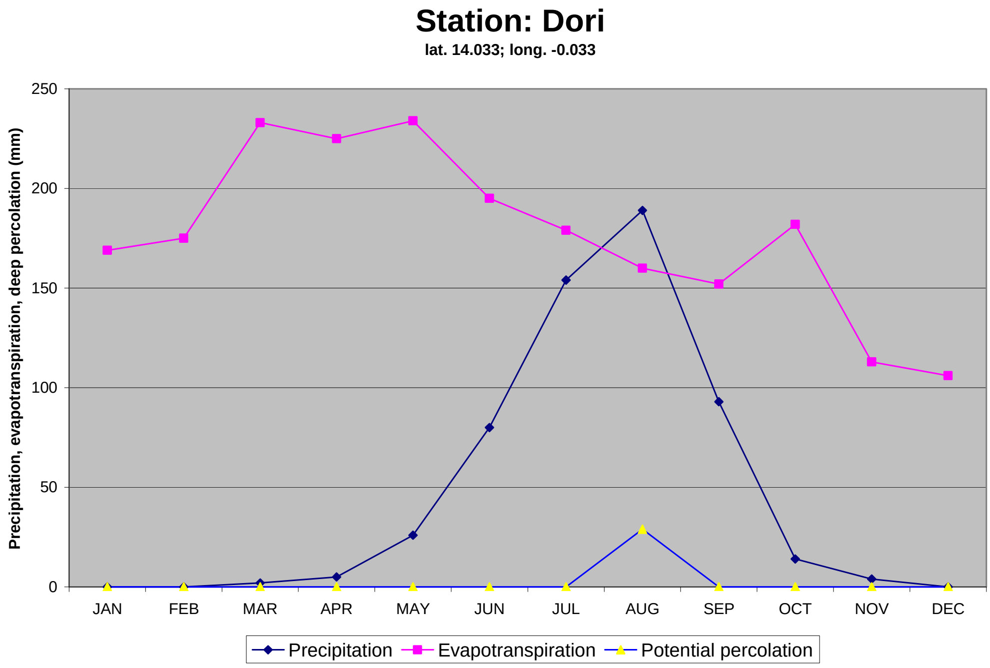

Figure 21: Water balance in the northern White Volta basin

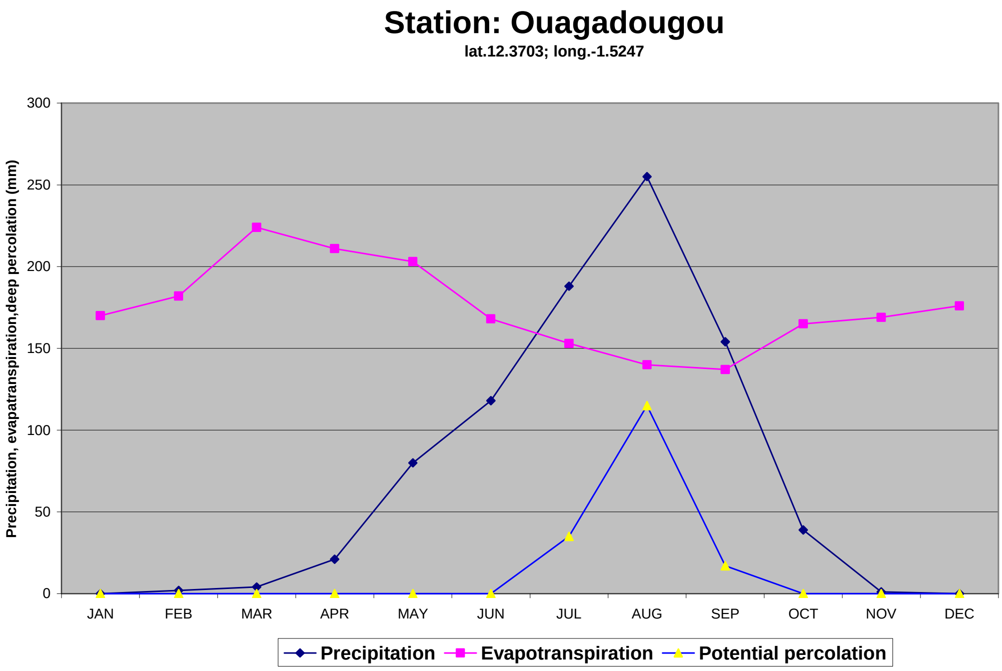

Figure 22: Water balance in central White Volta basin

The potential GWC sellers are not well defined. They range from dryland farmers, to irrigators and small reservoir managers - so contracts will be complex.

There is a big potential for *green* water management by rain-fed farming. However, potential benefits will be mainly local - in the shape of improved crop yields. Rainfall is modest; it is expected that the potential contribution to the river base flow, and thus *blue* water services for downstream users, will be limited. (Figure 21 and Figure 22) show a brief period between mid-June and mid-September when mean monthly rainfall exceeds potential evapotranspiration (even shorter in the north where the period is restricted to 2 months). Water losses by unproductive evaporation from bare soil and flash runoff can be reduced by mulching but surplus crop residues are not available for this so innovation will be needed. The current water overdraft has lowered water tables, resulting in a decrease in river base flow. Reversing this process will take several years. Reduction in proposed afforestation should also be considered; it is becoming more and more evident that the assumed positive impact of forest on water resources is a myth (Economist 2005, Hayward 2005); forests consume a lot of water by transpiration, always more than bare soils, often more than the natural vegetation.

4 Tana River: Kenya

4.1 Overview

The Tana basin (Figure 23) encompasses 100 000 km^2, and supports more than 4 million people. The river rises the highlands of the Aberdare and Mount Kenya ranges of central Kenya and runs through the dry eastern part of the country to enter the Indian Ocean. It is a vital water resource, the only perennial stream in this dry region (IUCN 2003).

The Tana River is heavily utilized for hydro-power. Five major reservoirs have been built on the upper reaches: Kindaruma in 1968, Kamburu in 1975, Gitaru in 1978, Massing in 1981, and Kiambere in 1988 (Figure 24). Together, these provide three quarters of Kenya's electricity and regulate the river flow (Bobotti 2000). A new hydro-power scheme is proposed at Mutonga-Grand Falls, below the existing dams, with a reservoir surface area of between 100 and 250 km^2 and a rated power output of between 60 and 180 MW. Dam construction has dramatically changed the downstream flow; previously, biannual flooding of the floodplain and delta supported lakes, seasonal streams, grasslands, riverine and mangrove forests.

Extreme climatic events bring loss of life and property, damage to infrastructure, disruption of power supply, water shortage, famine and migration. Examples include the 1997/98 floods which were followed by the 1999-2000 drought. The World Health Organization (WHO) reported on January 10^{th}, 2006, that the 'short rains' are failing and that drought is becoming more frequent and prolonged. This year, 17 districts across the country are experiencing severe food shortage. For the Tana River basin, the Global Acute Malnutrition index is 19 per cent and the Severe Acute Malnutrition index is 3 per cent (WHO 2006).

The Tana River is the main water supply for Nairobi (NCC-WSD); supply is pumped from a distance of around 50 km. Following water source expansion projects in 1984 and 1995, the available supply has increased to some 520 million $l\ d^{-1}$ by 2002, which meets the growth in demand up to 2006. Although enough under normal conditions, supply is not reliable during drought and is also endangered by siltation of the reservoirs. *This situation may be an opportunity for adoption of GWC*. The supply problem is aggravated by the poor state of the distribution system with losses of about 50% due to leaks and illegal connection (Foster and Tuinhof 2005).

Figure 23: Tana Basin, location

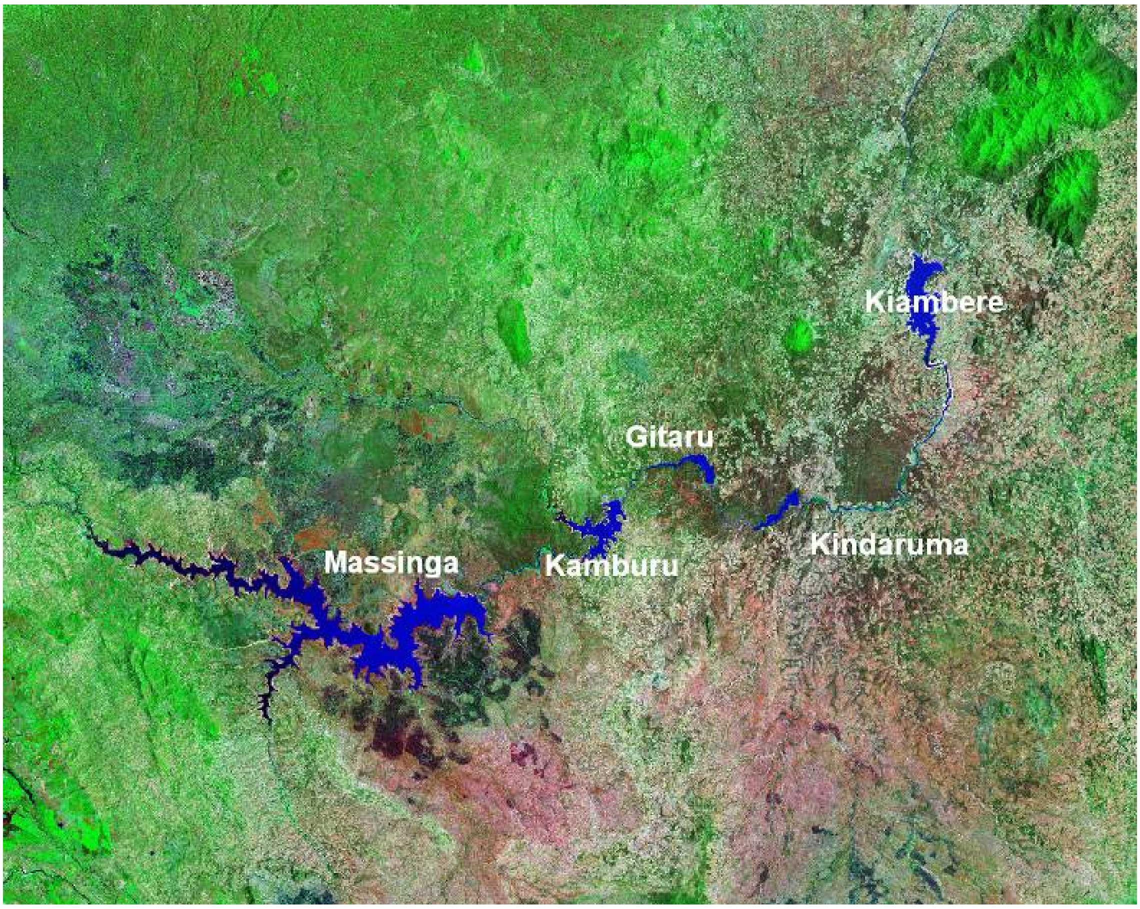

Figure 24: Upper Tana, location of reservoirs
(extent 90 x 70 km)

4.2 Physical data

4.2.1 Terrain

Basin identification concentrated on the Upper Tana (Figure 26). The headsprings are in the forested highlands of the Aberdare Mountains and Mt Kenya at elevations over 3 500m (Figure 25). From higher to lower altitudes, several production zones can be distinguished; cropland occurs below about 2 500m and from the point of view of improving green and blue water resources the key areas are upstream of the lowest reservoir (Kiambere); there is little rain-fed cropping further downstream.

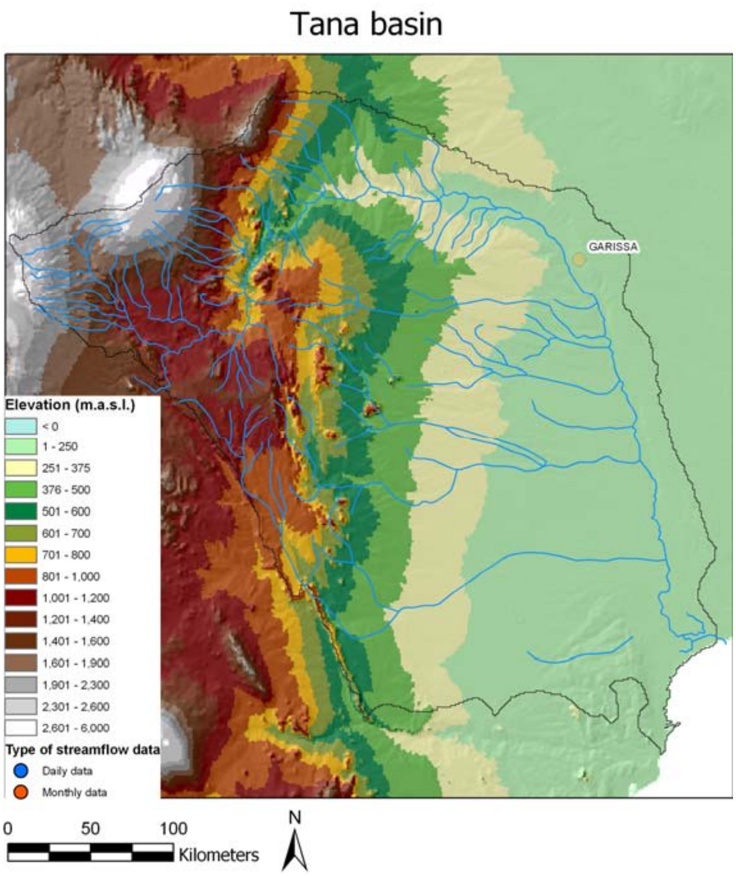

Figure 25: Tana basin, elevation and location of stream gauges

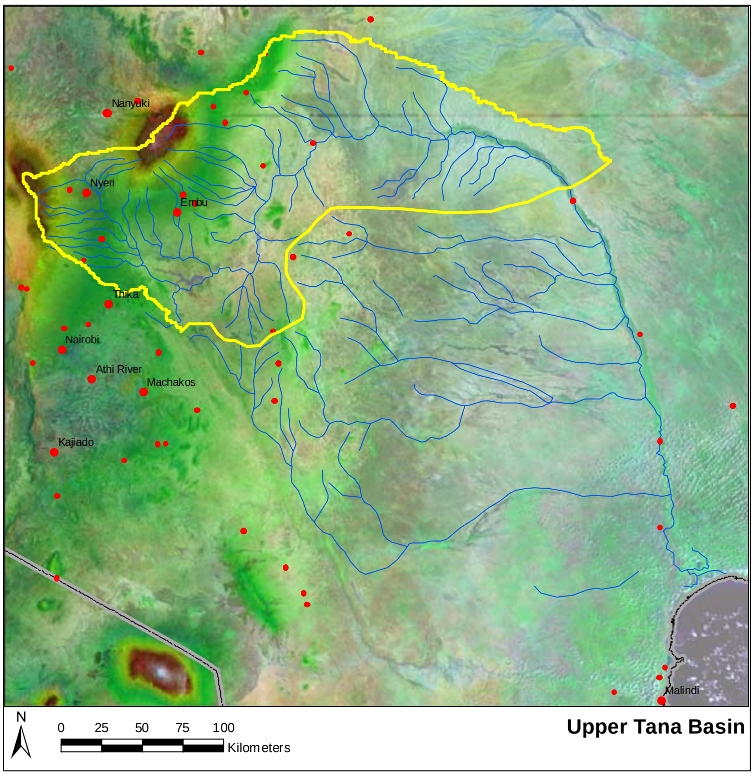

Figure 26: Upper Tana basin, boundaries

4.2.2 Meteorological data

The CRU TS 2.0 dataset of the University of East Anglia comprises 1200 monthly grids for the period 1901-2000, and covers the global land surface at 0.5° × 0.5° resolution (Mitchell and others 2003). The dataset comprises: cloud cover, diurnal temperature range, precipitation, temperature and vapour pressure. The CRU dataset is based on raw station data, which are scarce in some regions and periods. A method called 'relaxation to the climatology' was used to create continuous grids. This implies that, for some areas or regions, data are less accurate. Two locations were selected, here referred to as Upstream and Downstream (of Kiambere). The monthly averages over the last 100 years as well as the annual trends are shown in Figure 27 and Figure 28.

A second global dataset, the World Water and Climate Atlas (IMWI 2000) was used to show the fine-coarse spatial resolution of precipitation patterns (Figure 29). This dataset has a spatial resolution of 18 km^2, but data is only available as monthly averages over the period 1961-1990.

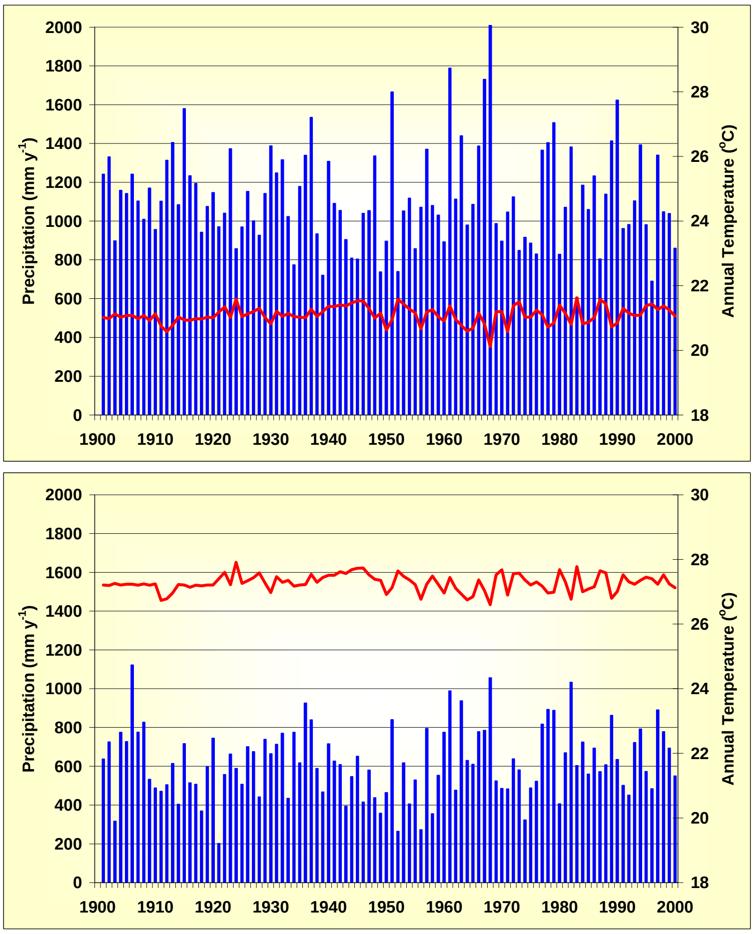

Figure 27: Tana basin, annual precipitation and temperature Upstream (top), and Downstream (bottom)
Source: Mitchell and others 2003

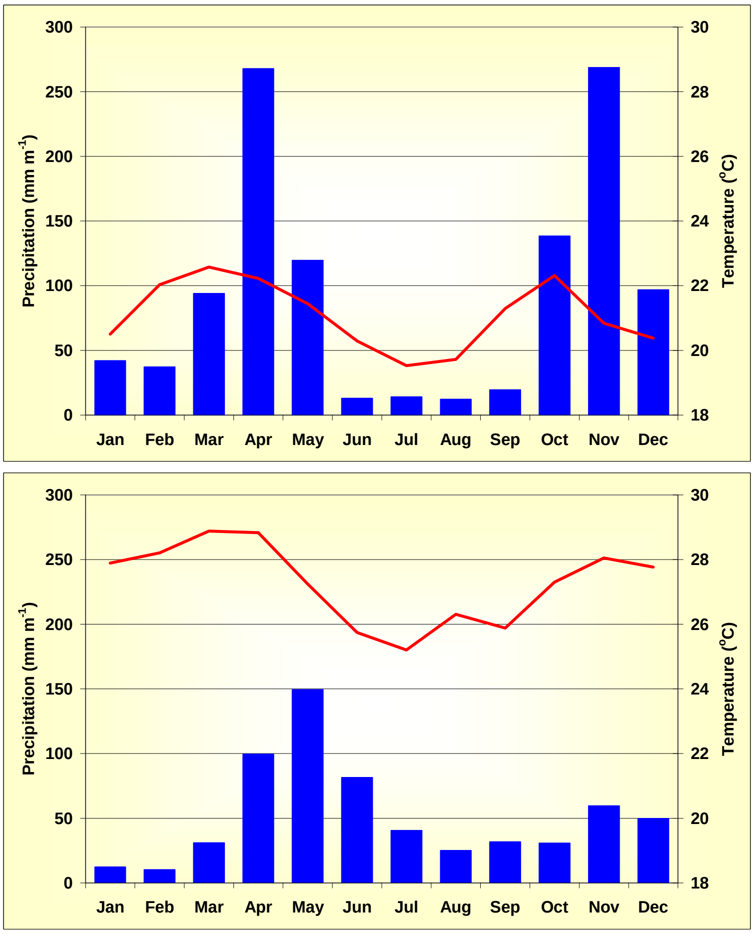

Figure 28: Tana basin, monthly average precipitation and temperature Upstream (top) and Downstream (bottom)
Source: Mitchell and others 2003

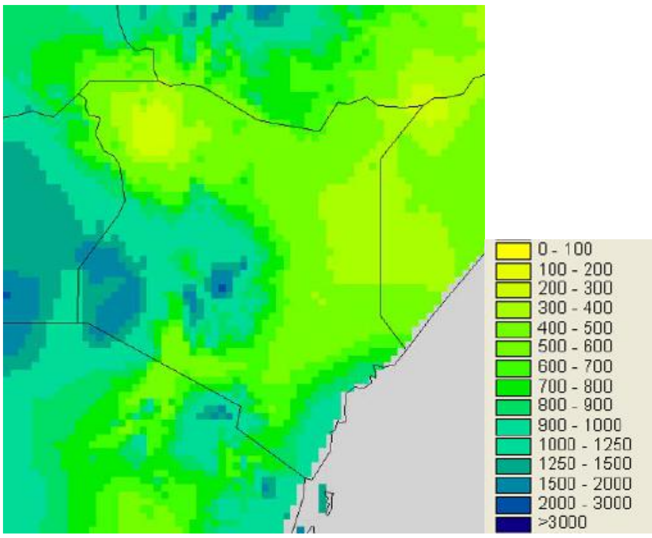

Figure 29: Tana basin, mean annual rainfall
Source: IWMI 2000

4.2.3 Hydrological data

Stream flow data for up to 10 stations have been collected by the Kenya Electricity Generating Company (KENGEN). GRDC has monthly stream flow data from Garissa over 1934 to 1975 (Figure 32). Annual stream flows are very variable because of variable rainfall and flow decreases markedly downstream (Figure 30 and Figure 31).

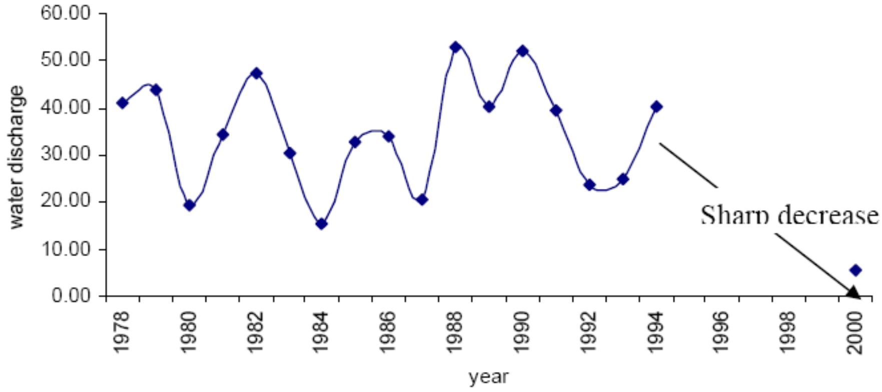

Figure 30: Mid-Tana, discharge 1978 – 2000 (m^3s^{-1})
Source: UNEP 2000

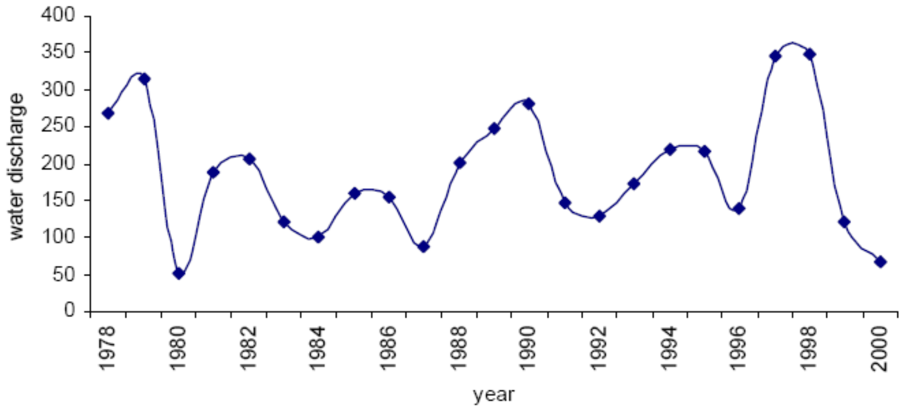

Figure 31: Upper Tana, discharge 1978 – 2000 (m^3s^{-1})
Source: UNEP 2000

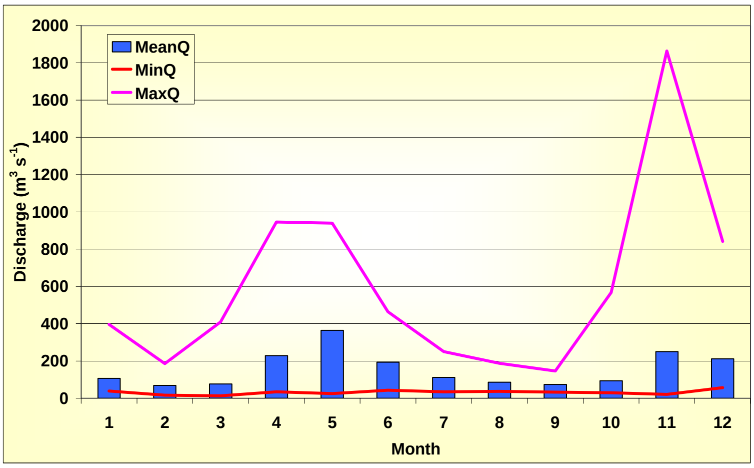

Figure 32: Discharge of the Tana at Garissa, 1934 - 1975
Source: GRDC

Other sources:

- Ministry of Water Resources Management and Development
- Jacobs *et al*. 2005

4.2.4 Land use and land cover

There is substantial cropping, especially in the western part of the basin, at elevations up to about 2500m (Figure 33) shows this intensive rain-fed cropping in the catchments of the reservoirs. In recent decades, cropland has encroached steeper slopes, conservation measures are mostly absent, and soil erosion is widespread (Jacobs and others 2004). However, there are several institutions set up to implement optimal land and water management, including a National Environmental Management Authority (NEMA), which has the mandate and legal framework to undertake protection and conservation of the environment.

The Landsat image of the lower Tana reveals hardly any farmland (Figure 35) shows a typical area around Garissa). More than 75 % of the basin is used for grazing (Figure 33 and Table 2) especially the drylands of the middle and lower basin (FAO 2001).

Table 2: Tana basin land cover, per cent (2000-2003)
Source: NEMA

Cultivated and Irrigated	*Cultivated and non-irrigated*	*Range/Pasture*	*Forest and woodlands*	*Other land*
0.3	1.5	76.2	21.0	0.9

Table 3: Tana District, crop production 1992 (from Ministry of Agriculture District Annual Reports)
Source: UNEP 1998

crop	*tonnes*
mango	8736
banana	8530
tomato	1776
maize	1317
kale	1040
cotton	992
cassava	427
coconut	414
rice	292
onion	210
green gram	167
cow pea	104
citrus	95
pawpaw	80
beans	72
water melon	24
cashew	10
simsim	1

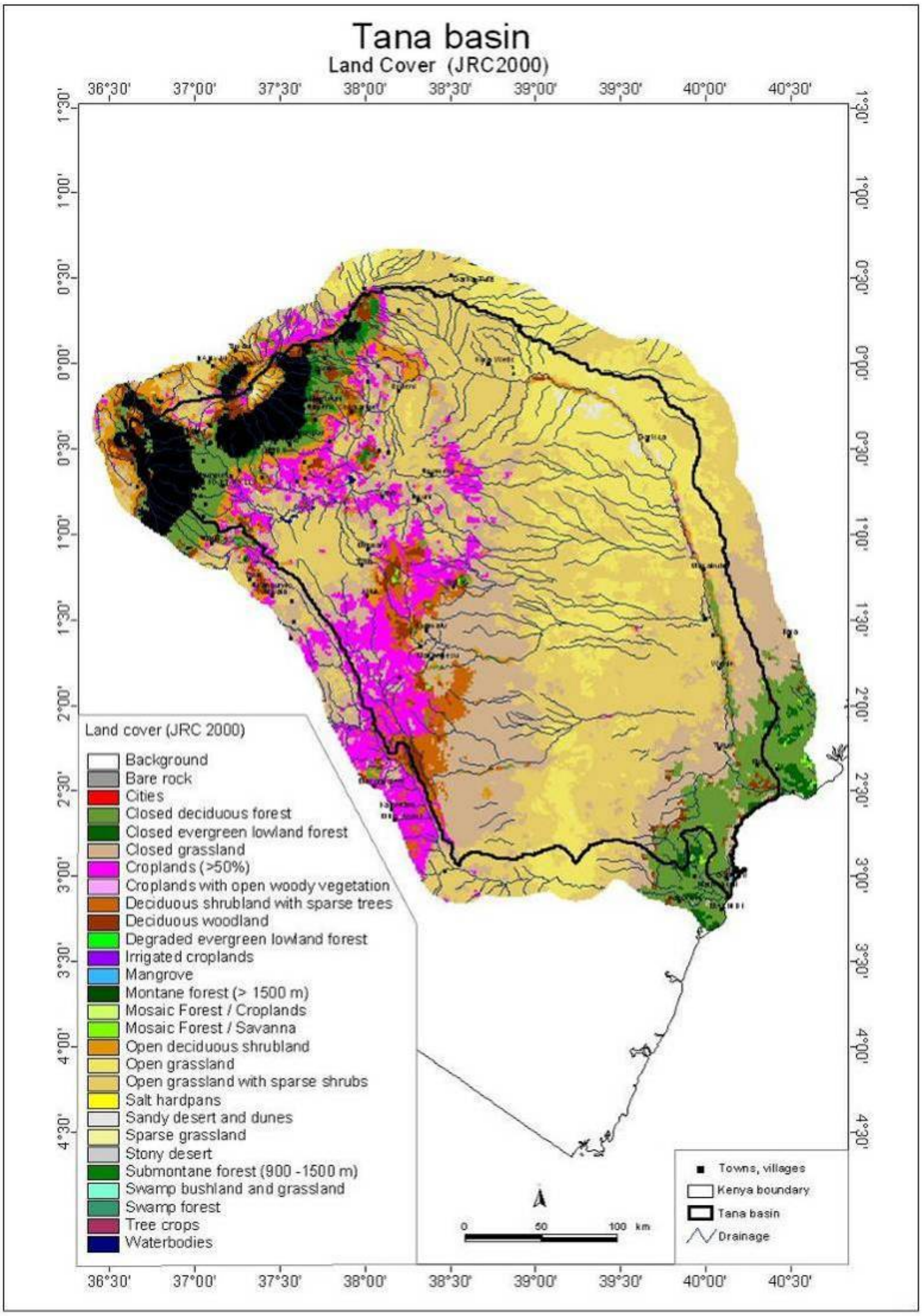

Figure 33: Tana Basin, land cover
Source: Joint Research Centre 2000

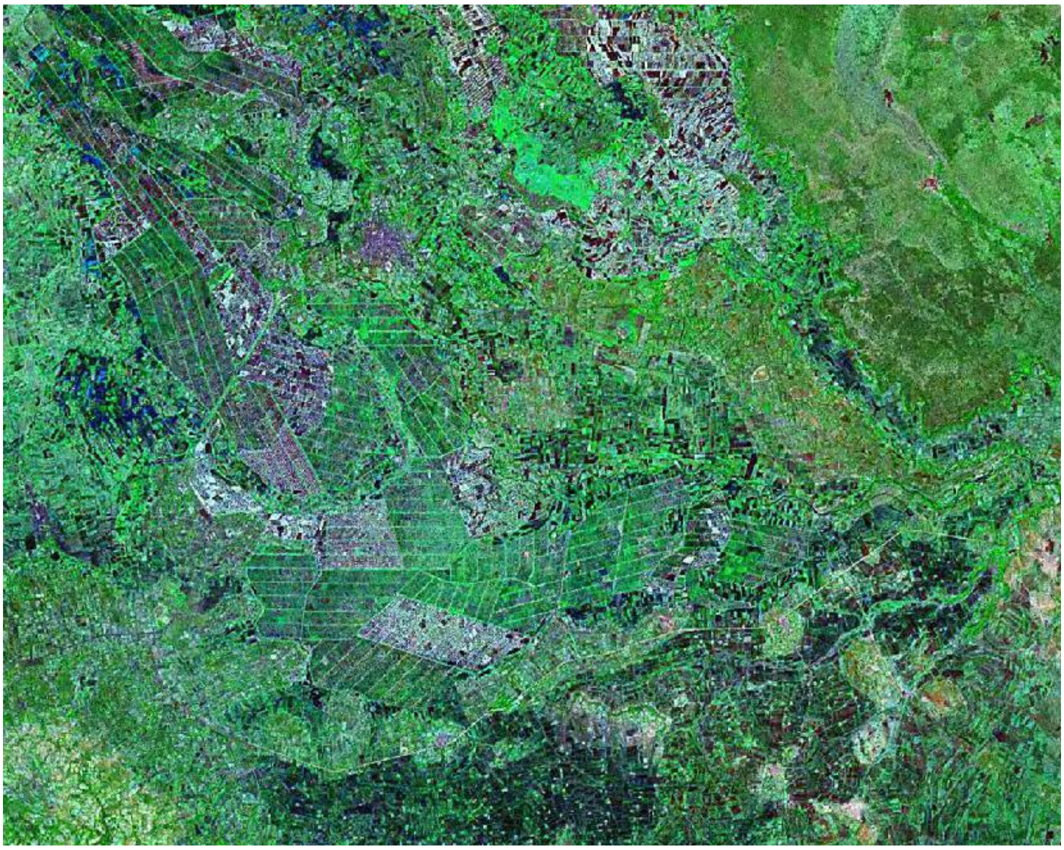

Figure 34: Farmland 25 km north-west of the Masinga reservoir
(extent 20 x 16 km)

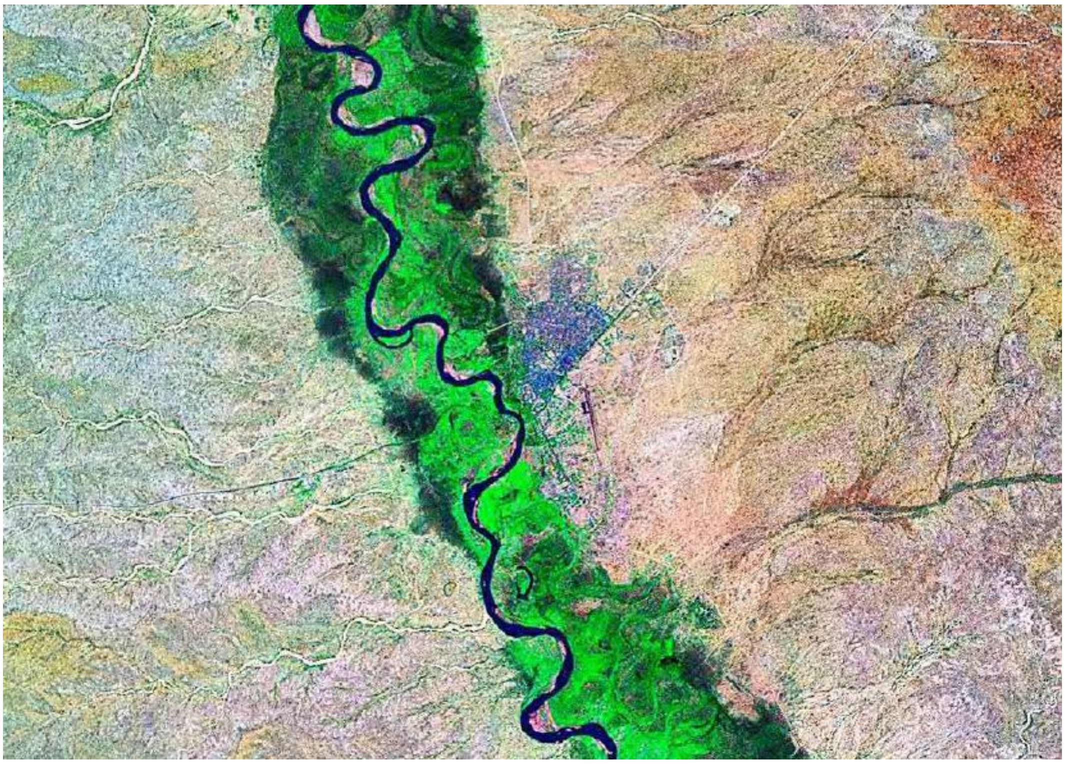

Figure 35: Vegetation along Tana River close to Garissa
(extent 20 x 14 km)

4.2.5 Soils

A useful and convenient soil data source is the KENSOTER database at a scale of 1:1 million which includes 115 profiles of which about 40 have water retention data, 10 from the Tana basin. The ISRIC Soil Information System (ISIS) holds an additional 30 profiles from basin (Figure 36), of which 20 have water retention data.

The following reports with accompanying maps at reconnaissance level are available from the Kenya Soil Survey, covering all the upstream (upper) parts of the Tana River basin.

Report	***No of profiles***	***Remarks***
Soils of Chuka-Nkubu area	*43*	*pF and bulk density data lacking*
Soils of Chuka area	*38*	*pF and bulk density data lacking*
Soils of Murang'a area	*30*	*pF and bulk density data lacking*
Soils of Kindaruma area	*18*	*Data complete*

The ISRIC library holds various soil survey reports (See annex 3).

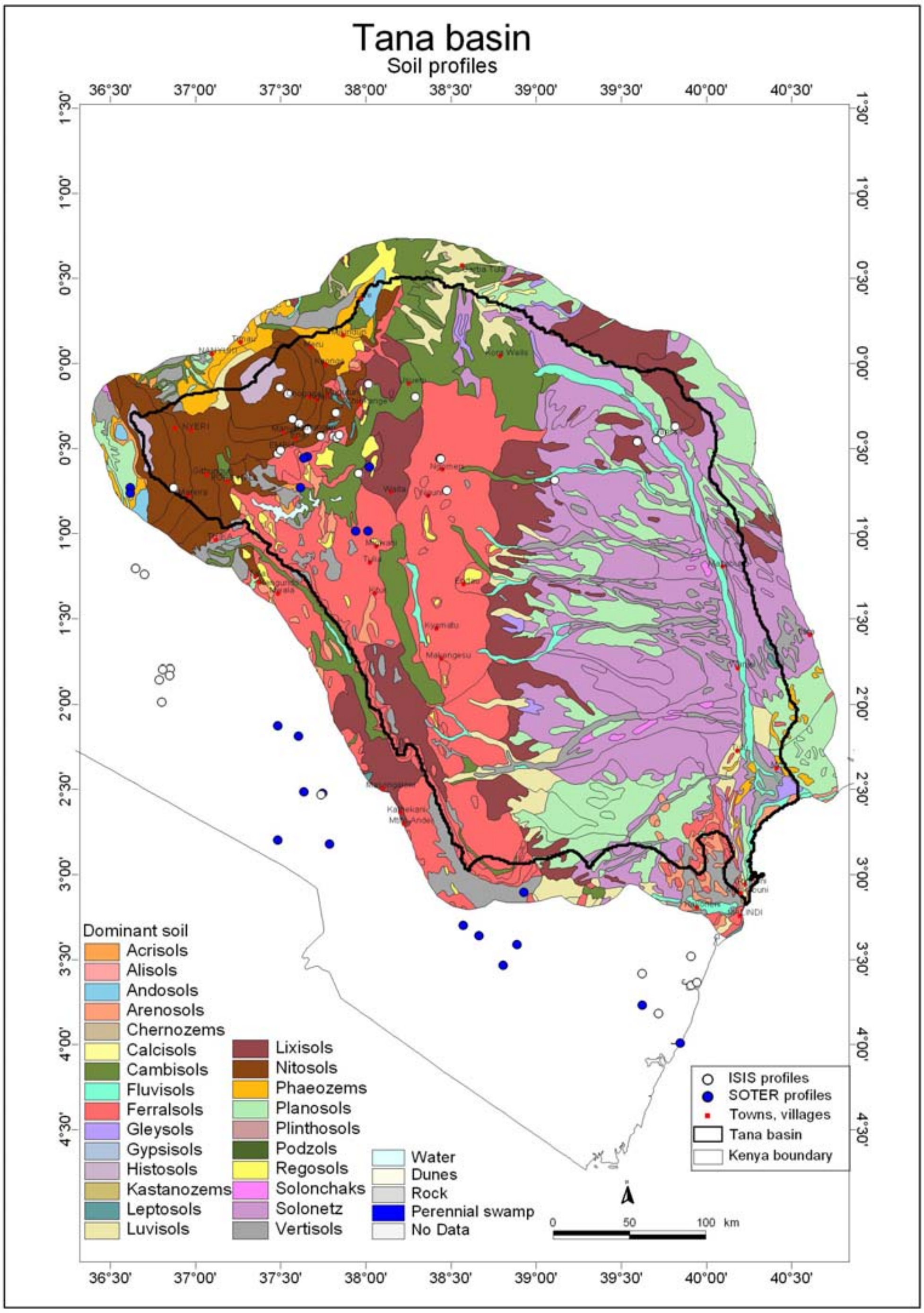

Figure 36: Tana Basin, soil groups and availability of soil profile data
Source: ISRIC Soil Information System

4.3 Socio-economic data

4.3.1 Population

Apart from the high-rainfall areas in upper Tana, most of the basin is sparsely populated (Figure 38). Increasing rural population, drought, and changes in flood regime in the Lower Tana (as a result of dam construction) have increased pressure on resources shared by farmers and pastoralists; despite agreements such as recognised access corridors for livestock to rivers for watering, disputes are commonplace - customary systems of access to floodplain farmland and grazing resources have been rendered increasingly redundant by increasing reliance on state authority and services (Acreman 2000).

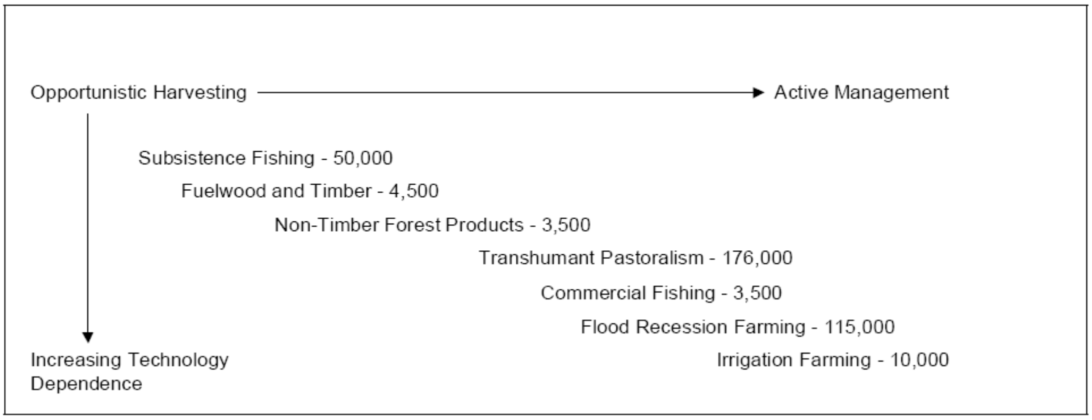

Figure 37: Tana basin, numbers of people dependent on various natural resources
Source: Acreman (2000)

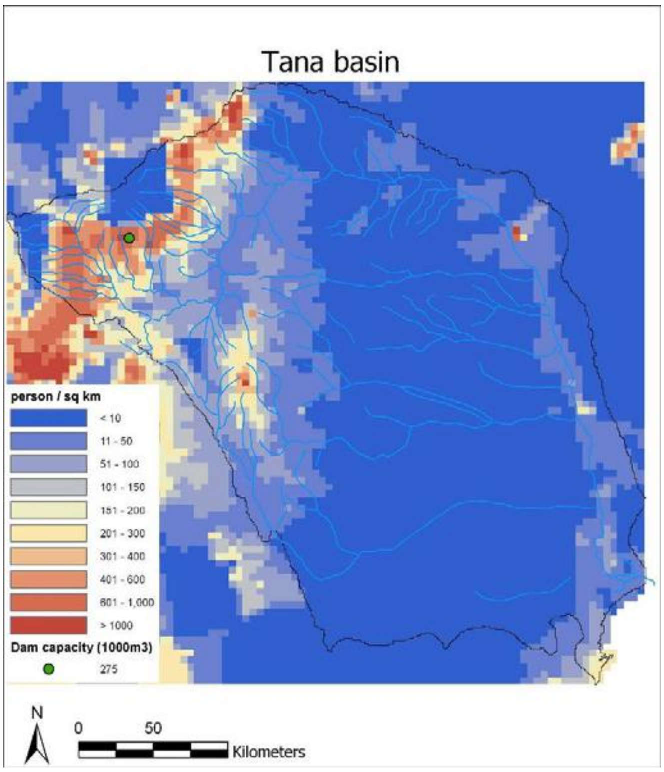

Figure 38: Tana Basin, population density and location of dams
(CIESIN 2005, FAO 2005)

4.3.2 Economic situation

In the upper Tana, there is rainfall enough for a variety of crops (Table3). Below 1000m, rainfall is too little for cropping and stock rearing predominates. More than a million livelihoods depend on the flooding regime of the river: 800,000 nomadic and semi-nomadic pastoralists, 115 000 practising flood recession cropping, fishers, and traders. With dam construction, the possibilities for floodplain agriculture have diminished and it is likely that, after the construction of the Mutonga-Grand Falls Dam cropping will be limited to riverbanks (IUCN 2003).

4.3.3 Hydro-power

The 7-Forks cascade hydro-power stations on the upper Tana include: Massinga (40 MW), Kamburu (84 MW), Gitaru (225 MW), Kindaruma (40 MW) and Kiambere (144 MW) (Table 4; Figure 24). The sixth and the seventh power stations yet to be completed are Mutonga (60 MW) and Grand Falls (140 MW). The Seven Forks provides about 65% of the country's electricity. Massinga Dam, with a catchment of 7 335 km^2 is the main storage reservoir, holding up to 1 560 million cubic metres. Any inflow in excess of the generation capacity is stored and released during dry months. The Grand Falls has relatively small storage in comparison to flood volume so flooding will not be further reduced.

A report of the World Commission on Dams (Acreman 2000) reports on the Massinga dam:

- Domestic, industrial and irrigation water continues to be abstracted from the tributary rivers upstream of the scheme, including water transfers to Nairobi, without conflicts with hydro-power generation and downstream users (Note: As mentioned earlier, shortage of water will emerge in 2006).
- **Operation and life span of Massinga reservoir as a water storage is under imminent danger from the 7 335 km^2 catchment area soil erosion and sedimentation.** At the design stage, the design sediment load into the reservoir was estimated to be 3 million m^3 per year: it is now estimated to be 11 million m^3 per year. Soil erosion on farmlands, access tracks and roads coupled with clearing of forests without effective soil conservation measures is blamed.
- Recognizing that silt is as important as water for the maintenance of the productivity of the floodplain, the designers are looking at the potential for releasing silt together with the flood water.
- The main problems faced by the engineers is inadequate knowledge of the amount of water required to simulate a natural flood, and the timing of such releases in relation to upstream and local rainfall.

Table 4: Dams in Tana River
Source: FAO-Aquastat 2005

name	*year of completion*	*height of dam*	*capacity of the reservoir*	*area of the reservoir*	*purpose*
		(m)	(x1000 mc)	(x 1000 mq)	
Kindaruma	1968	24.3	16 000	250	Hydro-power
Kamburu	1974	56.0	150 000	15 000	Hydro-power
Gitaru	1978	30.0	20 000	310	Hydro-power
Massinga	1980	69.5	1 560 000	120 000	Hydro-power, flood control
Kiambere	1987	112.0	585 000	25 000	Hydro-power

Further sources:

- Dr Christopher Oludhe, Department of Meteorology (Flows from reservoirs and economic data on potential beneficiaries)
- Prof. Laban A Ogallo, IGAD Climate Prediction and Applications Centre

4.3.4 Water Management Organisations

The following are responsible for water management in the in Tana Basin:

- Tana and Athi Rivers Development Authority: the main body for water resource planning and development, under supervision of Ministry of Regional Development until 1997, when KenGen assumed power generation assets
- Kenya Electricity Generating Company (KenGen): a private company that generates about 80 per cent of national supply, 75 per cent of this by hydro-power. KenGen is the successor of Kenya Power Company (KPC) since 1998
- Ministry of Water[3]: responsible for all water issues including Water Resources Management Policy, Water and Sanitation Services Policy, Water Quality, Dam Construction, Flood Control, National Irrigation Policy.
- National Environment Management Authority (NEMA): mandated to coordinate environment matters; responsible for Multilateral Environmental Agreements.

[3] Official name according to Kenya's official governmental website. Other names still in use are: (i) Ministry of Water Resources Management and Development, (ii) Ministry of Water and Irrigation.

4.4 Partnerships / projects

4.4.1 Potential Partners

Tana & Athi Rivers Development Authority
Bobotti, Kamau
PO Box 47309, Nairobi
Tel: +254 2 535834
Fax: +254 2 535832

Department of Meteorology
University of Nairobi
Dr Christopher Oludhe
PO Box 30197, Nairobi
E-mail: coludhe@uonbi.ac.ke

University of Nairobi
Prof. Eric Odada
PO Box 30197 , Nairobi
Tel: +254 2 4447740
E-mail: eodada@uonbi.ac.ke

ICPA
Prof. Laban A Ogallo, Director
PO Box 10304, 00100, GPO, Nairobi, Kenya
E-mail: director@icpac.net; or: logallo@icpac.net

National Agricultural Research Laboratories
Dr Patrick Gicheru, Director
PO Box 14733-00800, Westlands, Nairobi, Kenya
Tel: +254 020 4443376/4443926
E-mail: cdnarl@iconnect.co.ke

Ministry of Water and Irrigation
Ms Evangeline Diana Marigu Mbatia
Deputy Director, Irrigation and Drainage
Maji House, PO BOX 49720, Nairobi, Kenya
Tel-1: +254 20 9716103
Tel-2: +254 20 9716103 ext 42194
Mob: ++254 722 306452
Email: edmmbatia@yahoo.com

For hydrological data/policy issues:
Water Resources in the Ministry of Water and Irrigation
Mr Ndegwa Irungu, Director
E-mail: irungu2005@yahoo.com

For land use policy:
Ministry of Lands
Ms Rosemary W Wachira

PO Box 45025, 00100 Nairobi, Kenya
Tel: +254-020-2718050 ext 4654
Email (personal): wachira@landpolicy.com
Email (official) info@landpolicy.com
Website: www.landpolicy.or.ke

Tana and Athi Rivers Development Authority
Mr PC Kamau
PO Box 47309, 00100 Nairobi, Kenya
Tel: +254-020-252587
Email: pckamau@yahoo.com

Soil and Water Management Research Network (SWMnet) of ASARECA
Dr Nuhu Hatibu
ICRAF Complex, Gigiri
PO Box 39063, 00623 Nairobi, Kenya
Tel: +254-20-7224565

4.4.2 Relevant projects

- IUCN hydro-power study, completed in 2003
- Texas A&M: Application of SWAT in developing countries using readily available data. Jennifer H Jacobs, R Srinivasan, Jay Angerer and Jerry Stuth
- World Bank: Tana river primate national reserve conservation project, 1996-2005

A reforestation study in the upper reaches of the Tana River using the SWAT model was undertaken by Texas A&M University. Scenarios with 30 to 55 per cent increase in forest areas in the upper catchment showed a reduction in the sediment load of the river and, thereby, siltation of the reservoir as well as more predictable stream. The simulations highlighted that the Thiba River, which accounts for less than 3 per cent of the catchment area, contributes 40 per cent of the flow and 44 per cent of the sediment load into the reservoir (Jacobs and others 2005). **Changes in agricultural use and practices to arrest siltation and increase blue water flows were not taken into consideration by Texas A&M**.

4.5 Green Water Credits Potential

The hydrology of the Tana has been substantially altered over recent decades by the construction of dams which enable power generation and reduce downstream floods. Flood recession cropping is hardly possible but regular irrigation has expanded.

The potential GWC buyers are: KenGen, Nairobi City Council–Water Supply Department (NCC-WSD), the irrigation sector, and the Kenya Wildlife Conservation Department. The following issues are of interest:

i. KenGen is more focused on the siltation issue than water supply;

ii. NCC-WSSD wants to overcome low flows during dry spells, after 2006 supply will be inadequate;
iii. The irrigation sector requires increase in total water availability;
iv. Tana River Primate National Reserve occupies the upper delta, about 75 km from ocean, 169 km^2. Water requirements have not been specified.

The potential sellers are mainly the land users in the catchments of the reservoirs. Their services may include measures to minimize runoff and erosion, and measures to maximize infiltration and deep drainage to promote groundwater recharge and extended periods of stream flow.

The Ministries of Agriculture (MoA) and Water & Irrigation, through their affiliated institutions, are mandated to oversee the effective use of water. The MoA considers GW management as a core concept, which they promote through appropriate soil and water conservation approaches. The necessary legal frameworks exist and most of these activities have been identified as necessary to attain the Millennium Development Goals.

5 Ruvu Basin: Tanzania

5.1 Overview

The source of the Ruvu River[4] is the Uluguru mountains; the basin has a total area of 17 700 km^2. The river system can be divided into: the Upper Ruvu, the Mgeta plains, the Ngerengere and the lower Ruvu flood plain which extends over 100 km to Bagamoyo into the Indian Ocean (Figure 39). The lower Ruvu floods frequently but is sparsely populated; in a few places, the floods are exploited for rice cultivation and the high water table allows cropping during the early dry season.

The Ruvu is the major source of water for Dar es Salaam, also Bagamoyo and Kibaha and other small urban centres. The mean river flow is 65 m^3 s^{-1} at gauging station 1H8 at Morogoro Road Bridge (Figure 41). It is believed that only 60% of the current water requirement in Dar es Salaam is met and dry season supply is problematic. A city population of 6 million is expected by the year 2020. If the *per caput* consumption of water is taken at 220 litres, the water requirement for Dar es Salaam will be about 1.3 million m^3 d^{-1} (~15 m^3 s^{-1}), which is a quarter of ADF and a dam will have to be constructed upstream of gauging station 1H8 (Nnunduma 2005). Apparently, distribution losses account for 60-80 per cent of the pumped water (Niemczynowicz 2001).

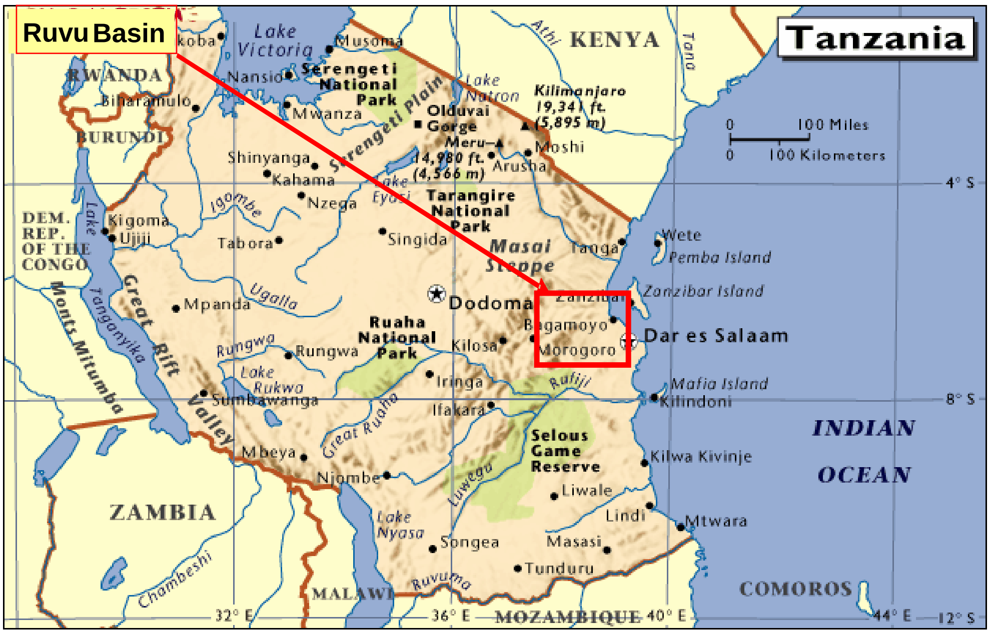

Figure 39: Ruvu basin, location

[4] Not to be confused with the small river also called Ruvu located at the border between Tanzania and Kenya. (See Annex 4)

5.2 Physical data

5.2.1 Terrain

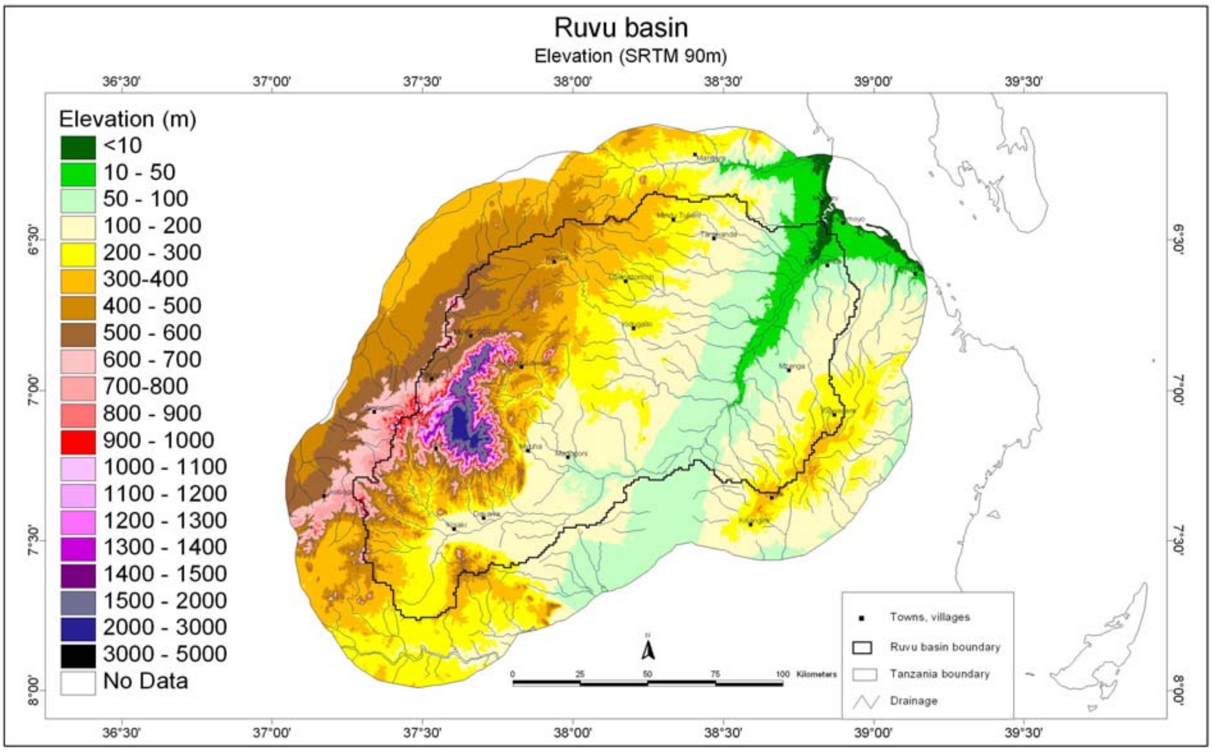

Figure 40: Ruhu Basin, elevation
SRTM data

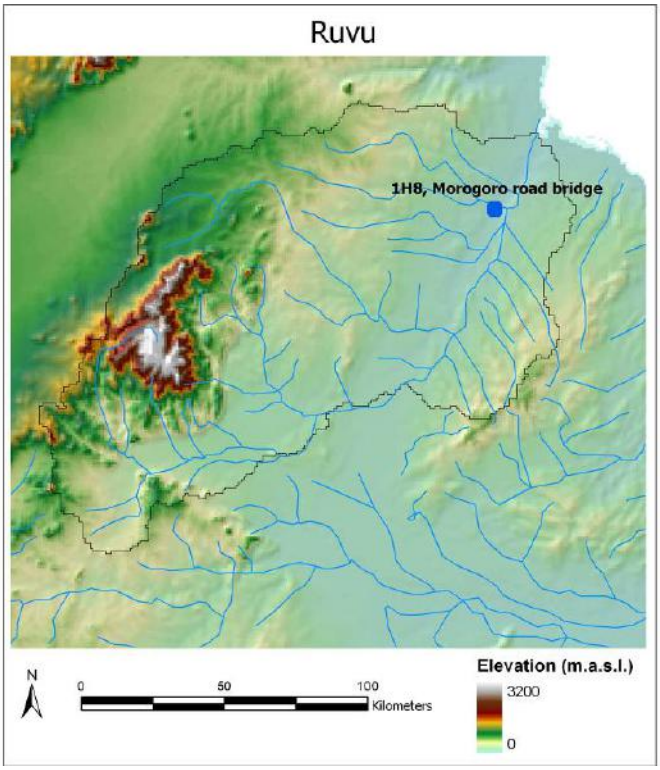

Figure 41: Ruvu Basin, boundary and location of gauging station

5.2.2 Meteorological data

Mean annual rainfall of more than 2500 mm is recorded on the eastern slopes of the Uluguru mountains, while the western part lies in the rain shadow. The Nguru-Rubeho mountains receive between 800-1200 mm, the Ukaguru mountains 1000-1800 mm. Rainfall is much less in the plains; 800-1000 mm near the coast but only 500-600mm inland towards Dodoma and north of Wami basin (Nnunduma 2005).

Long-term climatic data from the CRU TS 2.0 dataset of Climate Research Unit of the University of East Anglia comprise 1200 monthly grids of observed climate, for the period 1901-2000, and covers the global land surface at 0.5° × 0.5° resolution (Mitchell and others 2003). The dataset comprises: cloud cover, diurnal temperature range, precipitation, temperature, and vapour pressure. The dataset is based on raw station data; since data can be scarce in some regions or periods, a method called 'relaxation to the climatology' was used to create grids. This implies that, for some areas or regions, data are less accurate. For the Ruvu, one location was selected and the monthly averages over the last 100 years as well as the annual trends are shown in Figure 42 and Figure 43**.** Another global dataset, the *World Water and Climate Atlas* (IWMI 2000), was used for its somewhat finer spatial resolution of 12 km, but data are only monthly averages over the last 30 years (Figure 44).

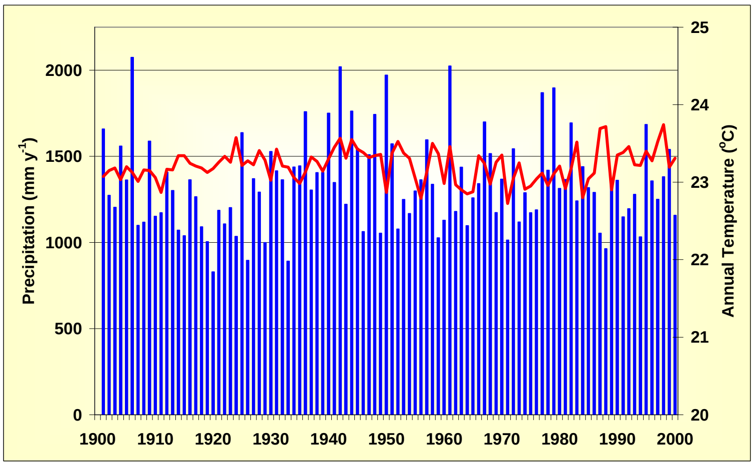

Figure 42: Ruvu Basin, annual rainfall and temperatures
(Mitchell and others 2003)

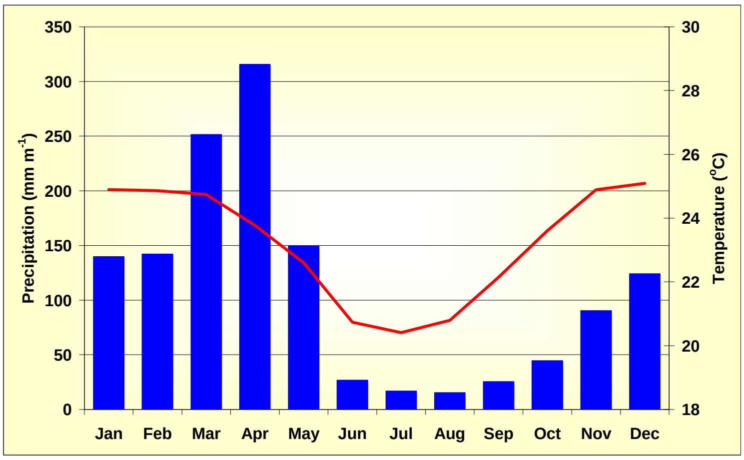

Figure 43: Ruvu Basin, monthly mean rainfall and temperature
(Mitchell and others 2003)

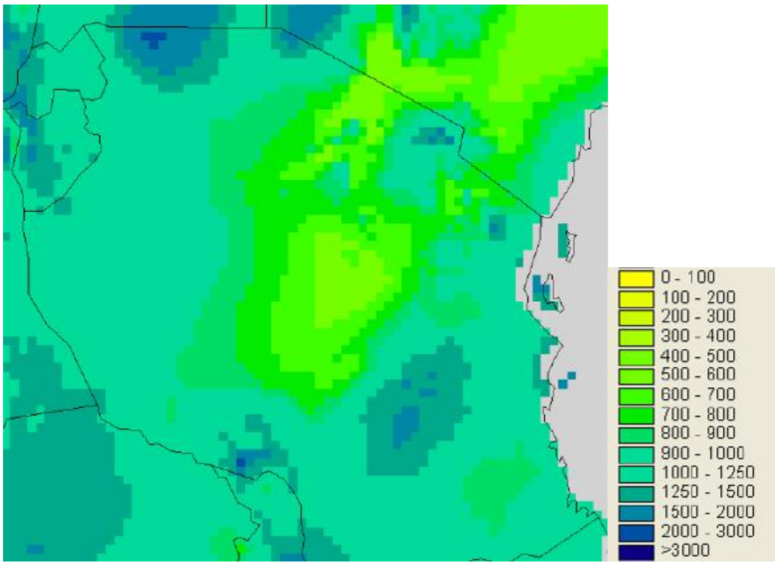

Figure 44: Ruvu Basin, mean annual precipitation
(IWMI 2000)

The FAOCLIM database includes the parameters as listed in Annex 1. Again, only monthly averages over the last 30 years are given, whereas the erratic rainfall patterns are considered as the major problem in the area. However, for a number of stations climate time series are given and some records are available over the period 1922-1972 onwards.

The following global datasets can also be considered:

- Global Change Master Directory: http://gcmd.gsfc.nasa.gov/
- Climate Change Data: http://ipcc-ddc.cru.uea.ac.uk/ddc_climscen.html
- Tropical Rainfall Measuring Mission (TRMM): http://trmm.gsfc.nasa.gov/

5.2.3 Hydrological data

The basin has an area of 13 300 km^2 above the lowest gauging station, 1H8, where the mean annual flow is 65 m^3 s^{-1} (Figure 45).

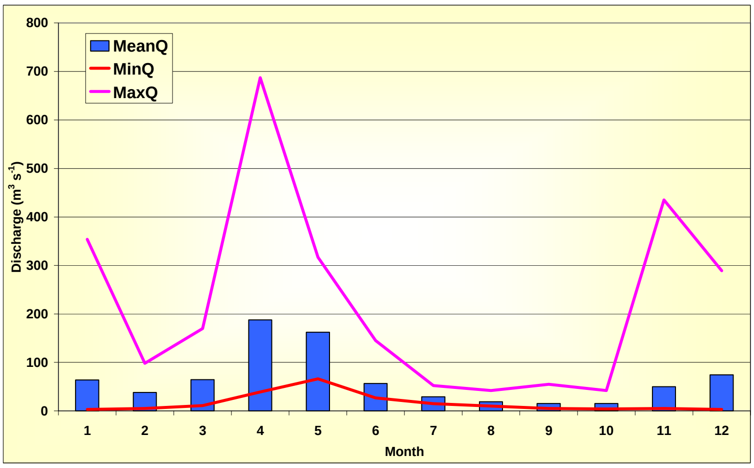

Figure 45: Ruvu River discharge at IH8, 1959-1978
Source: GRDC

5.2.4 Land use and land cover

Irrigated land is found in the lower Ruvu and the western slopes of the Uluguru mountains. There have been several irrigation projects in the lower Ruvu, of which few are now operational; the irrigated area is about 340 ha; the main crop is rice. In Uluguru West, in the foot slopes of the Mgeta Mountains, there are 68 irrigation canals amounting to about 170 km, irrigating about 2060 ha vegetables, maize, beans and fruit (Nnunduma 2005).

Figure 46 shows the Ruvu part of the SADC Regional Land Cover Database. The LC2000 land cover map of Africa (Mayaux and others 2000) was also consulted. Figure 47 and Figure 49 depict some of the irrigated areas. Landsat images reveal that cropland is limited; most of the basin is scrub used for extensive grazing and browse (Figure 48).

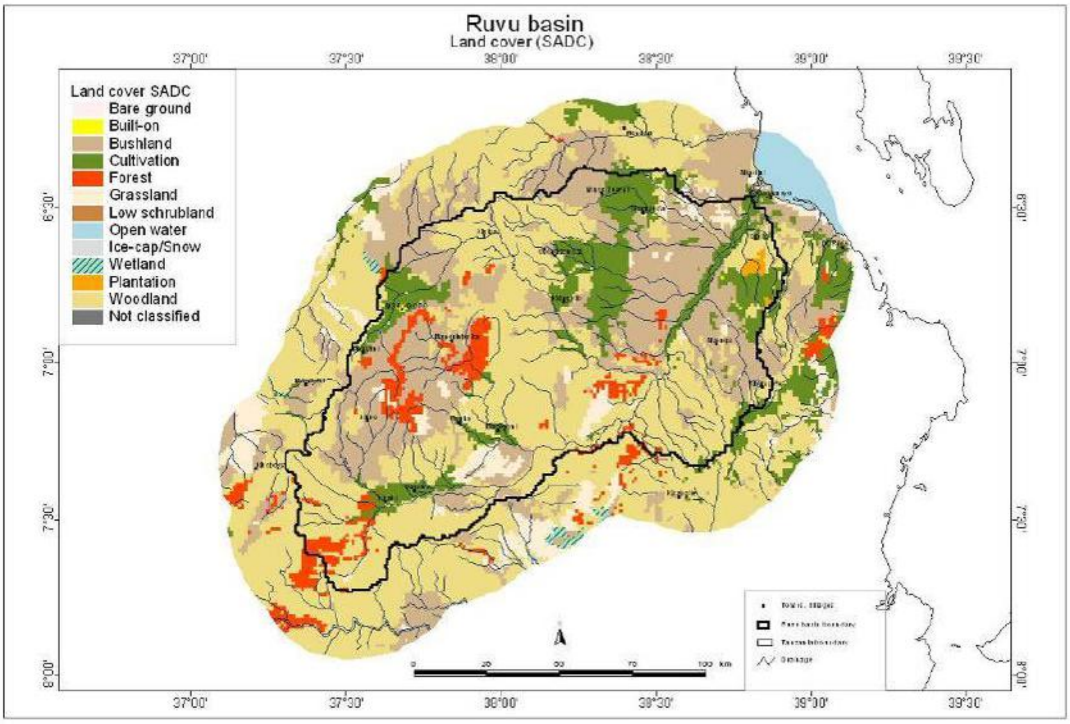

Figure 46: Ruvu Basin, land cover
Source: SADC Regional Land Cover Database Project

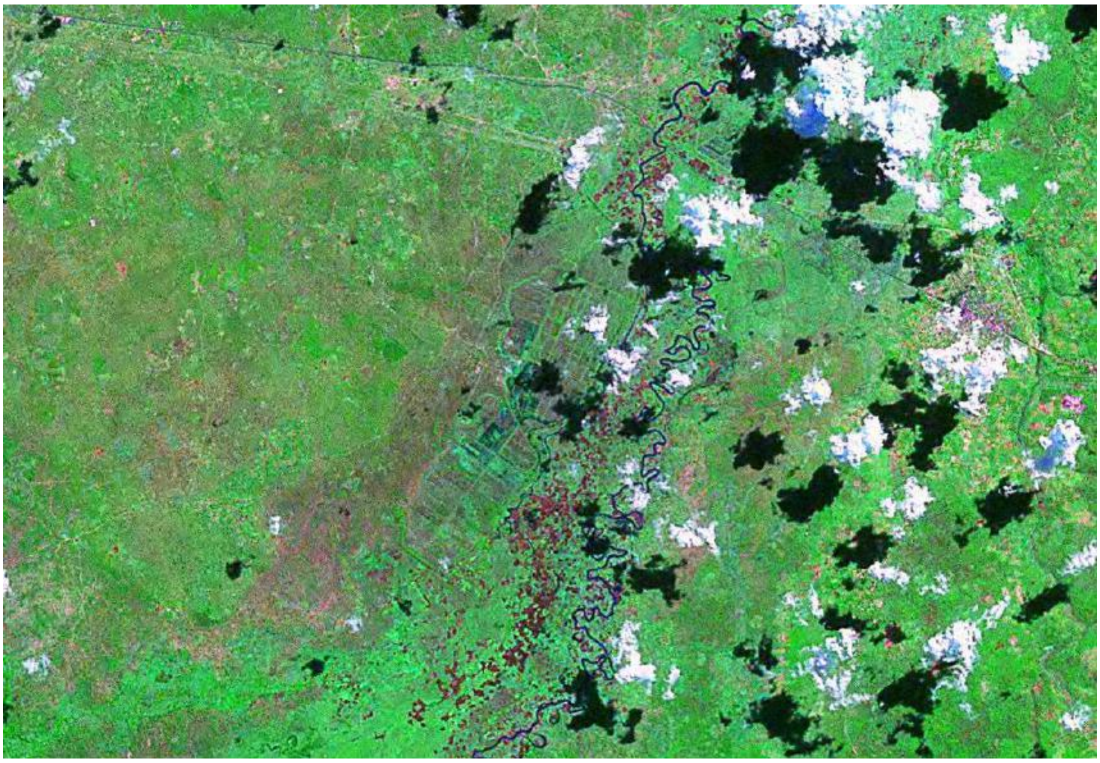

Figure 47: Irrigation system close to IH8
(extent 17 x 12 km)

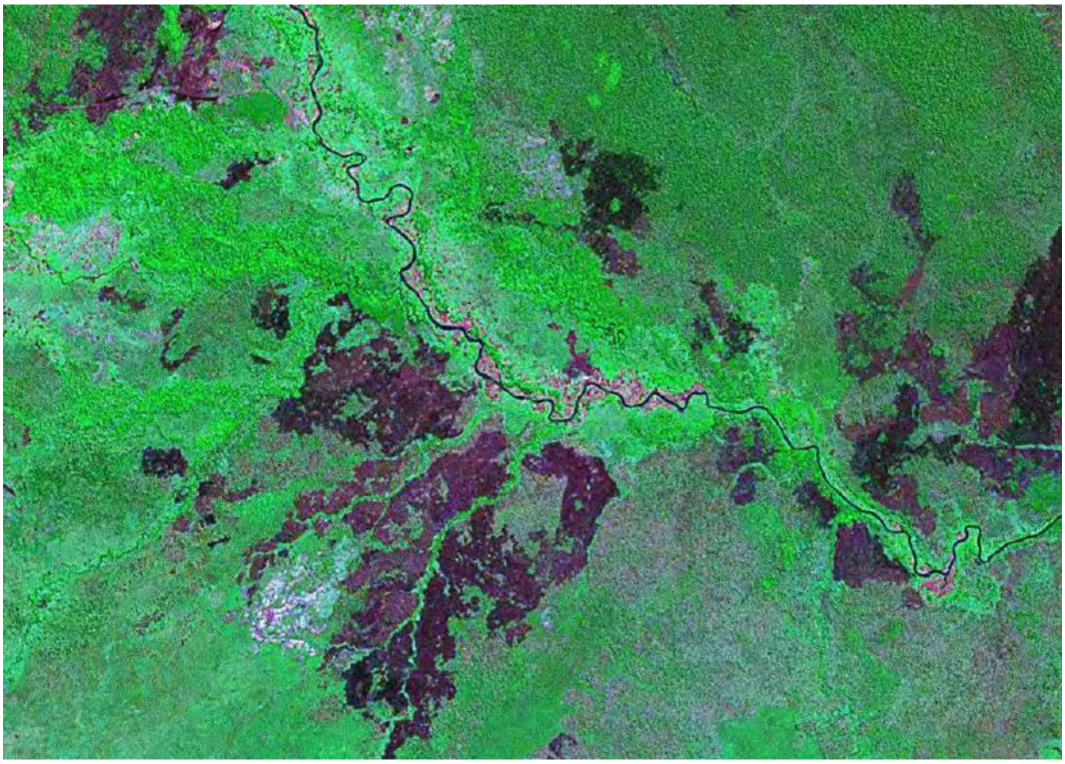

Figure 48: Cropland upstream
(extent 17 x 12 km)

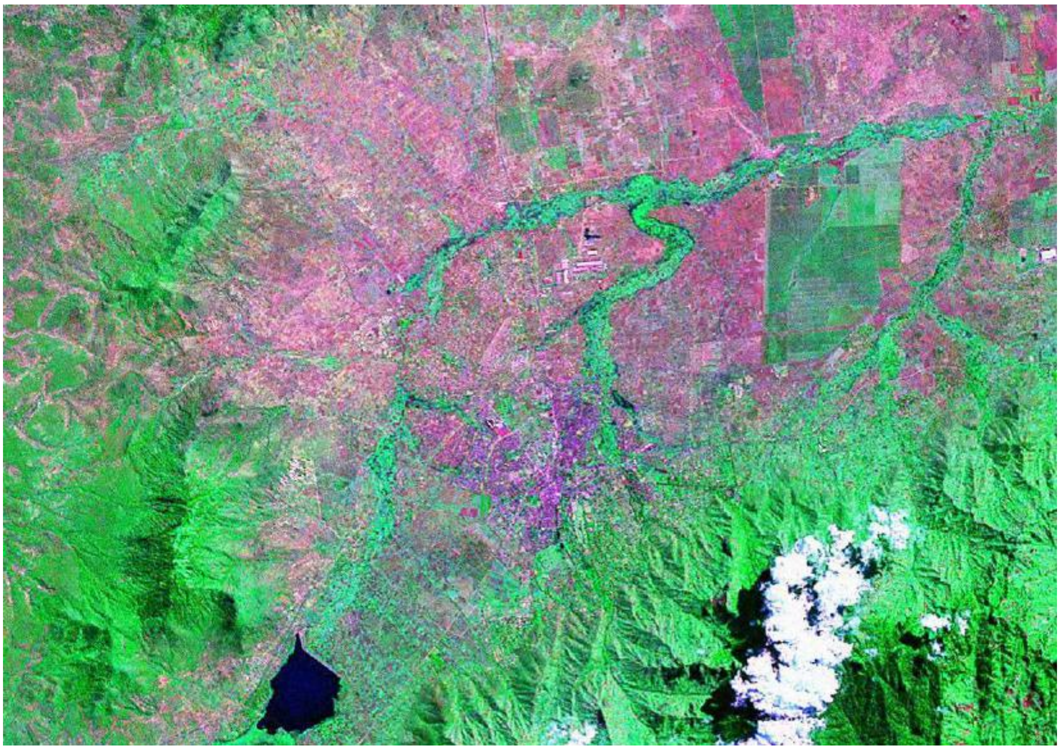

Figure 49: Irrigation systems on the Wami River and Mindu reservoir, Morogoro
(extent 22 x 16 km)

5.2.5 Soils

The SOTER database for Southern Africa (SOTERSAF) provides coverage at scale 1: 1 million (Figure 50). The National Soils Research Institute at Mlingano holds more profiles, probably few with soil water data. The ISRIC library holds a few soil survey reports of the area (Annex 3).

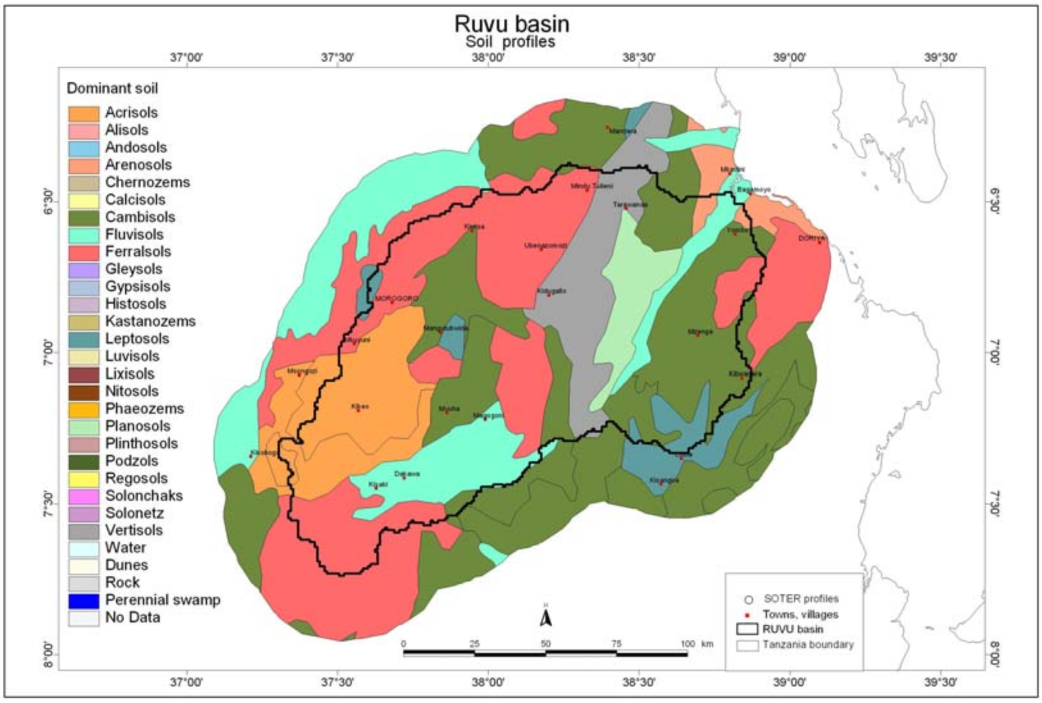

Figure 50: Ruvu Basin, soils

5.3 Socio-economic data

5.3.1 Population

Population is sparse (Figure 51). In 1999, only 45 per cent of the rural population of Tanzania and 68 per cent of the urban population had a safe water supply, and only about 7 percent of city dwellers are connected to piped sewerage.

5.3.2 Economic situation

Agriculture employs about 80 per cent of Tanzania's population and accounts for half of GDP. Most farming takes place in valleys and flood plains.

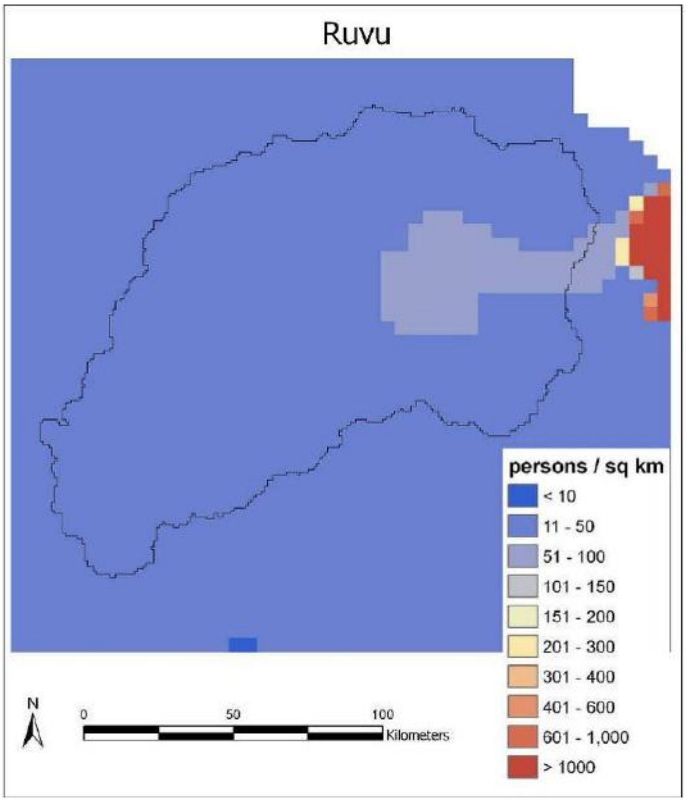

Figure 51: Ruvu Basin, population density
(CIESIN 2005)

5.3.3 Water Management Organisations

Two organisations are responsible for water management issues:

a) The River Basin Management (RBM) concept was introduced in 1981 with the creation of Basin Water Boards. Nine basins were established including the Ruvu-Wami Basin (Kashaigili 2002);
b) Ministry of Water and Livestock Development.

5.4 Partnership

- There is a World Bank project examining options for future water supply to Dar es Salaam
  http://www.watres.com/bulletin/currentbulletin.pdf

- Dar es Salaam Water and Sewerage Authority:
  http://www.psrctz.com/Utilities%20&%20Major%20Transactions/dawasa.htm

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Soil and Water Management Research Network (SWMnet) of ASARECA
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ICRAF Complex, Gigiri, PO Box 39063, 00623 Nairobi
Tel: +254 20 7224565

5.5 Green Water Credit Potential

Potential buyers:
- Dar es Salaam municipal water supply
- Irrigators downstream

Potential sellers:
- Irrigators Upstream - few
- Rain-fed agriculture in the upper Ruvu river basin - little

The potential of *green* water management for downstream *blue* water services is limited by the limited area of rain-fed and irrigated agriculture in the upper Ruvu. Probably, there are easier ways to fix the immediate problems of Dar es Salaam water supply, such as renewing intake works and reticulation.

6 Great Ruaha Basin: Tanzania

6.1 Overview

The Great Ruaha encompasses 83 970 km^2; it is part of the Rufiji Basin which covers a quarter of Tanzania (Figure 52) and includes the Poroto Mountains, the Usangu and Pawaga Plains, and the Utengule Swamps. The Great Ruaha is made up of three river systems: the Great Ruaha, the Njombe (Little Ruaha) and the Kisigo. From the west, the Kisigo River starts from Manyoni and Rungwa Game Reserve and drains the drylands of the Ruaha National Park, joining the Great Ruaha at Mtera (Figure 53). The Great Ruaha is sourced in the Poroto Mountains; many streams flow to the Usangu plains and the vast Utengule swamps. It passes the National Park Plains and collects the Njombe (Little Ruaha) and Kisigo. It then flows east through the Ruaha Gorge into Kilombero Plains before joining the Rufiji. The many swamps along the Great Ruaha moderate floods and, also, cause significant evaporation losses.

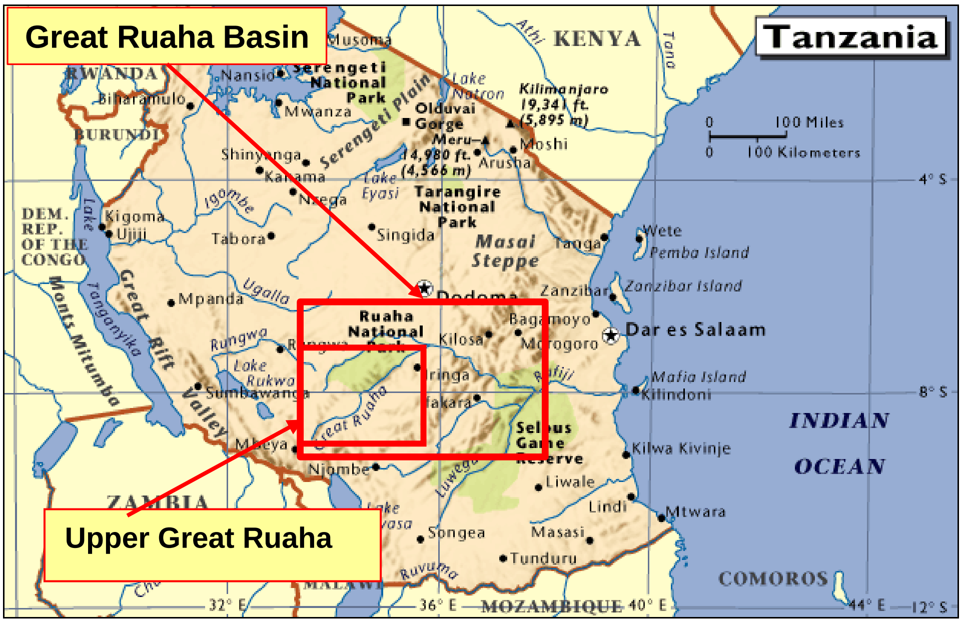

Figure 52: Great Ruaha Basin, location

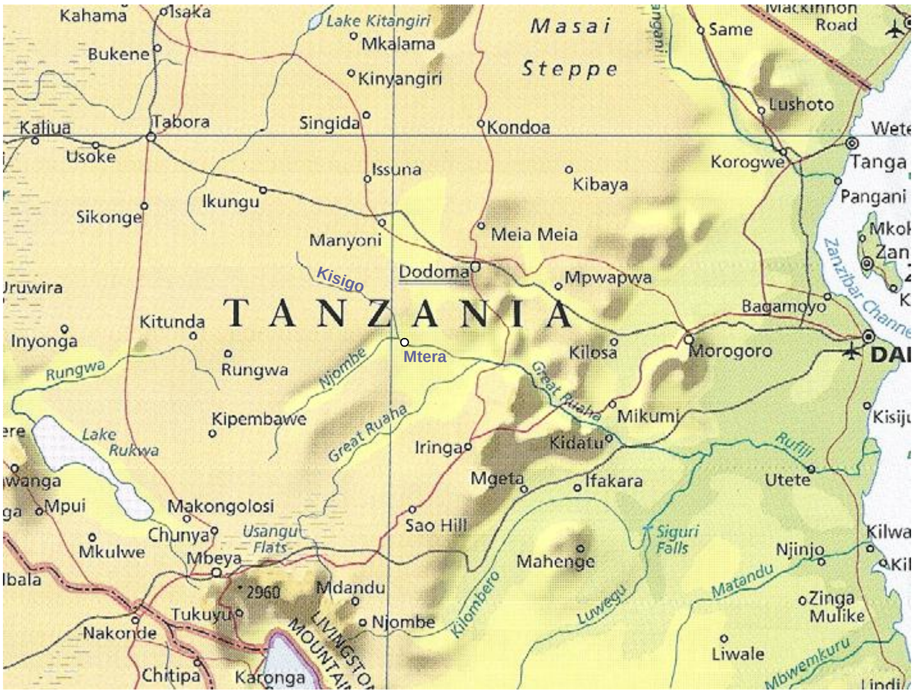

Figure 53: Great Ruaha Basin, relief and drainage

The Mtera reservoir, operating since 1980, is the largest man-made lake in Tanzania; it feeds the hydro-power plants Mtera and Kidatu that, together, provide 85 per cent of the national electricity supply. 'Hydrological change was the rationale for the project "Sustainable Management of the Usangu Wetland and its Catchment" which resulted from national and local concerns about the management of water and other natural resources in the Usangu basin. In particular, national power shortages in the mid-1990s were attributed to low flows to the Mtera/Kidatu hydropower schemes from the Ruaha. A reduction in flows in the Great Ruaha where it passes through the Ruaha National Park was also noted. There has now been a succession of years in which the river in the park has dried up completely during the dry season, and for increasing periods. An increase in competition for water was noted in Usangu itself, leading to conflict and sometimes violence. Concern was also expressed that the wetlands in the project area were diminishing and degrading, and that a valuable natural asset was being lost' (SMUWC 2001).

There are serious water-use conflicts in Tanzania, attributed to uncoordinated developments by different sectors; for example, conflict between the hydro-power sector and the farmers, between groups of farmers (upstream and downstream), between the farmers and pastoralists, between institutions and other users including the environment of national parks and tourism (Kashaigili 2002).

In the upper Basin, water-use conflicts are associated with irrigation. Cultivators have been attracted from the highlands and pastoralists from northern and central Tanzania; conflicts have arisen due to abstraction of water for irrigation causing water shortages downstream, particularly during the dry seasons.

6.2 Physical data

6.2.1 Terrain

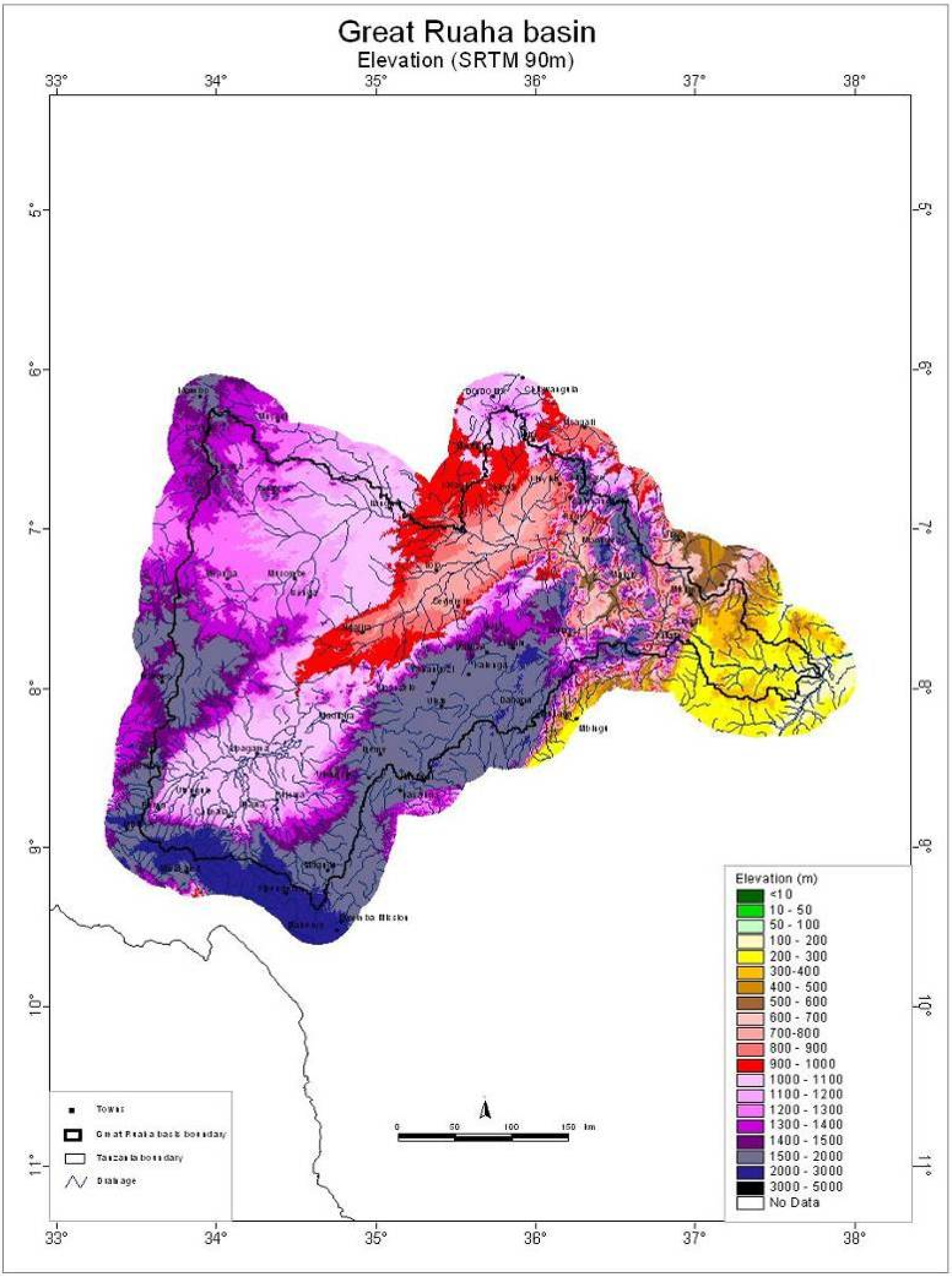

Figure 54: Great Ruaha Basin, elevation
SRTM data

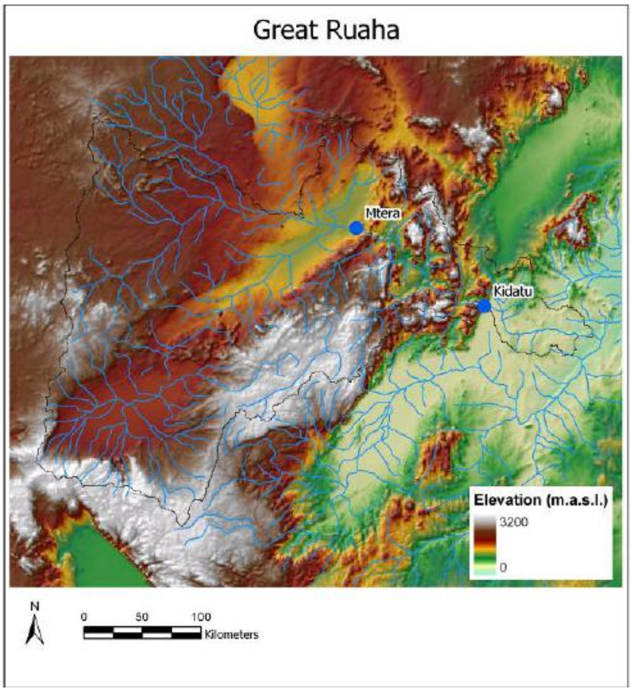

Figure 55: Great Ruaha Basin, location of stream gauges

6.2.2 Meteorological data

There is a single rainy season from November through to May. Approximately 150 rainfall stations are located within the Great Ruaha Basin but there are significant gaps in the records, in particular after mid-1980s (Jensen and others 2004). Nnunduma (2005) provides an isohyet map. As well as the UEA global dataset (Mitchell and others 2003), the following global datasets may be considered:

- Global Change Master Directory: http://gcmd.gsfc.nasa.gov/
- Climate Change Data: http://ipcc-ddc.cru.uea.ac.uk/ddc_climscen.html
- Tropical Rainfall Measuring Mission (TRMM): http://trmm.gsfc.nasa.gov/

6.2.3 Hydrological data

The Global Runoff Data Center has two useful stations with daily stream flow data from 1954 to 1978: Mtera, located in the Great Ruaha, and Swero, just outside. The mean flow of the Great Ruaha at Mtera (Gauging site 1KA5, Figure 55) is 140 $m^3 s^{-1}$. The reservoir at Mtera can hold the mean flow of the river so the river is completely regulated downstream. The mean flows of other rivers in the basin are: Great Ruaha at Iringa (20 $m^3 s^{-1}$), Mbarali River at Great North Road (17 $m^3 s^{-1}$), Lukosi River at Mtandika (25 $m^3 s^{-1}$), and Great Ruaha at Great North Road (16 $m^3 s^{-1}$) (Nnunduma 2005). Lankford and others (2004) summarize ideas about how and why the wetland and river in the Usangu Plains are drying up.

In 1976, a 200 MW hydro-power plant was commissioned at Kidatu, just before the Great Ruaha River enters the Kilombero valley. A 125 million m^3 reservoir is situated 10 km upstream and is capable of regulating flow up to 70 m^3 s^{-1}. In 1982, Mtera Dam was constructed with storage of 3 200 million m^3 to regulate flows to Kidatu power plant and a further power plant with a capacity of generating 80 MW is installed at Mtera.

Hydro-electric power generation and irrigation are in direct conflict. All irrigation projects in the Great Ruaha are above Mtera dam and the hydro-power plants.

6.2.4 Land use and land cover

In the Usangu plains (Figure 56 and Figure 58), approximately 49 000 and 5 000 ha are irrigated during wet and dry seasons, respectively; shortage of water during the dry season limits the area which can be irrigated during this period (Jensen and others 2000). Indiscriminate tree cutting and poor agricultural practices have brought about land degradation, increased incidence of flooding, sedimentation, reduced dry season flows, and degradation of wetlands (Nnunduma 2005). Governance is urgently needed to restore perennial flow in the Great Ruaha; Mtahiko and others (2005) argue that livestock should be removed from the eastern Usangu wetlands and dry season irrigators should return to the river at least 25 per cent (~4 m^3 s^{-1}) of the water now abstracted.

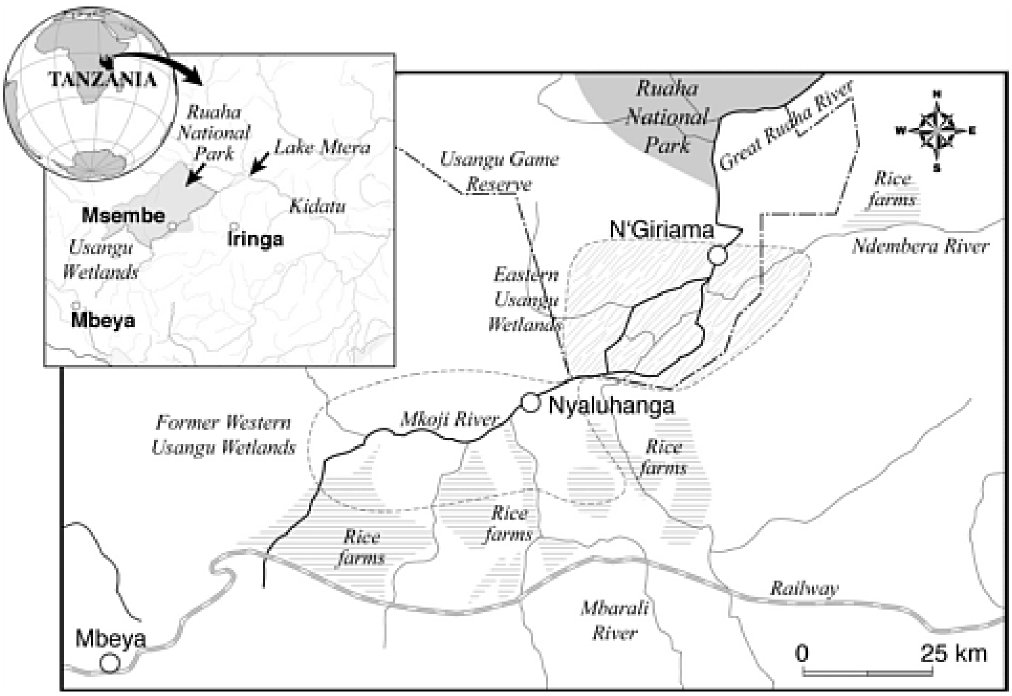

Figure 56: Usangu plains
After Mtahiko and others 2005

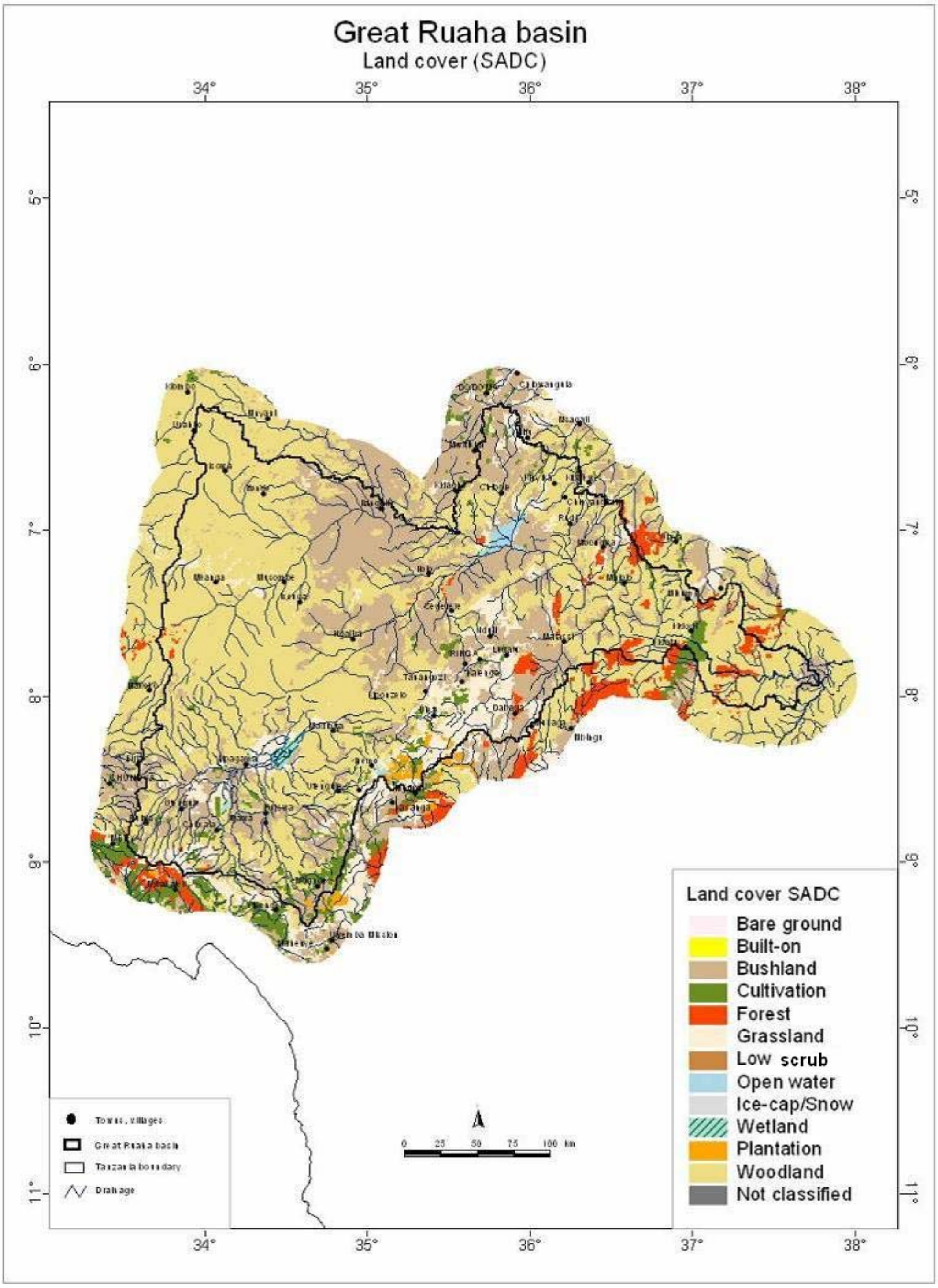

Figure 57: Great Ruaha Basin, land use
Source: SADC

Most irrigation is located in the upper plains: large, state-owned farms, traditional smallholders, improved smallholders, and smallholders peripheral to the state farms. Since 1970, the area has increased from 10 000 ha to over 45 000 ha today (SMUWC 2001), with 20 000 and 40 000 ha irrigated, depending on water supply (Figure 59, Figure 60 and Figure 61). The large state farms also provide domestic water through canals to the villages that have grown up within them (Lankford *et al*. 2004). The main crop is rice, maize and vegetables are grown too. Rain-fed farming occupies a far greater area, 20 percent of the Usangu catchment, compared with 3.5 percent of the catchment under irrigation (Figure 57).

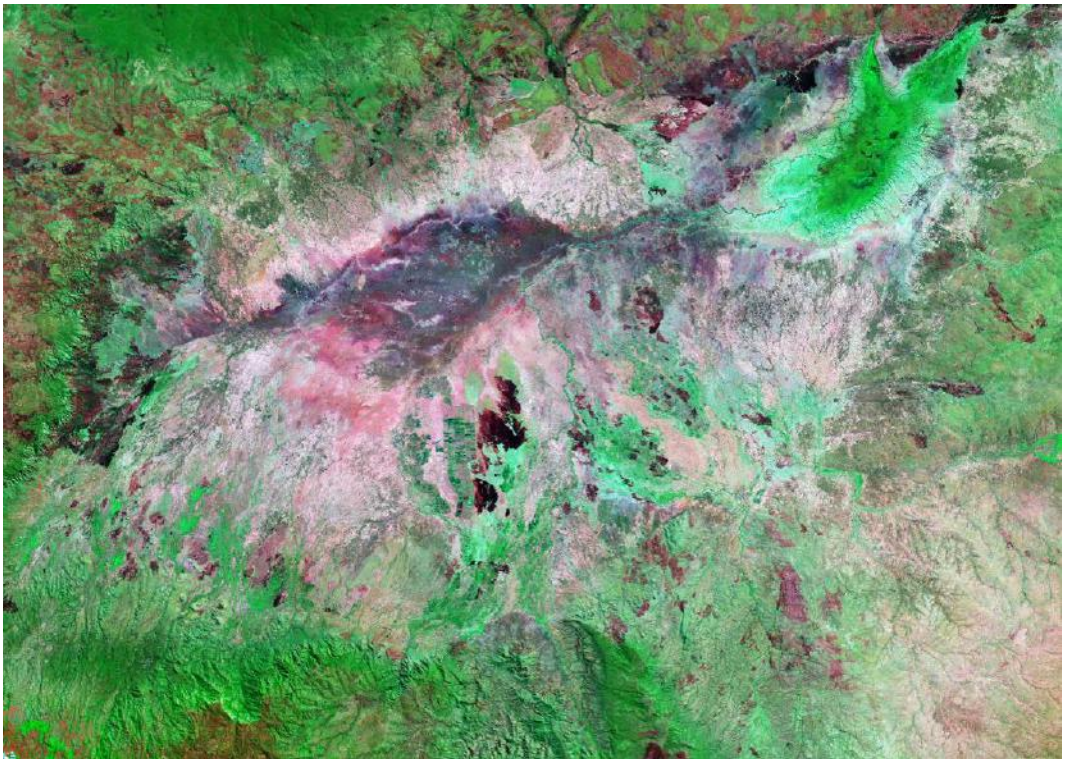

Figure 58: Overview of the Usunga area
(extent about 122 x 68 km)

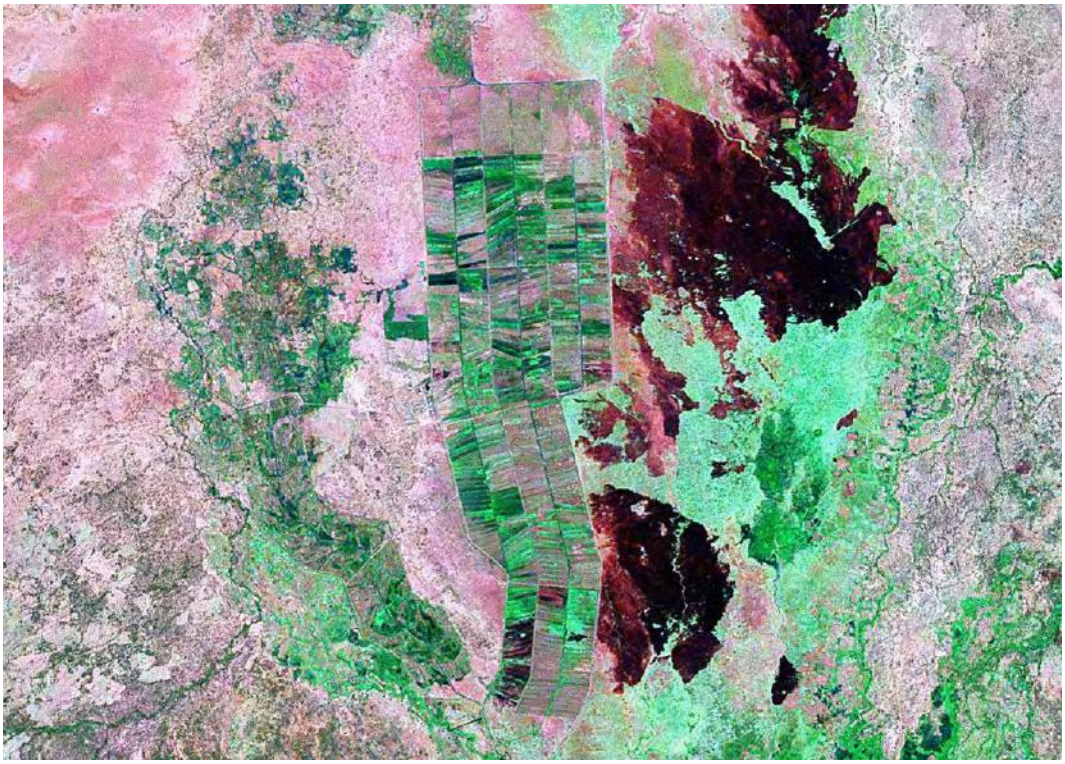

Figure 59: Irrigated agriculture in the Usunga area
(extent 22 x 16 km)

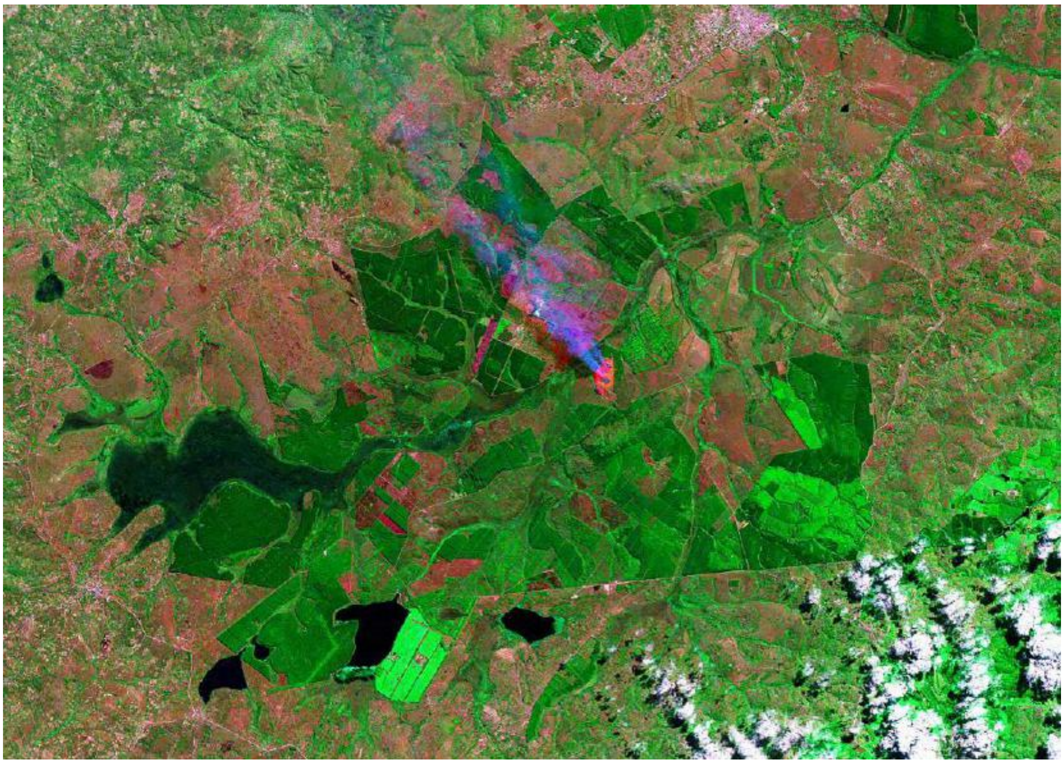

Figure 60: Irrigated agriculture in Usunga close to Sao Hill
(extent about 43 x 23 km)

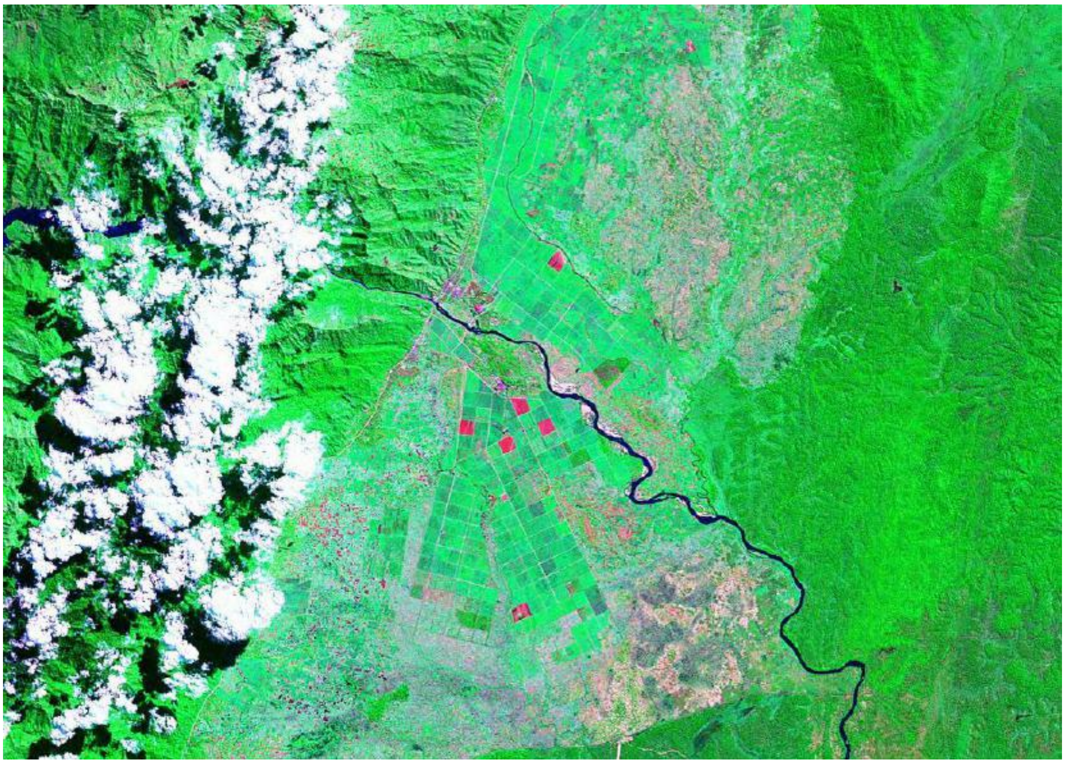

Figure 61: Irrigated agriculture just below the Kidatu dam
(extent 37 x 26 km)

6.2.5 Soils

The SOTER database at scale 1:2 million includes hardly any profiles within the basin (Figure 62). The National Soil Survey at Mlingano holds data for 300 soil profiles - about 200 in the areas with irrigated agriculture, and about 100 profiles in upland areas with rain-fed agriculture, some have soil water data. The ISRIC library holds a few soil survey reports dealing with a part of the basin (Annex 3).

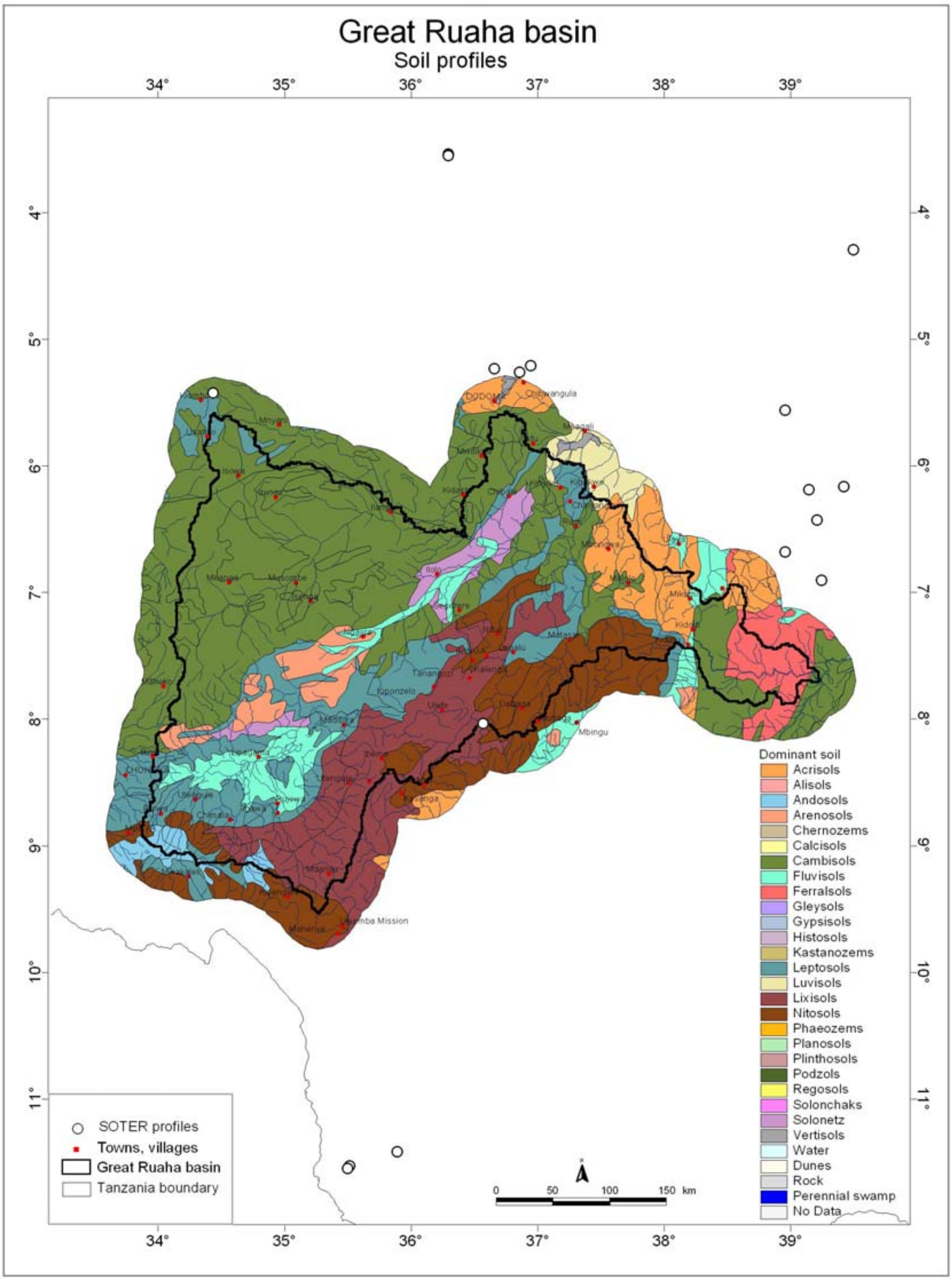

Figure 62: Great Ruaha Basin, soils and location of soil profile data

6.3 Socio-economic data

6.3.1 Population

Population has grown with the development of irrigation starting in 1940 when Baluchi farmers first settled the Usangu plains. In the central Usangu plain (Mbarali district), the population has grown six-fold in the last 50 years (SMUWC 2001).

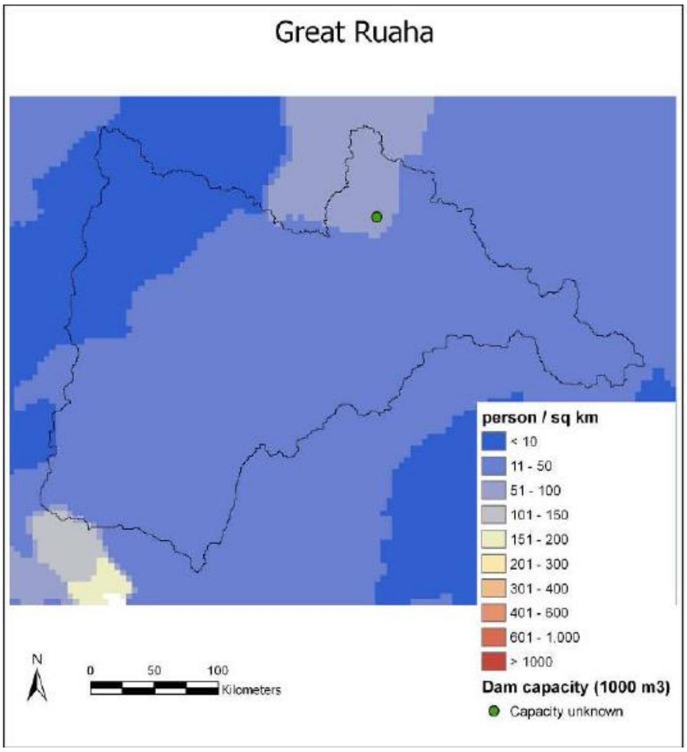

Figure 63: Population density (CIESIN 2005) and location of the Mtera dam

6.3.2 Economic situation

This basin is of national importance for rice production, a RAMSAR wetland site, the Ruaha National Park and for the generation of hydro-electric power. The main water users are: rain-fed farmers in the high catchment and on the plains, irrigators on the plains, pastoralists and fishers in the central wetland, the Ruaha National Park, the Mtera/Kidatu hydro-power stations, and the Kilombero irrigated sugarcane scheme just below the Kidatu dam.

6.3.3 Water Management Organisations

The following are responsible for water management:

- Rufiji Basin Water Board
- Rufiji Basin Development Authority (RUBADA), established in 1975 by an Act of Parliament; responsible for development of hydro-power as well as promotion, regulation and coordination of development activities in other sectors

- Ministry of Water and Livestock Development
- Ministry of Natural Resources
- Ruaha National Park
- Worldwide Fund for Nature (WWF), involved in projects aiming at the return of a perennial flow in the Ruaha
- Tanzania Electricity Supply Corporation.

6.4 Partnership

- World Bank project the River Basin Management and Smallholder Irrigation Improvement Project - RBMSIIP (World Bank 1996)
- DFID Sustainable Management of the Usangu Wetland and its Catchment 1998-2002 (SMUWC 2001)
- DFID/IWMI-funded Raising Irrigation Productivity and Releasing Water for Inter-sectoral Needs
- The Rufiji Basin Development Authority

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Soil and Water Management Research Network (SWMnet) of ASARECA
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PO Box 39063, 00623 Nairobi
Tel: +254-20-7224565

6.5 Green Water Credits Potential

The new National Water Policy emphasises increased involvement of local government and provides for representation in decision making. It also emphasises increased participation of water users and consumers in the water sector. The National Strategy for Growth and Reduction of Poverty (MKUKUTA) also emphasises conservation and water harvesting for increased crop production http://www.onao.go.tz/standard/MTRfinalreport.pdf

Green Water Credits potential buyers:

- Kidatu/ Mtera hydro-power systems, both for better water supply and to arrest siltation of reservoirs
- Irrigated agriculture (especially the sugar industry at Kilombero)
- Usangu National Park and Usangu Game Reserve, which includes the endangered wetlands

Green Water Credits potential sellers:

- Irrigators upstream Mtera (to reduce water consumption)
- Rain-fed agriculture in the upper catchment, particularly in hilly catchment above the Usangu plains

7 Basin ranking

The candidate basins were ranked using the matrix in Annex 1.

1: Tana, Kenya

The Upper Tana has good rainfall and many farmers, so there is a high potential for *blue* water benefits for downstream users. Important downstream water users are in a position to pay for water management services over the long term: KenGen, Nairobi City water supply, and irrigators.

Current political and economic initiatives in the water sector in Kenya may also be favourable for introduction of *Green Water Credits*; both Nairobi water supply services and KenGen are being opened to private capital.

2: Great Ruaha, Tanzania

The Upper Great Ruaha around Usangu Plains has good rainfall and a fair number of upland farmers, so there is good potential of *blue* water benefits for downstream users. There are important downstream water users: hydro-power, irrigators and the Usangu Plains and Ruaha National Park.

The Great Ruaha presents a more complex situation for *Green Water Credits* than the Tana: there are small irrigators and wetlands between the main source region and the main water users. These are in competition for water with the hydro-power and irrigation schemes downstream.

3: White Volta

The catchment of the White Volta in Burkina Faso is extensively cultivated but the rainfall is low; in Ghana, there is higher rainfall but few farmers; both situations limit the opportunity for improving *blue* water supply downstream.

In Burkina Faso, the downstream water users are hydro-power, Ouagadougou city, and irrigators. In Ghana there is a major demand from hydro-power generation but lack of effective cross-border organisation and the problematic nature of cross-border payments of *Green Water Credits* is a complicating factor.

4: Ruvu

The upper Ruvu has good rainfall but few farmers, so there is a low potential of *blue* water benefits for downstream users. The important downstream *blue* water user is Dar es Salaam city.

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Useful dataset links

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GRDC, Global Runoff Data Center. http://grdc.bafg.de/

Discharge of selected rivers of the world. http://espejo.unesco.org.uy/

FAO Geonetwork. http://www.fao.org/geonetwork/srv/en/main.search

Annex 1: Basin selection matrix

Name of Basin: ____

	VR[1)]	MR	LR	NR	NI	Comments
How relevant are *water scarcity* and *poverty issues*						
Can *green* water management make a difference at the basin scale? 1. Does the catchment have: a) a significant proportion of arable and/or b) pastoral land use that induces: - run-off, - high evaporation, - erosion? 2. Where are the potential *blue* water benefits observed: - upstream in the catchment and/or - downstream?						
Which are identifiable *downstream water users* able to pay? a) hydro- power b) irrigation c) urban and major industrial users d) other (specify…………………………………..)						
Which identifiable *downstream environmental water uses* should be considered a) wetlands b) natural parks c) fragile coastal ecosystems d) other (specify ……………………………………)						
	VA[2)]	MA	LA	NA	NI	Comments
Do the following conditions exist to support Green Water Credits a) *Political will*. Will the proof-of-concept study be well supported, and will the concept attract political backing? b) Necessary *legislation* in place, or likelihood that it will be introduced? c) *Effective institutions at national or basin level*?						
Are there *effective institutions* to support and assist improved green water management *at farmers' level*?						
Are adequate *baseline data* available for scenario analyses? a) climate b) hydrology c) soils d) land use/cover e) socio-economic						
Can the results from the basin be applied elsewhere?						
What *synergies* are possible from current projects or partners? (specify ……………………………………..)						
Is there correspondence with *donors' interests* : poverty reduction, environment protection, water, specific countries or regions?						
Is there *conflict* over water use between upstream land users and downstream users?						

1) VR=very relevant; R=relevant; MR=moderately relevant; LR= little relevant; NR=not relevant; NO = no information
2) VA-very adequate; MA=moderately adequate; LA=hardly adequate; NA=not adequate; NI = no information

Annex 2: Parameters in FAO-CLIMWAT database

Climate Parameter ID	SOTER Code	CLICOM Code	Description	Unit	Remarks
1	RAIN	E208	Precipitation total	mm	
2	RDAY		Number of rainy days	days	
3	RMAX		Maximum 24-hour rainfall	mm	
4	RR75		Rainfall reliability (75% quantile)		
5	TEMP	E203	Mean temperature during 24-hour period	C°	
6	TMIN	E202	Minimum temperature during a 24-hour period	C°	
7	TMAX	E201	Maximum temperature during a 24-hour period	C°	
8	RADI	E280	Total radiation	MJ/m²/day	FAO CLIMWAT 2 non-standard CLICOM code
9	SUNH	E299	Bright sunshine	hours/day	FAO CLIMWAT 2 non-standard CLICOM code
10	CLOU		Degree of cloudiness	octas	
11	VAPP	E298	Vapour pressure	mBar	FAO CLIMWAT 2 non-standard CLICOM code
12	HUMI	E258	Average relative humidity during 24 hour period	%	
13	HMIN		Minimum relative humidity during 24 hour period	%	
14	HMAX		Maximum relative humidity during 24 hour period	%	
15	WIND	E297	Mean wind velocity at 2 m during 24 hour period	m/s	FAO CLIMWAT 2 non-standard CLICOM code
16	PETT		Thornthwaite potential evapotranspiration	mm	
17	WDAY		Wind speed during day at 2 m during 24 hour period	m/s	
18	WNIG		Wind speed during night at 2 m during 24 hour period	m/s	
19	WDIR		Dominant wind direction at 2 m during 24 hour period		
20	WRIS		Risk of occurrence of adverse weather events (0.0-1.0)		
21	EPAN		Class A pan evaporation	mm	
22	ECOL		Colorado pan evaporation	mm	
23	EPIC		Evaporation, Piche	mm	

Climate Parameter ID	SOTER Code	CLICOM Code	Description	Unit	Remarks
24	PETP	E294	Penman potential evapotranspiration	mm	FAO CLIMWAT 2 non-standard CLICOM code for Penman-Monteith potential evapotranspiration.
25	PETH		Hargreaves potential evapotranspiration	mm	
26	SUNF	E296	Sunshine fraction (0 - 1)		FAO CLIMWAT 2 non-standard CLICOM code. Non-standard SOTER code (v5.1).
27	TDAY	E293	Mean day-time temperature	C°	FAO CLIMWAT 2 non-standard CLICOM code. Non-standard SOTER code (v5.1).
28	TNHT	E292	Mean night-time temperature	C°	FAO CLIMWAT 2 non-standard CLICOM code. Non-standard SOTER code (v5.1).
29	TDEW	E251	Dew point temperature	C°	Non-standard SOTER code (v5.1).

Annex 3: Natural resource information available in ISRIC

Ghana , Burkina Faso, Kenya and Tanzania

Source: ISRIC - World Soil Information Library Database

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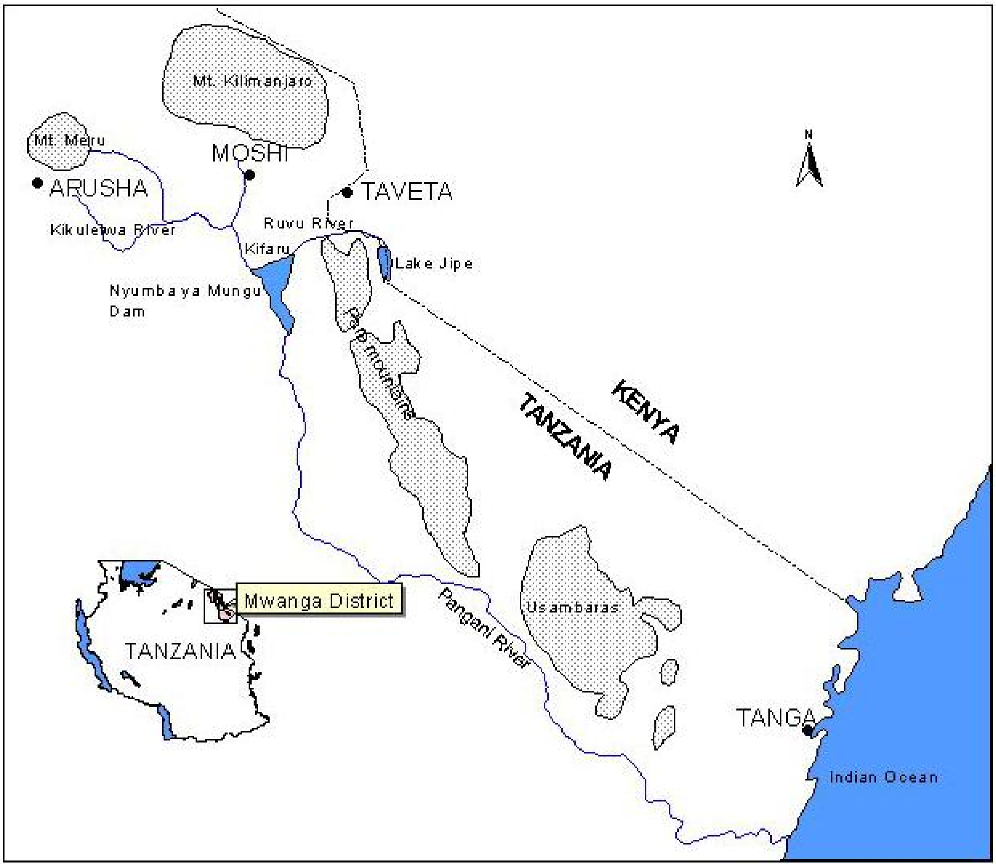
Annex 4: Other Ruvu River



This map shows the Ruvu Basin located between Tanzania and Kenya. This is NOT the Ruvu Basin as described in this document.

Green Water Credits reports

GWC 1	*Basin identification*	Droogers P and others 2006
GWC 2	*Lessons learned from payments for environmental services*	Grieg-Gran M and others 2006
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