COASTAL IMPACTS OF WATER ABSTRACTION AND IMPOUNDMENT IN AFRICA: THE CASE OF RUFIJI RIVER

PART 1: INTRODUCTION AND BACKGROUND

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1.1 Study objectives and scope of work

Construction of large dams with reservoir type storage impound water behind them for seasonal annual, and in some cases for multi-annual storage and regulation of a river. Similarly, tubewells abstract surface and ground water bodies from their natural flow. The impoundment of water by damming and its abstraction through tubewells are common practices in the world and even within the Africa region (WCD, 2000). Globally, the number of large dams has grown at a tremendous pace during the last 50 years (Fig. 1.1) The fast growth in dam construction is driven by an increasing demand of water from urban and rural communities for reliable freshwater supply, agricultural irrigation and hydro-electric power. As these practices become more widespread, they are leading to significant reductions in the fluxes of water and river-borne sediment that are discharged through catchment to coastal sea systems. These flux reductions are contributing to changes in the state of the coastal environment and these changes are in turn impacting coastal communities through issues including coastal erosion, estuarine salinisation and the depletion of nutrients in the coastal sea.

The present study is a short-term study on the Rufiji (Fig. 1.2), the largest river in Tanzania, with a total area of 177,000 km^2 (20% of the area of the country). The study is conducted within the framework of the African River Catchments (AfriCat) study, which consist of six selected rivers in four African countries. The six rivers and the countries are: Sebou and Moulouya–the two largest rivers in Morocco (both of which have been dammed), the Senegal, a large West African river (dammed in its lower course); the Tana (a dammed river) and Sabaki (a yet un-dammed river) in Kenya and the Rufiji, where plans for future damming are in place. In both the Rufiji and Sabaki which are currently un-dammed there is an opportunity to analyze the changes that have taken place (before damming), are currently taking place, and can be expected to take place in the future (after damming) within the coastal environment.

The study is focusing on the linkages between water impoundment/abstraction in catchments and the impacts and issues at the coast. The study is intending to explore the strengths and weaknesses of the assessment, appraisal and response approach as set out, drawing attention to important information gaps and, importantly, to the essential links for effective information transfer between the scientists and the managers and stakeholders. Pressure/drivers other than impoundment/abstraction and prediction of additional changes that could be expected as a consequence of damming are also considered The study will therefore review the impacts of past climate change and documented extreme events, as well as considering the consequences of predicted future climate and socio-economic changes.

The specific goal of this work is to synthesise the existing information on Rufiji (which is currently widely scattered) to provide a comprehensive understanding and forecasting of the effects of water abstraction and impoundment by the planned multipurpose dam at Stiegler's Gorge, some 180km upstream from the coast, on the structure and functioning of the downstream ecosystems, in particular those at the coast. Priority will be accorded to the impacts on vegetation (especially mangrove), fisheries and biodiversity of the Mafia Marine Park located off the river's mouth. New and existing information on other potential impacts of impoundment including reduced sediment and nutrient discharge increased estuarine salinity effects on groundwater discharge and consequences for carbonate sedimentation will also be examined.

It is important to realise that the above-mentioned impacts can be exacerbated by changes in the climate, adding further to the deteriorating situation. For example a sustained increase in mean

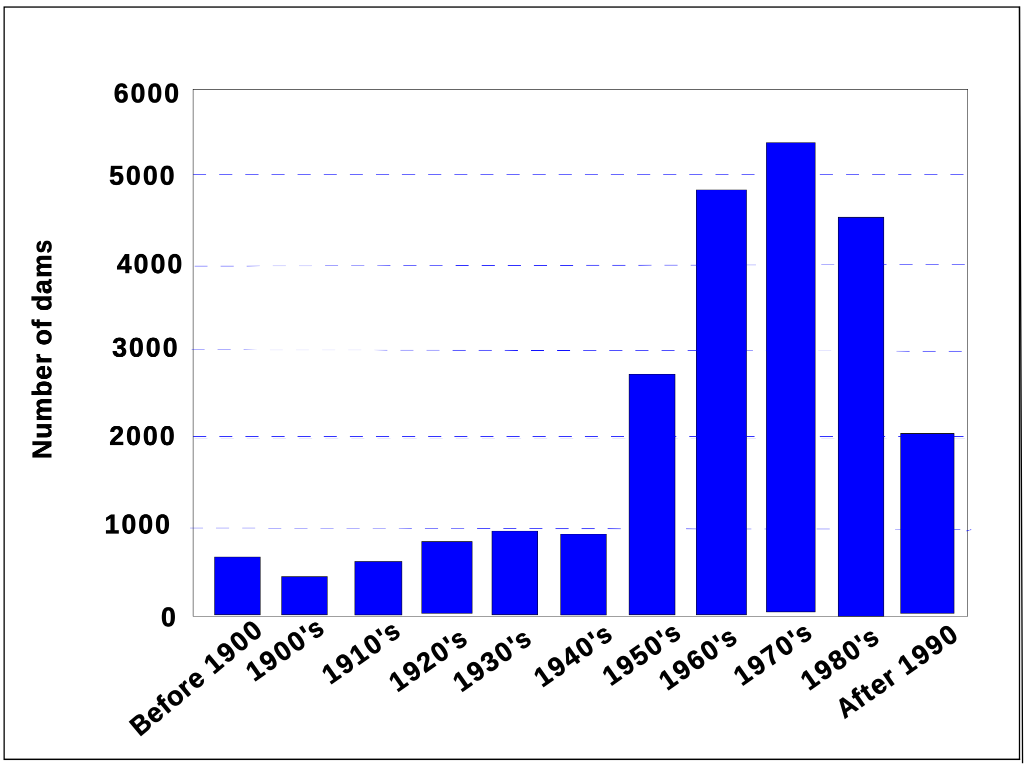

Fig. 1.1. Large Dams commissioned per decade during the 20th Century. Observe the different trends prior and after 1950's. Source: ICOLD, 1998 (Note: Information excludes dams in China).

Temperatures may cause significant changes in the catchment, which may have similar implications as water abstraction. Reduction in precipitation can have serious negative hydrological balance in the catchment.

Other drivers with similar effects include population growth, degradation of watersheds caused by land use changes and siltation. The socio-economic aspects related to water abstraction and impoundment of the river, including the history and forecasting of land-use and demographic changes, and the changing demand for freshwater would therefore be studied. The coastal areas especially in the delta can be adversely affected by sea-level rise associated with climate change. This work will therefore assess the coastal changes that are vulnerable to future climate change and reduced sediment and water discharge. The low-lying lagoon areas and delta can be very susceptible to erosion due to sea-level rise and climatic variations, which often reduce the buffer effect of coral reefs and mangrove forests. The consequences in terms of biodiversity loss can be devastating. The historical information in climate change and recent events will therefore be analyzed, including the frequency and severity of major floods, and predicted changes.

In summary, the work will address the following issues at the coast, both in historical and contemporary contexts, and how they are likely to change as a consequence of the construction of the dam and increased abstraction in the catchment:

- Geomorphological change
- Water flow and flushing through the delta
- Estuarine/deltaic salinisation/salinity changes in the coastal sea
- Nutrient supply to the coastal sea
- Biodiversity in the delta and coastal sea
- Socio-economic aspects and impacts
- Climate change

The study will highlight the principal data/information gaps in the understanding of the catchment-to-coast system and will review and make recommendations for management and policy responses in respect of the coastal impact of damming in the Rufiji system.

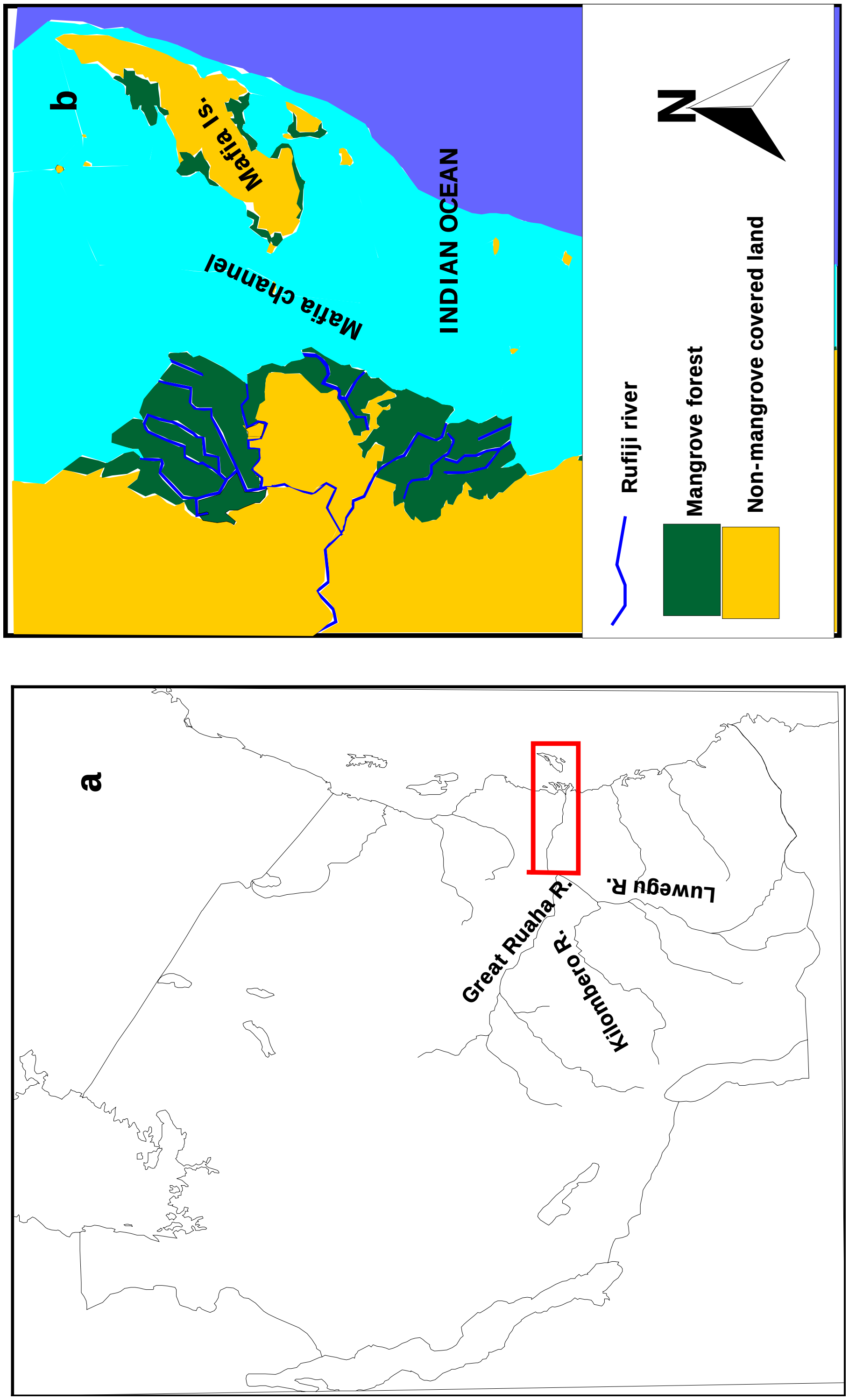

Fig. 1.2. Map of Tanzania (a) showing the approximate location of the study site (the red rectangle), Rufiji River (with its main tributaries). The associated coastal features (namely the mangrove forest of the Rufiji delta and Mafia island) are Highlighted in (b).

1.2 Physical, geographic and climatic setting of the study area

The main focus of the present study is on the Lower Rufiji river catchment (with a catchment area of about 19,215), its flood plain and delta and the adjoining coastal waters including the Mafia Marine Park (Fig.1.2-1.3). However, relevant linkages drawn from the Upper Rufiji river catchment will also be considered. The geomorphological history of the area has produced three main units:

- The Rufiji Flood Plain, which is covered by recent alluvial soils, and where flood inundation occurs
- The Delta, which constitutes a prolongation of the Flood Plain, but where in addition to flood inundation, seawater intrusion became important.
- The Terrace area, which borders the Flood Plain to the north and south, and which is developed on an old sedimentary complex consisting principally of the sands.

The FloodPlain itself can be further subdivided into zones, reflecting the depositional pattern of the sediments, with the coarser, less fertile material being predominant in the upper reaches and finer material occurring in the lower reaches. The zones are the Upper, Middle and Lower Floodplain (Fig. 1.3), which together with the Delta form four agro-economic Zones (Agrar-und Hydrotechnik, 1981).

The Rufiji river, with a mean annual discharge of about 30×10^9 m^3 (euroconsult, 1980a) is formed by three main tributaries, Luwegu, Kilombero and Great Ruaha, supplying respectively 18%, 62% and 15% of the total inflow to the Rufiji. From its start at the confluence of the Kilombero and Luwegu rivers, the Rufiji flows for about 100 km to the Pangani Rapids at the entrance of the Stiegler's Gorge, where the river cut through a low ridge, forming a steep-sided narrow gorge, about 8 km long. The Lower Rufiji river catchment starts from Stiegler's Gorge and runs to a distance of about 180-km downstream to the shore of the Indian Ocean. The general flow direction of the river is from west towards east.

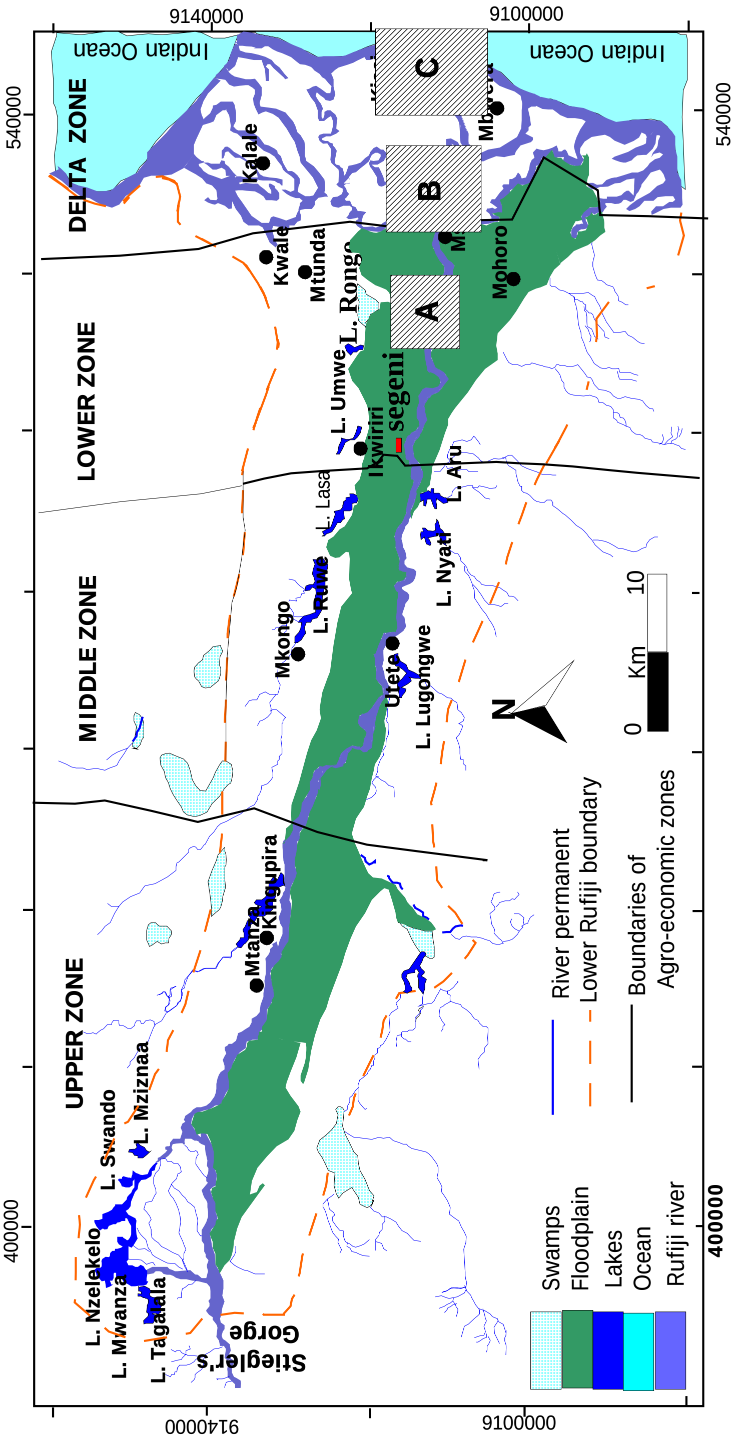

Fig. 1.3. Map showing the Lower Rufiji catchment, with the four agro-economic zones (Upper, Middle, Lower and Delta) and the Segeni pilot farm (red rectange) south of Ikwiriri. The three hatched rectangles A, B and C indicate the approximate locations of the areas investigated using aerial photographs to quantify landuse changes.

From Stiegler's Gorge (located at an elevation of about 65 m above sea level), the river runs into a deep alluvial flood plain which is contained within a low and relatively narrow valley with width varying from 7 - 30 km (Turpie, 2000). The flood plain, which is seasonally inundated, covers approximately 1450 km^2. It comprises a mosaic of former river channels, levees and shallow depressions supporting sparse shrub, intensive cultivation, scattered treecrops or tall grasslands, palm trees and *acacia* woodlands (Ochieng, 2002). Another important feature of the lower Rufiji flood plain is the presence of permanent lake system. There are altogether 13 permanent lakes on the flood plain (Hogan et al., 1999), giving a total area of 2850 ha, which is more than 50% of the surface of standing water bodies in the valley (Mwalyosi, 1990, Ochieng, 2002). These permanent water bodies are surrounded by forests and are connected to the river via small inlets or channels. Seasonal discharges of fresh water get into the lakes through these inlets/channels. Hippos and crocodiles are common in most of the lakes as well as the river.

The Rufiji delta, is crescent shaped (VHL, 1979). It is 23 km wide, 65 km long and protrudes 15 km into the Mafia channel, covering an area of about 1200 km^2 (Kajia, 2000). The delta coastline is approximately 90 km long. The delta is formed by 7 main distributary channels (Fig.1.4) interwoven with smaller channels and creeks (Kajia, 2000). The delta contain the largest estuarine mangrove forest in East Africa, with an estimated coverage of 559 km^2 or 53,200 ha (Semesi, 1991; Kajia, 2000). The Rufiji delta mangrove forest constitutes of about 46% of the total mangrove forest coverage in Tanzania. The islands of the delta have been built mainly by mangroves, which by accumulating washed-in silt and their own production of detritus raise the ground level to form land (Mgaya, 2004). A number of islands are inhabited. Delta north for instance consist of 6 villages and Delta south consist of 12 villages. It is also linked to a system of ocean currents and coral reefs surrounding Mafia Island in the East and it influences fisheries production in the islands of Zanzibar (Unguja and Pemba) through the northerly flow of marine currents.

The coastal area enclosed between Rufiji delta, Mafia island and the Mafia channel forms one of the finest complexes of estuaries mangrove coral reefs and marine channel ecosystem; all lying within an area of some 1500 km2 (Darwall and Guard, 2000; Mgaya 2004). Mangroves frequently occur in conjuction with coral reefs and seagrass beds and they often interact between one another and with the terrestrial and open ocean areas (Mgaya, 2004). The ecosystem of the coastal zone comprising these elements has been termed as a seascape (Moberg and Folke, 1999). Mangroves and seagrass beds filter freshwater discharges from land promoting the growth of coral reefs offshore. Without this function, high sediment loads derived from upland activities and then transported by rivers would be detrimental to corals. Corals in turn, are physical buffers for oceanic currents and waves, creating, over geologic time, a suitable environment for seagrass beds and mangroves (Moberg and Folke, 1999; Mgaya, 2004). The detritus from mangroves provides nutrients for marine environment and support a wide variety of sea life. Mangroves provide refuge and nursery grounds for juvenile fish, crabs, shrimps and molluscs, and host a wide variety of bird species (Mgaya, 2004). The interdependence between different elements of the seascape means that if one element of the seascape is exposed to natural or human-induced pressure, its effect may be transmitted to other elements of the seascape.

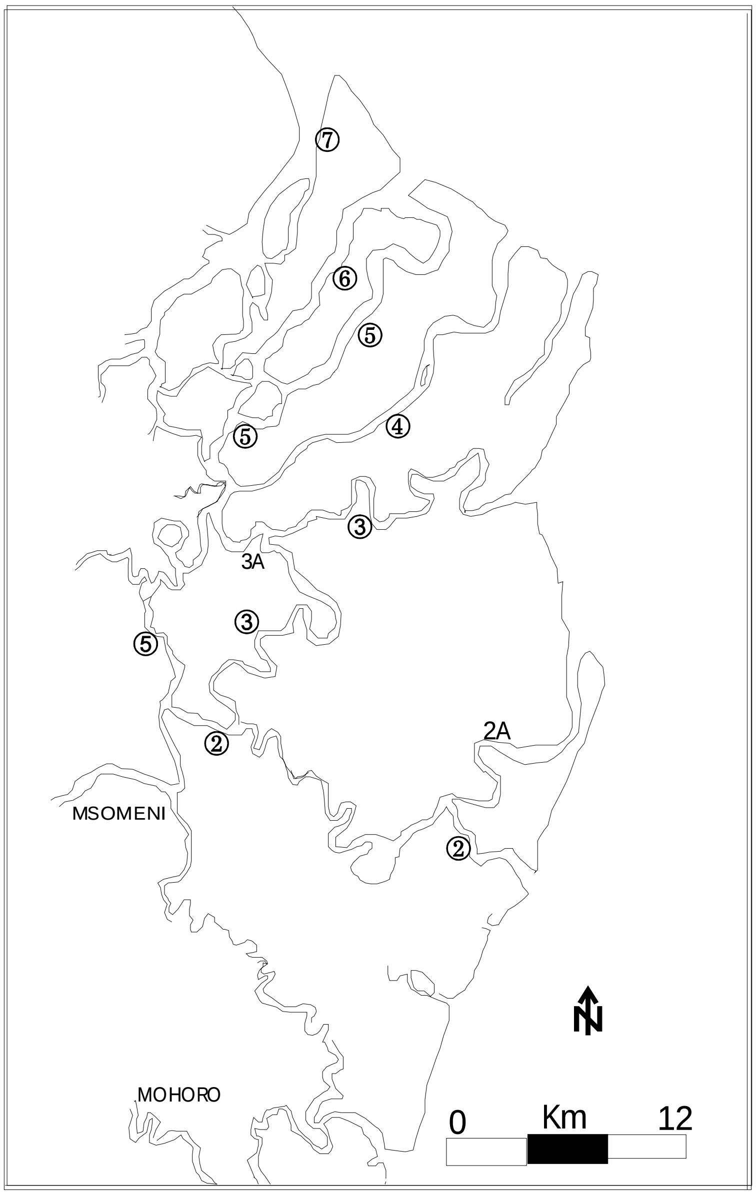

Fig. 1.4. Sketch map of Rufiji delta channels and islands. Observe that the channels shown by the numbers 5, 4 and 3a were during the 1978 flood event. Source: Kajia (2000).

1.3 River morphology and delta hydrodynamics

According to the hydraulic study carried by the River and Harbour Laboratory (VHL, 1979), the general shape of the river is described as sinuous or moderately meandering. The slope of the riverbed varies between 0.00045 and 0.0002, being steepest in the upper zone and gradually decreasing towards the delta area. The riverbanks are generally and in many place vertical due to active erosion. The bank-full river is 250 – 1000 m wide (Fig. 6), with depths up to 8m during wet season and the water level decreases to about 4 m from the bank-full level during the wet season. The most common widths are ranging from 400 – 600 m and the most common depths of the river are between 5 and 6 m depth. Rock outcrops on the riverbed are rare, and the riverbed and riverbanks consist of fine sand with median grain size (d_{50}) of about 0.4 ± 0.15 mm. In the delta, the banks of the river branches are mostly covered by mud, but clean sand is also found in some parts especially the southern branches. The sand sediments found in the delta are generally finer than the sand sediments on the flood plain. The mud consists of fine silt particles mixed with organic materials.

A significant proportion of the river water flows between levees that are 1 – 2 m higher than the flood plain. The suspended sediment concentration in the river is usually in the range 100 – 1000 mg/l, typical values for the dry and wet season being 150 and 500 mg/l respectively. The bank-full discharge varies along the river, but it is usually in the range 2000 – 3000 m^3/s. the river discharge is rarely less than 100 m^3/s and floods exceeding 12,000 m^3/s are also uncommon. Normal big floods are in the range 600 – 800 m^3/s. The annual fresh water discharge is about 900 m^3/s. Annual sediment discharge is estimated at 15 – 25 million tons. There are two deposition sites: A minor deposition site at Mloka (on the Upper reaches) and a major deposition site on the delta and the coastline. It is reported that about 50% of the suspended sediment load of Rufiji river is advected through the river mouths and deposited in the nearshore are by wave action (Ochieng, 2002). As a result of deposition of the sediment load carried by the Rufiji towards the coast, the shoreline has shifted seawards, protruding some 15 km into the Mafia channel (euroconsult, 1980c). However at present it appears that the delta is neither prograding nor eroding substantially, with the exception of local changes resulting from a re-distribution rather than a variation of sediment fluxes (Ochieng, 2002). The input of sediments into the delta is therefore approximately in equilibrium with the subsidence and the longshore drift.

The beach sediments on the delta have variable characteristics. Continuous sandy beaches characterize the coastline between branch 1 and 3 (Fig. 1.4), but north of branch 3 and south of branch 1 the muddy sediments dominate the beaches. However, secondary sandy beaches are common inside the muddy beaches in many places. The beach sediment characteristics is controlled by the level of the land, which is higher in the middle area. Most of the area between branch 3 and 7 is submerged during high tides, except along these secondary branches.

The tidal range at spring tides may be as high as 4 m (Turpie, 2000) with considerable effect upstream of the main delta channels (VHL, 1979). Salt intrusion along the delta branches is considered to depend on four factors: 1- Fresh water discharges, 2-tides, 3-depth of river and 4- slope of riverbed. Low fresh water discharge with high tide, Deep River and gentle slope gives the maximum intrusion. The river slope and depth do not differ significantly among the different delta branches. However, the amount of fresh water discharges and tidal action among the different branches varies considerably. The estimated flow distribution through the different branches (Table 1.1) show that most of the discharges of the river during both the low flow (dry season) and wet season (high flow) passes through branch 6 and the lowest flow at all times is found in branch 1.

Table 1.1: Flow distribution (in percent) at the coastline in the main branches during low and high river discharges. Source: VHL (1979).

Branch No	**Discharge (100-400)m^3/s**	**Discharge (1000-2000)m^3/s**	**Outlet**
1	**0**	**10**	**A**
2	**15**	**15**	**B**
3	**10**	**15**	**C**
4	**10**	**10**	**D**
5	**10**	**15**	**F**
6	**50**	**25**	
7	**5**	**10**	**G**

The salinity measurement carried out in different branches demonstrated that the length of salt intrusion at the different branches is related to the above flow distribution pattern (Ngana, 1980). Branch No. 1, which has the lowest discharge, yielded the maximum salt intrusion. The length of salt intrusion in branch 1 during high tide was up to 40 km. The branch with the highest discharge (branch 6) yielded a minimum salt intrusion of about 5-km.

Tides also influence the sedimentation pattern in the delta. During low flow, fine sediments are being deposited along the branches in the delta where the saline wedge causes flocculation, with very little sand transport into the delta. During higher discharges more sand, where branch 6 carries most of its sand load all the way off the beach, while the northern middle branches deposit their sand inland or at the beach. Fine particles are either carried offshore or deposited on the flooded areas between the branches, especially where there are mangroves, which slow the currents.

PART 2: ANTHROPOGENIC PRESSURE ON LOWER RUFIJI CATCHMENT

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The major anthropogenic pressure on the Lower Rufiji catchment are associated with the socio-economic activities such as agriculture (farming), fishing and various local and external commercial trades. Most of these activities have taken different shapes during the course of time, and are currently pausing significant negative effects to the future sustainability of the natural resources present in the catchment. The future trends on these activities are considered to be a function of demographic changes (Fig. 2.1), climate and the future proposed impoundment of the river at Stiegler's Gorge, amongst others.

2.1 Agriculture

The agriculture system in the Lower Rufiji catchment has been changing gradually through time (Cook, 1974). Its evolution through time has been influenced by the interplay between natural, ecological and anthropogenic factors. The natural factors include: rainfall, floods, and droughts. Ecological factors include issues such as locust's inversion; pests, weeds etc. and anthropogenic factors include demographic changes, political decisions, and lifestyle, amongst others. Significant number of studies conducted in the area reveal that the Lower Rufiji catchment has been and is still an area of great agricultural potential (Cook, 1974; VHL, 1979; Bantje, 1979, 1980, 1981; Ngana, 1980; euroconsult, 1980a-d; Kajia, 2000; Turpie, 2000; Ochieng, 2002).

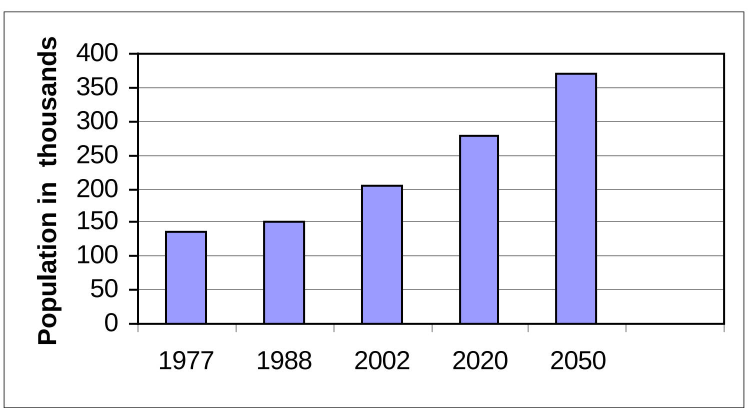


Fig. 2.1. Population statistics in Lower Rufiji catchment. Observe that The figures for 2020 and 2050 have been estimated using the trends from The previous years.

According to Bantje (1979, 1980) and Ochieng (2002), large quantities of foodstuffs (namely beans, maize, rice and sesame seeds) and livestocks (sheep, cattle and goats) used to be exported to areas as far north as Zanzibar and occasionally even to India.

While the historical record reports more than 20 occasions of serious food shortages and famines between 1880 and 1980 in Rufiji (Bantje, 1980), it is generally believed that the export of agricultural products was probably the dominant trend during the 19^{th} Century. During those “good old days”, the agricultural production in most villages produced beyond self-sufficiency to create surplus for export outside tribal boundaries (Ochieng, 2002).

Today, the old trend has significantly changed. The present agricultural production in Rufiji is not even enough for subsistence. For instance as at 21/8/1997 the Food balance sheet for Rufiji District show that, while the total amount of food requirements in terms of cereals and legumes was 33,548 and 4,793 tons respectively, the balance was 30,761 and 605 tons, indicating a deficit of 2,787 and 4188 tons, respectively. Ochieng (2002) notes that, today no export of foodstuffs are reported and food remain the main expenditure item as quantities of food crops produced are inadequate to cover all the household needs of food and cash.

Despite the dwindling trends of agriculture, various studies indicate that, agriculture is still the main occupation of many households in the Lower Rufiji catchment. It is estimated that today, more than 90% of households in the floodplain and the delta consider agriculture as their main occupation (Ochieng, 2002). The agricultural system of the Lower Rufiji Catchment has for a long time been influenced by a combination of both rainfall and flooding of the Rufiji. (Marsland, 1938, Cook, 1974, Bantje, 1980; Kajia, 2000; Ochieng, 2002).

While flooding of the Rufiji has generally been considered to be one of the most important factors for the agricultural surplus in Lower Rufiji, flooding has at times threatened the agriculture system of the Lower Rufiji. The seasonal flood of the river which inundate most parts of the flood plain and the delta, compensate for a shortage of rainfall, help to control vermin, regenerate soil fertility with fresh silt deposits and create opportunity for second crop season (Bantje, 1980). Apart from sustaining agriculture, floods also stimulate fish production and also sustain mangrove production in the delta. However, excessive floods especially when they occur in January have been attributed to serious damage of crops and famine. .

Prior to 1969, the agriculture system in Lower Rufiji used to be totally dependent on the natural interaction between rainfall and flooding of the river. However after the villagization policy which took place between 1969 and 1973 (Cook, 1974; Bantje, 1979, 1980; Kajia, 2000; Ochieng, 2002) the agriculture system in the Lower Rufiji catchment took a new shape. The policy forced most households to move from their settlements on the wet lowlands of the river valley to drier areas on the uplands, away from the flood plain. Although the policy was formulated as a safeguard measure to protect the people against flood risks (Bantje, 1979; Ochieng, 2002), the policy had a number of negative effects:

1. The upland farm fields are generally less fertile than the floodplain fields (Cook, 1974; Ochieng, 2002).

2. The agriculture on the upland farm fields is entirely dependent on rainfall (Ochieng, 2002).

3. Households, which needed to maintain farmlands on the floodplain, had to travel large distances to their fields (Cook, 1974). Due to this inconvenience, most households have, small houses (*madungu*) in their floodplain farm fields (Turpie, 2000) which are used as temporary homes during the farming season. The whole family therefore stays in the temporary houses, except children who are still in school (who stay with the farther in the village). The long time separation of families due to the division of labour has a negative impact to the social well being of households. This might have corresponding multiplier effects to agriculture and other economic activities.

4. Due to the fact that settlement on the floodplain is not permanent, pest damage is reported to have increased significantly (Cook, 1974; Turpie, 2000).

5. Due to the lower fertility of the farm fields on the uplands, the farm fields are usually abandoned after few years. Shifting cultivation is therefore the present common type of farming on the uplands (Ochieng, 2002). This type of cultivation has a devastating effect to the conservation of biodiversity as most of the farmlands are formed from cleared forests and woodlands.

The villagization policy did not only affect the agriculture system on the floodplain, but also affected the agriculture system on the delta islands. Prior to the villagization policy, the inhabitants of the delta had their rice fields in the floodplain upstream from the mangrove areas where they established temporary settlement during the farming season (Ochieng, 2002). After, the farming season, they would return to their permanent settlements on the delta islands for doing other activities such as fishing, pole trade etc. During the villagization campaigns everyone was moved away from the floodplain. Mangrove forest clearing was taken as an alternative to maintain their former subsistence agriculture, which used to be practiced on the floodplain. They therefore started to clear certain types of mangrove forest (namely those forests in areas which are not permanently flooded by salt water) to establish their farms.

Unlike the floodplain agriculture, which evolved from a flood dependent agriculture to a flood independent agriculture, the agriculture system in the delta islands continued to be flood dependent. The changing nature of flood regime and the ecological characteristics of the delta have greatly controlled subsequent evolution of the *mlau* cultivation on the delta islands. It is reported that in 1978 the river created a new inlet to the delta (Fig. 1.4) and brought more fresh water to some areas of the mangrove forest. Consequently the cultivation of rice in the mangroves increased. Shifting cultivation is also a common practice in the delta agriculture. The rice seedlings are often affected by crabs, and farmers respond by using DDT to kill the crabs (Semesi, 1991). The application of DDT to kill the crabs has negative effects in the conservation of biodiversity as it kills also other species (Kulindwa et al., 2001). Finally, the mangrove farm fields are usually abandoned after few years because of colonization by weeds. Since the regeneration of mangroves in those areas does not take place spontaneously, this type of cultivation is therefore considered to be a threat to the conservation of biodiversity (Ochieng, 2002).

2.2 Fishing

Fishing is another important economic activity in the Lower Rufiji Catchment. Although at a local level, there are some villages (around some of the permanent lakes) where fishing may be ranked as the first important activity (Hogan et al., 1999) it is on the average ranked 2nd to farming (in terms of labour time spent). There are two main factors which make the local people consider fishing to be of importance: 1- the agriculture is generally below subsistence level, and 2- fishing is the main source of getting animal protein needs. In the three eco-regions; floodplain, transition zone and delta, surveyed by Turpie (2000), approximately 56%, 52% and 61% households, respectively, are involved in fishing. In the three eco-regions, floodplain, transition and delta, the household effort was estimated at 86, 56 and 123 days per year. In the Floodplain and transition zone, fishing is exclusively regarded as men's activity, but in the delta eco-region both men and women are involved in fishing. In the later case, women participate in shrimp, octopus and squid fishing, but do not generally participate in finfish fishery. The majority of the fishers in all the three eco-regions use nets, although traditional traps and hooks are also used.

Within the floodplain, fishing is mainly done in the freshwaters of the permanent lakes which provide suitable breeding habitats for fish and are regularly replenished by the seasonal floods (Turpie, 2000). Fishing is not carried in the river for fear of crocodiles and hippopotamus and the fast flow of the river (Hogan et al., 1999). Fishing is carried throughout the year but with a strong seasonal change in effort corresponding to periods of flooding (Turpie, 2000). It is reported that the freshwater fishing in the area is generally unselective in terms of both species composition and size. The negative effect of this practice is that, the fish resources are not given the opportunity to regenerate. In the delta, fishing is carried in the estuaries and in shallow inshore waters along the coast.

The marine catches are generally constant throughout the year as the fishers have the options of fishing finfish as well as prawns. Rufiji delta is the most important wild prawn fishing in Tanzania, contributing over 80% of all prawn caught in Tanzania (Mwalyosi, 1990, Kulindwa et al., 2001, Fottland and Sorensen, 2001).The prawn fishery in Rufiji delta employ more than 3000 artisanal fishermen, but other economically valuable fish are also caught in the delta. It is estimated that a total of 7,000 people (about 20% of the delta population) make a living from fishing in the delta.

The bulk of prawn fishery in Rufiji delta takes place either from the artisanal fishermen or from industrial trawlers (Gibbon, 1997). The artisanal prawn fishery does not operate from villages, but from fishing camps where both the fishermen and the fish traders stay (Fottland and Sorensen, 2001). Four camps are reported to exist in the delta and the largest at Kibanju consist of up to 3000 artisanal fishermen (Gibbon, 1997). Women have separate camps, located at Dima and Pombwe. Dima is the larger of the two, with up to 600 women (Gibbon, 1997). Each camp has a camp leader who is responsible for maintaining moral values in the camp.

The fishing in men's camps is mostly effected by dug-out canoes, using 2-ply gill nets, 15 m long by 1.5 m deep, with meshes of 2-2½ inches. The artisanal fishermen, who usually fish in pairs, follow targeted prawn species, which are concentrated at various sites in a well-known annual cycle, which is related to the prevailing winds (monsoon). According to the stage of the fishing cycle, the prawns are fished by men from open rivers, estuaries, lagoons, shallow tidal creeks and mudflats. Most of the fishing is concentrated during the spring tides. The prawn caught are directly sold to collectors (salesmen) who usually follow the fishermen from camp to camp and often on the water itself to the actual fishing site. Traditionally they operated individually, without helpers, with their own canoes, weighing scales, small-insulated boxes and ice (Gibbon, 1997). One collector may have between 10 to 30 pairs of fishermen tied to him. The average daily collection for one collector may be as high as 150 kg per day. The prawn are sold to the collectors at the price of US $ 10 per kg. The average daily catch of prawn is estimated at 3 tons ((Fottland and Sorensen, 2001), which gives an estimate of more than 1000 tons per year. Prawn purchased by the collectors has two principal destinations. The first is the processing plants and the second small exporters. In addition, some prawn is exported direct by large collectors themselves. While the processing plants (factories) exports their processed products to northern hemisphere countries in refrigerated containers, small exporters mainly serve 'neighbouring country' markets with frozen prawn, with a few exporting chilled prawn by air further afield, including the Gulf and Europe.

Fishing in women's camp targets for locally valued shrimps (*uduvi*) and fishing is concentrated during neap tides. Fishing is done using hand held nets. The shrimp caught are sun-dried and sold to visiting traders. It is estimated that approximately 20,000 sacks of shrimp are sold annually from Dima camp alone (Fottland and Sorensen, 2001).

The rapidly expanding prawn fishery has attracted trawlers into the area. Most of Tanzania's marine trawlers are of the smaller industrial category, between 100 and 200 gross registered tons (grt), with engines of 500-1000 BHP and have on-board processing and chilling facilities. Regulation of trawler prawn fishery involves two major issues: Firstly, each trawler is allocated one of three fishing zones (some of which are not productive), on the basis of strict rotation. While this procedure has conserved prawn in the main fishing grounds it has been associated with relative over-fishing in the less productive ones. Secondly, trawling is limited to the period between March and November, and to the 12 hours of daylight. This regulation was formulated not only to conserve the resource, but also as a safety measure to prevent collisions with artisanal vessels. The prawn trawlers are often specially designated to operate into the shallow waters and the targets are prawns migrating along the sea bottom at the mud flats, the minimum depth limit at which they are allowed to operate being 3 m. Since the coming of the trawler prawn fishery there has been conflicts between trawler operators with the artisanal fishermen. This is mainly because some of the trawlers also operate in the tidal flats, over the drying mud banks where the artisanal fishers have installed their fishing gears. Apart from destroying the fishing gears of the artisanal fishers, other bad fishing practices practised by trawlers operators include: discarding non targeted but locally valued fish species. and destroying the breeding habitat of many fish species (TCMP, 2000; Fottland and Sorensen, 2001). The prawns from the trawler operators are directly sold to the European markets.

2.3 Firewood, charcoal, timber and poles

Economic activities related with wood products include firewood, charcoal, timber and poles. While firewood harvest and woodland poles are generally considered as subsistence activities, charcoal, timber and harvest of mangrove poles are often regarded as commercial activities. The later activities require licenses but studies in the area indicate that illegal harvest of the resources for these activities is very high. Most of the historical data available do not qualify for making future projections of the long-term trends because of two major shortcomings 1- The data are of shorter durations (5 – 10 years), 2- They consist of the licensed trade which is considered to be far lower than the un-licensed trade (Kulindwa et al., 2001). While more reliable data is found from specific studies (e.g. Turpie, 2000; Kaale et al., 2000; Kulindwa et al., 2001 etc.), these studies are only giving the present situation. Thus, historical data, which could be very useful in predicting future trends is generally lacking. Using the data from the later studies, which estimated the present harvest of the various natural resources in the area using household's surveys, here we are attempting to reconstruct the historical trend (from 1977) and future trends (up to 2050) of the consumption of fuelwood (Fig. 2.2), which is dominantly controlled by demographic changes. Projections for the other woodland resources such as charcoal, mangrove poles and timber has not been attempted as they are externally driven. But it is generally noted that their future trends would be influenced by the growth of urban centers such as Dar es Salaam, Zanzibar, etc. and the national policy for international trade (for the case of timber. Some further discussion on the harvest of each woodland resource is discussed in the foregoing sections.

2.3.1 Firewood and charcoal

Firewood and charcoal are the main sources of fuel in the Lower Rufiji catchment (Kaale et al., 2000; Turpie, 2000; Kulindwa et al., 2001). Fuel wood by far is the first major source of fuel contributing to about 80-85% of the total household energy used. While charcoal contribute to between 10-15% of the total household used (Kaale et al., 2000). Other less important sources of fuel include kerosene (3-4%), and electricity (<1%). Apart from the Ikwiriri town centre, most of the areas in the catchment are not yet electrified. According to Kaale et al. (2000) the use of electricity as a source of fuel in the Ikwiriri town centre is limited to few private enterprises (e.g. Bridge Construction Company, few timber sawmills, welding workshops, few individual households).

Opportunity for upward switch from fuel wood to commercial energy in the electrified places is hindered by low income (estimated average income per capita per annum for

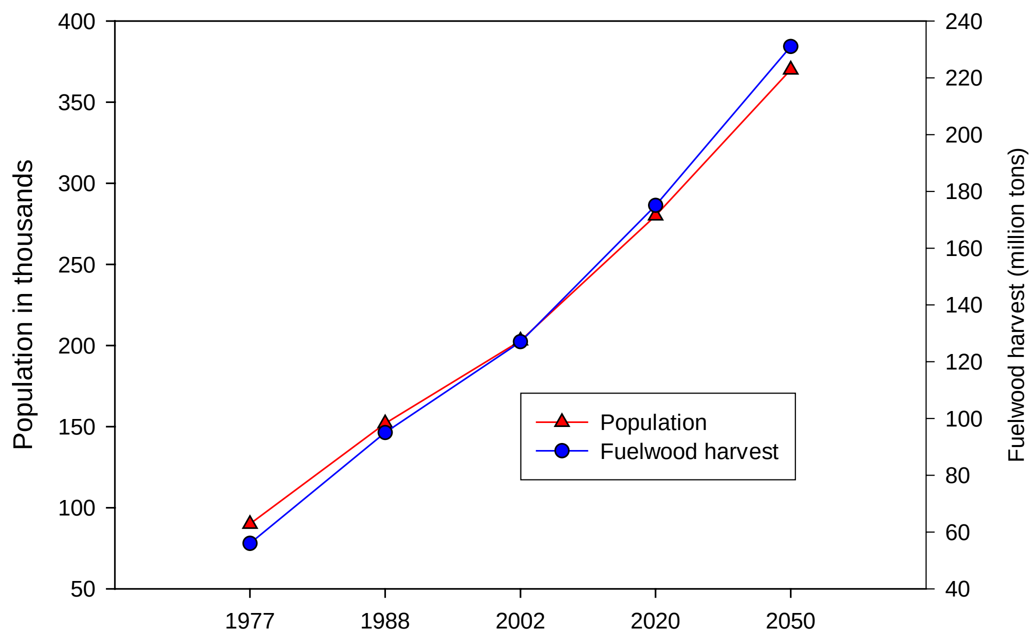


Fig. 2.2. Projection for the future trends on the consumption of fuel wood as a function of demographic changes, based on present per capita consumption of fuel wood of 625 kg (Kaale et al., 2000).

Coast region and Rufiji district residents is about US $ 29). Fuel wood is generally collected by women, although men occasionally assist (especially in big occasions). It is estimated that over 2.5 million bundles (logs) of fuel wood harvested per year, most of which is for subsistence use. Per capita consumption of fuel wood is about 625 kg; corresponding to an annual total of 62500 tons at present (Kaale et al (2000). If the present per capita harvest of fuel wood are maintained then the annual harvest of fuel wood due to demographic changes is expected to rise to over 52,000 in 2050 (Fig. 3.1).

In the floodplain, fuel wood is collected from the farm fields, woodlands and to a lesser extent in the forest reserve. In the delta, fuel wood is collected from the mangrove forests. According to Kaale et al (2000), most of the woodlands consist of secondary regeneration with dense growth of shrubs and small trees. The woodlands are not managed and there are no restrictions in using them for firewood. Due to the increasing user pressure, availability of dry wood for fuel is at present becoming difficult. At present, the use of the fuel wood from farm field is facing a user pressure problem; due to the fact that roaming goats limit any active tree planting campaign. Although fuel wood harvest is not permitted in the forest reserve, absence of clear boundaries on the ground to distinguish between the public land and forest reserve make the people harvest the fuel wood from the forest reserves. In delta, the collection of fuel wood is from the mangrove forest. Mangrove wood is reputedly reported to make better fuel wood than woodland wood

(Turpie, 2000). Fuel wood harvest from the mangrove forest has been singled out as one of the root cause of the loss of biodiversity (Kulindwa et al., 2001).

In the Lower Rufiji catchment, mangrove forests from the delta are not harvested for making charcoal (Turpie, 2000). Charcoal is often made from miombo woodlands from the floodplain. Most type of miombo woodlands are suitable for charcoal (Chidumayo, 1991 in Turpie, 2000). Production of charcoal is generally for commercial purposes. Despite that the activity require a license, illegal harvesting is reported to be extremely high, accounting to as much as 90% of the total (Kulindwa et al., 2001). Due to the fact that most of the charcoal production is unlicensed and therefore unrecorded in official statistics (Turpie, 2000), most of the estimates on the amount of charcoal produced per year are generally unreliable. Luoga et al (2000) examined the economics of charcoal production in the miombo woodlands of eastern Tanzania. The study noted that charcoal is the most commercialized resource in the eastern Tanzania, yielding a Net Present value (NPV) of US$ 511 ha^{-1}. The profit from charcoal production is attributable to its very low capital outlays, 'free' own labour, 'free' raw materials, and lack of concern about associated external costs and high demand of charcoal. When the cost of labour, raw materials and opportunity costs are considered, the NPV value was negative (US$ -868 ha^{-1}), indicating that profit realization is accomplished at the expense of other potential use of the woodlands. The study concludes that, although commercialization of wood resources provides tangible monetary benefits to rural communities, it also contributes to the resource depletion that will ultimately threaten their long-term survival. The present study notes that to a large extent the growth of charcoal trade to Dar es Salaam and other urban centers is influenced by the higher tariff rates of electric energy in Tanzania. Due to the high tariff rates of electricity most people in urban centers, which are already electrified prefer to use charcoal and kerosene for cooking than electricity. Thus, unless some measures are undertaken to significantly reduce the cost of electric energy, the growth of this trade is expected to increasingly pose more pressure on the woodland resources in the catchment.

2.3.2 Poles

Harvest of poles from the woodlands and mangroves is another economic activity taking in the area. In the floodplain villages, poles are usually cut from the woodlands within 1.5 to 3 hours of a village (Turpie, 2000). Most of the pole harvest is done to meet local demand, mainly house construction. Thus, although some pole cutters use the activity as an alternative source of income, the pole trade is generally between households in the area. While cutting of poles for own consumption is generally overlooked, cutting for commercial requires paying a license fees, of which most of the pole traders are not willing to pay. Much pole cutting is therefore done illegally. It is estimated that the annual harvest of poles in the area is about 1.3 million poles with a gross volume of 5000 m^3 (Turpie, 2000). Due to the fact that a significant proportion of the harvest (two third) is withies (very thin poles), the future sustainability of the activity is also uncertain.

Cutting of mangrove poles is a major activity in the delta. In the Rufiji delta, a mangrove management plan has been instituted in place (Semesi, 1991) to control the harvest of mangrove products (including mangrove poles). The management plan has identified zones in which various activities could be undertaken. Zone I are mangrove forest under total protection, which is about 31% (1,657.5 ha) for Rufiji delta. Zone II (59% or 31,522 ha) are protected forest. Zone III (8.3% or 4,437.7 ha), and Zone IV (1.3% or 718.3 ha) is development area. Although the management plans hinges around joint management, with active participation of local communities it has side effects which make legal cutting rather complicated (Turpie, 2000). Legal commercial cutting of mangrove poles involve getting permission from the Ward and Village Executive Officers of the area concerned, then taking the permit to the a forest officer to get a license, and making payments to all three parties. Using the current exchange rates (1 US$ = Tshs 1000) the fees for the three parties are US $ 2.27 (village application fee), US$ 0.07 and 0.22 per score; 20 poles (Village Government and District Council levy) and US$ 100 (license cost, valid for one year).

Because of the capital required for permits, most permits are in the hands of traders from large centres, outside the Rufiji delta who employ local people to do the cutting. Most harvesting is reported to be illegal, unselective and unsustainable (Kulindwa et al., 2001). The major commercial argents in this trade order between 20 – 100 scores at a time and can cut 100 – 1000 scores per month (Turpie, 2000). The mangrove cutters are paid about US$ 2 per score by their clients (Turpie, 2000) which is a very low price compared to the market value. The cutters have little bargaining power, as there are always other cutters willing to do the job for less payment. It is estimated that about 126,000 scores are exported annually, out of which only 14,565 scores are from licensed traders (Turpie, 2000). The future trends on this trade will likely be influenced by the demographic changes in the delta as well as its external demand. In the absence of historical demographic data for the delta future projections are difficult to make.

2.3.3 Timber

Timber cutting is an economic activity taking place in all villages with access to the woodland resources. This excludes the residents of the delta. Like the charcoal and mangrove pole trade, the timber trade is externally driven by its demand from business traders from Dar es Salaam and other major centers who transport who export them abroad. The activity requires a license whose cost varies from specie to specie. The most preferred hardwood species from the area at the moment are *Afzelia quanzensis* (mkongo) and *Dalbergia* (mpingo), and the license fees for these species are Tshs 50,000/m^3 (US$50/$m^3$) and Tsh 70,000/$m^3$ (US$ 70/m^3), respectively. Significant transport costs are also involved to transport the product to the market centres. Because of the large capital needed for such costs, the trade is also controlled by external traders who operate on a large scale (Turpie, 2000). Logs are either cut and sold directly, or logs of about 3ft diameter, selected and cut into 6ft lengths before sawing each into at least ten planks of 6ft x 1ft x 1in. One mkongo tree may yield up to 40 pieces. At least 12,000 trees (equivaent to 18,000m^3 or 12,600 tons) are estimated to be harvested annually for timber trade (Turpie, 2000; Graham et al., 2000). Here also, lack of historical data on demographic changes for the villages with access to the timber resource does not permit forecasting of future trends of this resource.

During the present Field visit to the area logging activities were observed in all the villages from Mtanza to Mloka. The logging operations employ strong people and therefore often involve young men. Our interview to few villagers revealed that currently most of the logging traders are Chinese business men. There is presently no control by the forest department over the location and extent of timber harvesting (Wells et al., 2000). This raises doubt on the future sustainability of the resource. Some of the recent studies report that currently logging is very low in the woodlands due to the unavailability of timber saw log sizes (Malimbwi, 2000; Herlocker, 1999; Graham et al., 2000). Similar scarcity of timber logs is also found in some forest reserves, which are supposed to be protected areas (Kaale et al., 2000).

2.4 Hunting

Hunting is a regulated activity in the Lower Rufiji catchment (Turpie, 2000). Hunting requires a licence. Hunting is not allowed after the closure of the hunting season (January to June). There is also a general ban on certain species such as crocodiles, turtiles and dugong, although in life threatening situations the banned species may be shot. There are several negative environmental problems associated with hunting:

1- Hunters, regularly burn woodland areas to encourage production of grass, which in turn attracts grazers such as impala (Turpie, 2000). Fires are also used by some hunters to scare the animals so that the animals can be hunted easily. This has detrimental effect to the production of other forest resources, including timber. Another detrimental effect of bush fires is that some of the animals may be forced to be away from their natural environment.
2- Illegal hunting and abuse of hunting licenses is a common practice. For instance, many of the regular hunters purchase licenses for one or two animal species but hunt far beyond their permits allow. This may pose potential threat to the conservation of some animal species.
3- Some of the hunters use traps to catch the animals. The traps are generally unselective and this may pose similar potential threats cited in 2.

PART 3: POLICY AND LEGAL FRAMEWORK FOR RESOURCE MANAGEMENT IN THE LOWER RUFIJI RIVER BASIN

G.U.J Mwamsojo

The ever-increasing political tension and conflicts among riparian communities over the use of natural resources are perhaps inevitable given the fact that human life is said to be impossible without it. Natural resources are the basis for livelihood of economically deprived communities in the world. It is directly linked to daily needs of the people especially in rural areas. Policies and regulations governing resource management in Lower Rufiji basin are concerned with the control or guidance of resource development. They represent the actual decision concerning practice on how resources should be allocated and under which circumstance resources may be developed. This report covers regulatory framework and institutional arrangement applicable to Rufiji and Mafia Districts as the main authorities found within lower Rufiji River basin including Mafia Channel and the Island.

3.1 Institutional arrangement and Legal framework

In Tanzania, natural resources such as water, land, minerals, wildlife, fish are owned by the state and they are regarded as public property. Power to manage and regulate the use of these resources is given to various ministerial sectors and public institutions for all Tanzanians. Individuals and private organizations are given rights of access and use for specified period of time through statutory licenses but no private ownership is envisaged.

The responsibility to manage various resources of lower Rufiji River Basin is given to various ministerial sectors and public Institutions. These derive their powers from relevant policies and legislation. Each has legal mandate and operational sovereignty over specific resources that have been placed under its charge. The management of resources through this mechanism is mainly sectoral and not holistic. Those legislation provide for functions which are allocated to various institutions which require among other things distinct expertise, effective and efficient functioning in generating data for decision making, policy setting, regulation enforcement and operational tasks. The most relevant ministerial sectors include water, land, human development and settlement, environment, tourism, forestry, fisheries, beekeeping, wildlife, mining, agriculture, culture and sports, antiquities and the Local Government.

3.2 The major legislations

(i) The Land Act No 5 of 1999

This Act define the term “land” to mean the surface of the earth and all substances other minerals and petroleum forming part of the below of the surface, things naturally growing on the land building and other structures permanently to the land. This legislation classifies land in three categories and these are the general land, village land and reserved land. It stipulates that all land in Tanzania shall continue to be public land and remain vested in the President as a trustee on behalf of all citizens.

(ii) Village Land Act No. 4 of 1999

This Act governs land affecting the rural populations of Tanzania. It provides that a certificate of village land shall be issued in the name of the President and such certificate shall confer upon the village land. The certificate affirms the occupation and use of the village land by the villagers under and in accordance with the Customary Law applicable to land in the area where the village is situated. The Act entails the village council in the management of the village to take regard to the principles of sustainable development in the management of village land and the relationship between land use, other natural resource and the environment in and contiguous to the village land.

(iii) Water Utilization (Control and Regulation) Act, 1974

This is the main and directly relevant law regulating water sector in Tanzania Mainland. This Act is amended by the Water Utilization (Control and Regulation) Amendment Act of 1981 and by the written laws (Miscellaneous) Act of 1989 Act No.17

The Act defines water to mean "all water flowing over the surface of the ground or contained in or flow in or from a spring or stream or natural lake or swamp or beneath a water course and all water made available from subterranean sources by means of works but does not include tidal water or water which is used solely for the purpose of extracting minerals therefrom. The Act stipulate that all water in Tanganyika is vested under United Republic and essentially this means that water is a national resource and property and the issue of ownership of water is vested in the nation. It divides water into drainage basins under the basin water boards.

According to this Act the country is divided into nine hydrological areas termed as river basins for the purpose of water resources administration and the Rufiji Basin is among them. The management of water resources is under the Ministry responsible for water resources. The Act provides the right to use water, control on water pollution, fees power to create easements right to call information, etc. prominent water right holders include large scale farmers who irrigate their lands, hydroelectric power stations, industries and mining concerns.

The Act provides under part III for inherit rights, to the use of water. These include right to water for domestic purposes where an individual having access to any water is allowed to extract and use that water for domestic purposes. It also includes right of an individual to limited quantities of underground and the casual water. According to section 11 the owner or occupier of land enjoys this right. Such an owner is allowed to sink or enlarge a well or borehole in that piece of land and abstract water not exceeding 22,700 liters in any day. These inputs extend to construction of works for conservation of rainfall and the abstract and use that water. The right to use water applies also to a holder of mining lease, a mining claim and a prospecting right. It also covers a holder of an exclusive license to take trees and timber granted under forest Act.

The Act empowers a water office to provide water use rights to any person; it includes the right to divert dams, store, abstract and use of water from such source indicated in the grant. The grant includes the quantity of water to be abstracted and it will indicate a period of the grant indicating whether it will be definite or indefinite. The Act has provisions on water pollution and it imposes conditions on water right holders not to pollute the water to such an extent as to be likely to cause injury either directly or indirectly to public health.

The Act provides that precaution must be taken to the satisfaction of a water officer with a view of preventing accumulations in any river, stream or water cause of silt, sand, graved, stones, sawdust refuse, sewerage, sisal waste or any other substance likely to affect injuriously the use of water subject to water right.

(iv) The Rufiji Basin Development Authority Act

This Act establishes the Rufiji Basin Development Authority (RUBADA). It provides for both functions and powers of RUBADA.
The Act enumerates the functions of RUBADA as follows:

a. To generate electricity by means of hydro-electric works in the development area and to supply on such terms and conditions as the Board may subject to the provision of this Act, approve electricity so generated for the promotion of industries and general welfare of the people of the United Republic.
b. To undertake measures for flood control
c. To promote and regulate industrial activities within the development area
d. To promote and regulate agricultural activities within the development area
e. To promote and regulate development of forest within development area and to take measures to ensure the prevention or minimization of soil erosion
f. To promote and regulate fishing industry in the rivers, lakes and dams within the development area.
g. To promote and regulate public inland water and road transport system within the development area
h. To promote tourism within the development area and to provide for or encourage the provision of facility necessary or expedient for the promotion of tourism

(v) The National Environment Management (NEM) Act

This Act establishes the Council known as NEMC, The National Environment Management Council, which is a national and semi-autonomous government institution responsible for advising the government on all issues pertaining to environment. The Act defines the term environment to mean land, water and atmosphere of the earth.

NEMC is empowered to formulate and design programmes that aim at achieving effective management and enhancement of environmental quality. Further more NEMC has to formulate standards, norms and criteria for the maintenance of the quality of environment. NEMC is also vested with powers to review policies and activities geared towards the control of environmental destruction, degradation and pollution.

(vi) National Land Use Planning Commission Act,1984

This Act establishes National Land Use Planning Commission, which is the principal advisory organ of the government on all matters pertaining to land use (section 4). The Commission is responsible for formulating policy on land use planning; specification of standards, norms, and criteria for the protection of beneficial uses and maintenance of the quality of the land and for the preparation of physical plans and ensure their implementation by the regions. The commission has been given added mandates to intervene in issues pertaining to the use and management of fragile land such as catchments areas or areas that are susceptible to erosion (see the Village Land Act No. 5 of 1999.

(vii) The Local Government Acts

There are two legislation enacted under the Local Government (District Authority) Act. The Local Government (District Authority) Act of 1982 provides for "interalia" the establishment, composition of township councils and village.

Governments for example at village level there is a village committee dealing with matters such as forest conservation and water resources. This Act give powers to the district councils to perform functions and roles including that of planning and coordinating of activities rendering assistance and advice to villagers engaged in agriculture, forestry, or any other activities and to encourage village residents to undertake and participate in communal enterprises.

The village councils or District councils do have powers to propose, make and pass by-laws within their areas of jurisdiction. District Councils are required to take the necessary measures to control soil erosion and desertification, to regulate the use of poisonous and noxious plants drugs or poison, regulate and control the number of livestock, maintain forest, manage wildlife, ensure public health, provide liquid and waste management, protect open space and parks.

(viii) Territorial Seas and Exclusive Economic Zone Act No.3 of 1989

This Act as noted earlier was enacted to provide for the implementation of the law of the Sea Convention to establish the Territorial Seas and Exclusive Economic Zone Act of the United Republic adjacent to the territorial /sea and the exercise of sovereign rights to the united Republic and to make conservation and management of resources of the sea. The Act define territorial sea to mean an area of sea which is under 12 nautical miles from one shores of the land and the exclusive economic zone is that area which is 200 nautical miles from the shores of the land. The Act is under jurisdiction of the Ministry of Foreign Affairs and International Cooperation. It empowers the minister responsible for foreign affairs to make regulations intended to regulate number of activities in the EEZ.

(ix) The Marine Parks & Reserves Act, 1994

This Act was passed to provide for the establishment, management and monitoring of Marine parks & Reserves. It establishes the unit known as Marine Parks and Reserve Unit. The Minister responsible for Marine Parks is vested with power to appoint Board of Trustee for Marine Parks and Reserves. The Minister is given power under this Act to declare any area within a territorial waters or island or coastal area to be a marine park if he /she feels that its protection will further the objective of the Act, or the area is of natural, scenic its protection historical or other importance or value, or preservation or management of the area is necessary to properly protect, permit access to or allow public viewing of enjoyment of the area (section 8(2))

(x) Electricity Ordinance Cap. 131

This legislation gives power to the minister responsible for energy to authorize the sequence and manner in which works in relation to contraction of powerhouses and supply of electricity. Further it vest mandate to the Minister to approve plans and drawing of dams, weirs, canals reservoir, tunnel, etc.

(xi) The Plant Protection Act, 1997

This Act provides for safeguard against pollution of ground water and natural environment by plant protection substances. Natural environment as per the Act include its components soil, water, air, species or wild flora and wild fauna as well as interaction between them.

(xii) The Wildlife Conservation Act, 1974

The Act was enacted in order to make provisions for the protection, conservation, development and regulation and control of fauna and its products. The administration of the Act is vested to the Director of Game appointed by the President, whose power is to administer the Wildlife Protection Unit **.**The Director has power to restrict the carriage of weapons in Games Reserves as well as powers to protect vegetation against burning or cutting.

(xiii) Fisheries Act No. 6 of 1970

This legislation was passed to make provisions for the protection, conservation, development, regulation and control of fish products aquatic flora and products thereof. The Act vest power to the Minister to prohibit fishing collecting, gathering or manufacturing fish products or importing or exporting of fish unless the license is issued by the chief fisheries officer. The Minister is empowered under the Act to impose restrictions on fishing by declaring any area or water to be a controlled area or portion of territorial waters is declared to be a controlled no person shall engage in or do any fishing in such are or water unless the authority is served in writing to the Chief Fisheries Officer.

3.3 By -Laws Related to Resource Management in Rufiji River Basin

Generally it can be noted that Local Government have wide range of duties, some of which are environmental in character which include the conservation of natural resources, prevention of soil erosion, prevention and control of agriculture activities in ecological sensitive areas

3.3.1 Implementation of By-Laws

The implementer of by-law is the one that formulated it. In the case of lower Rufiji River Basin are sets of by-laws. One set refers to those established by District Councils of Rufiji and Mafia and the other set is of those developed by RUBADA. The implementation of these by-laws needs to be supported by principle legislation. Where by-law contradicts directives of one or more of the principle legislation, its implementation may lead to conflict among the community.

3.4 National policies

There are various policies in Tanzania that have implication to the resources of the lower Rufiji River basin. These policies are developed by sectors and therefore known as sectoral policies. There is also a National Environmental Policy (NEP) of 1997 that serves as an umbrella policy providing general framework for environmental management. Most of these sectoral policies do contain provisions that put strategies on how to manage resources.

The management of the resources of the Rufiji river basin takes place within the framework of shared responsibility within district accountability. This requires that all actors understand their individual roles and responsibilities. The management of resources consists of management of specific resources such as agriculture, mining, fisheries, land, forest, wildlife, water and many others.

The management of resources in respect of Rufiji river basin is embodied in the country's policy, domestic law and practice.

(i) The National Environmental Policy (NEP) of 1997.

This policy acts as a roadmap to guide determination of priority actions and provides for monitoring and regular review of policies, plans and programs. The policy advocates for the formation of environmental committees to coordinate natural resource management at the Regional, District, Ward and Village levels. It further provides that environmental committees shall be responsible for coordination and advising on obstacles to the implementation of environmental policy and programs.

(ii) The National Land Policy 1995

The objective of this policy is to promote equitable distribution and access to land by all citizens to ensure that existing rights in land especially customary rights of small holders (i.e. peasants and herdsmen) who are majority of population in the country are recognized, clarified and secured in law and to protect land resources from degradation for future needs. The policy commits to protect sensitive areas including river basin and banks, national heritage and areas of biodiversity. All land in Tanzania is public and vested in the president trusteeship**.**

(iii) The National Water Policy (2002)

This new policy is guided by the global guiding principles in the management of water resource management. It states that water resource management should be based on participatory approach involving users, planners and policy makers at all levels. Further more another principle is that the river basin will be a planning unit for effective management of both quantity and quality of the water resource. The vision of this policy is to achieve sustainable socio-economic development alleviate poverty and improving the well being of the people through equitable utilization of and benefit from the use of the country's water resources including the use of shared water resources.

(iv) The Wildlife Policy, 1998

This policy introduces concepts and principles such as involvement of stakeholders and community participation in wildlife management. The purpose of this is to ensure that benefits derived from wildlife resource are equitable distributed on sustainable utilization and lay strategies for the development of protected areas. The aim is to conserve areas with significant biological diversity and to administer wetlands to conserve water catchments and soil resources. The Management of Selous Game Reserve is guided by this policy.

(v). The National Fisheries Sector Policy and Strategy Statement, 1997

The overall objective is to promote the conservation, development and sustainable management of fisheries resources and habitats for the benefit of the present and future generations. The specific objective of the policy is to protect productivity and biological diversity of coastal and aquatic ecosystem through prevention of habitat destruction, pollution and over exploitation and to promote small scale, semi intensive aquaculture systems. About 80% of exported shrimps in Tanzania are caught in the area influenced by Rufiji River.

(vi) National Human Settlement Policy (2000)

This policy outlines major objectives, which among others include protecting the environment of human settlements and of ecosystems from pollution, degradation and destruction in order to attain sustainable development. Rufiji District Headquarters, a number of villages have land use plans.

(vii) National Health Policy, 1990

The policy promises to provide sufficient quantities as well as its sound use, encourage safe basic hygienic practices and maintenance of clean environment. This policy is silent on issues of quality of water and liquid waste that result from the use of water.

(viii) Agriculture and Livestock Policy 1997

The policy aspires to improve the well being of people whose agriculture is the main source of livelihood (mainly small holders and livestock keepers who do not produce surplus). One of the most important objectives of this policy is to promote integrated and sustainable use and management of natural resources such as land, soil, water and vegetation in order to conserve the environment. Other objectives include assurance of food security through increased production of food crops, improved living standard through increased income generation and foreign exchange from agriculture and livestock, improved supply of raw materials for agro- processing industries, develop and introduce new technologies, develop human resources, and provide support services to agricultural sector.

Lower Rufiji River basin is potential for both rain fed and irrigation agriculture. Some pilot irrigation rice fields have been practiced in Rufiji District by a Korean firm. The main occupation of local communities is small-scale agriculture. Livestock keeping was not significant in lower Rufiji River basin in the past because principal livestock keepers in Tanzania (Masai, Sukuma and Gogo) had plenty of pastureland in central and northern parts of the country. As quality of pastureland continues to degrade in those areas the Masai livestock keepers have started to migrate to Lower Rufiji River valley.

(ix) Forest Policy, 1998

The objective of this policy is to enhance national capacity to manage and develop forest sector in collaboration with other sectors including ensuring ecosystem stability through conservation of forest biodiversity, water catchments and soil fertility. Policy statement No.19 directs that new catchments reserves for watershed management and soil conservation will be established in critical areas. The policy acknowledges various types of investment projects in forest areas accompanied by Environmental Impact Assessment (EIA) prepared for the development with potential of damaging the forest environment. These developments include agriculture, dams, farming and tourism. Conservation forests surround the lower Rufiji River basin.

(x) Mineral Policy, 1997

The policy advocates that in order to ensure the sustainability of mining there is a need to integrate environment and social concerns into mineral development programs. It further advocates that there is a need to initiate actions to reduce or eliminate adverse environmental effects of mining to improve health and safety of the mining areas. This policy is important to Rufiji River basin on the fact that it spells out strategies for protecting environment by abating the use of toxic chemicals and pollutants by promotion of mining in restricted areas such as forest, sources of water and other designated areas.

3.5 Natural resource management tools

There are many resource management tools that apply to the lower Rufiji River situation. These range from National to Local level strategies, guidelines, management plans. Action plans. These are mainly translating nation policies and regulations into practical implementation. Examples of such tools include National Integrated Coastal Environment Management Strategy (2003). This is probably the most crosscutting strategy that addresses management of all coastal resources in holistic manner. The strategy spells out that its overall vision is to have a coast with thriving coastal settlements where people rely on the coast and its abundant resources for their food and their livelihood and actively working to sustain the resource base.

The strategy is an important tool that aspires to implement the National Environmental Policy (1997) and other environmental related policies that address conservation, protection and sustainable development of Tanzania’s coast resources for use by present and future generations, to ensure food security and support economic growth. It should be born in mind that the political boundary (land wards) of the National Integrated Coastal Environment Management Strategy is the coastal District boundaries. A large part of the lower Rufiji River basin is within Rufiji and Mafia Districts, which are located in the coast.

Other resource management tools include Forestry Action Plans, Land use guidelines, Coastal tourism Guidelines, Coastal aquaculture Guidelines, Mangrove Management

Plan, Selous Game Reserve Management Plan, National Ramsar Strategy, Mafia Island Marine Park General Management Plan and Village land use plans where exist

3.6 International treaties and conventions

Tanzania is a party to various treaties and conventions, which govern and set obligations for the management of resources as well as the management of the environment. There are two types of treaties: those having universal application and those limited to African Regions. Following the Stockholm Conference on human Environment in 1972 and the establishment of African Ministerial Conference on environment and natural resources in 1985, most African countries including Tanzania established policies and laws in an effort to meet needs of their people while pursuing economic development.

In 1992 Tanzania presented a National report on environment and development to the UN Conference on Environment and Development held in Rio de Janeiro, Brazil, a process which highlighted the need for review of environmental laws, policy framework and institutional arrangement. The outcome of the summit entails agreements such as the Rio Declaration that endorsed many principles. At the global level Tanzania is a party to various Multilateral Environmental Agreements (MEA's). Treaties and conventions relevant to resources management in the lower Rufiji are discussed below.

(i) African Convention for the Conservation of Nature and Natural Resources of 1968.

This convention urges contracting parties to adopt policies for conservation, utilization and development of underground and surface water and take appropriate measures to ensure inter-alia the preservation and control of pollution in water. The convention requires that where surface or ground water resource are shared by two or more contracting parties they should act in consultation and if need arises setup inter-state commission to study and resolve problems as well as to develop and conserve their resources. Lower Rufiji River is an internationally important ecosystem that bring significant ecological influence to the sea and is rich in wildlife including fish, forests water, birds and agricultural land.

(ii) Convention Concerning the Protection of the World Cultural and Natural Heritage

This convention was adopted by UNESCO and came into force in 1975. It has been instrumental in the protection of fragile or ecologically significant parts of state parties to it. Part of lower Rufiji river basin (Selous Game Reserve) is a World heritage site and there area many more cultural sites in Mafia Island.

(iii) Convention on Wetlands of International Importance (Ramsar Convention)

This convention came into force in 1975, Tanzania became party (ratified) in 2000 and therefore assumed the legal responsibilities to identify wetland sites of international importance and ensure that they are appropriately managed. The Wildlife Division of the Ministry of Natural Resources established a Wetland unit in an effort to comply with the convention. The unit is charged with the responsibility of guiding efforts towards the implementation of the convention's obligations including revamping a wetland policy formulation dialogue. The Rufiji Delta and Mafia Channel are included in the proposed Marine Ramsar site.

(iv) United Nations Convention on the Law of the Sea, UNCLOS, 1982

This convention is the basic legally binding international instrument providing the basis for the protection of the Marine environment from the impact of social economic activities of human being. Member states are bound to adopt laws, regulations and other measures to prevent, reduce and control land based pollution of Marine environment. Tanzania has incorporated the obligation of this convention to domestic legislation vide the Territorial Sea and Exclusive Economic Zone Act.

(v) The Convention on Biological Diversity (CBD), 1992

This convention came into force in 1993 and Tanzania ratified it in 1996. It addresses three levels of biological diversity that is genetic resources, species and ecosystems. It is gives legal recognition to conserve biological diversity and invest in conservation for the realization of environment economic, social and cultural gains. A study on the country biodiversity was conducted and a National Biodiversity Strategic Action Plan is now in place. Example of field based programs that address issues of biodiversity in the lower Rufiji basin include Mafia Island Marine Park, Mangrove Management Project, Rufiji Environment Management Project and Selous Game Reserve.

(vi) The Nairobi Convention of 1985

This convention deals with the protection, management and development of Marine and Coastal Environment of the East African Region. There are two protocols under the convention and Tanzania has ratified both protocols on the protected areas of wild fauna and flora and on matters of wild cooperation in combating Marine pollution in cases of emergency in East African Region.

The convention set obligations to member states to take appropriate measures to reduce and combat environmental damage and in particular the ecosystems. It further require the assessment of potential environmental effects of major projects likely to cause substantial pollution or significant and harmful changes to the convention area

Tanzania has put in place some strategies to comply with the provision of the convention a good illustration is the preparation of the National Integrated Coastal Environment Management Strategy of 2003.

(vii) The Treaty for the Establishment of the East African Community, 1999.

The treaty has provisions on issues requiring cooperative actions in the area of natural resources and through it Tanzania recognizes development activities that have negative impacts on the environment leading to degradation of the environment and depletion of natural resources. The country has domesticated this treaty by enacting a legislation to incorporate the provisions of the treaty (Act No. 4 of 2001).

3.7 Poor enforcement of policies and legislation

Enforcement of legislation is generally weak in Tanzania principally because they are too sectoral focusing on specific resource. Other reasons are as follows:

- Most of the existing legislations were developed without consultation with people at the grass root. The adopted system was top-down approach. Therefore do not consider needs of the people who area the enforcers. As a result, enforcers do not know them or fail to interpret them into practical implementation because do not match with real situation
- Many legislation have been adapted from colonial period, thus are outdated and would need review.
- There is weak capacity to enforce legislation in terms of human resources, skill and equipment
- Many Acts and policies overlap or conflict each other leaving gaps and there is no mechanism to harmonize conflicting/overlapping areas and abridging gaps
- Failure to address the problem of poverty, which is the root cause of many observed cases of poor resource management.

It is also important to note that most of them are concerned with utilization of natural resources for fast revenue generation rather than addressing sustainable management of the resources.

3.8 Centralization

The institutional arrangement for resource management in the lower Rufiji River basin follows a general framework that has been established by the Government. According to the existing framework all ministerial sectors are given the role of regulatory and provision of policies and guidance, whereas, local government, NGOs, public and private institutions that act as agencies of the government are supposed to do the enforcement, monitoring and provision of technical advisory to the government. Resources management powers have been given to people at the grass root. Therefore centralization refers to regulatory functions only.

3.9 Institutional conflicts

Most of the Institutional conflicts arise due to failure to interpret laws and policies that guide management of resources. The establishment of many institutions with overlapping mandates exacerbates the problem. The Ministry of Agriculture for instance, established

RUBADA that is cutting across all other sectors with a prime objective of promoting resources of Rufiji basin. RUBADA is also mandated to monitor, regulate and control water use. This function is also given to the Rufiji Water Basin that was established by the Ministry of Water.

RUBADA promotes and regulates natural resources, facilitates investors and enters into joint venture with private companies to exploit natural resources. RUBADA has power of doing this without consultation with lead sectors in the Ministry of Natural resources and Tourism. This contradicts the idea of enforcing national regulations and demoralizes the spirit of other actors and renders guidance and action plan provided by the ministry meaningless.

RUBADA has developed by-law (1994) to collect registration fees from any investor that makes application to Rufiji basin. This by-law overlooks the responsibility of Tanzania Investment Center (TIC) that acts as a one-stop center that facilitates all investments in the country. Ideally registration for investment is supposed to be done at TIC. The by-law also conflicts the interests of local government that would like to collect revenue from such investors.

Act No. 5 of 1975 is also giving RUBADA powers to construct, maintain, operate, manage and control works for hydro electricity production, make by-laws to protect electricity or restrict access to any part of the project. This function conflicts the role of Tanzania Electric Supply Company (TANESCO) which is the sole company given responsibility of supplying electricity in the country.

3.10 Recommendations on policy options

The existence of institutional conflicts threatens the future of lower Rufiji River basin ecosystem. The required approaches would those that seek the involvement of all key stakeholders in the planning and implementation process that build on integrated principles and define roles and responsibilities to avoid overlaps.

One of the best policy options to resolve conflicts is to refrain from formulating more policies, instead engage in developing policy-implementing tools. This process will involve policy reviews to identify conflicting areas and gaps. The identified weaknesses would be addressed in resource management strategy (general resource management plan) for the entire area of lower Rufiji basin including Mafia. The recommended general resources management plan will provide a framework and guidance that will be used to refine the existing area specific or resource specific management plans and develop more others. Land use plans will be part of the resource management plan.

Another important option of harmonizing policies and filling up existing gaps is the undertaking of Strategic Environmental Assessment (SEA) for the entire area. This approach will assist in setting up priority economic and social development options. The process will also determine the relative carrying capacity of the area. The two options complement each other. None of the two will be able to solve the existing problem in isolation.

PART 4: THE PATTERN OF LONG-TERM CLIMATIC VARIABILITY

Y.W. Shaghude, E.J. Mpeta, M.R. Matitu. and E.E. Matari

4.1 General climatic setting

The climate of the Lower Rufiji river catchment is tropical climate with narrow variation in monthly temperature and day length. Like most parts of eastern Tanzania, the rainfall pattern of Lower Rufiji catchment is controlled by the Inter-Tropical Convergence Zone (ITCZ) and the monsoon winds from the Indian Ocean. According to Nyenzi et al (1999) the rainfall in Tanzania is characterized by two main regimes: 1- the unimodal regime characterized by a continuous rainfall from October to April/May, and 2- the bimodal regime characterized by a short rain season from October to December and a long rain season from March to May.

In the present study, rainfall data from three meteorological stations (Stiegler's Gorge, Kingupira Wildlife and Utete Agriculture centre) was analysed (Fig. 4.1). For each of the three stations the data consists of monthly precipitations, for different time periods. Utete station has the longest historical data (1921 – 2000). The Stiegler's Gorge data is from 1955 to 1990 with a gap in 1959 and the Kingupira data is from 1968 to 2000 with gaps in 1980, 1996 and 1997.

The mean monthly rainfall for the three stations show that the rainfall season start in October/November through May, with rainfall peak in March/April (Fig. 4.2). The presented data is similar to rainfall data reported from other stations in Lower Rufiji by other workers (e.g. Sørensen, 1998 in Turpie, 2000). It can therefore be concluded that the rainfall pattern of Lower Rufiji catchment conform to the unimodal regime. The Lower Rufiji catchment and most parts of the eastern coast of Tanzania, south of Dar es Salaam are located in region VII (Ogallo, 1980 cited in Nyenzi et al., 1999), which experience unimodal rainfall pattern. Thus the above rainfall parttern is as expected for the investigated area. The mean annual precipitation for each of the three stations are generally similar (Stiegler's Gorge = 884.4 mm, Kingupira = 839.4 mm and Utete = 872.0 mm). They all suggest that the area does not receive abundant rainfall. This is one of the major climatic factors, which has historically shaped the agriculture system in the Lower Rufiji catchment. Thus, because of the fact that the rainfall is generally not abundant, the agriculture in the area does not totally depend on rainfall, but rather depends on both rainfall and flooding. While the former is generally controlled by the local geographic regime (an internal factor), the latter is largely influenced by the 'external' geographic regime. That is flooding in the Lower Rufiji very much depend on the precipitation from the Upper Rufiji which receives much higher precipitations (Fig. 8). In the present study, rainfall data from three stations (Mahenge, Kilombero and Ifakara) of Upper Rufiji were analyzed. Mahenge, like Utete (from Lower Rufiji) has the longest historical data (1921-1997). The Kilombero data is from 1962-2002 and the data from Ifakara is from 1958 –2002. Here we present the data for Mahenge and Utete for comparisons. The data show that Mahenge receives much higher precipitations than

Utete. The precipitations in the other two stations (Kilombero and Ifakara) are slightly lower than the precipitation at Mahenge, but generally higher than at Utete.

Unlike most parts of Tanzania which have either one or two agricultural seasons, Rufiji District is peculiar in that its agriculture year is characterized by three seasons (Bantje, 1979; Hamerlynck and Duvail, in prep.): 1- the short rain season (*Vuli*), which involves planting of maize in November/December and harvest in February/March, 2- the flood season or long rains season (*Masika*), which involves planting of rice in December/January and harvest in June/July and 3- the flood recession season (*Mlau*), which involves planting of maize and pulses in May/June and harvest in August/September (maize) and October/November (pulses).

4.2 Inter-linkages between rainfall, flooding and agriculture

Rainfall and flooding are the two dominant environmental factors in Lower Rufiji catchment which control agriculture and the livelihood of people. In good years, they both complement each other so as to create favourable conditions (especially for rice cultivation). In bad years, their interaction may result in either drought or disastrous flooding. According to Bantje (1979), good or poor harvest is determined by the quantity, timing and duration of both rainfall and flooding, and these conditions vary from year to year. A failure of short rains may cause food shortage unless rainfall and flooding in the flooding season are favourable. Thus, if the failure of short rains is followed by no floods (i.e. prolonged draught), poor harvest of both maize and rice will result, leading to serious famine. However, if the failure of short rains is followed by adequate floods, good mlau harvest would result with poor maize harvest, leading to less serious famine. The other scenario of a good short rain season followed by poor flood season would lead to a more serious famine than the scenario of poor short rain season followed by good flood season. Several studies in the area recognize that the exceptional potential of Lower Rufiji lies in the floodplain (rather than the upland areas), which has its fertility regenerated yearly by the river flood (e.g. Cook, 1974; Bantje, 1979, 1980, 1982; Kajia, 2000; Ochieng, 2002).

Using a 23-years (1979 – 2003) daily rainfall data at Utete, Hamerlynck and Duvail (in prep.) discusses the seasonal risks of crop failure under different combinations of rainfall and floods (Table 4.1). From his analyses, he notes that the likelihood of having no floods is 0.60 (i.e. 6 years out of 10), the likelihood of having adequate floods is 0.25 (i.e. once every 4 years), etc. By multiplying the different probabilities, the likelihood of a combination can be calculated if the events in themselves are not correlated. For example, no food and inadequate short rains will occur in 0.60x0.65 = 0.39, thus in about 4 years out of 10. He also notes that different types of crop failure do not have the same impact on the duration of food shortages and therefore on the risk of famine (Table 4.2).

Table 4.1: Probabilities of different flood and rainfall events on the Lower Rufiji floodplain farming in any single agriculture year (Source: Hamerlynck and Duvail, in prep.)

Flood	None	Adequate	Excessive
	0.60	0.25	0.15
Short rains		**Long rains**	
Inadequate	0.65	Inadequate	0.35
Adequate	0.35	Adequate	0.65

Table 4.2: Number of months of potential food shortage in Lower Rufiji catchment for different combinations of short rains and floods (Source: Hamerlynck and Duvail, in prep).

	No flood	**Adequate flood**	**Excessive flood**
Inadequate short rains (<400 mm)	15	7	10
Adequate short rains (>400 mm)	9	0	4

As can be seen from Table 4.2, the worst case scenario is a failure of the short rains, followed by a year without flood, which is associated with 15 months of potential food shortage. The frequency of occurrences of such a combination is once every 7 years. The second longest food shortage risk occurs in a year with inadequate short rains and excessive floods, which is associated with a 10-month potential food shortage period. This combination occur in about 1 year out of 10. The famine risk is however relatively low because of the compensatory high fish yield (Hemerlynck, in prep.). The third longest food shortage risk period occur in a year with adequate short rains in combination with the absence of a flood, which is associated with a 9-months potential food shortage period. Here again the famine risk (especially before villagization programme) is considered to be relatively lower because of the dependability between floodplain dwellers and the hill dwellers. The adequate short rains would lead to good harvest on the hills, which would support the floodplain dwellers. In case of failure of short rains and adequate flood, the potential food shortage period is 7 months, which occurs once every 6 years. Due to the dependability between floodplain dwellers and the hill dwellers, this also would lead to relatively low famine risk. Adequate short rains and excessive floods is a combination which with a relatively short food shortage period (4 months). Therefore does not carry a very high famine risk unless they are excessive. Early floods occur in about 1 year out 5 but the combination will occur once in every 14 years (Hamerlynck and Duvail, in prep).

A review of relationship between food shortages and flood/draught events using a 100 years (1880 – 1980) historical records (Bantje, 1980) show that drought and floods as single causes of food shortages are both listed 8 times, while the combination of flood and draught is also reported to occur 8 times. The above results emphasize two main points, 1- the floods is the main protection against famine for the Lower Rufiji farmers and 2- short rains is another safety protection net against famine for the Lower Rufiji farmers.

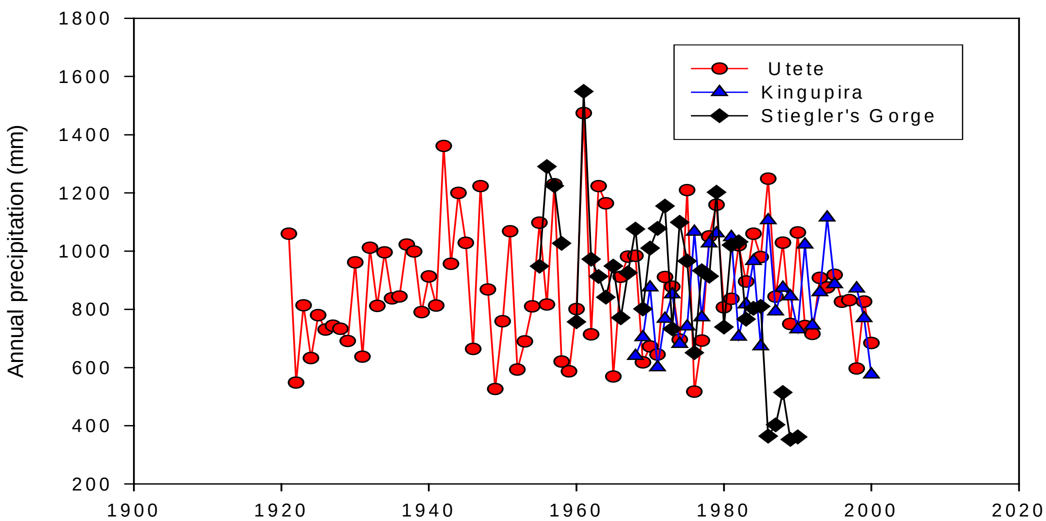


Fig. 4.1. Annual precipitations at three meteorological stations (Utete, Kingipira and Stiegler's Gorge) on Lower Rufiji catchment.

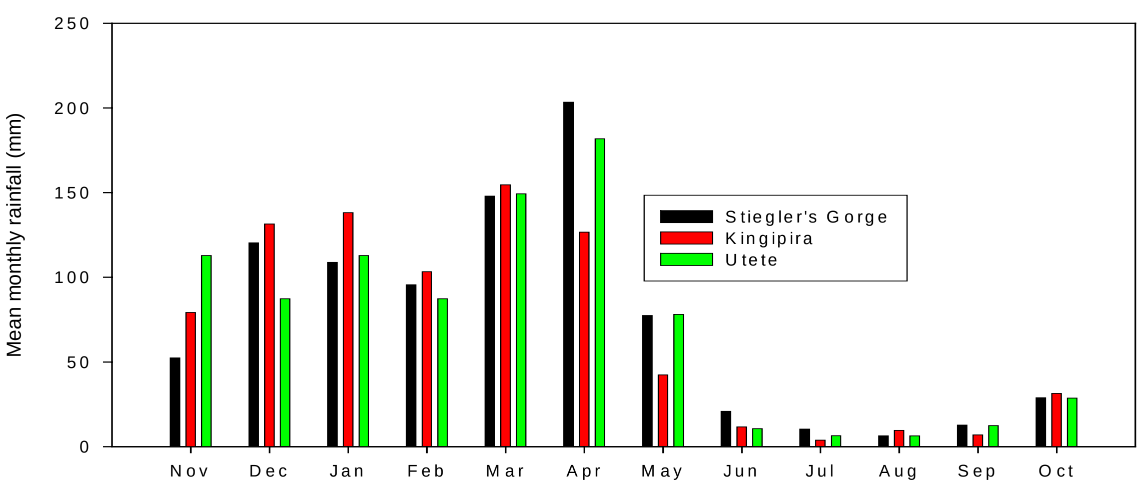


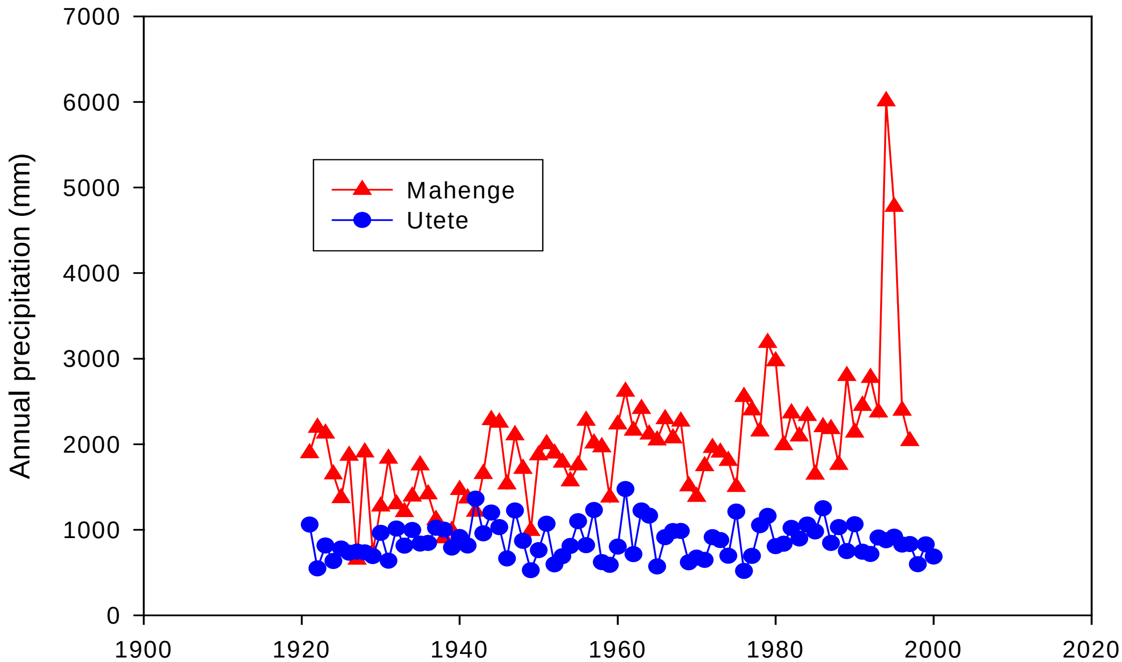
Fig. 4.2. Mean monthly rainfall at three meteorological stations (Utete, Kingipira and Stiegler's Gorge) on Lower Rufiji catchment.

4.3 Analysis of the pattern of long-term climatic variability

Investigation on the nature of the long-term climatic variability, namely rainfall and flooding in the Lower Rufiji catchment has been and is still a subject of interest by many workers. Understanding of the long-term climatic variability and how they interact with the physical environment is considered to be one of the key element needed in the future management of the agriculture system, other economic activities (e.g. fisheries) and future planned projects (such as damming) in the area. Despite this general understanding, very little is at present known concerning this subject.

As discussed previously, the longest monthly rainfall historical record in the Lower Rufiji catchment is the data for Utete Agriculture Centre, which dates as far back as 1921. Data for other stations are available for shorter periods. Our present investigation of the temporal and spatial rainfall data from the three stations cited above (Utete, Stiegler's Gorge and Kingupira) show that, although the mean annual precipitation is broadly similar, local variation exist, particularly in the yearly total precipitations Banje (1979) who used monthly rainfall records from other stations (Utete, Mtanza and Mohoro) reports significant difference in annual precipitation for the three stations investigated (Utete = 868 mm, Mtanza = 700 mm and Mohoro = 1100 mm) and concluded that the total amount of rainfall in the catchment decreases rapidly when going inland from the coast. Thus, while rainfall records for Utete may be considered to represent the average rainfall precipitation for the areas on the floodplain, the data might not be a good representative for the areas on the delta. Mohoro data could best represent these areas, but the data like other rainfall records in the Lower Rufiji catchment is of shorter duration (Bantje, 1979). Thus, here we use the long-term temporal rainfall data for Utete for interpretation of the average climatic conditions of the Lower Rufiji catchment with this caution.

It is also worth noting that the long-term historical rainfall data is characterized by peaks of different amplitude (Fig. 4.3). In the present study spectral analyses have been done to investigated the periodicity of the long-term rainfall data from three stations on Lower Rufiji catchment and three other stations on the Upper Rufiji catchment (Table 4.3). Initial analysis the data revealed that spectral amplitudes of high frequency overshadowed low frequency signals. To go about this problem the data was filtered into two frequency bands; high frequency band (period between 2-12 months) and low frequency band (period above 12 months) and the upper limit was restricted by the rainfall sample length. The graphs showing the position of various spectral bands and their respective spectral heights for Mahenge (Upper Rufiji) and Utete (Lower Rufiji) are presented in Fig. 4.4 – 4.5. The graphs for the other stations have not been presented in the text but are generally similar to the one presented.



.**Fig. 4.3** Annual rainfall patterns at two stations; one taken from Lower Rufiji (Utete) and the other taken from Upper Rufiji (Mahenge). Observe that Mahenge receives much higher precipitations than Utete.

Table 4.3: Stations from Upper and Lower Rufiji whose historical rainfall data were investigated for spectral analyses.

	Station	**Latitude**	**Longitude**	**Duration**
	Kilombero	7.40°S	37.00°E	1962 -2002
Upper Rufiji	Mahenge	8.41°S	36.43°E	1921-1997
	Ifakara	8.90°S	36.39°E	1958-2002
	Stiegler's Gorge	7.48°E	37.55°E	1955-1990
Lower Rufiji	Kingupira	8.23°S	38.37°E	1968-2000
	Utete	8.10°S	38.45°E	1921-2000

Table 4.4: Rainfall spectrum in the Low Frequency Band (LFB)and High Frequency Band.(HFB).

Stations	Cycles in years (LFB)			Cycles in months (HFB)		
Mahenge	8.4	3.4	1.9	12	6	4
Kilombero		2.8	1.7	11	5.7	4
Ifakara	7.4			11	5.7	4
Kingupira		2.1		11	6	4
Stigler's Gorge			1.7	11		4
Utete	8.4	4.2	2.8	11	6	4

The spectral characteristics for all the six stations are summarized in Table 4.4. They all suggest a similar climatological pattern, demonstrating that, rainfall spectral amplitudes in the Rufiji basin are similar. It is here suggested that rainfall in the Rufiji Basin is associated with QBO (Quasi Biennial Oscillation) and ENSO (El Nino Southern Oscillation) in the spectral bands 1.5-3 years and 3-8 years respectively. High frequency spectral bands are associated with annual and seasonal cycles e.g. 12 months, 6 months and 4 months.

Spectral analysis was also done for river flow data for three stations, Sanje (7.36°S 36.54°E), Hagafiro (9.23°S 34.49°E) and Mpanga (8.56°S 35.48°E), located in the Upper Rufiji. The results are summarized in Table 4.5. The graphs from which the numerical information of Table 4.5 were derived are similar with those discussed above for the rainfall data, and are therefore not presented in the text.

Table 4.5: River flow rates spectrum in the low frequency band

Station	Cycles in Years for the Peaks	
Mpanga	3.8	2.1
Sanje	4.2	2.1
Hagafiro	3.3	

Like the rainfall data, the river flow spectral analysis shows cycles for 2-3 years, which are associated with QBO (Quasi Biennial Oscillation) and 3 – 5 years, which are also most likely associated with ENSO events. The similarity in pattern between the rainfall data and discharge data suggests a positive association between river flow and rainfall.

Further investigation of the relationship between rainfall and river discharge data was made using correlation analyses. Thus, monthly rainfall data of the six stations was correlated with monthly river flow rates of the three stations (with flow duration in brackets), Sanje (1962-1980) Hagafiro (1980-1991) and Mpanga (1957-1977). Very low correlation coefficients were obtained, suggesting that monthly averages of rainfall precipitation are not good in estimating river discharges. The correlation coefficients were also poor when the correlation analyses were done using daily rainfall and flow data (January – May 1965). All in all there should be a significant relationship between flow and rainfall if good quality data is used.

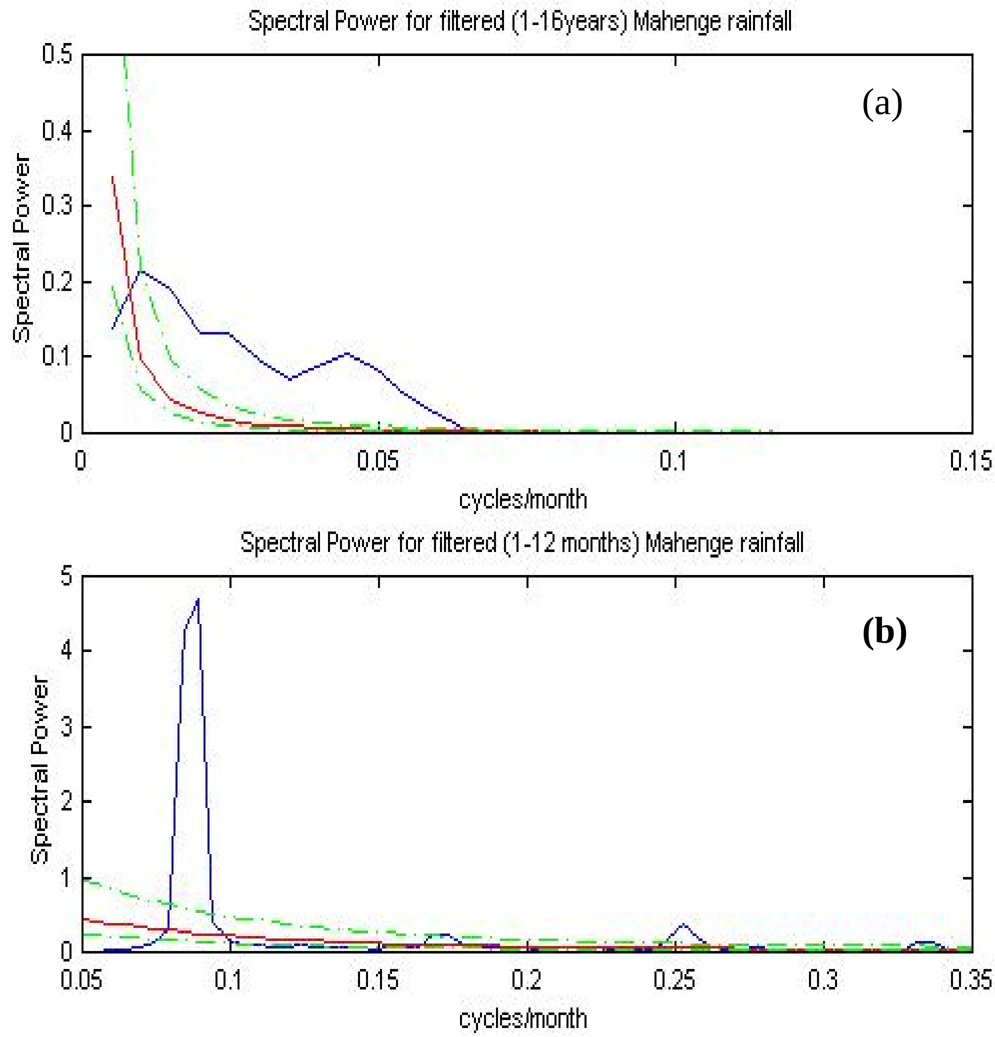


Fig. 4.4. Low (a) and high (b) frequency spectral bands of the filtered (1-16 years) and 1-12 months, respectively rainfall spectrum for Mahenge .

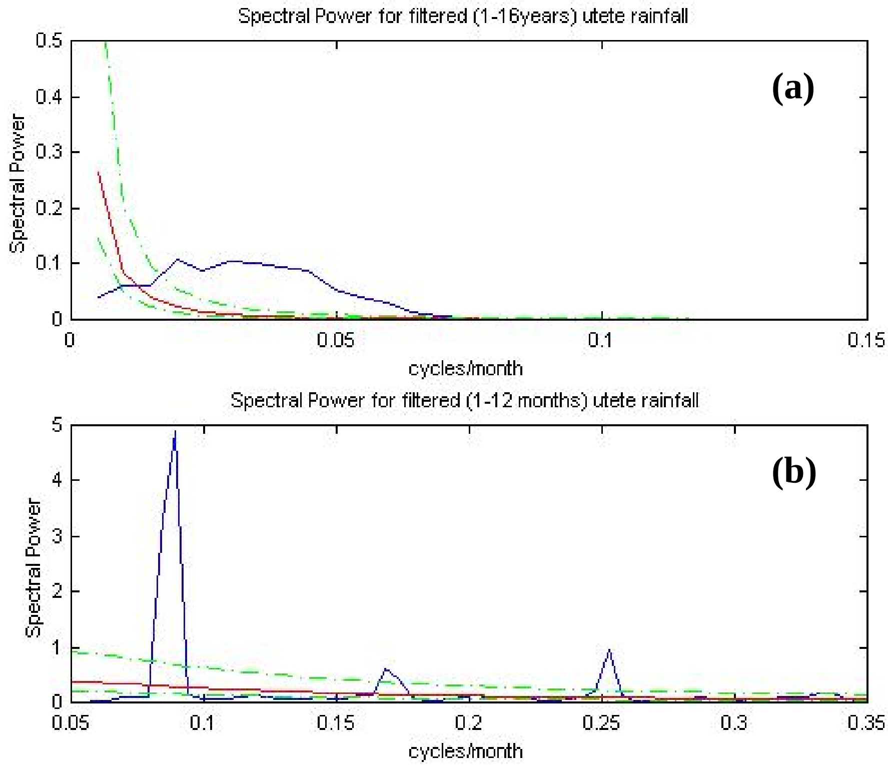


Fig. 4.5. Low (a) and high (b) frequency spectral bands of the filtered (1-16 years) and 1-12 months, respectively rainfall spectrum for Utete.

4.4 Flood characteristics of the Rufiji

Important flood characteristics of Rufiji floods have been discussed by Hafslund (1980) and Hamerlynck and Duvail (in prep.). The major characteristics are as presented in Fig. 4.6 which consist of a 29 year record (from 1957 to 1984) of the flood discharge data. The data show shows the discharges of the two tributaries, namely Kilombero and Luwegu. The discharges from Kilombero tributary are characterized by regular flood peaks which are generally beneficial. The discharges from Luwegu tributary are on the other hand irregular and often of very high magnitude. Most of the early floods (January flood), which are often destructive comes from Luwegu. The regular non-destructive character of the Kilombero floods is attributed by the fact that, the Kilombero drains the still well forested highlands along the western escarpment and flows through a substantial floodplain with braided channels so that there is a great opportunity for the floods to be attenuated before the Kilombero enters a much narrower bed at Shughuli falls (Hamerlynck, Personal communication). Not much is presently known about Luwegu river, which drains about 14% of the basin, as there are neither rain gauges, nor stageboards in its basin. Hamerlynck (personal communication) point out that even the 18% estimated flow from this tributary is an ‘educated guess’ calculated from the estimated flow at Stiegler’s Gorge, minus the known flows of the Kilombero at Ifakara and the known releases from Mtera (for the Great Ruaha river). The presented results show that, along with the option of regulating the floods by river impoundment at Stiegler's dam, another alternative is taming (controlling) the Luwegu which is responsible for most destructive floods.

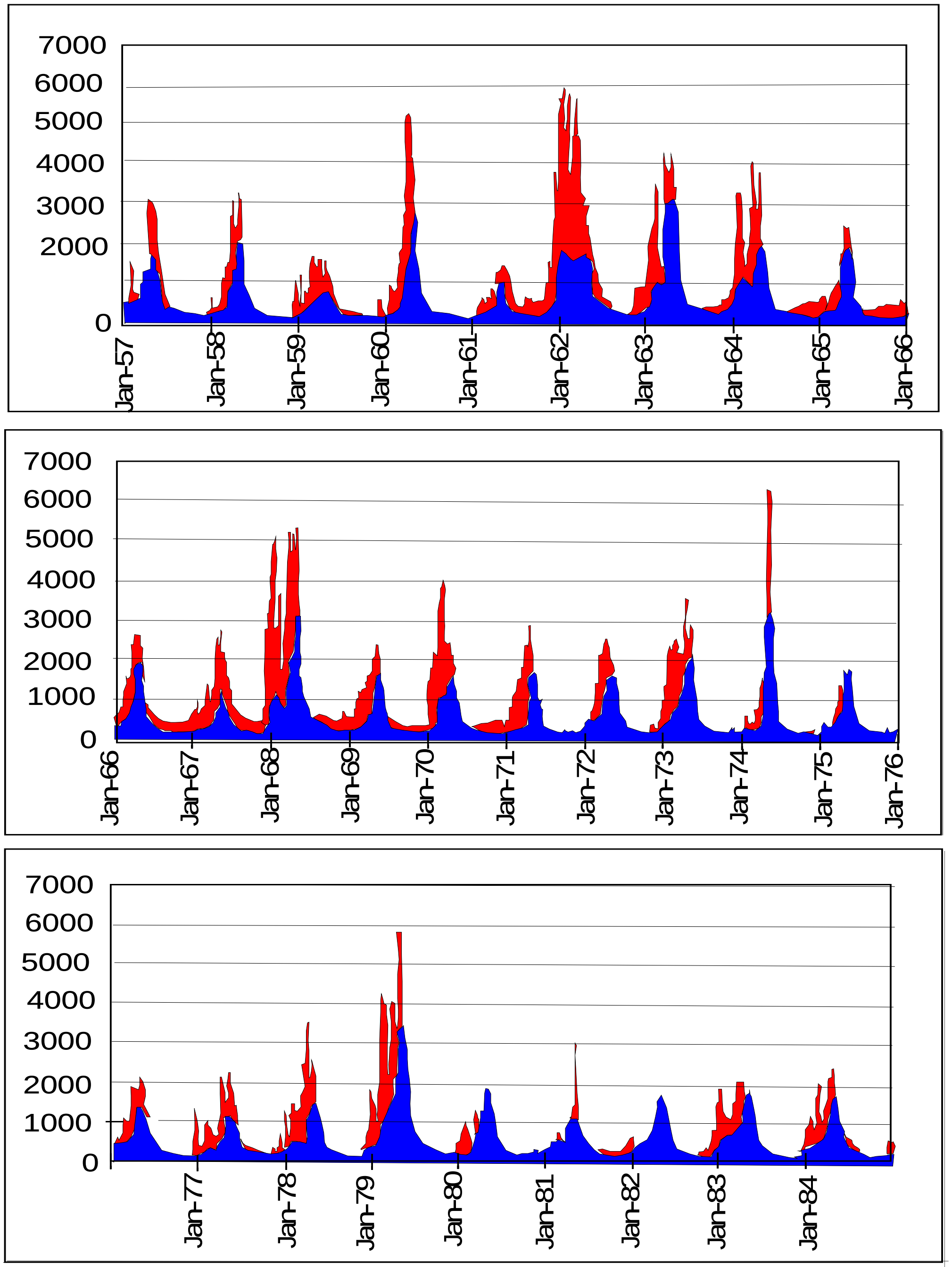


Fig 4.6. Hydrograph of the Rufiji river between 1957 and 1985 (flow in cumecs). The contribution of the Kilombero tributary are shown in blue, characterized by regular fluxes with late flood (April) peaks (1000 – 3000). The contribution of the Luwegu tributary are shown in red, characterized by irregular early (January – February) flood peaks (2000-4000 cumecs). Source (Hamerlynk and Duvail, in prep.)

4.5. Fitting of the long-term rainfall pattern with other climatic models

In recognition of the current increasing rate of global warming due to green house effects development of climatic change scenarios have been an interesting theme of research. In the case of Tanzania, the existing climate change scenarios have been discussed by Mwandosya et al (1998). In this model, the climate change scenarios compare baseline climate with the climate that could be expected if anthropogenic greenhouse gases in the atmosphere increased to twice the baseline concentration (which is projected to take place at the beginning of the next century), and the associated changes in temperature and rainfall. The model suggests an increase in temperature of between 2.5 – 4.5^{o}C under doubling effect of CO_2 throughout the country. The model also suggest a decrease in the amount of rainfall of up to 15% in the central, southern and south western sectors of the country and a decrease of up to 10% in the long rains season in the eastern bimodal sector. The remaining sectors would have rainfall increases ranging from nil to 45%. The Rufiji basin (Upper and Lower) in general lies within the sector, which is projected to be associated with an increase in rainfall.

In the present study trend analyses have been conducted in our historical rainfall data to investigate whether they reveal increasing trends. The trends indicated for two stations from Upper Rufiji (Mahenge and Ifakara) are presented in Fig. 4.6. The results of other stations are as summarized in Table 8. With the exception of Kilombero (which indicate a constant trend) the other two stations suggest an increasing rainfall trends. There was no consistent trend indicated by the stations from the Lower Rufiji. Increasing rainfall trends are also reported in the upper catchments rivers Tana and Sabaki in Kenya (Kitheka et al, 2004). The increasing rainfall trends in the lower Rufiji catchment will ultimately give rise to higher flood magnitude.

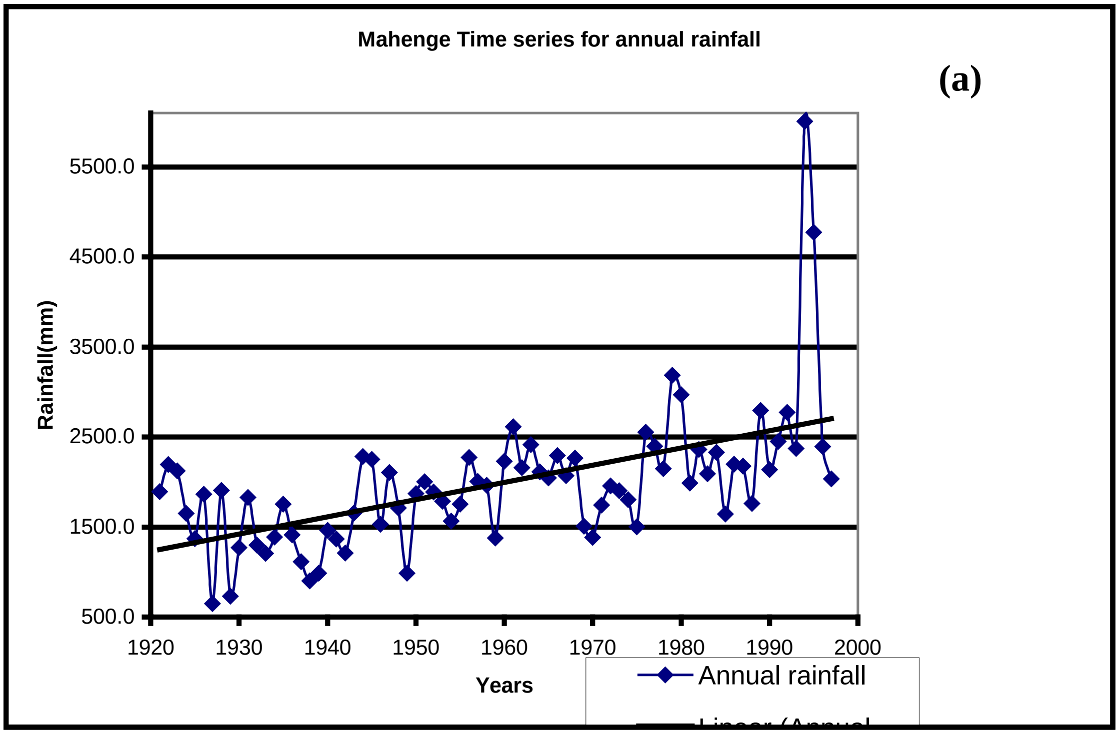
Table 4.6: Summary of analyses of rainfall trends

Station	**Rainfall trend**
Ifakara	Increasing
Mahenge	Increasing
Kilombero	Constant
Stiegler’s Gorge	Decreasing
Kingupira	Increasing
Utete	Constant

The long-term trend of the Rufiji river floods have been discussed by Savile (1945), Bantje (1979) and Ochieng (2002). These studies reveal that prior to 1935 serious floods with major crop damage occurred only once in every 12 – 15 years. Recorded serious floods before 1935 occurred in 1875, 1890, 1905, 1917 and 1930. After 1935, serious floods with damaging effects to crops occurred at a much higher frequency (1936, 1940, 1942, 1944, 1945, 1956, 1958, 1959, 1962, 1963, 1964, 1968, 1972, 1974, 1979 etc). Savile (1945) who was the first to observe this pattern used the existing rainfall records (prior to 1945) and found no evidence of increased rainfall. He therefore concluded that the cause must be increased run-off, which was also associated with the occurrence of sharper flood peaks (more rapid rise and fall of water). The increased run-off was attributed to the changes in the land use pattern on the Upper Rufiji Catchment, such as deforestation due to increased agriculture. Thus, it can be concluded that the Lower Rufiji river catchment will potentially face the threats of more floods, which will be influenced by the increasing rainfall in the Upper Rufiji catchment as well as the anthropogenic pressure.

Elevation atmospheric CO2 levels is expected to induce profound increase in global temperatures (IPCC, 2001), which will be accompanied by global sea level rise. The Intergovernmental Panel on Climate Change (IPCC) has predicted that sea level will rise to between 20 and 80 cm over the next century (IPCC, 2001). In the case of Rufiji, it has been predicted that atmospheric doubling of the CO2 level which is expected during the next century will give rise to increased rainfall as well as sea level rise (Mwandosya et al., 2001). The effects of the projected sea level rise, increase in rainfall and flood events in Rufiji have been discussed by Mwandosya et al. (2001) and Mgaya (2004). The likely response of mangrove to rising sea levels depends upon a variety of factors (Mgaya, 2004). The relative rate of sea level rise and sedimentation will determine the local change in water depth (Mgaya, 2004). If for instance, sedimentation rates (due to flooding) exceed sea level rise rates, the mangrove area may expand seaward. On the other hand if the sea level rise outpace the sedimentation rate, the mangrove area would have to retreat towards the land. Increased rainfall is expected to suppress the seawater salinity intrusion, thereby resulting in retreating of the mangrove seawards. Thus, whether mangrove forest will advance landwards or retreat towards the sea, this will be determined by the net balance between the three discussed climatic agents, rainfall, sea level rise and floods.

Mangroves are envisaged as integral part of the coastal seascape comprising coral reefs, sea grasses and mangroves (Mgaya, 2004), so that the health of one component of the seascape depends on how the other components of the seascape respond to climatic changes. Rising sea surface temperatures have led to massive coral bleaching events and mass mortality of corals reefs in many places, including the corals in the Mafia Marine Park, Tanzania (Obura, 2002, Muhando, 1998, 1999, 2002, 2003a, 2003b, Muhando and Mohammed, 2002). The projected future rise in global temperature is therefore expected to cause massive coral bleaching and mass mortality of corals. This will have profound impacts not only on the corals, but also on the mangroves, which are part of the seascape. Increased flooding events might also give rise to higher level of siltation of fine sediments offshore, with accompanied detrimental effects to the coral reefs in the Mafia Marine Park. This would similarly affect the mangroves.



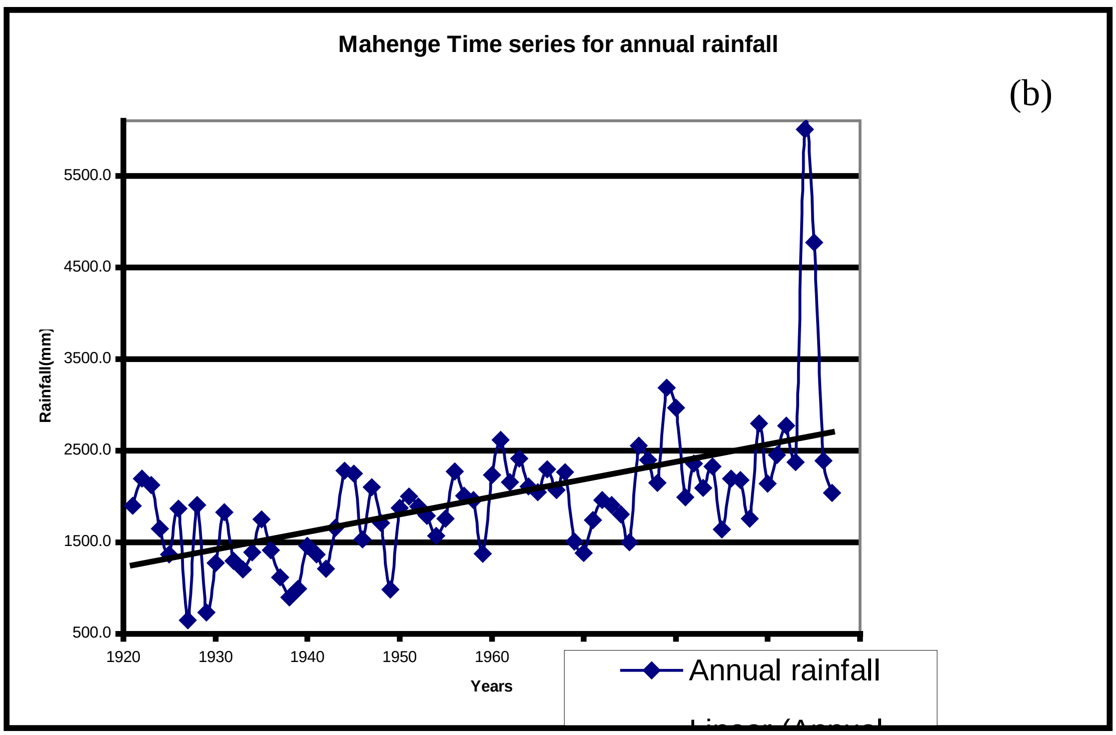


Fig. 4.7. Estimated long-term linear rainfall trends for Mahenge (a) and Ifakara (b).

PART 5: QUANTIFICATION OF WATER ABSTRATION AND LANDUSE CHANGES IN LOWER RUFIJI CATCHMENT

Y.W. Shaghude, A.L. Lobora and J.S. Mayunga

5.1 Water abstraction pattern

According to the statistics available at the District water Office, per capita daily domestic per water consumption is estimated at 30 litres, which gives an average of per capita annual consumption of 10.97 m^3. Thus (using the population statistics for the year 2002; 203,000) the present domestic annual consumption of water is estimated at 2,226,910 m^3. On the basis of the expected future demographic changes (Section 2.1)), estimated domestic water demand during 2020 and 2050 would be 3,071,600 and 4,058,900 m^3.respectively. According to the information from the Coast Region Water Engineer's office the majority of the rural population in Rufiji district get their domestic demand from shallow wells or directly from the river and the existing natural lakes. There exist 33 pumped water schemes in Rufiji district but only 9 of them are currently functioning. The National Policy and overall objectives of the Water Sector in Tanzania is to provide safe and clean water to the whole population within a distance of not more than 400 metres. Increased pumped water schemes are therefore expected to meet the increasing water demand for the rural population in Lower Rufiji catchment.

Recent study on water consumption trends in Tanzania (Mujwahuzi, 2003) show that while the mean per capita use of water in piped water schemes has declined from 1960's to 1990's from 144.8 to 80.2 litres, the mean water consumption in the un-piped water schemes has increased from 13.5 to 18.6 litres during the same period. The mean per capita water consumption in Lower Rufiji is therefore significantly higher than the present mean per capita water consumption in the country for the un-piped water schemes, suggesting that water availability is not a critical problem. The future plan to extend the piped water services is expected to increase the water consumption pattern to levels which would be more than two times higher than the projected levels given above.

5.2 Future planned irrigation projects in the Lower Rufiji floodplain

In recognition of the existing agriculture potential of the Lower Rufiji floodplain and delta and the historical problems caused by the wild floods of Rufiji river, the Rufiji Basin Development Authority (RUBADA), which was vested with the responsibility of promoting, coordinating and facilitating sustainable and balanced long-term ecological and socio-economic development activities in the Rufiji Basin conducted feasibility study to investigate the future irrigation potential of the floodplain and the delta.. On the basis of the conducted study, the floodplain and delta was delineated into 9 development blocks and three different development scenarios were formulated:

Scenario 1: Present situation without Stieg'lers Gorge dam

Under this scenario, the existing natural regime of wild flooding of the river would continue.

Scenario 2: With Stiegler's Gorge dam as designed

Under this scenario, Stiegler's Gorge dam would be operated for power and partial flood control as proposed by Hafslund (1980). This implies a significant reduction in both the present magnitude and the frequency of floods.

Scenario 3: Stiegler's Gorge dam operated for optimum flood protection.

Under this scenario, the dam will be operated to give more flood protection than scenario 2

Under all the three scenarios, flood protection works in the form of earth fill bunds have been proposed. The bund height and hence cost would depend on the expected frequency and cost of flood damage. Scenario 1 would therefore have the highest protection bunds. Scenario 2 would have reduced height of flood protection bunds due to the effect of the Stiegler's Gorge dam in reducing the size of the flood downstream. Scenario 3 would have further reduction of the bund heights. A total of 86,000 ha was considered, but this was reduced to 65,000 ha after omitting the least economic areas within the earmarked blocks.

5.3 Quantification of water abstraction under future irrigation development

In order to assess the future feasibility of developing the large scale irrigation on the floodplain and the delta, a pilot farm which has a net area of about 50 ha has been developed at Segeni, about 5 km south of Ikwiriri town (Fig. 1.3). During our Field trip to Rufiji, the pilot farm at Segeni was visited. The farm is maintained by three pumps, two of which are 25 Hp while the third pump is a 16 Hp. Most of the water to the farm comes from Ruwe lake via Mbunju river. Another supplementary potential source of water is from Ube lake. Our study have attempted to use the existing water consumption pattern at Segeni pilot farm to estimate the future water demand for the planned irrigation blocks of the Lower Rufiji floodplain.

Rice being the staple food for most of the people of Lower Rufiji floodplain, it is considered to be the main crop under the planned irrigation development, but other crops such as maize, groundnuts and cotton have also been earmarked as supplementary crops. Here we use the water requirements for rice (whose water demand is higher than any other crop) to estimate the maximum water requirements for the planned irrigation developments. The existing pilot farm at Segeni reveal that the average water demand for a single irrigation of a rice farm is about 700 m^3 per ha. Thus, a single irrigation of 65,000 ha of the net farmland in the Rufiji Lower floodplain would need about 45.5million m^3 (45.5M m^3). Assuming an irrigation frequency of 3 times per season, this would need about 136.5M m^3 of water. This is the maximum amount of water that would be abstracted from Rufiji river per year to sustain the future planned irrigation on the floodplain. However, the water demand for other crops such as maize, groundnuts and cotton is lower than for rice, the actual amount of water needed would be lower than the projected 136.5M m^3.

5.4 Quantification of landuse changes in Lower Rufiji catchment

When the present study was being formulated, our original intention was to use remote sensing satellite approach to estimate the pattern and magnitude of landuse changes in the Lower Rufiji catchment. However, the stage of literature searching at Tanzania Coastal Management Partnership (TCMP) and Rufiji Environment Management Project (REMP) which holds a good number of literature used in this study it became known to us that another contemporary study (Wang et al, in press) on the area using the same approach was going on. Since the other study was already at an advanced stage we opted to use the result of this study instead of duplicating the same information. However, for the sake of our study we decided to use few sets of aerial photographs to acquire additional independent information over the study area. Here we report the results of the two studies.

5.4.1 Adopted methodology

The presented study used 18 aerial photographs obtained from the National Department of Mapping Division. The 18 photographs analysed were selected from three distinct zones of the Lower Rufiji Catchment, ranging from the Lower part of the floodplain going downstream to the outer part of the delta. (Fig. 1.3). The three zones are designated as A, B and C. Analyses of the aerial photo used a methodology consisting of four main steps: 1- Visual interpretation of the aerial photographs to produce landuse/landcover maps, 2- Creation of digital database, 3- Landuse/landcover area calculation and 4- Landuse/landcover replacement (succession) analysis. The four steps are diagrammatically shown in Fig. 5.1.

Step 1: Visual interpretation of aerial photographs

An experienced cartographer at the Institutes of Resources Assessment (IRA), of the university of Dar es salaam, did the Visual interpretation of the three sets of aerial photographs of the study area. The final output was the landuse /land cover maps of the area with the following dominant Cultivation, Cultivation with Bush, Open Bush land, Dense Woodland, Grassland, Bushed Grassland, Bare/Sand/Mud, Mangrove Forest, and Dense Bush land. For the purpose of this study each land use / land cover for each area (Area-A, Area-B and Area-C) was assigned a code to easy the analysis process (See Table 1, 2 and 3). The output of the visual interpretation (the hard copy maps) were then taken to the GIS Unit, at the Centre for Information and Communication Technology (CICT) at the University College of Lands and Architectural Studies (UCLAS) where they were further processed.

Step 2: Creation of digital database

The hardcopy maps of the visual analysed aerial photographs were first converted into digital database, using two Geographic Information System (GIS) softwares, namely; Integrated Land and Water Information Systems (ILWIS 3.2) and the ArcView GIS 3.2. The whole process involved, scanning of the image, followed by georeferencing the image and finally actual digitization of the image using the on screen digitization technique. The final output was a vector land use /land cover database of the three Zones (A, B and C).

Step 3: **Rasterization and cross operations**

The output from step 3 were rasterized to obtain the raster database for the computation of the areas with ILWIS software. Cross operations were performed between two sets of Landuse/landcover maps (1977 and 1999) to obtain a quantified overview of the type of change.

Step 4: Area calculation of the land use/land cover

Using the raster database generated, the area coverage of each land use/land cover class in 1977and 1999 was computed and expressed in Ha units. From the raster maps of each Zone (A, B and C) and each year the attribute table showing the number of pixels for each Landuse/landcover class and the total area for each class in square meter (m^2) was produced. Using the column operation function, the area coverage in the respective Landuse/landcover classes was calculated.

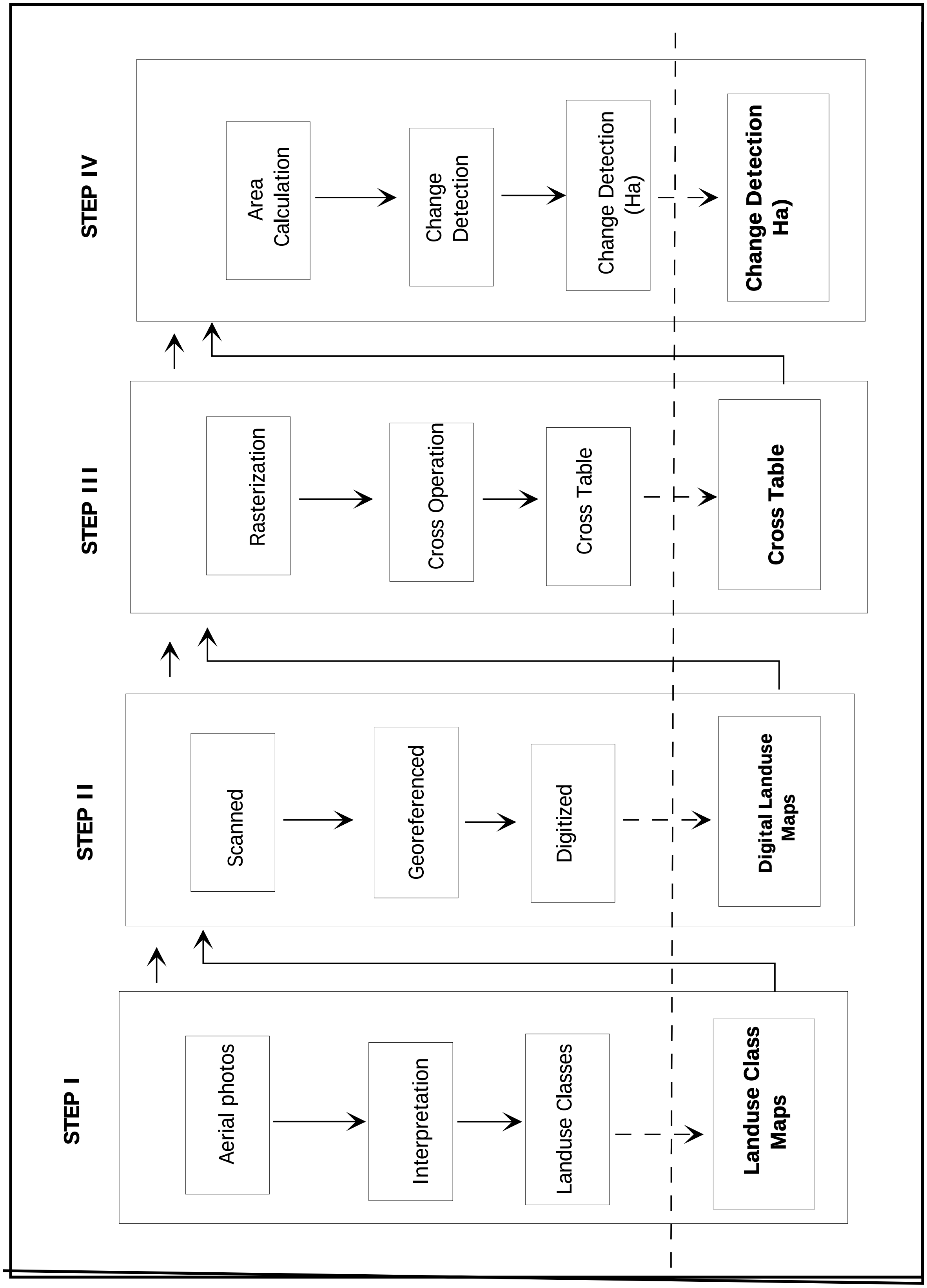


Fig. 5.1 Methodological flow chart used during the present the aerial photo analyses.

Map 2: Landuse/Landcover 1977 (Area - A)

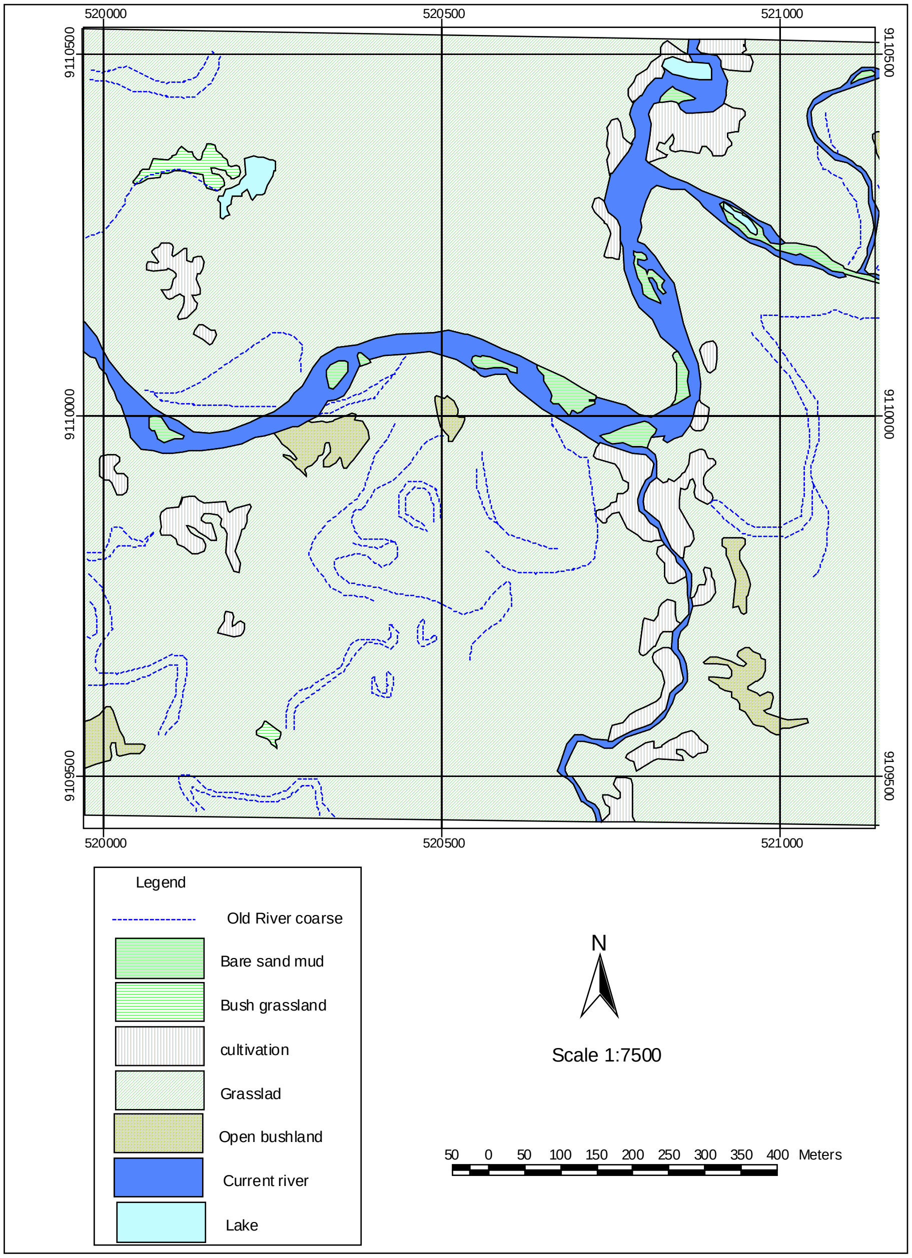


Fig. 5.2. Map showing the existing Landuse/landcover classes in 1977 for zone A.

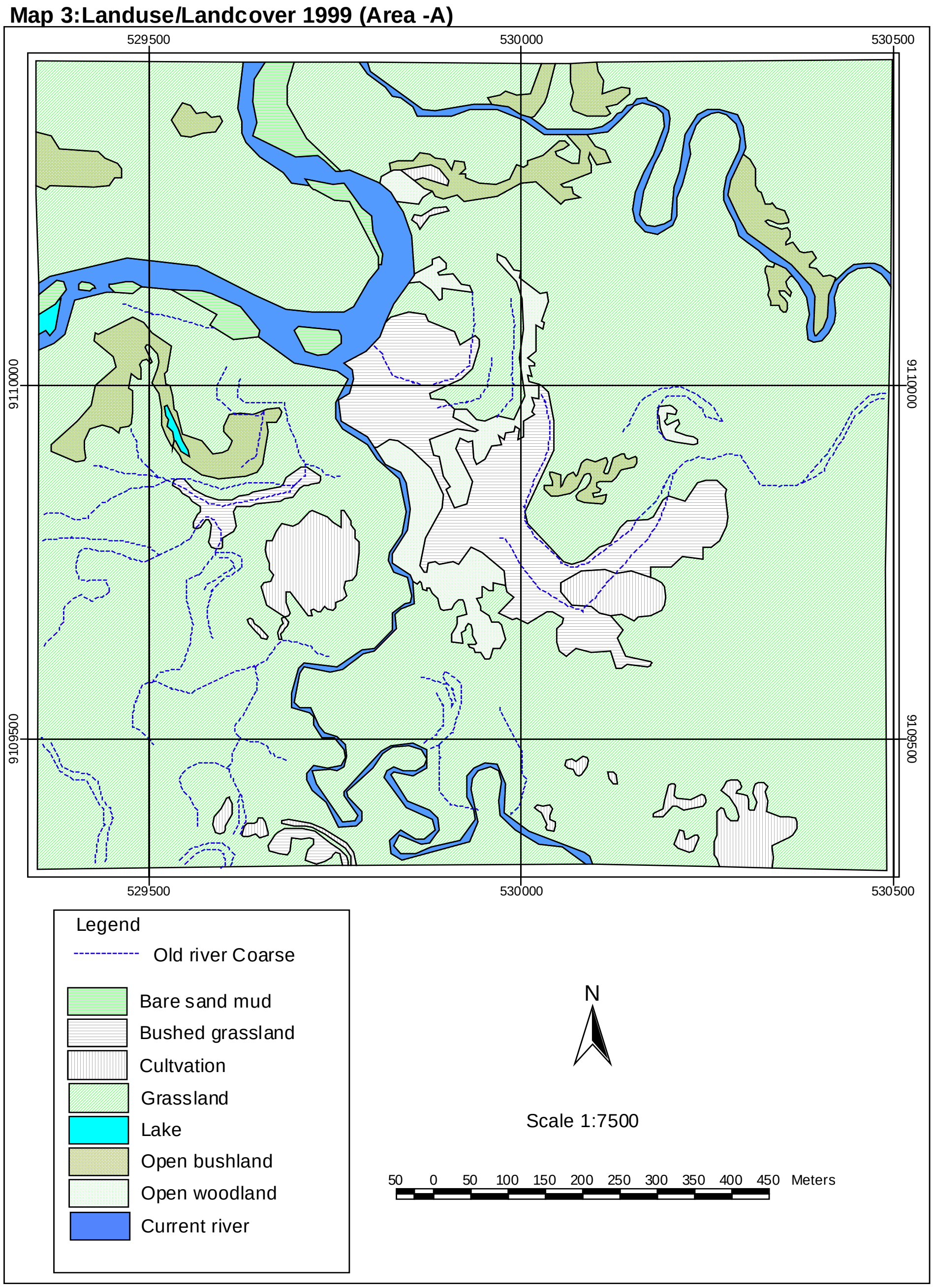


Fig. 5.3. Map showing the existing Landuse/landcover classes in 1999 for zone A.

Map 4:Landuse/Landcover 1977 (Area - B)

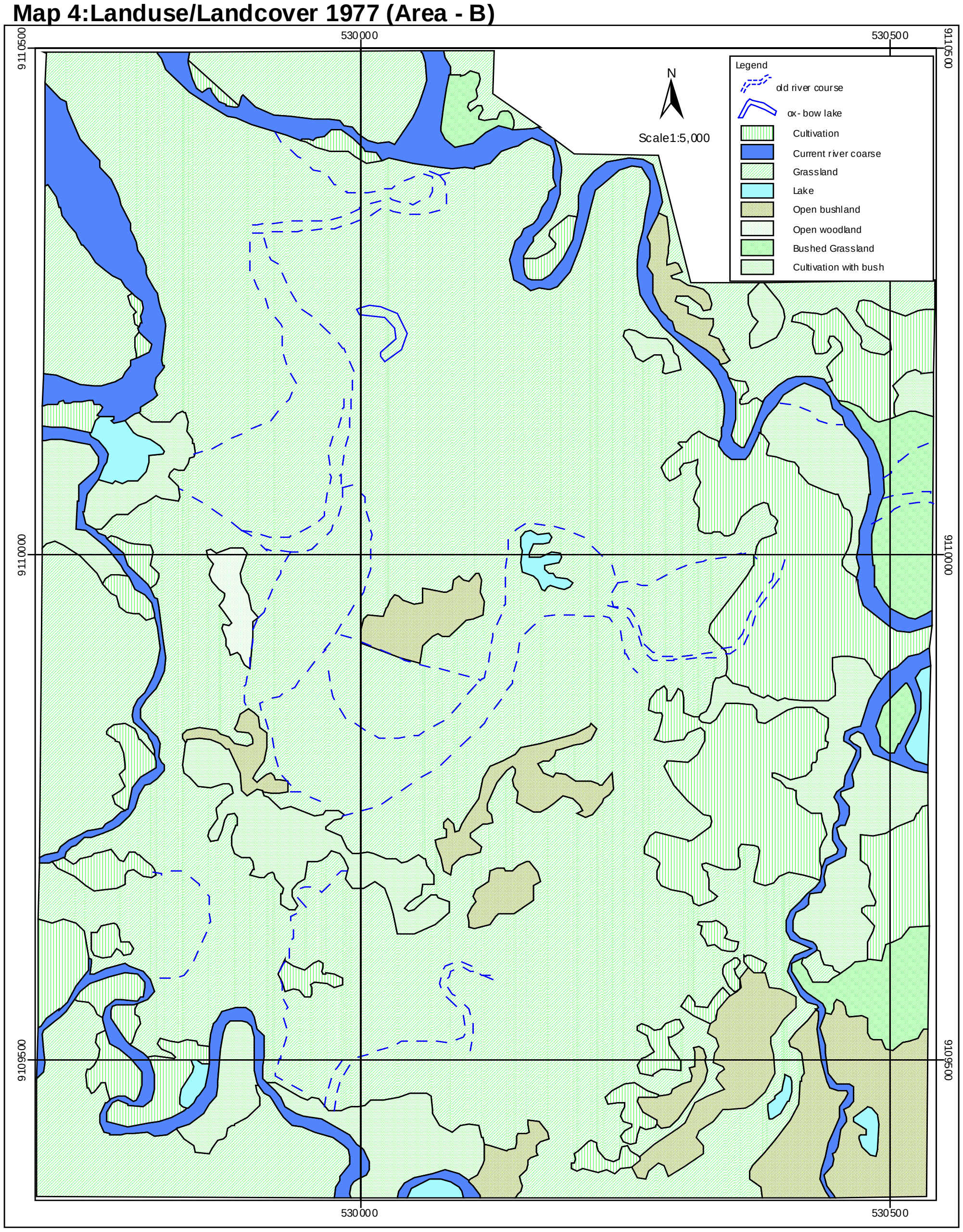


Fig. 5.4. Map showing the existing Landuse/landcover classes in 1977 for zone B.

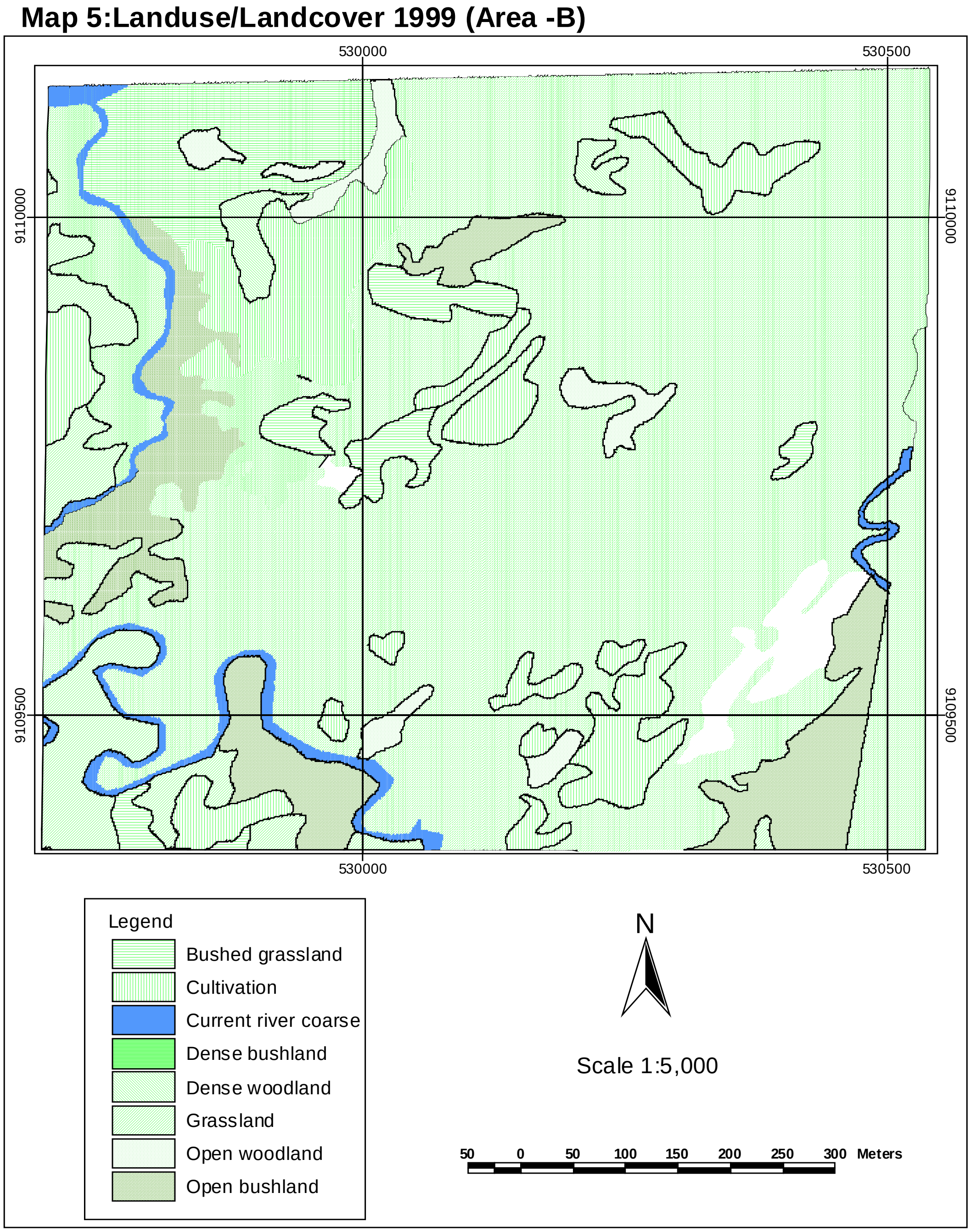


Fig.5.5. Map showing the existing Landuse/landcover classes in 1999 for zone B.

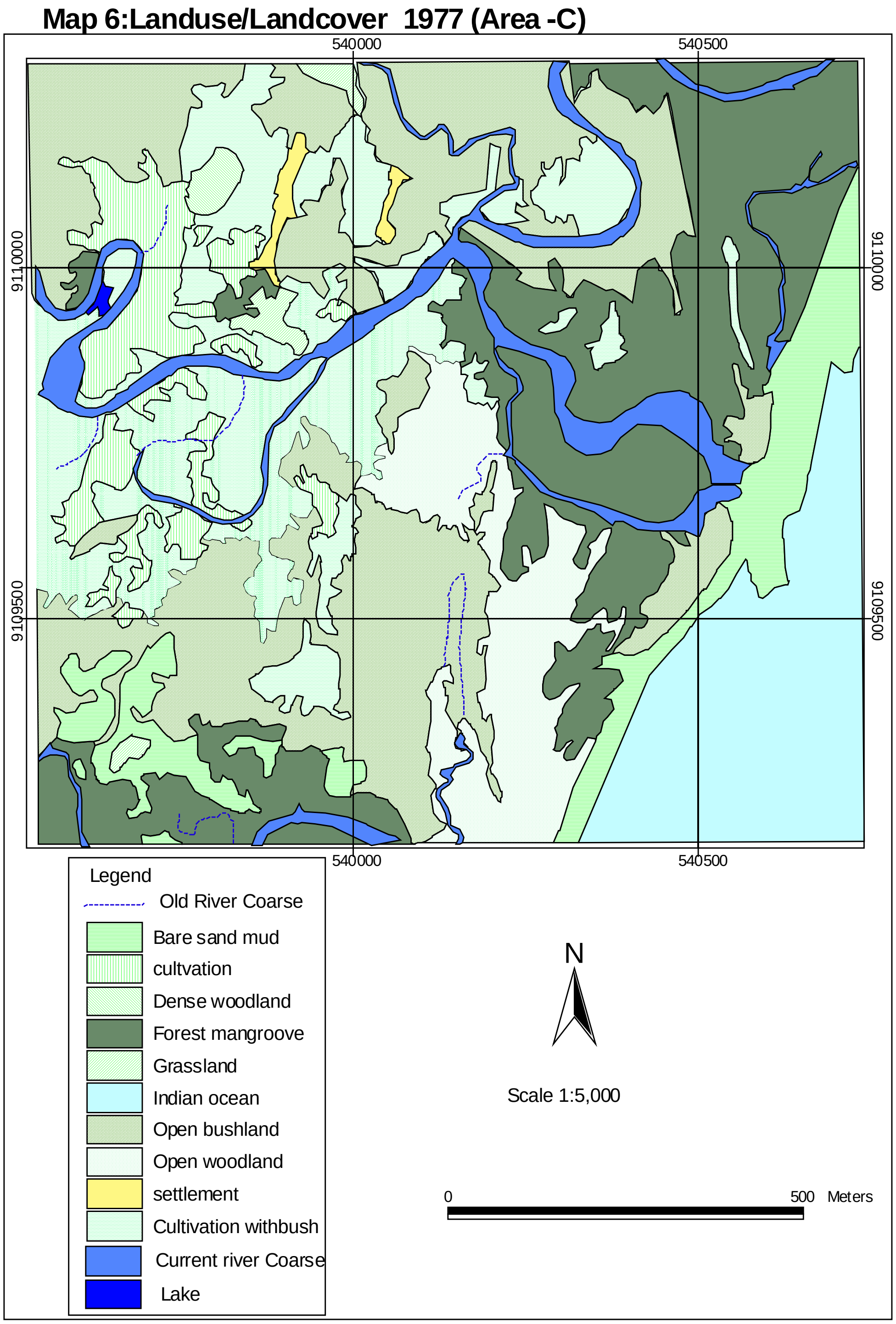


Fig. 5.6. Map showing the existing Landuse/landcover classes in 1977 for zone C.

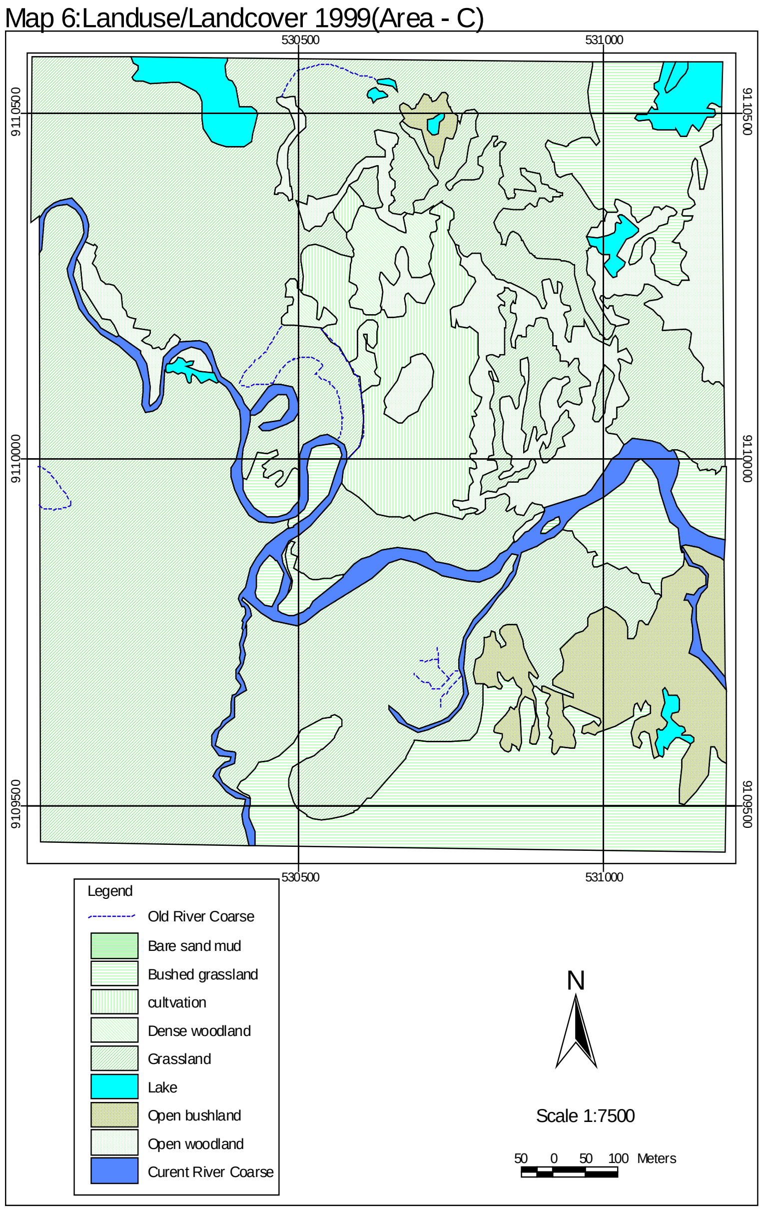


Fig. 5.7. Map showing the existing Landuse/landcover classes in 1999 for zone C.

5.4.2 Results

The main landuse/landcover types (and the corresponding codes used) in the three zones investigated for the two sets of the aerial photographs are presented in Tables 5.1 to 5.3. Using the raster database generated the computed area coverage of the different landuse/landcover classes are presented in Tables 5.4-5.6. The Tables express the size of each landuse class in ha and also as a percentage of the total landuse classes in a given Zone. In Zone, A which is on the Lower parts of the floodplain, grassland is the most dominant landuse/landcover class. The results show that this landuse type decreased from 70.22 to 54.92 ha between 1977 and 1999. Open Bush land increased from 1.6 to 4.9 ha. Bushed grassland increased from 0.1 to 7.6 ha within the same period, while the area covered by the river increased slightly from 4.5 to5.2 ha. The remaining landuse classes are considered less dominant as none of them exceed 5% of the total landuse classes in any of the two time limits.

In Zone B, which is part of the outer delta, grassland represent more than 60% of the total landuse classes, but it shows only slight changes between 1977 and 1999. This class decreased slightly from 41.2 ha to 39.0 ha. Open Bush land increased from 2.8 to 5.7 ha, while Bushed grassland increased from 1.5 to 4.6 ha. Cultivated land decreased from 8.0 to 6.5 ha. Cultivation with bush decreased from 6.8 to zero. The remaining landuse classes are generally insignificant.

In Zone C, Open Bush land decreased from 21.4 to 5.4 ha, while cultivation with bush (18.1 ha in 1977) is completely replaced with other landuse classes from. Bushed grassland (a new class in 1999) increases from zero to 13.8 ha. Open woodland increased from 3.8 to 5.7, while cultivated land decreased from 6.5 to 4.9 ha. The remaining landuse changes are again insignificant.

Table 5.1: The main Land use/Land cover Class in 1977 and 1999 in Zone A

SET I: ZONE – A			
Code	**Land use/cover Class (1977)**	**Code**	**Land use/cover Class (1999)**
OB	Open Bush land	OB	Open Bush land
G	Grassland	G	Grassland
BG	Bushed Grassland	BG	Bushed Grassland
C	Cultivated land	C	Cultivated land
BSM	Bare/Sand/Mud	BSM	Bare/Sand/Mud
R	River	R	River
OL	Oxbow Lake	OL	Oxbow Lake

Table 5.2: The main Land use/Land cover Class in1977 and 1999 in Zone B

SET II: ZONE – B			
Code	**Land use/cover Class (1977)**	**Code**	**Land use/cover Class (1999)**
OB	Open Bush land	OB	Open Bush land
OW	Open woodland	OB	Open Bush land
G	Grassland	G	Grassland
BG	Bushed Grassland	BG	Bushed Grassland
C	Cultivated land	C	Cultivated land
CW	Cultivation with Bush	DW	Dense woodland
R	River	BSM	Bare/Sand/Mud
OL	Oxbow Lake	R	River
		OL	Oxbow Lake

Table 5.3: The main Land use/Land cover Class in 1977 and 1999 in Zone C

SET III: ZONE – C			
Code	**Land use/cover Class (1977)**	**Code**	**Land use/cover Class (1999)**
OB	Open Bush land	OB	Open Bush land
OW	Open wood land	OW	Open woodland
G	Grassland	G	Grassland
BG	Bushed Grassland	BG	Bushed Grassland
DW	Dense woodland	DW	Dense woodland
C	Cultivated land	C	Cultivated land
MF	Mangrove Forest	BSM	Bare/Sand/Mud
BSM	Bare/Sand/Mud	R	River
S	Settlement	OL	Oxbow Lake
R	River		
OL	Oxbow Lake		

Table 5.4: The main Land use/Land cover in 1977 and 1999

SET I: ZONE - A							
Code	**Land use/cover Class (1977)**		**%**	**Code**	**Land use/cover Class (1999)**		**%**
OB	Open Bush land	1.58	1.97	OB	Open Bush land	4.88	6.06
G	Grassland	70.22	87.46	G	Grassland	54.92	68.17
BG	Bushed Grassland	0.06	0.07	BG	Bushed Grassland	7.60	9.43
C	Cultivated land	2.80	3.49	C	Cultivated land	2.05	2.54
BSM	Bare/Sand/Mud	1.08	1.35	BSM	Bare/Sand/Mud	1.93	2.40
R	River	4.49	5.59	R	River	5.17	6.40
OL	Oxbow Lake	0.06	0.07	OL	Oxbow Lake	0.19	0.24
				OW	Open Woodland	3.32	4.76
Total		**80.29**	**100.00**	**Total**		**80.06**	**100.00**

Table 5.5: The main Land use/land cover in 1977 and 1999

SET II: AREA - B							
Code	**Land use/cover Class (1977)**	**Ha**	**%**	**Code**	**Land use/cover Class (1999)**	**Ha**	**%**
OB	Open Bush land	2.77	4.40	OB	Open Bush land	5.69	9.03
OW	Open woodland	0.29	0.45	DB	Dense Bush land	2.78	4.42
G	Grassland	41.13	65.32	G	Grassland	39.03	62.00
BG	Bushed Grassland	1.54	2.45	BG	Bushed Grassland	4.63	7.36
C	Cultivated land	8.04	12.77	C	Cultivated land	6.54	10.39
CW	Cultivation with Bush	6.79	10.78	DW	Dense woodland	1.48	2.35
R	River	2.41	3.83	OW	Open woodland	1.34	2.13
				R	River	1.46	2.32
Total		**62.97**	**100.00**			**62.95**	**100.00**

Table 5.6: The main Land use/Land cover in (Ha &%) 1977 and 1999

SET III: AREA - C							
Code	**Land use/cover Class (1977)**	**Ha**	**%**	**Code**	**Land use/cover Class (1999)**	**Ha**	**%**
OB	Open Bush land	21.43	37.23	OB	Open Bush land	5.44	9.46
OW	Open wood land	3.84	6.67	OW	Open woodland	5.70	9.91
G	Grassland	0.13	0.22	G	Grassland	22.78	39.62
CB	Cultivation with bush	18.06	31.38	BG	Bushed Grassland	13.84	24.07
DB	Dense Bush land	0.49	0.89	DW	Dense woodland	0.64	1.12
C	Cultivated land	6.50	11.29	C	Cultivated land	4.89	8.52
MF	Mangrove Forest	2.81	4.88	BSM	Bare/Sand/Mud	0.03	0.05
BSM	Bare/Sand/Mud	0.28	0.49	R	River	3.75	6.52
S	Settlement	0.64	1.10	OL	Oxbow Lake	0.42	0.73
R	River	3.29	5.71				
OL	Oxbow Lake	0.08	0.14				
Total		**57.55**	**100.00**	**Total**		**57.49**	**100.00**

5.4.3 Landuse/landcover replacement succession

The results obtained from the cross operation analyses are presented in Tables 5.7 to 5.10. The results presented gives an insight on the dynamics of the landuse/landcover changes in the investigated area. In the cross tables (Tables 5.7 to 5.10) the unchanged areas are indicated in the diagonal cells. The row cells explain which land use/land cover classes in 1999 in (Ha) replaced the former land use/land cover (loss) in 1977, while the columns describe the new land use/land cover classes in (Ha) established (gains) in 1999. Table 5.7, for instance indicates that, (1.95 ha) of Grassland in 1977 was replaced by cultivation in 1999, and (3.37 ha) of the same grassland class was replaced by open woodland.

From these Tables one can easily see the possible linkage between some of the changes and the socio-economic activities and the natural processes discussed in the previous sections. In Zone A for instance, the replacement of cultivated land by grassland (1.76 ha) might be associated with shifting cultivation which is a common practice in the floodplain agriculture. The same reasoning may apply for the replacement of grassland with cultivated land (1.95). On the other hand the replacement of grassland with Open Bush land (4.35 ha), Bushed grassland (7.02 ha), Open woodland (3.37 ha) might be associated with relatively low human pressure in those sectors, allowing the natural agents such as rainfall and floods to change the ecology. The replacement of the River with grassland (2.25 ha) might be attributed to the natural sedimentation or flood events, which at times change the course of the river.

Similarly in Zone B, the change from Open Bushland to grassland (1.29 ha), Bushed grassland to Open Bushland (0.24 ha), Bushed grassland to grassland (1.21 ha) could possibly be linked with the discussed human pressure on woodland resources due to the increasing demand of firewood. The changes from Cultivated land to Open Bushland (0.42 ha), Cultivated land to Grassland (6.39 ha) and Cultivation with bush to Open Bushland and Cultivation with bush to Grassland (3.94 ha) could possibly be associate with the shifting cultivation practice. Similar reasoning can be extended to zone C. All in all the results show that the system is highly dynamic, where the cited landuse classes succeed one another. While some of the changes are induced by the existing human pressure some of the changes are purely naturally induced. The smaller coverage of the zones A, B and C investigated during the present study does not allow us extrapolate these changes for the entire floodplain and the delta but the results suggest that aerial photographs may be used to quantify the extent of the presented socio-economic dynamics in the area.

Table 5.7: Land use/landcover succession from 1977 to 1999 (in ha) in Zone A

Land Use classes 1977	Land use classes 1999							
	OB	G	BG	C	BSM	OW	R	OL
OB	0.11	0.96	0.03	0.00	0.00	0.43	0.01	0.00
G	4.35	48.22	7.02	1.95	1.13	3.37	2.95	0.19
BG	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
C	0.00	1.76	0.50	0.10	0.08	0.02	0.27	0.00
BSM	0.03	0.43	0.00	0.00	0.13	0.00	0.49	0.00
R	0.12	2.25	0.04	0.00	0.59	0.00	1.43	0.00
OL		0.06	0.00	0.00	0.00	0.00	0.00	0.00
Total (1999)	**4.61**	**53.73**	**7.59**	**2.05**	**1.93**	**3.82**	**5.15**	**0.19**

Table 5. 8: Land use/landcover succession from 1977 to 1999 (in ha) in Zone B

Land use classes 1977	Land use classes 1999								
	OB	G	BG	C	DB	OW	R	DW	OL
OB	0.72	1.29	0.29	0.18	0.03	0.06	0.00	0.19	0.00
OW	0.00	0.00	0.03	0.11	0.00	0.00	0.00	0.15	0.00
G	3.31	24.81	3.35	5.61	1.58	1.26	0.42	0.79	0.00
BG	0.24	1.21	0.00	0.00	0.09	0.00	0.00	0.00	0.00
C	0.42	6.39	0.10	0.58	0.27	0.02	0.26	0.00	0.00
CW	0.64	3.94	0.79	0.06	0.69	0.00	0.32	0.35	0.00
R	0.36	1.40	0.07	0.00	0.12	0.00	0.46	0.00	0.00
Total 1999	**5.69**	**39.04**	**4.63**	**6.54**	**2.78**	**1.34**	**1.46**	**1.48**	**0.00**

Table 5.9: Land use/landcover succession from 1977 to 1999 (in ha) in Zone C

Land use classes 1977	Land use classes 1999								
	OB	G	BG	C	BSM	OW	R	DW	OL
OB	1.47	6.34	7.69	0.85	0.00	3.77	0.42	0.57	0.30
OW	2.52	0.49	0.72	0.00	0.00	0.00	0.06	0.00	0.05
G	0.00	0.04	0.00	0.00	0.00	0.09	0.00	0.00	0.00
DB	0.00	0.00	0.00	0.12	0.00	0.37	0.00	0.00	0.00
C	0.16	4.45	0.37	1.05	0.00	0.04	0.36	0.00	0.07
CB	0.40	10.39	3.04	2.31	0.02	1.13	0.69	0.07	0.00
S	0.00	0.12	0.00	0.30	0.00	0.23	0.00	0.00	0.00
FM	0.81	0.20	1.26	0.26	0.00	0.00	0.28	0.00	0.00
BSM	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00
OL	0.00	0.00	0.03	0.00	0.00	0.00	0.05	0.00	0.00
R	0.09	0.75	0.47	0.00	0.01	0.06	1.89	0.00	0.00
TOTAL 1999	**5.45**	**22.78**	**13.84**	**4.89**	**0.03**	**5.69**	**3.75**	**0.64**	**0.42**

5.4.4 Results of the satellite remote sensing study

The contemporary study (Wang et al, 2003) used satellite remote sensing to investigate the landuse/landcover changes along the coast of Tanzania, including Rufiji District (Lower Rufiji catchment). The associated landuse/landcover changes for Rufiji are summarized in Table 5.10. The results show net losses of all the major landuse/landcover classes during the two time limits (1990 and 2000). Exception to this general trend is the urban class, which have expanded during the two time limits. Here again, the observed negative changes in the landcovers for the bushland, mangrove forest and woodland may be associated with the human activities discussed in the former sections (see part 2).

It should be noted that, Table 4.11 gives quantitative changes for the primary classes, and the detailed quantitative changes at the subclass levels (e,g. Woodland - closed woodland, open woodland, dense woodland; Bushland – open bushland, dense bushland etc.) have generally been masked. It is therefore not easy to see the details on the dynamics on the landuse/landcover changes. However, their study also noted replacements of some landuse/landcover type with other types, namely conversion of open woodland to grassland, conversion from closed or dense woodland into open woodland and woodland with scattered agriculture etc.

Table 5.10 Landuse/landcover changes (expressed in ha) for the Lower Rufiji catchment between 1990 and 2000. Observe that the fourth and fifth rows of the Table gives the net change (negative sign indicating net loss, and positive sign indicating net gain) and the average annual change (rate of change), respectively.

Agriculture		**Bushland**		**Forest/Woodland**		**Mangrove**		**Urban**	
1990	**2000**	**1990**	**2000**	**1990**	**2000**	**1990**	**2000**	**1990**	**2000**
45,863	45,579	209,488	198,102	673,224	630,957	51,121	49,032	2,054	5,292
-284		-11,386		-42,267		-2,089		+3238	
-28		-1,139		-4,227		-209		+324	

Finally our study uses the data presented in Table 5.11 to make projections for total coverage of Bushland, Woodland and Mangrove resources for the year 2020 and 2050, assuming the presented annual rates of changes (Fig. 5.8). The presented graph of Fig. 5.8 show that by the year 2050 the land coverage of the Bushland resource will be about 71% of the present coverage, while that of the Woodland resource would be about 67% of the present coverage. As for the Mangrove forest, the presented graph show that spatial coverage of this resource will be about 79% of the present coverage. The results further show that of the three resources, the Woodland resource is diminishing at the fastest rate, while the Mangrove forest are diminishing at the slowest rate. The slower rate of disappearance of the mangrove resource compared to other resources could possibly be to the Rufiji Mangrove Management Plan which was instituted since 1991. Wagner (2003) reports that the Rufiji mangrove forest is in the best health with respect to highest species diversity, height, and density of mature trees. Wang et al (in press) report similar finding, observing that the Rufiji mangrove forest are diminishing at a slower rate compared to other mangrove forests in coastal Tanzania. It is hereby suggested that similar legislations be imposed to manage the wood resources in the Bushland and Woodlands of the Lower Rufiji catchment.

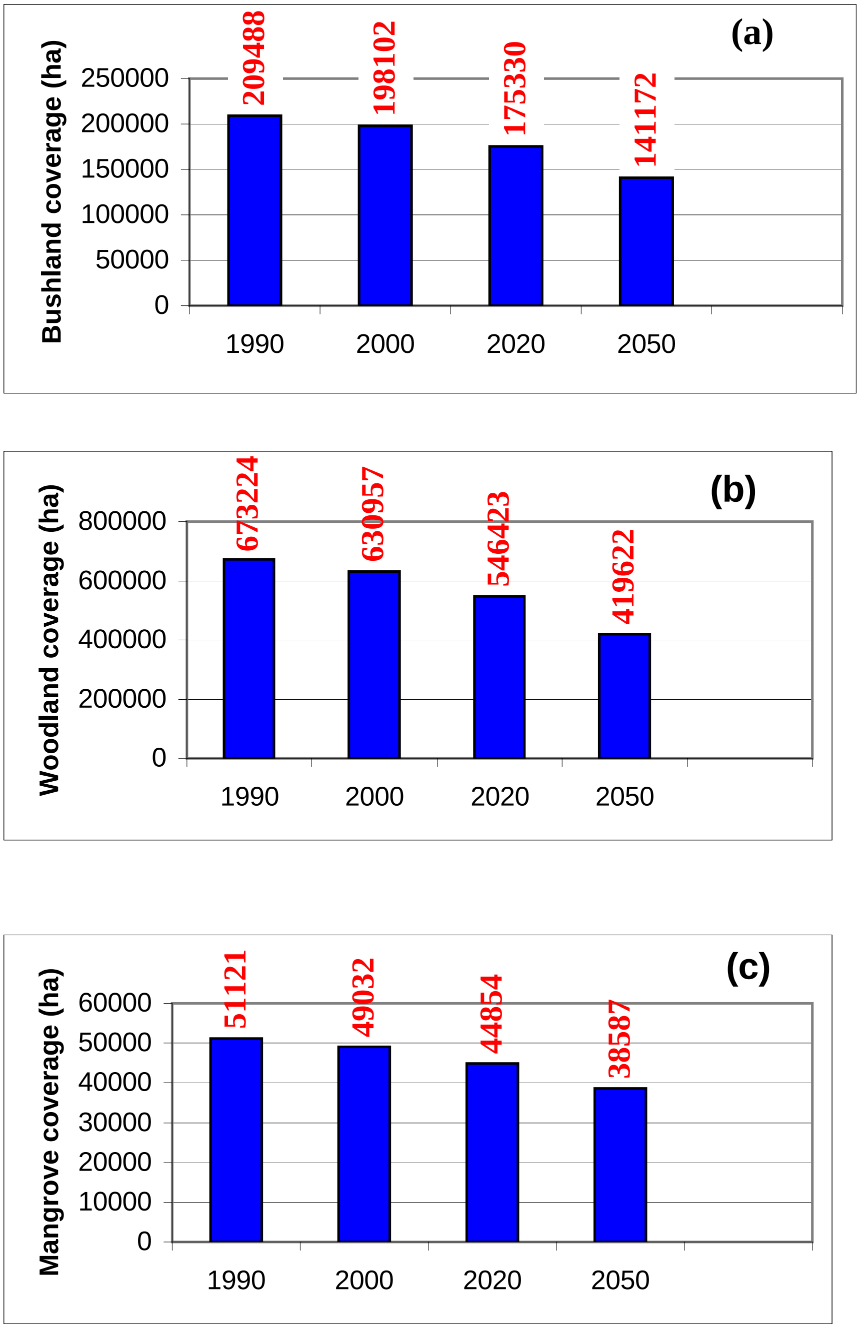


Fig. 5.8. Projected future coverage of the Bushland (a), Woodland (b) and Mangrove resources (c) in Lower Rufiji, based on the rate of changes suggested by the observed changes between 1990 and 2000. Observe that the labels on top of each histogram indicate their respective coverage (expressed in ha).

PART 6: ANTICIPATED POTENTIAL IMPACTS OF THE FUTURE RIVER IMPOUNDMENT AT STIEGLER'S GORGE

Y.W. Shaghude and A.L. Lobora

The proposed future impoundment of the Rufiji at Stiegler's Gorge was planned during the late 1970's. The proposed reservoir was designed to cover approximately 1250 km^2 at high-regulated water level, and 550 km^2 at low regulated water level (euroconsult, 1980a). The difference between high and low regulated water was estimated at 30 m with a typical annual drawdown of 8 metres. The Stiegler's Gorge project has been envisaged as a multipurpose project with several expected long-term benefits of which two were considered to be the most important 1- Its high hydropower potential (2100 MW) would facilitate the pursuit of Tanzania's policy for industrialization and further electrification (Fig. 6.1), which would in a long run enable Tanzania to become less dependent on expensive imported energy, 2- flood control would facilitate agricultural development on the Lower Rufiji flood plain as wild (natural) floods had been posing considerable limitation on the advancement of agriculture during the past (hafslund, 1980). The purpose of this section is to investigate the nature of the expected inter-linkages between the proposed river impoundment, flooding of the Rufiji, people's livelihood and the ecology of Lower Rufiji

6.1 Ecological impacts in the Selous Wildlife Reserve

One of the most significant ecological impact of the planned impoundment of Rufiji river at Stiegler's Gorge ecological will be associated with Selous Wildlife The planned reservoir will impound an area of approximately 1200 km^2 during high water level and 500 km^2 at low water level construction of the reservoir, with a water surface varying from 500 to 1200 km^2 (euroconsult, 1980a) which constitute about 1 to 2.5% of the total estimated area of the Selous Wildlife Reserve (48,000 km^2). Since the future reservoir is located in the inhabited Selous Wildlife reserve, a relatively large a number of animals will have to move out of the area. The new ecological system will be established during and after the filling of the reservoir. During the filling stage, the ecological processes in the reservoir will to a large extent, be determined by the input of degradable biomass in the form of flooded vegetation which puts a heavy demand on the oxygen supply to the water body, e.g stratification (euroconsult, 1980a). The resulting heavy oxygen demand would create anaerobic conditions in the reservoir with negative consequences on the aquatic life downstream of the reservoir. Such a situation would be particularly serious in the case of Stiegler's Gorge reservoir because at all times a certain minimum flow from the reservoir will be needed in the downstream river. No substantial tributary flow is available during most of the year, which might be used to provide sufficient minimum flows or to dilute water of poor quality from the reservoir (euroconsult, 1980a).

The initial period of filling and the water quality attained after filling play an important role in the behaviour of the water quality in the reservoir on the medium and the long term In addition to a new aquatic system, a new terrestrial ecological system will be created which will be concentrated along the shoreline of the reservoir (euroconsult, 1980a). Due to the changed water regime, the vegetation in this area will also change. Wildlife will be attracted to the abundance of drinking water and bathing and the newly created possibilities for grazing. Certain species of animals may be attracted to the new system. The new ecosystem and its potential value to the entire Selous Wildlife Reserve will be controlled by several factors, including cyclic changes in the reservoir, soil composition of the shoreline, etc.

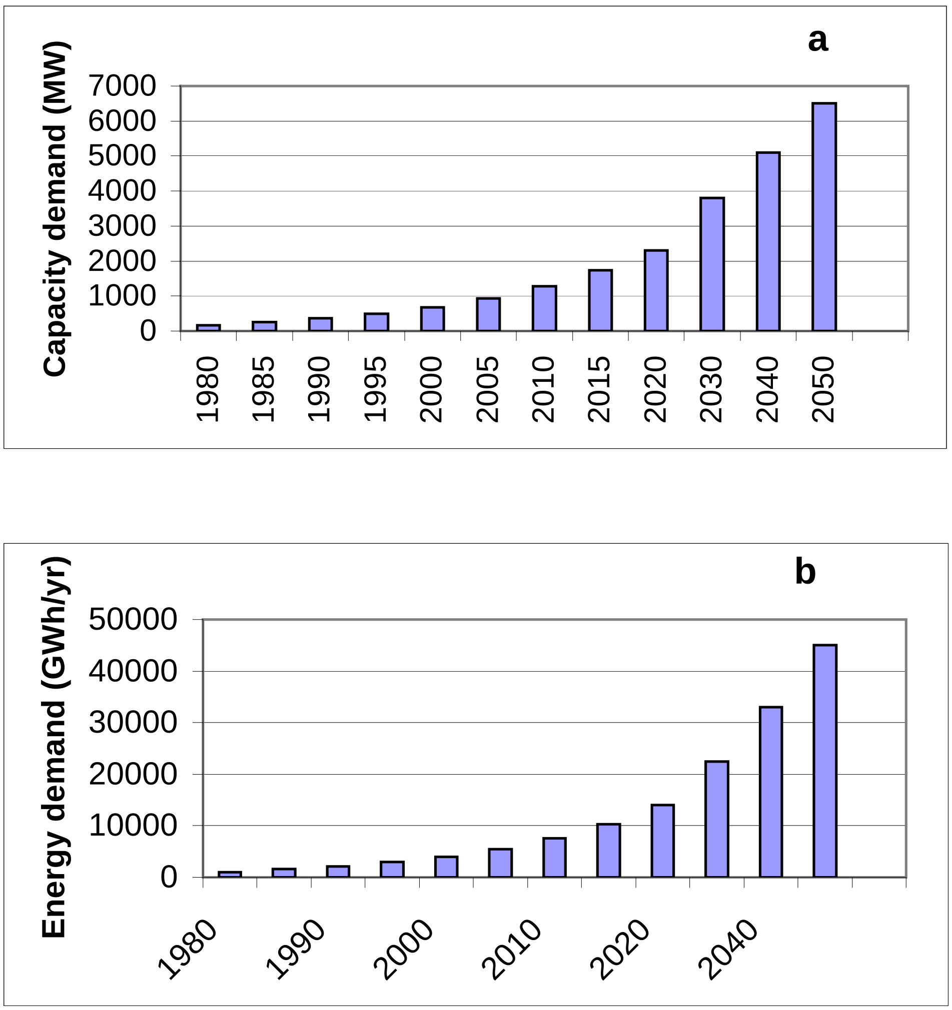


Fig. 6.1. Basic power forecast for extended Grid network in Tanzania
Source: Hafslund (1980).

6.2 Impacts associated with river bed degradation

One of the major physical impacts associated with the proposed river impoundment at Stiegler's Gorge is the problem of "river bed degradation". A well-known consequence of reducing a river system's supply of sediment. The resulting effect is that the lower riverbed equilibrium would change and it would begin to erode its bed. In principle, erosion would continue until a new equilibrium, flatter slope equilibrium corresponding to the new equilibrium is established. (Hafslund, 1980). Conducted studies (e.g. euroconsult, 1980c) have shown that strong degradation of the riverbed will occur. Under the present conditions, the wild flood irrigation in the downstream area require a discharge of at least 2500 m3/s at Stiegler's Gorge for three to four weeks annually. Excessive floods (floods exceeding 3000 m3/s) cause significant damage to crops. The resulting deepening of the main river channel would demand higher controlled irrigation floods with potential negative consequences to both agriculture and fisheries in the downstream areas. Furthermore, ground water levels in the floodplain are likely to fall, which would have direct effects on vegetation and agricultural activities in the floodplain. The total result of such processes is that the present production systems in agriculture and fisheries will after sometime have to be replaced by other systems of production.

Pumped irrigated agriculture has been planned for the long-term future development of the Lower Rufiji flood plain (Mwalyosi, 1982). During our present study a Field visit was conducted to Segeni pilot farm (Fig.1.3). The farm is maintained by three pumps (two 25 Hp pumps and one pump16 Hp pump). The farm is currently owned by the Segeni Farmers Union, consisting of 53 farmers. Our interview to one of the farmers revealed that during the early years of its existence (early 1990's), the farm used to be very productive, yielding optimum production of 40–60 bags of rice per acre. However, in the course of time, the production has fallen to less than 10 bag of rice per acre. Management of the pumps was reported to be one of the major causative factors for the poor yields as the farmers need working capital which is usually higher than they can afford. Thus, in the proposed future mechanized agriculture, if such management issues are not clearly addressed the local farmers will be the final losers.

6.3 Impacts associated with sediment trapping

Another major consequence of the proposed river impoundment at Stiegler's Gorge is associated with sediment trapping in the reservoir. The studies of Hafslund (1980) indicate that most of the course sediments would be trapped in the reservoir and few of the fine minerals and organic particles. Most of the fine minerals and organic particles are expected to pass past the dam to the downstream areas. Trapping of the course sediments is expected to have considerable consequences on the sedimentation pattern on the beach, migration pattern of the meanders and delta distributaries (channels). This will reverse the current pattern of delta and coastal accretion and beach and coastal erosion is expected to start. In Western Africa, damming of the Upper Niger, Benue and Volta rivers has altered the flow reaching the Niger Delta, and local subsidence is proceeding at 25 mm per year (GEO, 2000). In Ghana, construction of the Akosombo dam in 1965 accelerated coastal erosion west of Accra to 6 metres per year, and in Togo and Benin coastal retreat has exceeded 150 metres over the past 20 years (GEO, 2000). This will have negative consequence to the mangrove forest and its associated ecosystem, as its present potential to extend towards the sea will cease. Reduction in mangrove forest and offshore sediment substratum is expected to have associated multipliable effect on fisheries (including shrimp fishery). Reduction of the fine sediments means reduction in the average supply of nutrients to the floodplain and delta. This is expected to have significant consequences to agriculture, delta and offshore ecology. In the absence of nutrients, which used to be brought to the floodplain during the regular flooding of the river, the farmers are expected to use fertilizers to increase the productivity of their farms. The application of fertilizers is not expected to have no associated negative environmental hazards. However, the reduction of fine sediment to the offshore is expected to have positive impacts to the coral reefs as siltation of fine sediments is generally known to have detrimental effects to coral survival (Wagner, 1999).

6.4 Impacts associated with the disappearance of wild flooding

Another major consequence of the proposed river impoundment at Stiegle's is associated with the disappearance of wild flooding. Since one of the primary purposes of the dam is to control floods, once the dam is established, the natural floods are expected to cease (Hafslund, 1980). Natural inundation of the floodplain on seasonal cycles also ensures the long-term sustainability of the lake system, which plays a significant role in fisheries. Controlled floods, which would be used for irrigation when required, have been proposed to substitute the wild floods. The wild floods in the present natural conditions are associated with drastic negative consequences when the timing and the size of the floods are not properly determined (euroconsults, 1980-c). Despite the negative consequences of the wild floods, their positive consequences have far outreaching roles in sustaining the agriculture (see section 4.2) and the floodplain fisheries. Due to the fact that the major purpose of the proposed impoundment is to generate hydropower, there exist a great potential for competition between hydropower and the other secondary purposes of the reservoir. Since fishery is carrying less weight in the design purpose of the project, it is unlikely that excessive controlled irrigation would be allowed. Excessive floods have significant role in the long-term sustainability of the lake system.

6.5 Impacts associated with salt-water intrusion

Another anticipated consequences of the proposed river impoundment at Stiegler's Gorge is related with the salt intrusion from the sea. Under the present natural conditions, the river flow regime varies from a few hundred m^3/s (<500 m^3/s) during the dry season (June December) to peaks of several thousands of m^3/s (>2000 m^3/s) during the rain season. Studies (e.g. VHL, 1979) show that currently the maximum salt intrusion (during the dry season) is up to 40 km from the shoreline It is anticipated that after impoundment of the river by damming the frequency of low flow discharges (during the dry season) will be lower than at present. Reducing the

frequency of low discharges is expected to suppress the salinity intrusion. It is therefore expected that the upstream limit of the salinity intrusion will be lower than at present. This will positively influence the agriculture as most of the crops flourish well under fresh water conditions than under saline conditions. The reduction in salinity intrusion is on the other hand expected to reduce the land coverage of the mangrove forest, and therefore negatively affecting the mangrove ecosystem.

6.6 Impacts associated with water quality

Once the vegetation in the planned reservoir area is inundated it will decompose using oxygen. However, meteorological, physical and hydrological conditions may cause thermal stratification thus preventing oxygen reaching the deeper water layers where decomposition occurs. As a result, anaerobic conditions that are detrimental to aquatic life may occur. The occurrences of such anoxic conditions have been predicted. Flushing the reservoir especially during filling together with selective withdrawal will improve the reservoir water quality. Clearing the vegetation in the planned reservoir area will also improve water quality considerably (Mwalyosi, 1982).

If anaerobic water is discharged through the turbines, the River downstream of the dam will be anaerobic over a considerable distance. Apart from the dissolved oxygen content, the nutrient budget in the downstream area will also be influenced by the reservoir through sedimentation of nutrients attached to suspended solids, use of soluble phosphate by algae, denitrification et *cetera.* As a result the agricultural areas in the flood plain will reserve less nutrients and consequently may require artificial fertilization to compensate for this loss in fertility. Selective withdrawal using an upper gate will probably be the most efficient way of improving the water quality (Mwalyosi, 1982).

6.7 Fishery related impacts

The deeper areas of the reservoir (25m) will remain anaerobic for the first 18 months of the operation and even for the first 3 years, the oxygen concentration will rarely exceed 2mg/l (the threshold for the survival of most fish species). At the surface and within the first weeks, there will always be 6-8mg.0_2/l, which is sufficient for most aquatic life (Mwalyosi, 1982). Detailed study made on this subject (Mwalyosi, 1982) reveal that, the deeper areas (below 20m) will rarely support fish because of lack of food in such pelagic environment. Therefore, the position of withdrawal of water from the reservoir (bottom of surface throughout) is not important as far as fish productivity is concerned. Similarly, the presence of a thermocline at various times of the year will not have major effect on fish. Based on geomorphological characteristics, the nutrient budget, primary productivity as well as the indigenous fish stock, the annual fish catch from the reservoir will amount to 3,700 tones with a bloom peak production of 12,000 tones per year (Mwalyosi, 1982).

In order for fisheries to be maintained at its present production in the lower Rufiji an annual flow of roughly 2500m^3/sec would be essential. Unfortunately, predicted discharges of less than 1000m^3/sec will occur (after completion of the project) in eleven out of twenty years (Mwalyosi, 1982). This together with the expected riverbed degradation will significantly affect riverine fish stocks and fisheries in general. Control of these impacts can be achieved partially in three possible ways: -

(a) To construct protection bunds around development blocks and the River channels to effect direct connection between the latter and the floodplain lakes so as to allow for the necessary recharge of the lakes which are very productive.

(b) To introduce fish farming and develop it in an integrated form with irrigated agriculture.

(c) To improve capture fisheries by introducing modern gear and applying more effective catching methods as part of the integrated short term development.

6.8 Health impacts

The project will have negative effects on the health situation due to the increased potential for disease vectors in the reservoir area especially the potential incidence for schistosomiasis in the future irrigation scheme in the floodplain. Disease vectors in the reservoir can be controlled by maintaining an appropriate reservoir level while in the downstream area they can be controlled by an appropriate release pattern. The potential incidence of schistosomiasis in the future perennial irrigation scheme in the floodplain can be controlled more or less successfully by specific measures i.e. chemicals, specific construction or operating measures (Mwalyosi, 1982).

6.9. Impacts associated with the planned future irrigation developments

The planned irrigation developments is expected to supply sufficient water to sustain the future agriculture on the floodplain which is at present often threatened by floods, particularly the excessive early floods (see section 4.2). This will improve the life standards of people, which in turn will help the people to get rid of the present poverty problem. To a large extent most of the discussed environmental degradation problems such as overexploitation of woodland resources (fuel wood, charcoal and timber) are related to the existing wide spread poverty in the area. Under the existing poverty level most people cannot switch from fuel wood to electricity, although the National electric grid system is within their reach. Also most local people who sell the charcoal to trades from large urban areas, willingly accept being exploited by the charcoal traders who purchase the charcoal at very low prices because the poverty status of the local people deny them of equal bargaining power with the charcoal traders (Kulindwa et al., 2001). Improving the life standard of the people is expected reduce the exploitation of woodland resources for fuel wood as significant number of people would switch from fuel wood to electricity or at least reduce the use of fuel wood. Improving the life standard of people will also give them a better bargaining power in the charcoal trade, with the possibility of making the trade unprofitable for the external traders, which will in turn reduce the existing pressure on the woodland resource. Reducing the pressure on woodland resources will ultimately reduce the emission level of greenhouse gases, which is part of the global environmental problem.

REFERENCES

Agrar-und Hydrotechnic, 1981. Irrigated agricultural Development in the Lower Rufiji Valley: Pre-feasibility study, Final Report for RUBADA.

Bantje, H. 1979. The Rufiji agricultural system: impact of rainfall, flood and settlement. BRALUP Research Paper No. 62.

Bantje, H. 1980. Floods and famines: a study of food shortages in Rufiji district. BRALUP Research Paper No. 63.

Bantje, H. 1981. Ecological and political aspects of agricultural production in the Rufiji valley. Paper for the 1981 annual conference of the Tanzania Agricultural Economics Society.

Bantje, H. 1982. Household characteristics and nutritional status in the Rufiji valley. BRALUP, Research paper No. 72.

Chidumayo, E.N. 1991. Woody biomas structure and utilization for charcoal production in a Zambian miombo woodland. Biological Research Technology 37: 43-52.

Cook, A. 1974. Land use recommendations for Rufiji district. BRALUP Research Report No. 11.

Darwall, W.R.T and Guard, M. 2000. Southern Tanzania, In: McClanahan, T.R., Sheppard, C.R.C and Obura, D.O. (Editors), *Coral Reefs of the Indian Ocean: Their Ecology and Conservation*. Oxford University Press, New York, pp. 131-165.

euroconsult (1980a). Identification study on the ecological impacts of the Stiegler's Gorge power and flood control project, Part I, Summary, background and approach to the study.

euroconsult (1980b). Identification study on the ecological impacts of the Stiegler's Gorge power and flood control project, Part II, Methodology, definition of impact area and resources inventory.

euroconsult (1980c). Identification study on the ecological impacts of the Stiegler's Gorge power and flood control project, Part III, Analysis of physical and ecological impacts.

euroconsult (1980d). Identification study on the ecological impacts of the Stiegler's Gorge power and flood control project, Part IV, Synthesis, evaluation and recommendations.

Fottland, H. and Sorensen, C. 2001. Issues related to the establishment of prawn farms in Tanzania, with example of Rufiji delta. Catchment Forestry Project 96.4 as available on http://www.uit.no/semut/cfp/rep/CFP96_4_m.html

GEO 2000. Global Environmental Outlook 3, Past Present and Future Perspectives: Chapter 2, Coastal and marine areas, Africa, UNEP. As available on http://www.unep.org/geo/geo3/english/323/htm

Gibbons, P. 1997. Prawns and Piranhas: The political economy of the Tanzanians private sector marketing chain. Journal of Peasant Studies 25(1): 1-86.

Graham, A., Shah, A. & Olivier, R. 2000. The pattern of logging in Rufiji District. REMP, Utete – Rufiji.

Hafslund, A/S. 1980. Stiegler's Gorge Power and Flood Control Development. Project Planning Report, Vol. 1. Consultant Report submitted to RUBADA.

Hamerlynck, O. and Duvail, S. In prep. Floods, rainfall and food security in Rufiji.

Herlocker, D. 1999. Strategy for the assessment of woody vegetation of the Rufiji Environmental Management Project Area. REMP, Utete - Rufiji.

Hogan, A.R., Nandi, R.X.L., Mtiga, M.O., Chirwa, E.B., Kilonzo, P. and Peter, J. 1999. Selection of pilot villages: A report on the rapid appraisal methodology used and the selections made, together with eleven individual village profiles, REMP Technical Report No. 2.

ICOLD 1998. world Register of Dams 1998, Paris, France, ICOLD.

IPCC (2001a). Climate change 2001: The Scientific Basis. Cambridge University Press, Cambridge.

IPCC (2001b). Technical Summary, In: Manning, M and Nobre, C. (Editors), Climate Change 2001: Impacts, adaptation and Vulnerability, pp. 1-56.

Kaale, B.K., Ndilaha, A.E., Songela, F. and TaTeDO, A.H. 2000. Fuelwood and charcoal use with possible alternative energy sources in Ikwiriri township and Mbunjumvuleni village – Rufiji district. REMP Technical Report No. 4.

Kajia, Y.S. 2000. Assessment of the effects of rice farming in the mangrove forests of the Rufiji delta, mainland Tanzania. MSc. Thesis in ecological marine management, Faculty of Science, Free University of Brussels.

Kitheka, J.U., Ochiewo, J., Nthenge, P. and Obieyo, M. 2004. Landuse change and climatic variability in the Tana and Athi-Sabaki river basins and associated impacts on coastal resources in Kenya. Paper presented at START-LOICZ AfriCat workshop, 16-18 February 2004, Mombasa, Kenya.

Kulindwa, K., Sosovele, H. and Mgaya, Y.D. 2001. Socio-economic dimensions of biodiversity loss in Tanzania. Dar es Salaam University press.

Luoga, E.J., Witkowski, E.T.F. and Balkwill, K. 2000. Economics of charcoal production in miombo woodlands of eastern Tanzania: some hidden costs associated with commercialization of the resources. Ecological Economics 35(2): 243-257.

Malimbwi, R.E. 2000. Forest inventory Report. REMP, Rufiji District Council, Sokoine University of Agriculture.

Marsland, H. 1938. *Mlau cultivation in the Rufiji valley*. In Tanganyika notes and records No. 5, DSM, 1938, pp. 55-59.

Mgaya, Y.D. 2004. The vulnerability of mangrove and adjacent coral reefs to climate change in Rufiji delta. Literature review submitted to WWF Tanzania (The Eastern African Marine Ecoregion), January 2004.

Moberg, F. and Folke, C. 1999. Ecological goods and services of coral reef ecosystems. Ecological Economics 29(2): 215-233.

Muhando, C.A. 2001. The 1998 coral bleaching and mortality event in Tanzania: Implications for coral reef research and management. *In*: Richmond, M.D. and Francis, J. (eds.), 2001. *Marine Science Development in Tanzania and Eastern Africa. Proceedings of the 20th Anniversary Conference on Advances in Marine Science in Tanzania, 28 June-1 July 1999, Zanzibar, Tanzania.* IMS/WIOMSA, 329-342 pp.

Muhando, C.A. 1999. Assessment of the extent of coral damage, socio-economics effects mitigation and recovery of coral reefs in Tanzania. *In:* Linden, O and Sporrong N (eds). *Coral Reef Degradation in the Indian Ocean: Status report and project presentation.* CORDIO, Stockholm. pp 43-47.

Muhando, C.A. 2002. Seawater Temperature on Shallow Reefs off Zanzibar Town, Tanzania. *In*: O. Linden,D. Souter,D. Wilhelmsson, & D. Obura (Eds.), *Coral Reef Degradation in the Indian Ocean. Status Report 2002* (pp. 108). Kalmar: CORDIO. pp 40-46.

Muhando, C.A. 2003. Enhanced coral larval settlement and coral transplantation as means of promoting coral replenishment in Tanzania. PhD theses, University of Dar es Salaam. 285 pp.

Muhando, C.A. 2003. Trends in Reef Benthos After the 1998 Coral Bleaching Event in Mafia Island Marine Park, Tanzania. Western Indian Ocean Journal Marine Sciences. Submitted.

Muhando C.A. and Mohammed S.M. 2002. Coral reef benthos and fisheries in Tanzania before and after the 1998 coral bleaching and mortality event. Western Indian Ocean Journal of Marine Sciences, 1:43-52.

Mujwahuzi, M.R. 2003. Drawers of Water II, Tanzania Country Study as available on http://www.iiedi.org/sarl/dow/pdf/tanzania.pdf

Mwalyosi, R.B.B. 1982. Environmental Impact Assessment of the Stieglers Gorge Multipurpose project.

Mwalyosi, R.B.B. 1990. Resource potentials of the Rufiji River Basin, Tanzania. Ambio, 19:16-20.

Mwandosya, M.J., Nyenzi, B.S. and Luhanga, M.L. 1998. The assessment of vulnerability and adaptation to climate change impacts in Tanzania. The center for Energy, Environment, Science and Technology (CEEST), Tanzania.

Mwasumbi, L.B., Suleiman, H.O and Lyaruu, V.M. 2000. A preliminary biodiversity (flora) assessment of selected forests of the Rufiji floodplain. REMP Technical Report No. 10.

Nyenzi, B.S., Kavishe, M.M., Nassib, I.R. and Tilya, F.F. 1999. Analysis of the meteorological droughts in Tanzania. Proceedings of an interdisciplinary International Conference on Integrated Drought Management, 20-22 September 1999, Pretoria, South Africa.

Ngana, J.O. 1980. Hydraulic studies downstream of the proposed Stiegler's Gorge dam. BRALUP Research Report No. 35.

Obura, D. 2002. Status of coral reefs in East Africa. In Lunden, O., Souter, D., Wilhelmsson, D., and Obura, D. (Editors). *Coral Reef Degradation in the Indian Ocean*: Status Report 2002. CORDIO, Kalmar, Sweden, pp. 15-20.

Ochieng, C, A. 2002. Research masterplan for the Rufiji floodplain and delta 2003-2013. REMP Technical Report No. 28.

Ogallo, L.J. 1980. Time series analysis of rainfall in East Africa, PhD Thesis, University of Nairobi,Kenya.

Savile, A.H. 1945. A study of recent alteration on the flood regime of the Rufiji River, In: *East African Agriculture and Forestry Journal of Kenya*, *Tanganyika*, *Uganda and Zambia*, October 1945.

Semesi, A.K. 1991. Management plan for the mangrove Eco-system of mainland, Vol. 11: Mangrove Management Plan of all Coastal Districts, Ministry of Tourism, Natural Resources and Environment, Forest and Bee-keeping Division, Dar es Salaam.

Sørensen, C. 1998. Fisher, farmer, forestor: smallholder management in the Rufiji delta of Tanzania. A field report presented to the Danish Council for Development Research.

TCMP 2000. Pwani Yetu, The News Letter of The Tanzania Coastal Management Partnership, Issue No. 10, December 2000.

VHL 1979. Report on the hydraulic studies in the Lower Rufiji river, Vol. 1, Main Report.

Wagner, G. M. 1999. Coral Reefs: Importance, threats, conservation and resotoration. In K.M. Howell and Semesi (editors), *Coastal resources of Bagamoyo district*, *Tanzania. Proceedings of a workshop on coastal resources of Bagamoyo*, 18-

19 December 1997. Faculty of Science, University of Dar es salaam, Tanzania, pp. 27-32.

Wagner, G. 2003. State of Mangrove Forests in Tanzania, manuscript submitted to the Tanzania Coastal Management Partnership, University of Dar es Salaam, Department of Marine Biology, Dar es Salaam, Tanzania.

Wang, Y., Tobey, J., Bonynge, G., Nugranad, J., Makota, V., Ngusaro, A., and Traber, M., in press. Remote sensing of Land Cover Change Along the Tanzania Coast.

Wells, J., Syagga, P., Shao, I. & Lonner, G. 2000. Construction wood markets: Competing demands for renewable natural resources in the context of rapid urbanization. Unpublished report.

WCD (2000). Dams and Development: A new framework for decision making. The report of the world commission on dams, Nov. 2000. Earthscan publication ltd London and Sterling VA.

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AfriCat	African River Catchments
CBD	The Convention on Biological Diversity
CICT	Centre for Information and Communication Technology
EIA	Environmental Impact Assessment
ENSO	El Nino Southern Oscillation
GIS	Geographic Information System
HFB	High Frequency Band
ICOLD	International Commission of Large Dams
ILWIS	Integrated Land Water Information System
IRA	Institute of Resource Assessment

ITCZ	Inter-Tropical Convergence Zone
IPCC	Intergovernmental Panel on Climate Change
LFB	Low Frequency Band
MEA'S	Mult Environment Agreements
MW	Megawatts
NEMC	National Environment Management Council
NEP	National Environmental Policy
NGO's	Non Governmental Organisations
QBC	Quasi Biennial Oscillation
REMP	Rufiji Environment Management Project
RUBADA	Rufiji Basin Development Authority
SEA	Strategic Environmental Assessment
TANESCO	Tanzania Electric Supply Company
TCMP	Tanzania Coastal Zone Management Partnership
UCLAS	University College of Lands and Architectural Studies
UNESCO	United Nations Education, Scientific and Cultural Organisation
UNCLOS	United Nations Convention on the Law of the Sea
VHL	River and Harbour Labouratory at the Norwegian Institute of Technology
WCD	World Commission on Dams

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EXECUTIVE SUMMARY

The present study discusses the inter-linkages between the socio-economic dynamics and climatic variability on Lower Rufiji catchment. The study was conducted within the framework of African River Catchment (AfriCat) study, which examines the linkages between water impoundment/abstraction in six African river catchments (Sebou and Moulouya, in Morocco; the Senegal, in west Africa; the Tana and Sabaki in Kenya and the Rufiji in Tanzania) and the impacts and issues at the coast. The AfriCat study is also Investigating other pressure/drivers (apart from impoundment/abstraction) such as past climatic changes and documented extreme events, which may result into coastal changes. The major anthropogenic pressure on the Lower Rufiji catchment are associated with the

socio-economic activities such as agriculture (farming), fishing, hunting and various local and external commercial trades of the woodland resources.

Our study found noted that the evolution of agriculture system in Lower Rufiji has partly been influenced by, ecological and natural factors. The natural factors include: rainfall, floods, and droughts. Ecological factors include issues such as locust's inversion; pests, weeds etc. Apart from the ecological and natural factors, the agriculture has also been influenced by anthropogenic factors, which include demographic changes, political decisions, and lifestyle, amongst others Bantje, 1979, 1980, 1981, Ochieng, 2002). Historically, the traditional agriculture system which depended much on the interaction between the natural (wild) floods of Rufiji river and rainfall has to a great extent been affected by the National Villagization Policy of 1969, which forced the people to move out of the flood plain to upland areas and delta islands. To the Rufiji people, both rainfall and floods have always been viewed as the two important engines which drive and sustain farming. People have therefore continued to depend on rainfall and the wild flood of the river even after the Villagization Policy. The practice of shifting cultivation, which is now common both in the delta and floodplain agriculture is one of the most important negative impact which has resulted from the agricultural evolution in Lower Rufiji.

Two main factors have promoted the importance of fishery in the area: 1-Currently the agriculture is below subsistence level and, 2- fishery is the major source of getting the animal protein diet. The long-term sustainability of the fishery on the catchment is sustained by the Rufiji floods. It is generally known that, even the excessive floods (floods exceeding 2500 m^3/s), which could be destructive to farming, have got a positive effect in the lake fishery. Most of the fishery in the flood plain is done in the lakes, but fishery in the delta is done in the river as well as in the sea. The delta fishery involve the catches of finfish as well as prawns. Rufiji delta is the most important wild prawn fishing in Tanzania, contributing over 80% of all prawn caught in Tanzania (Mwalyosi, 1990, Kulindwa et al., 2001, Fottland and Sorensen, 2001). The bulk of prawn fishery takes place either from the artisanal fishermen or from industrial trawlers (Gibbon, 1997). The major threat to the existing fish resource on the catchment include, over-fishing which is partly contributed by increasing demographic changes and partly due to poor management and bad fishing practice (e.g., non selective fishery which is highly practiced in the floodplain fishery and discarding non targeted fishes which highly practiced by the shrimp trawler operators).

There is at present an increasing user pressure on the woodland resources that are harvested to provide fuel wood, charcoal poles and timber. To a large extent, the future consumption of fuel wood will be influenced by the demographic changes. The future harvest of other woodland resources such as mangrove poles, charcoal and timber will be controlled by the external demand of these resources from other growing urban centers (Kaale et al, 2000; Turpie, 2000), high tariff rates of electricity in Tanzania (for the case of charcoal) and poverty problem (Wang et al, in press).

Attempt has been made to quantify the water consumption pattern (both domestic water demand and water demand for the planned future irrigation developments), and the landuse changes. The present domestic water consumption has been estimated at 2.2 m^3 million, which will increase to about 3.1 and 4.1 m^3 million in the year 2020 and 2050 respectively. The future plan to extend the piped water services, which is in line with the National water Policy is expected to increase the domestic water consumption pattern to levels, which would be more than two times higher than the projected levels presented here. Both the present study, using aerial photograph and another contemporary study (Wang et al., in press) using satellite remote sensing, show that the system is highly dynamic, where different land use types succeed one another in the course of time, with changes being influenced by both human activities and natural climatic changes. The present land coverage of bushland, woodland and mangrove resource is estimated at 198,102 ha, 630,957 ha and 49,032 ha, respectively. The projected coverage (in ha) of these resources by the year 2020 and 2050 are 175,330 and 141172 (bushland), 546,423 and 419,622 (woodland) and 44,859 and 38587 (mangrove) respectively. These projections show that by the year 2050 the respective land coverage of these resources will be 71%, 67% and 79% of their present land coverage, suggesting that the woodland resource is diminishing at the fastest rate. The mangrove resource is on the other hand diminishing at the slowest rate. The slower rate shown by the mangrove resources is probably due to the Rufiji Mangrove Management Plan which has been instituted since 1991 (Semesi, 1991). Here we recommend similar management plans be instituted to other resources.

Major shortcomings of the existing Regulatory framework and legislations related to the management of the resources in Lower Rufiji include: 1- overlapping of mandatory power for different Institutions or ministries, with lack of mechanism to harmonize the overlapping or conflicting areas, 2- Most of the legislations were instituted without involving the people at the grass root, 3- Weak capacity in terms of human resources, skill and equipment. 4- Failure to address the poverty issue, which is the root cause of most of the discussed poor management of the Lower Rufiji resources.

The present investigation on the long-term climatic variability is in line with the projected future trends due to the predicted elevation level of atmospheric CO_2 (Mwandosya et al, 2001). The historical data collected from our study also suggest an increasing flood events partly due to the increasing rainfall and partly due to anthropogenic activities in the Upper Rufiji catchment. The increase in rainfall, flood events together with the increasing sea level and increasing sea surface temperature projected by other studies (e.g. Mwandosya et al, 2001; IPCC, 2001a-b) are expected to have significant ecological impacts in Lower Rufiji. The future fate of both mangroves and coral reefs will depend on the interaction between these climatic agents, rainfall, floods, temperature and sea level rise changes).

The major impacts of the planned impoundment of the river at Stiegler's Gorge are associated with: direct ecological impact in the Selous Wildlife Reserve, the river bed degradation problem, sediment trapping in the planned reservoir, disappearance of wild flooding, sea water salt intrusion, water quality, fishery, health and the projected future climatic regime. In general, the planned impoundment at Stiegler's Gorge is expected to induce both negative and positive impacts to the coastal ecology and people's livelihood of the Lower Rufiji.catchment.