


Environmental Profile of the Inkomati River Basin

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List of Abbreviations and Acronyms

ARA	Regional Administration of Waters
ARA-SUL	Southern Regional Administration
BWB	Bushbuckridge Water Board
CENACARTA	Centro Nacional de Cartografia e Teledecção (National Center for Cartography and Remote Sensing)
CNA	Conselho Nacional de Águas (National Council for Water)
DNA	Direcção Nacional de Águas (National Directorate for Water Affairs)
DNFFB	Direcção Nacional de Floresta e Fauna Bravia (National Directorate for Forestry and Wildlife)
DPCN	Department for Natural Disasters
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organisation
GPA	Global Plan of Action for the Protection of the Marine Environment
INIA	National Institute for Agriculture Research
IRG	Inkomati Reference Group
ICARM	Integrated Coastal Area and River Basin Management
IUCN	International Union for Conservation of Nature
KOBWA	Komati Basin Water Authority
JIBS	Joint Inkomati Basin Study
JWC	Joint Water Commission
MICOA	Ministry for Co-ordination of Environmental Affairs
MISAU	Ministry for Health
MOPH	Ministry of Public Works and Housing
NEMP	National Environmental Management Programme
NGO	Non Governmental Organisation
NIDMP	National Irrigation Development Master Plan
PAP/RAC	Priority Actions Programme Regional Activity Centre
PRONAR	National Rural Water Programme
SADC	Southern Africa Development Community
SADC-HYCOS	Southern Africa Development Community – Hydrological Cycle Observing System
TIA	Tripartite Interim Agreement
UGBI	Unity of Management of Inkomati Basin
UNEP	United Nations Environment Programme
UNHCR/UNDP	United Nations High Commission for Refugees/United Nations Development Programme
WHO	World Health Organisation
WHYCOS	World Hydrological Cycle Observing System
WIO-LaB	GEF funded Land-based Activities in the Western Indian Ocean Project

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Executive Summary

The Inkomati River Basin is one of the largest river basins in Southern Africa. The river is approximately 450 km long, and the surface area of the basin is about 46,800 km^2 of which 64% is found in South Africa and 5% in Swaziland. The Mozambican portion of the basin is 31%. The river drains into Maputo Bay, in Mozambique. The annual average rainfall and evapo-transpiration are 740 mm and 1900 mm, respectively. The total annual river runoff ranges between 700 and 1000 Mm^3 per year. The instantaneous river discharge ranges between 200 and 400 m^3s^{-1}.The water demand is continuously increasing so that the water available is not sufficient to meet the demand. Population growth, urban and industrial development are exerting increasing pressure in the river basin through increased demand for both land and water. The river water is abstracted in the upper riparian countries to irrigate sugar cane plantations and supply water to industries and for domestic use. Because agriculture in Mozambique is less developed and requires less water, there is no major abstraction of Inkomati River water in the Mozambican part of the basin.

The Inkomati River Basin is important from both ecological and socio-economic points of view. For instance, the Inkomati estuary is a habitat and breeding ground for various aquatic birds. It is also a nursery for important commercial fisheries, such as shrimp. The hydrodynamics and productivity of the Maputo Bay are to a large extent influenced by the freshwater input from the Inkomati River. Thus, reduction in river inflow has impacted negatively on the coastal ecosystems. The minimum environmental flow of 2 m^3 s^{-1} agreed among South Africa, Mozambique and Swaziland in 1991, has been violated several times by South Africa. The river flow was previously controlled in South Africa in order to exert political pressure against Mozambique government during the cold war. The flow was manipulated through the dams in South Africa to create either serious floods or droughts in Mozambique.

Some studies aiming at understanding the Inkomati River Basin system, and hence, establishing an Integrated River Basin Management System have been conducted, e.g. the Joint Inkomati Basin Studies initiated of 1992 and 2001; Shared River Initiative implemented during 2000-2001 and the Catchment to Coast carried out during 2002-2005. Negotiations on the Tripartite Interim Agreement on the Protection and Sustainable Utilisation of the Water Resources of the Inkomati and Maputo Watercourses (TIA) was initiated in 2001 and signed in 2002. Currently, further studies on Inkomati River Basin are planned and comprehensive agreement is possible in the near future.

Mozambique and Swaziland need assistance to improve their technical capacity in the negotiations for use of the shared water courses with South Africa. The end of the cold war and of apartheid; the studies carried out, particularly the Joint Inkomati Basin Studies; and the Catchment to Coast projects, created an enabling political and technical environment for fruitful negotiations towards Integrated River Basin Management of Inkomati.

Main river basin and coastal issues

The overriding issue in the Inkomati River Basin is the "Reduction in stream flow", which is also referred in Hoguane *et al.,* (2002) as the "Modification of stream flow," to reflect both the drought and flood situations. Modification of stream flow is considered as the main issue in the river basin because it contributes to other issues such as:

(i) Pollution of existing water supplies, since water shortage contributes to rapid deterioration of water quality due to reduction in the flushing time of the water (hence reduction in the self purification capacity of the river)

(ii) Modification of ecosystems and ecotones, since the reduction in river flow causes erosion and accretion along the coast and saltwater intrusion in the estuaries

(iii) Reduction in availability of the natural living resources (both fauna and flora) due to modification of ecosystems/ecotones

(iv) Severe damage to the riverine and marine habitats and infrastructures due to floods and coastal erosion (Hoguane *et al.*, 2002, Anon, 1998)

Water shortage is mainly caused by the increased demand of river water to meet the needs for agriculture, urban and industrial developments. The mean annual irrigation water requirement within the Inkomati River Basin is estimated as 1125.9 Mm^3. This is distributed as follows: South Africa (669.6 Mm^3), Mozambique (280.3 Mm^3), and Swaziland (174.9 Mm^3). In view of the fact that there are plans to increase the irrigated areas in South Africa, Swaziland and Mozambique (Van der Zaag and Carmo Vaz, 2003; Carmo Vaz and Lopes Pereira, 2002), it is likely that water abstraction from Inkomati River would even be much greater. As a result of increasing population with its attendant water requirements coupled with the increase in the urban areas as well as industrial development, the demand for water outstrips what the river can supply. Consequently more dams are being constructed across the Inkomati River resulting into increasing transfer of Inkomati river water into other basins (Anon, 2001).

As a result of water shortage, there has been a deterioration of water quality, leading to the occurrence of various water-borne diseases. Bacteria, *Vibrio parahaemolyticus* and *Vibrio mimicus,* have been found in clams in the Inkomati River mouth (Fernandes, 1996; Anon, 1998). Further the reduction in river runoff causes saltwater intrusion into the estuaries as well as into the groundwater aquifers thus reducing the beneficial uses of these waters. According to Gonzalez and Serraventosa (1999) and Hoguane (2002), saltwater intrusion extends between 40 and 80 km inland. According to Brockway *et al.,* (2005) the runoff required to keep the saltwater intrusion below 20 km upstream is 35 $m^3 s^{-1}$, which is much higher than the flow of 2 m^3s^{-1} set in the Piggs Peak Agreement. Reduction in sediment load transported by the river to the coast has led to a significant sediment load deficit that has triggered severe coastal erosion at the mouth of the Inkomati estuary.

Floods in the Lower Inkomati Basin occur at irregular intervals, with significant damage to agriculture, infrastructure and causing loss of life. The most devastating flood occurred in the year 2000 (Van Ogtrop et *al.,* 2005; Carmo Vaz and Lopes Pereira, 2000; Savenije, H. and I. Vaz, 1984).

The Inkomati River, because it’s shared among the three countries, is prone to transboundary conflicts (Anon, 1998). For instance the existing allocation of water to Mozambique is considered by the Mozambique government to be too low, raising the sensitive issue of international equity in the water allocation in the shared water courses (Anon, 2001).

Actions recommended

The water demand in the Inkomati Basin is increasing, and it has by far outstripped the water available in the Inkomati River. There are many stakeholders with different interests and water requirements. Thus, local and transboundary conflicts are eminent if the concerns are not adequately addressed. Hence, there is an urgent need to build consensus and a shared vision on the river’s future development, observing the basic principles of equity and sustainability in the water allocation and management of the river basin.

The Tripartite Permanent Technical Committee (TPTC) and the Joint Water Commission (JWC) provide an official forum for discussing issues across the three countries and for building consensus. Therefore, TPTC and JWC need to be strengthened by building on their current capacity. In addition, institutions responsible for management of the river basin should be strengthened by building the required technical and scientific capacity, particularly in the lower riparian countries. This will allow such institutions to fully participate in the monitoring of the processes and tripartite negotiations. Joint Inkomati Basin Study need to be supported and it is important that research methodologies are harmonised; instruments are inter-calibrated; and data and information is shared among the three countries so that they make informed decisions. This process will help speed up the building of consensus and trust, and accelerate negotiation processes among the three countries.

Lastly, because the coastal ecosystems sustain population and economy of Mozambique, the river flow required to sustain the coastal ecosystems should be taken into consideration by the upstream countries. There is need to undertake further studies on the linkages between Inkomati River system and the sustainability of the coastal and marine ecosystems, including the associated livelihood activities. This will help determine the impacts of the upstream activities including the effects of the river flow management on the coastal and marine ecosystems, and on the livelihood of coastal communities. This approach will allow Mozambique to come up with appropriate adaptation and management strategies that will enhance coastal water productivity.

1. Introduction

The Inkomati River Basin is shared by Mozambique, South Africa and Swaziland. The increased water demand for different uses, worsened by increasing population growth, urban and rural development in the riparian countries has hampered efforts towards sustainable use of the land, water and associated resources in the river basin. Although Protocols governing the use of shared rivers at the SADC level and among the three countries sharing the Inkomati River Basin have been signed, their enforcement is hindered by: the limited knowledge of the water and river runoff requirements for different water utilities; lack of capacity and political will; and limited capacity of the executing agencies. Of particular concern is the absence of consideration of the river runoff requirement for the health of the downstream ecosystems in most of the river runoff management models (Hoguane *et al.*, 2002). This is partially because the experts who traditionally discuss and set the river management models consist mainly of hydrologists, civil engineers and agriculturists. Environmental scientists and socio-economists are seldom involved in these discussions. The ideal approach should involve the stakeholders in all aspects of the river basin management. Thus, the main challenges for an effective Integrated River Basin Management (IRBM) are: (1) the consideration of the geographical extension of the basin with ecosystems that transcend national boundaries, hence requiring a joint management approach across the borders; (2) the consideration of multiple stakeholders with different and sometime conflicting interests, which require integrated and participatory approaches.

This *Environmental Profile of the Inkomati River Basin* is essentially a review of the bio-physical characteristics of the basin including the carrying capacity of the ecosystems found within the basin. It identifies the main stakeholders and the river basin resource-use drivers while highlighting the need for adoption of integrated and participatory management approaches. These are approaches that are necessary for achieving sustainability and equity in resource use and maximization of economic and social benefits derived from river basin resources. The main objectives of developing the Inkomati River Basin Environmental Profile are:

- Raise awareness on the need for adoption of transboundary Integrated River Basin Management principles, encourage cooperation and coordination among research and management institutions, and experts at national and regional levels
- Emphasize the need for establishing a network of river basin stakeholders to share information and also support activities where the principles of integrated management of ecosystems, biodiversity, water use and river basin are demonstrated
- Emphasise the importance of the involvement of the local communities and stakeholders as the ultimate beneficiaries and because of their potential to resolve and prevent conflicts in the use of Inkomati water resources.

1.1 Background

The *Environmental Profile of the Inkomati River Basin* was developed under the framework of the UNEP-GEF WIO-LaB Project focussed on addressing land-based activities in the Western Indian Ocean initiative. The WIO-LaB Project was designed to serve as a demonstration project of the UNEP's Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA), with the following three major objectives:

1. Reduce stress to the ecosystem by improving water and sediment quality
2. Strengthen regional legal basis for preventing land-based sources of pollution, including through the implementation of the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA)
3. Develop regional capacity and strengthen institutions for sustainable, less polluting development, including the implementation of the Nairobi Convention and its action plan as approved by participating Governments.

As part of the second objective of the WIO-LaB Project, the project focussed on the promotion of Integrated Coastal Area and River Basin Management (ICARM) principles through implementation of an ICARM demonstration project in the Inkomati Basin in Mozambique. The project was intended to provide support to the Ministry for Coordination of Environmental Affairs (MICOA) of Mozambique in order to design and implement this ICARM activity; and therefore improve Mozambique's negotiation capability in the Inkomati River Basin Management Committee. It was also intended that this component will enable documentation of experience in the implementation of ICARM Projects for wider application in the WIO region.

The ICARM Demonstration Project for the Inkomati Basin was to be implemented in two stages: Stage 1 was the formulation of an Environmental Profile and Stage 2 involved preparation of an ICARM Strategy, including a detailed Implementation and Monitoring Plan of Inkomati River Basin. The Environmental Profile of the Inkomati River Basin was developed under Stage 1 of the ICARM process. The profile contains data and information on the key bio-physical and socio-economic characteristics of the basin. The profile also identifies the existing and potential water resources management issues (conflicts and opportunities) and related institutional frameworks, including an analysis of land-cover and land use changes in the entire Inkomati River Basin.

2. Geographical location and physical characteristics of the basin

2.1 Location

The Inkomati River Basin is located in the South-eastern part of Southern Africa between latitudes 24º S and 26º 30´S and Longitudes 29º 70´E and 33º 35´E. The basin is shared by the Kingdom of Swaziland, Republic of South Africa and Republic of Mozambique (Figure 1). The basin extends from the mountains and plateau of Transvaal in South Africa at an altitude of about 2000 m in the western site of the basin. The river then flows through Swaziland and Northern Transvaal, before it discharges into Maputo Bay through an estuary located in Marracuane- a low-lying coastal plain in Mozambique. The basin borders Limpopo River Basin in the north, and the Umbeluzi and Maputo basins in the east and south, respectively (DNA, 2005; CONSULTEC, 1998). In Mozambique the river is called Incomati (or Inkomati).

2.2 Basin size

The basin is one of the largest in Southern Africa with a surface area of about 46,800 km^2, shared between the three countries as follows: South Africa (64%), Swaziland (5%) and Mozambique (31%). The instantaneous river discharge range between 200 and 400 $m^3 s^{-1}$, and the corresponding annual river discharge range between 700 and 1000 Mm^3 per year. The basin is composed of seven main catchments, namely: Komati (24%), Crocodile (22%) Sabié (15%), Massintonto (7%), Uanetze (8%), Mazimchope (8%) and Inkomati (14%) (Carmo Vaz and Pereira, 2000). The Komati and Crocodile are the main tributaries at the upper Inkomati. The Komati is the southernmost of the two tributaries and runs through Swaziland. The confluence of the Komati and Crocodile is located upstream of the Mozambique border, from where the river is known as the Inkomati. From the border downstream (i.e. in Mozambique territory), the river flows through Maputo Province in a large loop, first flowing east, then north, then east again near Magude, and finally south to enter the Maputo Bay through southern Marracuene (DNA, 1995). The Sabié, Massintonto and Uanetse rise in South Africa and flow through Kruger National Park before crossing the international border to join the Inkomati River in Mozambique territory.

2.3 Climate

The climate in the Inkomati River Basin varies from hot and humid in the Mozambique coastal plain to cool and dry in the Transvaal Plateau in South Africa. The average annual rainfall is about 735 mm, increasing from east to west. The average annual evaporation is about 1900mm, decreasing from east to west ((Leestemaker, 2000; JIBS, 2001).

The flow regime of the Inkomati River is characterised as torrential with high flows during the wet season, from November to March and relatively low flows in the dry season, from April to October. On average, 60% to 80% of the mean annual flow occurs in a few months of the year (DNA, 2000). As a consequence there occur extreme floods and droughts in the basin, particularly in Mozambique. Because Mozambique is located in the lower part of the basin, it suffers water shortage resulting from flow restriction in the upper riparian countries during dry season. It also experiences floods as a result of water release in riparian countries during rainy season. The most recent devastating floods occurred in the year 2000 with severe impacts on agriculture, infrastructures and loss of lives (Van Ogtrop *et al.,* 2005; Carmo Vaz and Lopes Pereira, 2000; Savenije, H. and I. Vaz, 1984).

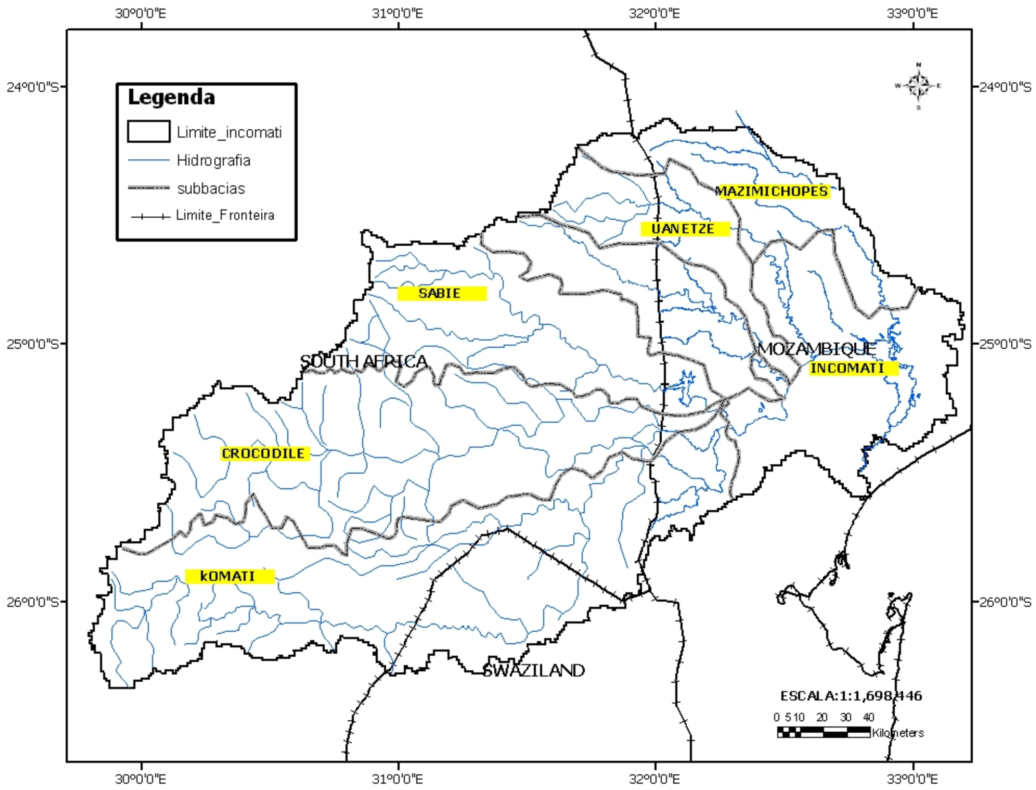


Figure 1: Inkomati River Basin, Carmo Vaz & Van der Zaag (2003).

2.4 Geomorphological characteristics

The relief of the basin is characterized by Great Escarpment at the Libombo area, which divides the basin into two major physiographic provinces, namely, the plateau area in the western site and the low-lying land in the eastern site of the basin (JIBS, 2001). Figure 2 shows the topography of the entire Inkomati River Basin, constructed from SRTM (Space Radar Topography Mission) data set. The elevation ranges from 2200m in western side in South Africa to the Mean Sea Level at the coast in Mozambique (Bydekerke, 2007). The lower part of the basin in Mozambique is highly vulnerable to flooding.

A slope map generated on the basis of the SRTM map shows that higher slopes of 10-15 degrees are found in South Africa, whereas near the cost in Mozambique the basin is rather flat, with the slopes of 5 degrees and decreasing to 0 as one approaches the coast (Figure 3). Along the South Africa and Mozambique borders, slopes are slightly higher (10-15 degrees as this is part of the Great Escarpment. Figure 4 and Figure 5 show the elevations and slopes in Mozambique part of the basin. Here the maximum elevation is about 450 meters.

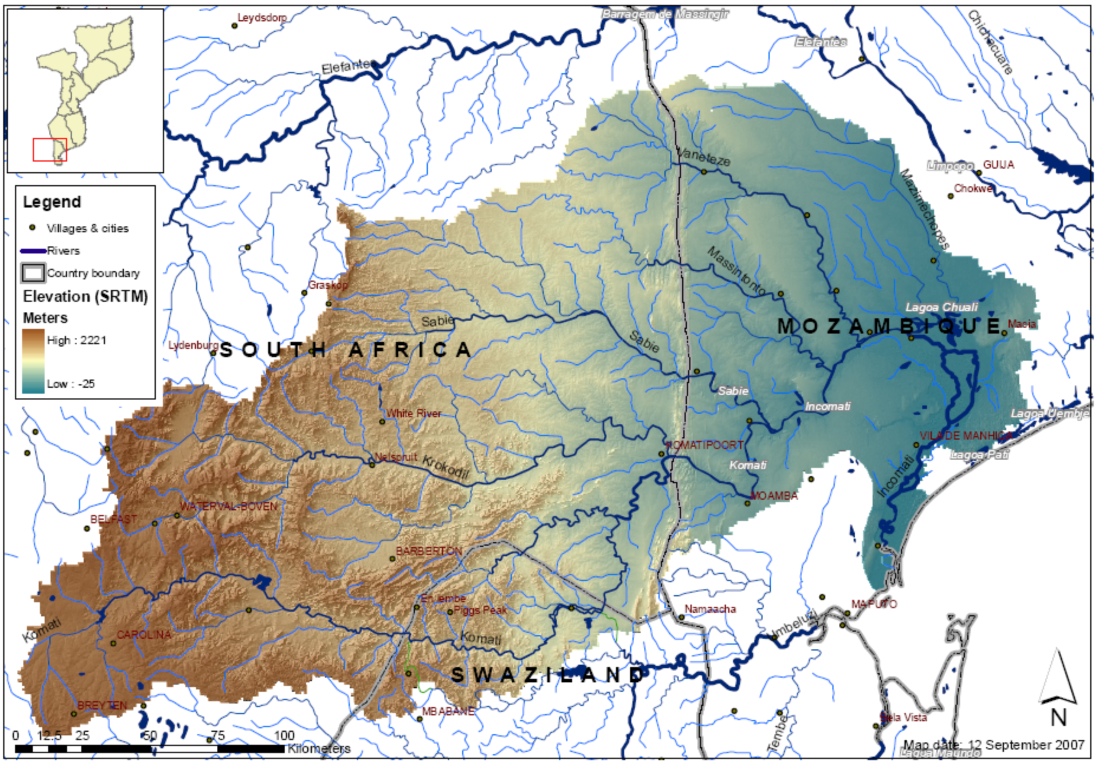


Figure 2: Overview of the Inkomati River Basin; Elevation is based upon SRTM data, Bydekerke (2007).

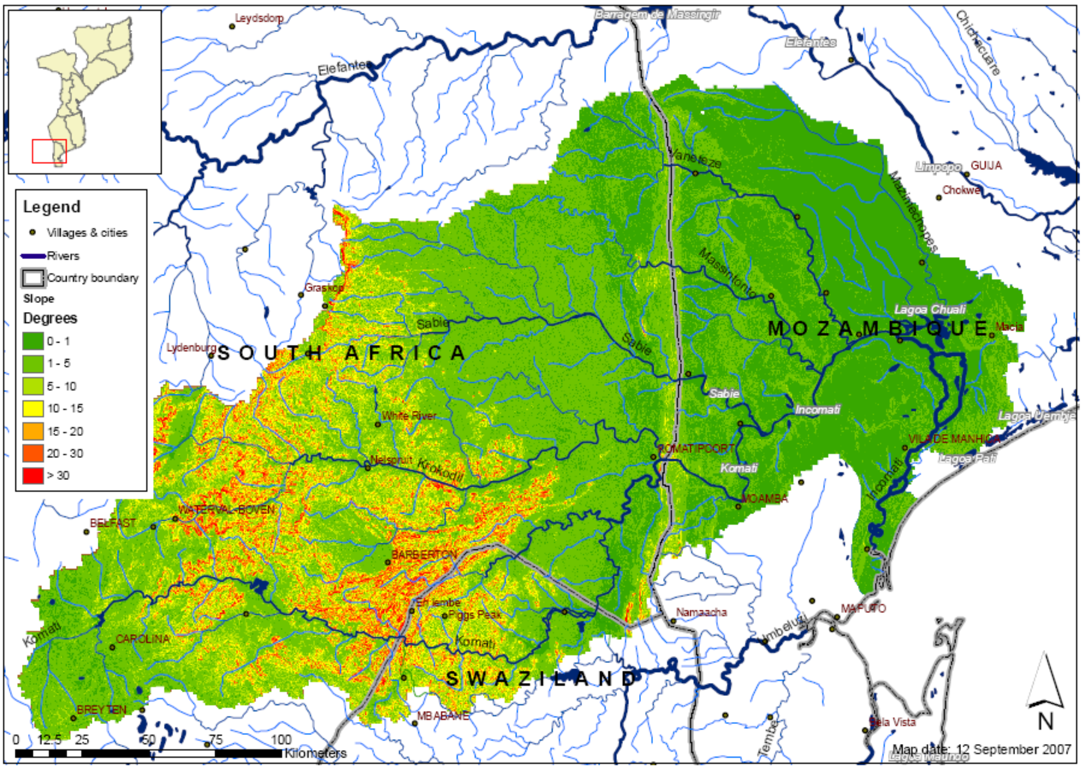


Figure 3: Overview of the Inkomati River Basin; Slope based upon SRTM data, Bydekerke (2007).

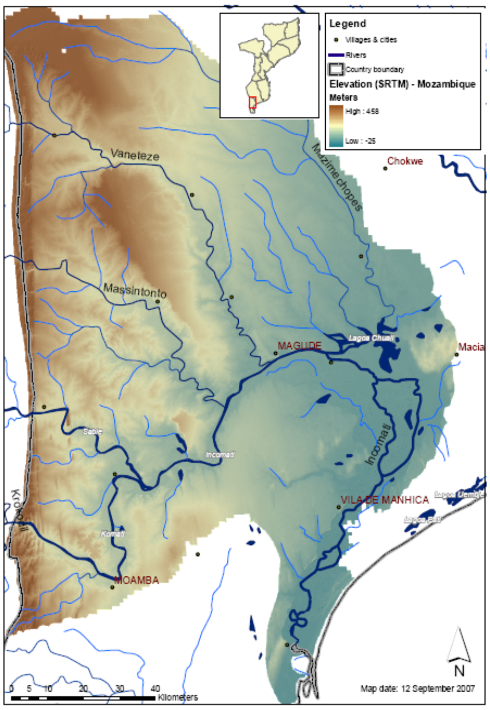


Figure 4: Overview of the Inkomati River Basin (Mozambique part). Elevation is based upon SRTM data, Bydekerke (2007).

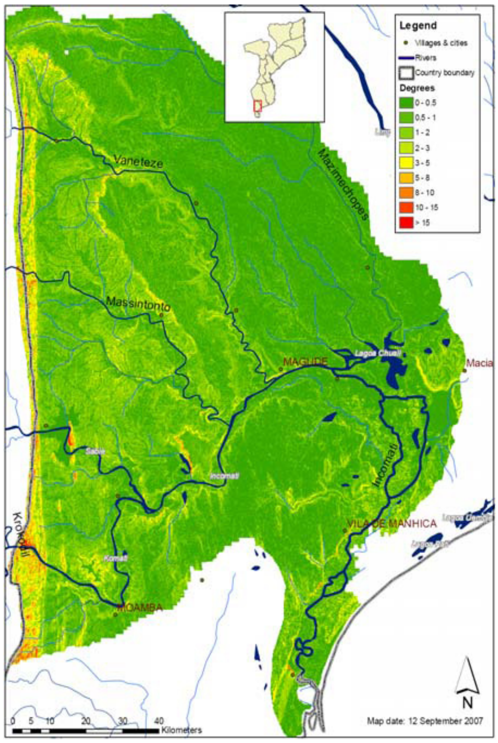


Figure 5: Overview of the Inkomati River Basin (Mozambique part). Slope based upon SRTM data, Bydekerke (2007).

3. Hydrological characteristics of the basin

3.1 River flow

The volume of surface and groundwater resources of the Inkomati Basin estimated by the Joint Inkomati Basin Study (JIBS, 2001) is 3,587 Mm^3 per annum (Table 1). In 2002, the estimated total consumptive water use was 1,800 Mm^3 per annum. Therefore, the total consumptive water use represents about 50% of the total volume of water in the basin. This level of consumption is high and it frequently leads to water shortages given the high variability of flow, both within and between years (Carmo Vaz and Van der Zaag, 2002).

Table 1: Water generation in the Inkomati River Basin, by Country (Mm^3 per annum)

Country	Catchment Area		Virgin Discharge	
	Mm^2	%	Mm^3	%
South Africa	28 556	61	2 937	82
Swaziland	2 545	5	479	13
Mozambique	15 647	33	171	5
Total	46 748	100	3 587	100

[Source: JIBS, 2001]

The hydrological year is October-September, and about 80% of all runoff occurs during the rainy season months of November-April. Figure 6 presents the average monthly river discharge over the period 1953-1979. Variations of discharge from year to year are significant with a coefficient of variation of around 50-65% (Smithers et al., 2001). Figure 7 shows the time-series of the monthly Inkomati River runoff at Magude runoff gauge station; it shows that there was long drought from mid 1980's to mid 1990's, with flow less than 200 $m^3 s^{-1}$ during the peak flows to nearly zero flow during the dry season. The extreme floods of the year 2000 exceeded 1000 $m^3 s^{-1}$.

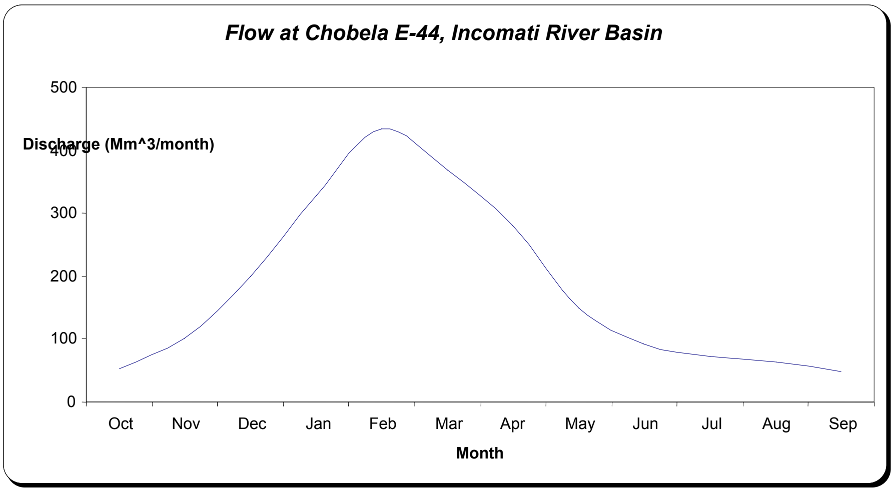


Figure 6: Mean monthly river discharge of the Incomati River at Chobela Station in Mozambique, E-44; 1953-1979.

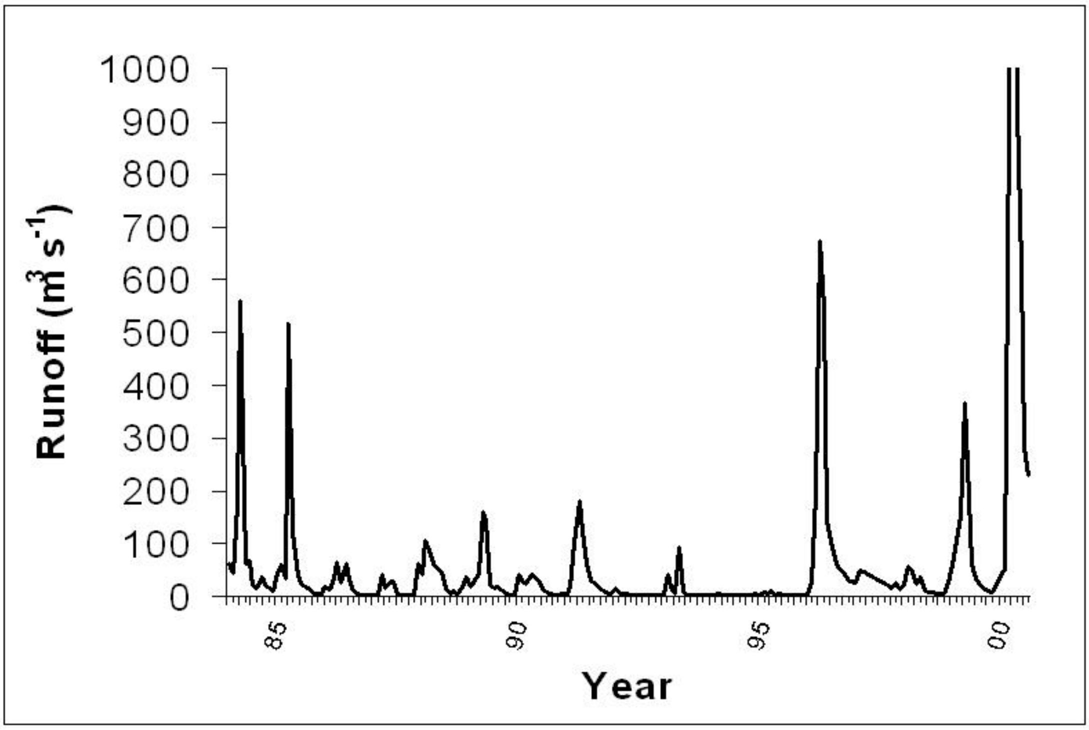


Figure 7: Time series of the Inkomati River runoff from October 1983 to September 2000 at Magude, Mozambique (Hoguane *et al.*, 2002).

Storms in the Inkomati River Basin cause soil erosion and associated high sediment loads in the river during high flow conditions. JIBS (2001) estimated that sediment production rate in the basin vary on average between 150 and 450 tons per km^2 per annum. This high rate of soil erosion mean that enormous volume of soil is carried with the river water leading to water quality degradation and thus limiting the use of water for domestic and urban use.

3.2 Groundwater resources

Groundwater occurs in sufficient quantities for large-scale development in the dolomites of Transvaal Sequence; the Barberton Greenstone Belt; the alluvium of Inkomati River valley in the Mozambique coastal plain and in the Aeolian sands of the Eastern Mozambique coastal plains (Tauacale *et al.* 2007). Within the Mozambique coastal plain, the estimated rate of groundwater recharge is of the order of 150 Mm^3 per annum, with most of the recharge been due to infiltration of rainfall.

The main groundwater aquifers (Figure 8) in the Mozambique part of the basin are characterised as follows: predominantly cracked aquifers (discontinuous), predominantly inter-granulate aquifers (continuous, generally not consolidated) and areas with local aquifers (inter-granulate or cracked) of limited productivity or with no significant water reserves (DNA, 1987).

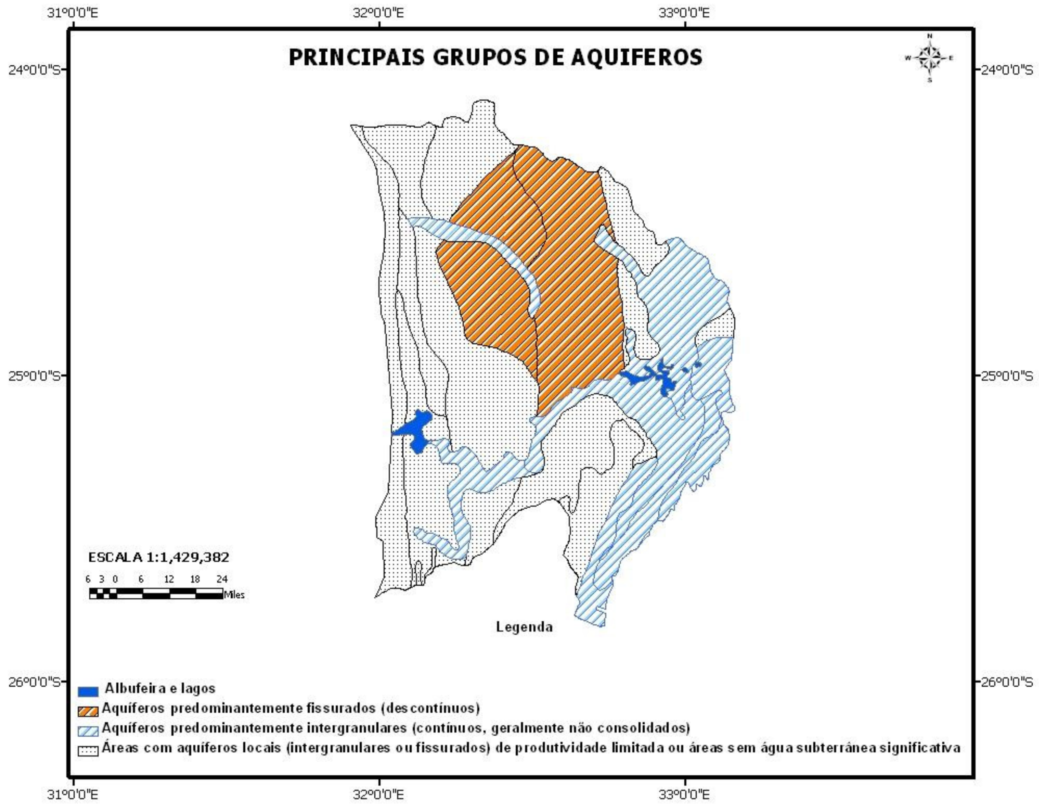


Figure 8: Main Aquifers in the Mozambique part of the Inkomati River Basin (Tauacale *et al.*, 2007).

4. Physical and ecological features of the Mozambique part of the basin

The Mozambique part of the Inkomati River Basin can be sub-divided into three major geo-ecological provinces, namely: the upper riparian- comprising the upper Inkomati River Basin from the border with the South Africa up to Sabié, at an altitude in between 100m and 500m; medium riparian, which comprises the area from the Sabié down to Manhiça District and the lower or coastal riparian, which extend from the District of Manhiça and ends in the river mouth in Maputo Bay (Figure 9).

4.1 Geological features

The upper Inkomati is characterised by old ancient rocks that form the Libombos chain, constituted by rialtos of the Karroo series (superior Carbon and inferior Jurassic). They are located near the border within the mountain chain. In the north-south direction, slightly to the East of the Moamba, there are found Cretaceous rocks, mainly the Incomanine sandstones. The western side of Chinhanganine is dominated by limestone of Tertiary age (DNA, 1991).

In the Middle Inkomati Basin, there are found the Quaternary rock formations, known as Magude formation. Essentially this region is composed of sandstone and ferruginous limestones. Along the main river in the border between the Moamba and Magude districts up to Xinavane, are found consolidated rocks and dolomites (Carmo Vaz, 1997).

The Lower Inkomati is characterized by alluvial flats that stretch out along the course of the main river. The coastal area is dominated by the yellowish or reddish coastal sand dunes and the sandy inner plains of the most recent formations of the Quaternary.

4.2 Climate

The Inkomati River Basin in Mozambique is characterized by an anticyclone regime and of middle latitudes depressions (Tauacale e*t al.*, 2007)). According to the Koopen classification, the basin has two principal climatic zones: Tropical wet climate (AW) along the coast (districts of Marracuene and Manhiça) and the dry steppe (BS and BSW) in the Middle Inkomati (Magude and Moamba).

In general, the climate of the basin is characterized by hot and rainy seasons in the period between November and April (with the peak rainfall in the period between December and March); and the dry season that occurs in winter in the remaining months.

Upper Inkomati

Middle Inkomati

Lower Inkomati

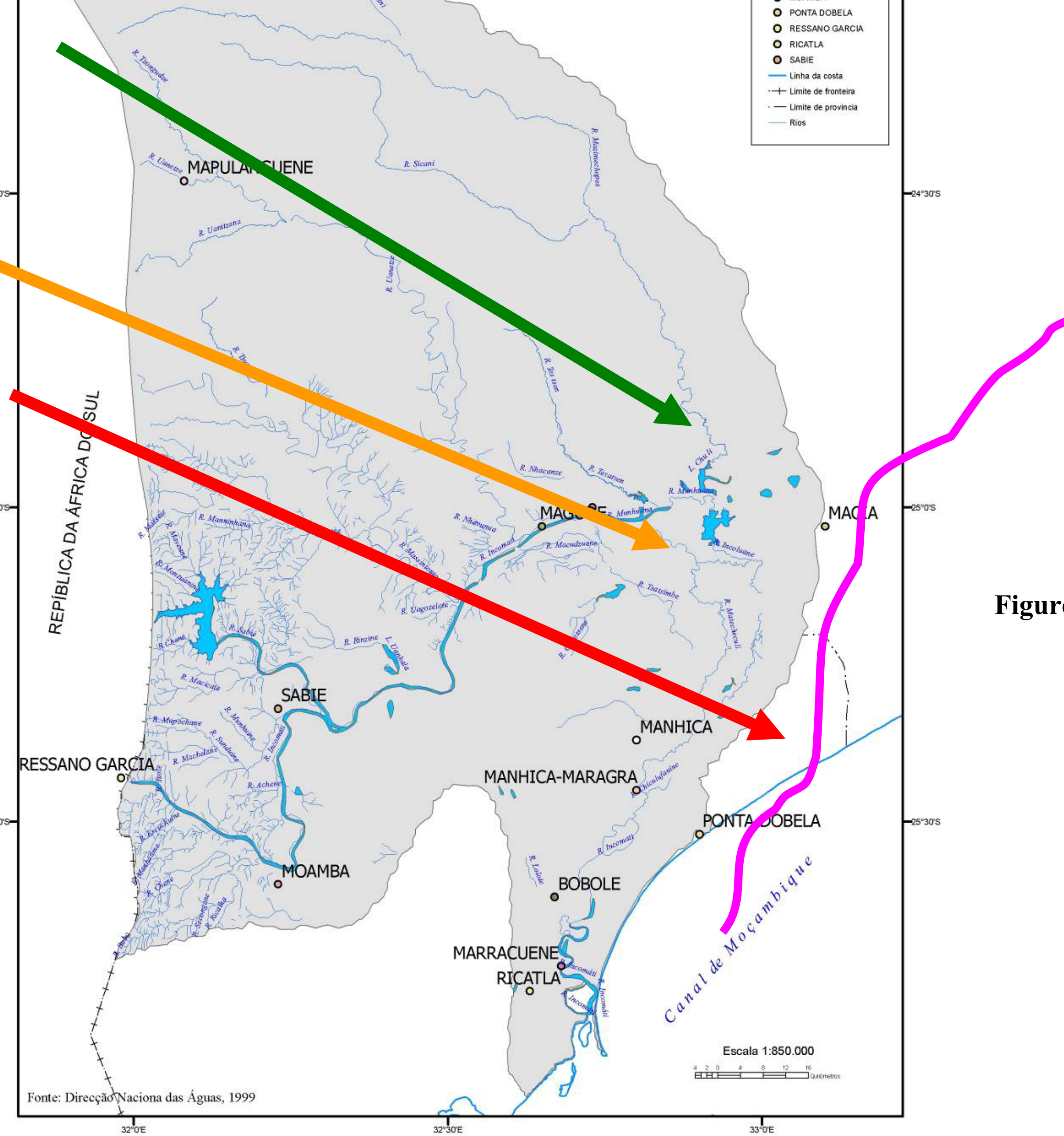


Figure 9: Ecological regions in the Mozambique part of the Inkomati River Basin (Tauacale e*t al.*, 2007)

The mean annual rainfall varies from 1073mm along the coast to 509mm near the border with South Africa. The overall mean annual rainfall in the Mozambique part of the basin is about 650mm (ARASUL, 2007).

The mean annual air temperature in the basin ranges from 23-24ºC. Maximum monthly temperature that is usually observed in January is 27ºC. The minimum observed in June is 18ºC. The relative mean monthly humidity varies from 75% near the coast to 70 % in the Upper Inkomati. The estimated annual potential evapo-transpiration is1390mm in the lower Inkomati; 1530mm in the Middle Inkomati and 1380mm in the Upper Inkomati. Thus, the highest rates of evaporation occur in the Upper Inkomati. The humidity is however higher in the Lower Inkomati along the coast and decreases towards the Upper Inkomati in the interior.

4.3 Agro-climate

According to Sogreah and Hidrogest (1993), the agro-climatic regions in the Inkomati River Basin (Mozambique part) are ecologically divided as follows (Figure 10 and 11):

a) *Upper Inkomati:* The area is characterised by dry steppe climate (BS) with maximum rainfall occurring in summer. A mean monthly air temperature varies between 18ºC (in June to July) to 27ºC (in January to February). Annual total rainfall is less than 600mm. Rainfall usually occurs during the period between November and February. On average, the total rainfall is equivalent to about 30% of the total potential evapo-transpiration and it is only in the period between December and February when total rainfall is equivalent to 50% of the potential evapo-transpiration (Figures 10 and 11).

b) *Middle Inkomati:* The climate is tropical dry steppe (BSW) with maximum rainfall in summer. The mean monthly air temperature varies between 19ºC (in June to July) to 27ºC (in January to February). The annual rainfall varies between 600 mm and 800 mm. Most of the rainfall occurs during November and February. On average the rainfall is equivalent to about 30% of the potential evapo-transpiration, and during the rain season (December to March) it ranges between 50% and 75 % of the potential evapo-transpiration (Figures 10 and 11).

c) *Lower Inkomati:* The climate is humid with dry winter. The mean monthly air temperature varies between 19ºC and 26ºC in winter (June to July) and summer (January and February), respectively. The annual total rainfall varies between 800mm and 1000mm. The rainfall occurs mostly from November and February, and is equivalent to about 25% to 35% of the potential evapo-transpiration (Figures 10 and 11).

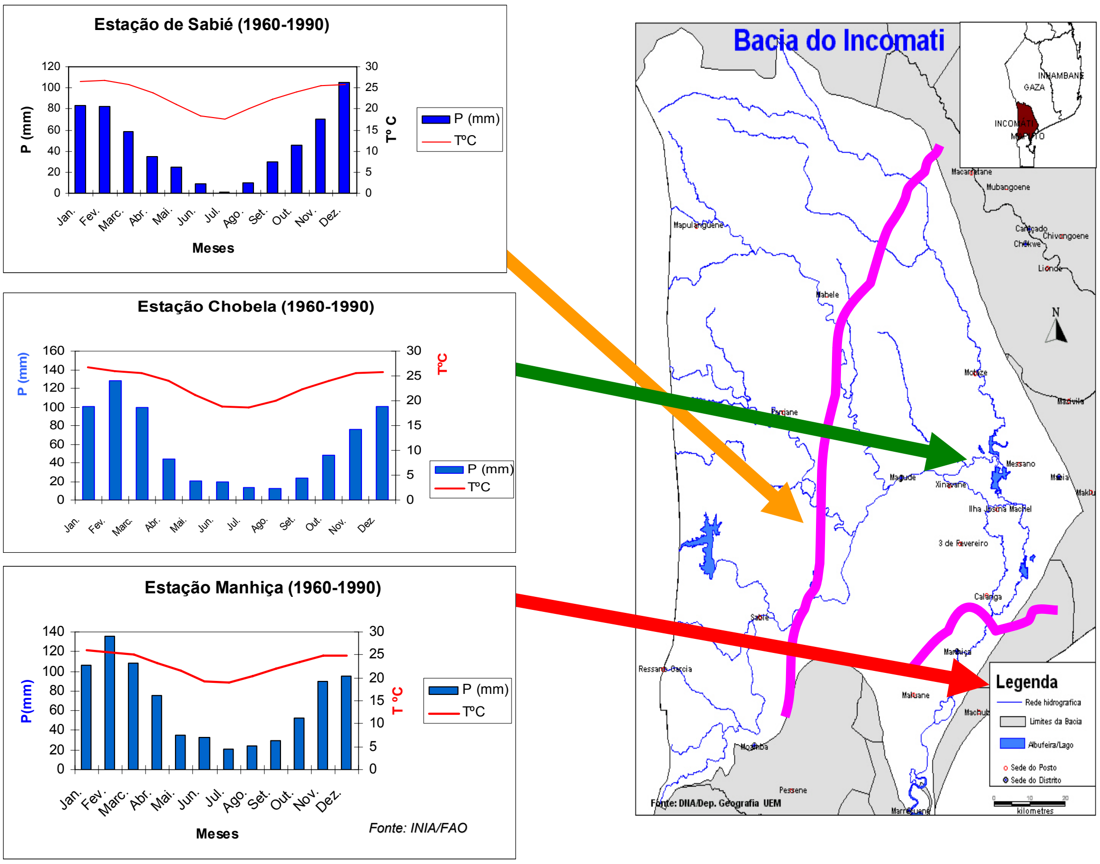


Figure 10: Agro-climate regions in the Mozambique part of the Inkomati River Basin, after Tauacale *et al.,* (2007).

4.4 Soils and vegetation

According to Bydekerke (2007), there are no densely forested areas in the Mozambique part of the Inkomati Basin. Significant forests formations are found in Swaziland and South African part of the basin. In the Mozambique part of the basin, forests appear only in patches and according to Metier (2005) quoting Mark (1976), the vegetation type of Inkomati River Basin is part of Sudano-Zambezian domain of South African savannah forests and they may be clustered in two main groups, as follows:

- Low altitude forests: these are characterized by thick forest with tall trees of about 3-7 m height. They occur in the middle and upper Inkomati in Sábiè and close to Massintonto River and northeast zone of the District of Moamba
- Thicket: They are characteristics of lagoons and swamps. They occur in Corumana and in small sections near the river in Moamba and in Chinhanguanine

Figure 12 shows the vegetation cover in the Mozambique part of the Inkomati River Basin, whose description is presented in the following sections.

Upper Inkomati River Basin vegetation

According to Gouveia (1954), this area is termed *Limbobiana Zone.* It includes the canyons of the Libombos' mountains. The soils are predominantly of the volcanic origin formed in the late Karroo and are intercepted by Tertiary and Quartetian formations. There are also shallow riolitic soils of basaltic origin, with coarse sediments scattered on the surface (Consultec, 1991). The vegetation is characterized by:

a) Dense forests of *Androstachys johnsonii*, ocuppying the V-shaped canyons, on red silty soils rich in organic matter.
b) Low and open forests, or savannah forests composed of *Bolusanthus specious, Peltophorum africanum, Mundulea suberosa, Combretum* spp. *(C. zeyheri, C. gueinzii), Sclerocarya caffra, Acacia nigrescens, Lannea discolor, Pterocarpus rotundifolius, Bauhinia galpinni, etc.,* with rich grasslands dominated by *Themeda*, on red silty soils, with patches and set of rock formations.

At south of Moamba, in between Sabié and Inkomati, the vegetation consists of the following;

a) Low evergreen humid forests of the type "*Licuati forests,*" comprising essentially sclerotic species such as: *Pteleopsis myrtifolia*, *Piptadenia pseudacacia*, *Spirostachys africana*, *Afzelia quanzensis*, *Balanites maughamii*, with a few small patches of *Entandophragma caudatum*, *Euphorbia spp*., *Aloe spp*. (*A.bainessii, A. marlothii*), shrub ever green and woody climber succulent.
b) Forests of *Acácia nigrescens, Sclerocarya color, Zizyphus mucronata*, with bush and dispersed shrubs of *Dichrostachys, Acacia,* etc., with abundant germanous stratus of *Themeda, Panicus, Setaria, Eragrotis, Chloris, Urochla*.
c) Bushes of *Spirostachys africana, Zyphus mucronata*, etc.
d) Savannah with *Sclerocarya caffra, Acacia spirocarpa, A. nigrescens, A. arabica, Kraussiana (A. benthamii),* with grass dominated by *Themeda, Setaria* and *Panicum*.
e) Rangelands dominated by *Themeda, Panicum, Setaria*.

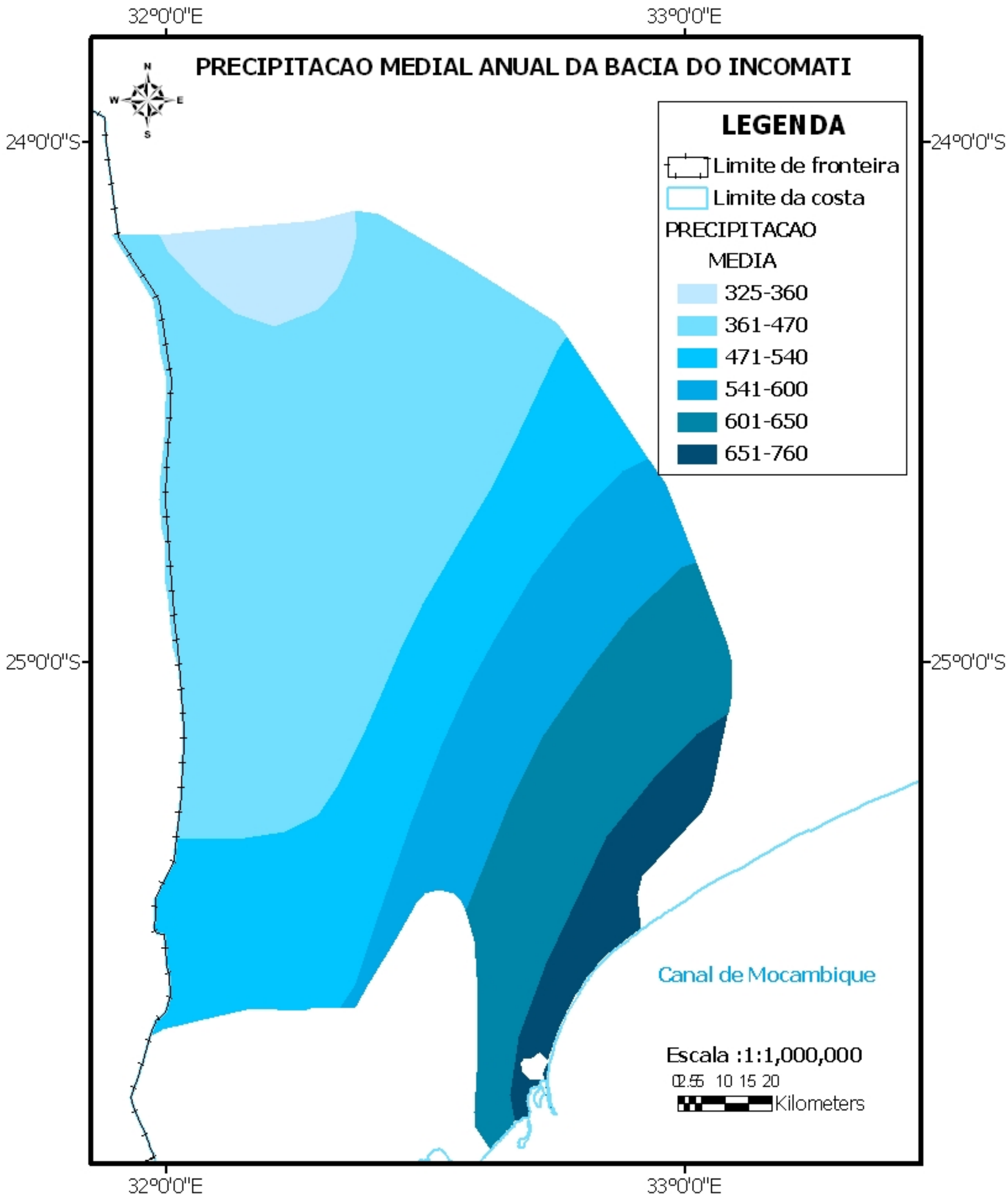


Figure 11: Distribution of rainfall in the Mozambique part of the Inkomati River Basin, after Tauacale *et al.,* (2007).

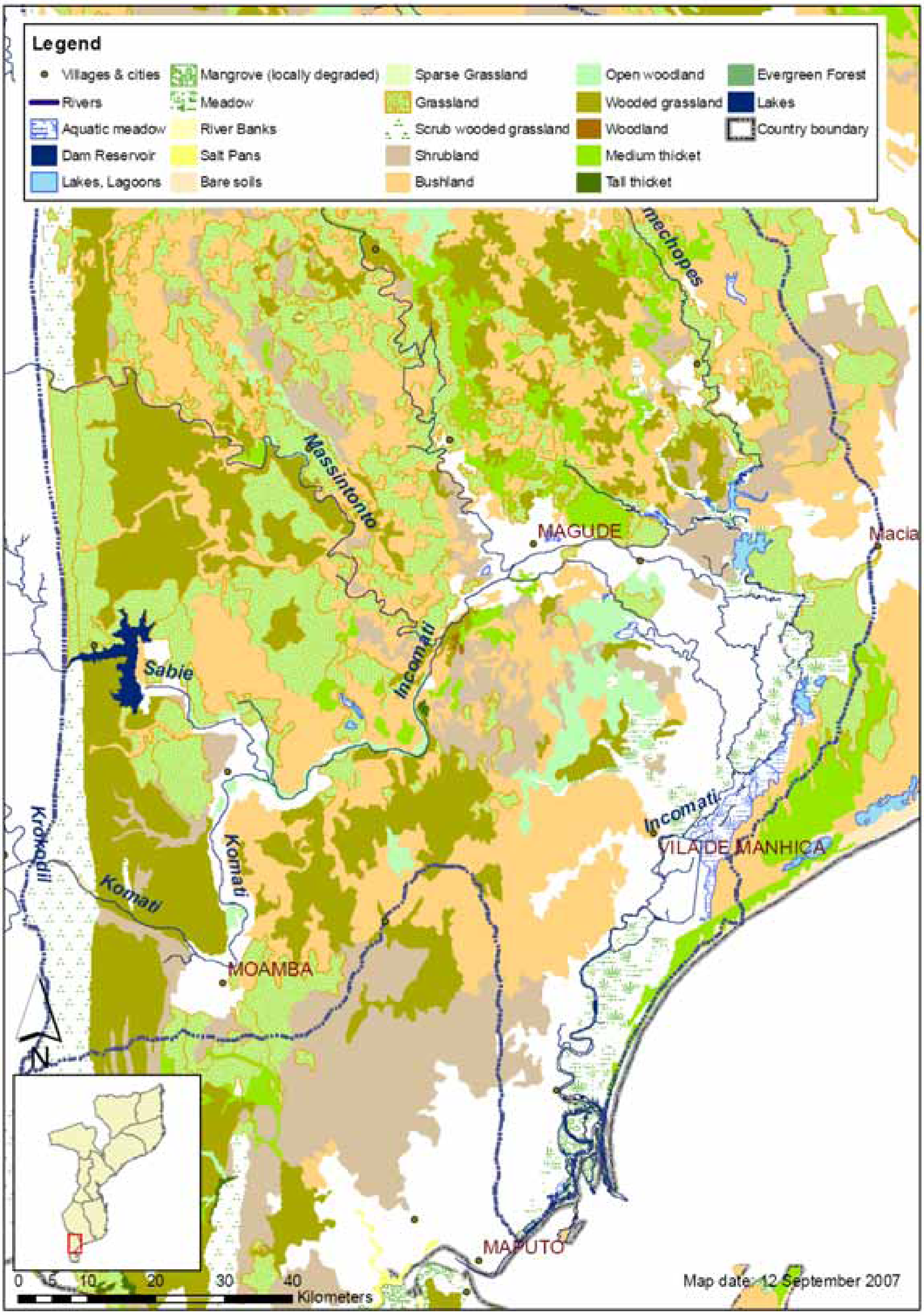


Figure 12: Land cover types in the Inkomati River Basin (Mozambique), natural vegetation, Bydekerke (2007).

Medium Inkomati River Basin vegetation

The major ecological features comprise the followings:

a) Patches of Savanna trees, humid gramineas, aquatic forest, involving acacia and Ficus trichilia

In this area, the river is characterized by meanders of almost 180^{o}. The floodplain is permanently inundated and poorly drained. The area is intercepted by gently well drained highlands. The vegetation is characterized by tree savannah, scattered shrubs, humid and dry grasslands and wetland vegetation with acacia. The area is suitable for grazing, with abundant grass species belonging to the family *Andropogoneae* and *Paniceae*. Within river valleys, there are recent and old sediment deposits of riverine origin, of medium and heavy texture, consisting of silt and marble material with iron patches. These soils are relatively good for irrigation.

b) Dry forest, semi-deciduous and brenya of low lands of sublitoral

This type of formation show variation accordingly to latitude and local conditions, but in general is related to sublitoral area of old dunes, and occur in sandy soils. The potential utility is limited to the extraction of high value wood and the conservation of flora.

c) Open forest with savanna of Albizia, Afzelia, Sclerocarya, Strychnos

Due to high population density, this type of vegetation is more or less degraded showing strips of secondary savanna and fruit trees. The original vegetation is naturally dense, and is dominated by species of Sapotaceae. It occurs in sandy soils, reddish, grey or orange of poor drainage and with black organic matter peat soils.

d) Tree savanna of medium altitude and valleys of the rivers

This type of formation includes various sub-types that are related with edaphic variation. The vegetation has xerophytic character that increases with salinity. It occurs in saline soils and in areas without clay or sandy soils. The area has good potential for livestock grazing.

e) Forest and grass Acacia savanna – combretum

Savanna occupies most of the area due to cutting and fires. The forest is found in small strips in valleys with clay soils of reolitic or basaltic origin.

Lower Inkomati River Basin vegetation

The Lower Inkomati River Basin extends from the estuary up to Manhiça, in the low lying areas. The main vegetation types include:

a) Ubperenifólia forest to subdecídua, with fringes of sub-humid forests, composed by*(Afzelia quasensis, Ficus* spp., *Brachylaena, Richilia emetica, Albizzia adianthifolia, Garcinia livingstonei, Strychnos* sp., *Conopharyngia elegans, Vernonia senegalensis, Tecomaria capensis, Acalypha* spp., on reddish sandy soils;

b) Secondary forests of *Sclerocarya caffra, Trichilia emeica, Albizzia verticolor, A. Adiantipholia, Alfzelia quazensis, Strychnos* spp., *Trema guineensis, Combretum, Conopharyngia elegans, Vernonia senegalensis, Tecomaria capensis, Clematis orientalis*, highly modified by antropogenic influence with exotic species such as *Mangifera indica, Anacardium occidentale*, on reddish and rough sandy soils.
c) Hydrophytes formations composed by *Phoenix reclinata, Syzygium cordatum, Voacanga,* com *Phragnites, Cyperus, Juncus, Pteridium aquilidum,* etc., on dark, organic rich and hydro-morphological soils.

Estuarine vegetation

The estuary presents extensive mangrove forests, some of which are still in pristine state, but others are heavily degraded. There are six mangroves species with *Avicennia marina* comprising 77% of the total mangrove species. *Rhizophora mucronata* and *Ceriops tagal* together make 18% of the species density (Bandeira *et al.*, 2004). The area covered by the mangroves in 2003 was estimated to be about 4451 hectares (Carmo Vaz, 2003, Bandeira *et al.*, 2004). These were clustered as follows:

- non-degraded or pristine mangroves (987 ha or 22 % of total area)
- degraded mangrove (1212 ha or 27%)
- degraded with reeds (*Phragmites australis*) (1627 ha, 37%)
- recovering mangroves after heavy deforestation (13 ha, 0.30%)
- dwarf mangroves (392 ha, 9%)
- new mangrove area, recently colonized after severe degradation (221 ha, 5%).

Estimates of the evolution of the mangrove vegetation cover over a period of 20 years (1984-2003) in two main islands in the Inkomati estuary indicated a decrease of the area covered by mangrove forests. In the Benguelene and Xefina Pequeña islands, the reduction is 40% and 25%, respectively. During the same period the area covered by degraded mangroves increased in similar amounts (LeMarie, 2005) (Figure 13). The overall mangrove deforestation rate in the Inkomati estuary is estimated to be 17 ha per year equivalent to about 0.4% (Bandeira *et al.*, 2004). Possible causes for these changes include the modifications of river flow regime, fluctuations in rainfall and increased rate of harvesting due to increased population pressure in the area.

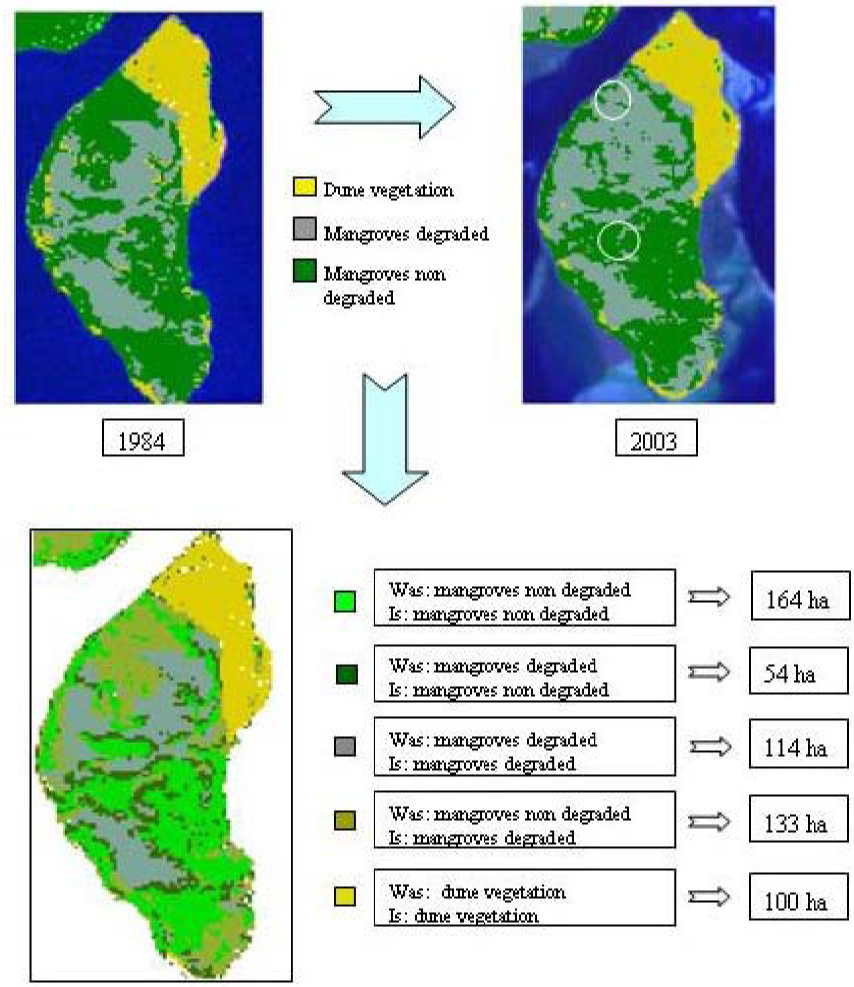


Figure: 13 Mangrove vegetation cover evolution in Xefina Pequena during the period 1984-2003, (LeMarie, 2005)

4.5 Fauna

The Inkomati Basin provides habitats for a rich variety of flora and fauna. These include endangered species and rare reptiles, amphibians and butterflies. In particular, there is abundance of bird life associated with the wetland environment characterized by swamps, grasslands, bushveld with mixed tree types (broad-leafed and thorny species), coastal bush, green forests (including riverine forest) (Carmo Vaz, 2003). More than 500 species of birds have been recorded in the Inkomati River Basin, of which 73 species are listed as threatened in South Africa. These include Wattled Crane, the Blackrumped Buttonquail, the Blue Swallow, the Egyptian Vulture and the Yellow-billed Oxpecker (Tauacale *et al.*, 2007).

The number of species of insects and invertebrates in the basin is not known, but it is probable in tens to hundreds of thousands. The Crocodiles are frequent in Inkomati River; the main species being *Crocodiles nilotics, Lanistes ovum Peters, Bellamya capillata* (Fraeunteld) *Gabbiela sp. Melanoides turberculata* (Muller), *Aspatharia wahlbergi* (Tauacale *et al.*, 2007).

There are about eleven endangered species of terrestrial mammals, which include the *Hippotragus equinus* (roan antelope), and the *Lycaon pictus* (wild dog), twelve species of fish, eight species of reptile and amphibian and 104 species of plants (Carmo Vaz, 2003).

Freshwater fish species

There is generally lack of information on freshwater species in the Inkomati River (Leestemaker and Tauacale, 2000, quoting Boane, 1998). The information that exists refer to the observations made in Lower Inkomati; in Palmeira, Munguine, Manhiça, Xichale, Marracuene and in Lake Chuali in Incoloane. Leestemarker (2000) observed about 38 species. According to Leestemaker and Tauacale (2000), quoting Boane (1998) about 38 freshwater fish species were observed in Lower Inkomati, of which 24 were also observed by Leestemarker (2000). Figure 14 shows a sample of freshwater fish catch and Table 2 presents the most recent species observed in Lower Inkomati by Boane (1998).

Cyprinus carpio is an exotic species with great tolerance to variations in river flow though it is abundant in Lake Chuáli, where it attains a maximum size of about 60 cm. *Serranochromis meridianus* prefers environments with slow river flow. Hence, it is abundant in lakes and in slow streams. It is also of high economic value.

The level of migration of the fish in the basin is limited by the water availability and the river flow regime. During the dry season, some sections of the river dry up and fish remains in sections of the river that retain water or migrate to the lakes. Cat fish performs both transversal and longitudinal migration in the river basin.

Figure 14: sample of freshwater fish species, after Tauacale *et al.,* (2007)

Table 2: Freshwater fish species observed in Inkomati River and Chuali Lake, Tauacale *et al.,* (2007).

Species	Chuali Lake	Palmeira	Manhiça	Munguine	Marracuene
Protopterrus annectens	-	+	+	-	-
Hydrocynus vittatus *	+	+	-	-	-
Marcusenius	+	+	-	-	-
Macrolepidotus *	+	+	+	+	+
Clarias gariepinus *	+	+	+	+	-
Synodontis zambezensis	+	+	+	-	-
Schilbe intermedius	+	+	-	-	-
Micralestes acutidens *	+	-	-	-	-
Cyprinus carpio	-	+	-	-	-
Labeo rosae *	+	+	-	-	-
Barbus paludinosus	-	+	-	-	-
Barbus sp	-	+	-	-	-
Opsaridium zambezense	+	+	+	-	-
Serranochromis meridianus	-	+	+	-	-
Tilapia rendalli	-	+	+	+	+
Oreochromis mossambicus	-	+	+	-	-
Brycinus Imberi *	+	+	+	+	+
Glossogobius giuris	+	+	-	-	-
Anguilla mossambica *	+	+	+	-	-
Anguilla bengalensis Labiata *	+	+	+	-	-
Anguilla marmorata *	-	-	-	-	+
Acanthopagrus berda *	-	-	-	-	+
Sillago sihama	-	-	-	-	+
Ambassis natalensis	-	-	-	-	+
Cynoglossus senegalensis	-	-	-	+	+
Prawn non observed specie					

Legend: + = Existent; - = Non observed; * Migrant fish species
Source: Leestemaker & Tauacale (2000)

4.6 Estuarine environment

The Inkomati River discharges in the northern part of the Maputo Bay. The estuary is about 40-50km long, and meanders within the coastal plains or lowlands- a manifestation of the sluggish nature of the river. The sides of the estuary gradually converge, resulting in a funnel-type shape (Figure 15). The surface area of the mouth during high water is about $9000m^2$ with a slope factor of about as $0.1km^{-1}$. The tides in the estuary are semi-diurnal. The maximum tidal range at the mouth is about 3m. The estuary is generally shallow and the deepest point at high tide is no more than 10 m (Brockway *et al.*, 2005).

The salinity in the estuary varies from vertically well-mixed during the dry season to partially mixed and stratified during the wet season (Figure 16). Saltwater intrusion varies depending on the volume of river discharge. Saltwater intrusion extents a few kilometers from the mouth during periods of high river discharge but it increases to the excess of 40km during periods of low river discharge (Hoguane, 2000; Brockway *et al.*, 2005).

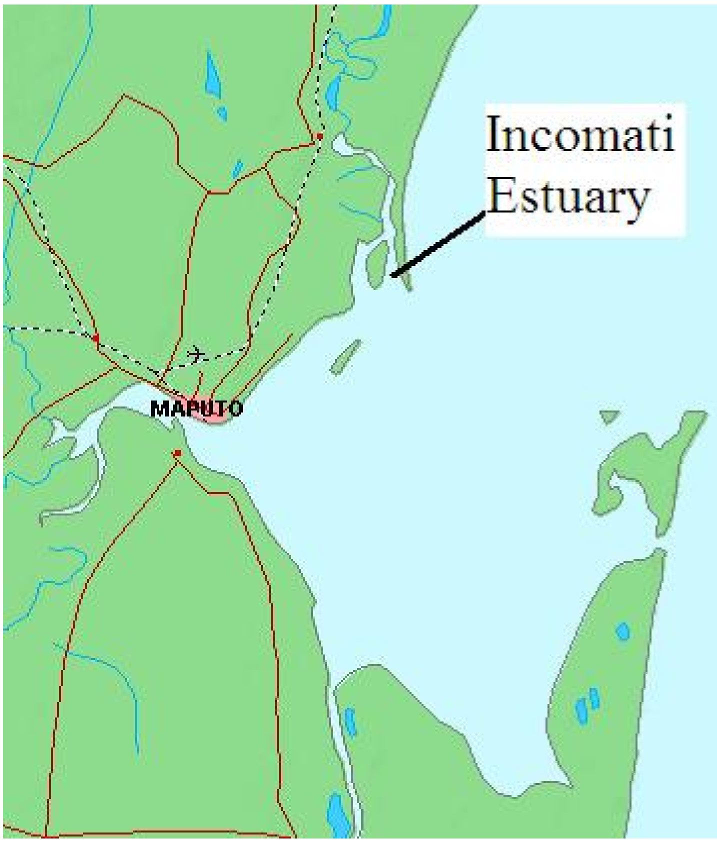


Figure 15: Maputo Bay and of the Inkomati estuary

The flushing time of the estuary varies with the tides and with the river runoff. During the dry season, the flushing time is due solely to semi-diurnal tides and varies from 6 days during spring tides to 17 days during neap tides. During high river discharge conditions, the flushing time reduces to 1 and 2.5 days (Hoguane, 2000; José, 2004).

The estuary exports nitrates (NO_3^-) and phosphates (PO_4^{3-}) to the Maputo Bay. The mangrove area is the main source of ammonia (NH_4^+) while the river is the main source of phosphates (PO_4^{3-}) and silicates (SiO_2) (Table 3) (Hallo, 2004).

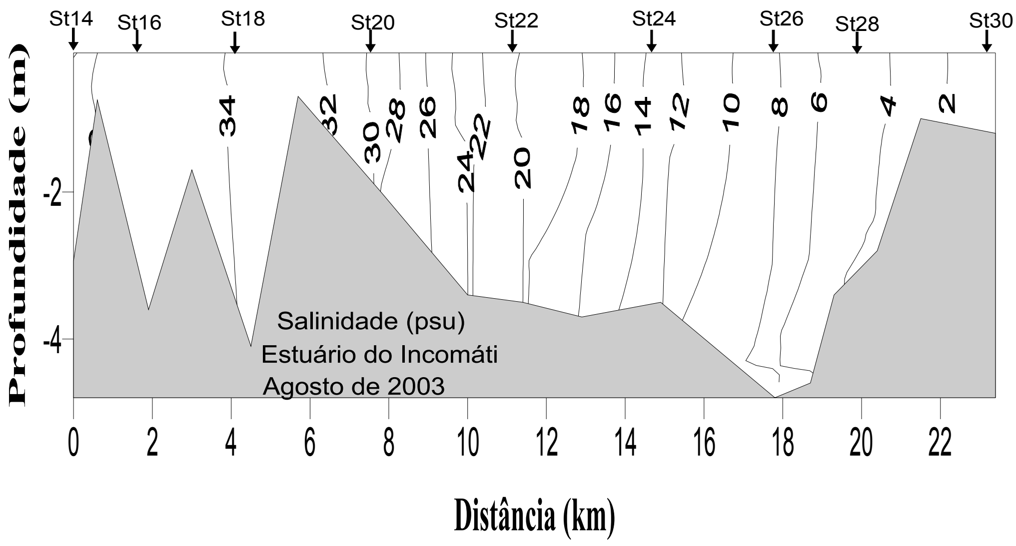


Figure 16: Typical salinity profile of the Inkomati Estuary (during low river discharge), August 2003 (Vassele, 2005).

Table 3: Mean nutrients concentrations with the tides at the Estuary-Bay boundary (Hallo, 2004).

Station	Tide	SiO_2		PO_4^{3-}		NH_4^+		NO_3^-	
		[µg/l]	[µmol/l]	[µg/l]	[µmol/l]	[µg/l]	[µmol/l]	[µg/l]	[µmol/l]
EB 01	Ebb	104.0	3.70	7.10	0.26	47.8	3.41	10.3	0.73
	Flood	87.5	3.10	5.10	0.16	27.7	1.98	6.20	0.45
EB 02	Ebb	72.5	2.58	5.90	0.20	34.7	2.45	5.10	0.37
	Flood	137.2	2.64	6.10	0.21	29.4	2.10	10.3	0.74
EB 03	Ebb	68.1	2.42	4.90	0.14	31.5	2.25	4.20	0.30
	Flood	56.9	2.00	5.30	0.17	18.4	1.31	3.60	0.26
EB 04	Ebb	22.9	0.81	3.90	0.11	21.0	1.50	3.90	0.28
	Flood	17.7	0.64	3.30	0.10	15.3	1.10	4.00	0.29
EB 05	Ebb	17.2	0.62	3.40	0.10	22.2	1.50	5.40	0.39
	Flood	16.4	0.59	3.60	0.11	21.1	1.51	3.80	0.27

The Inkomati estuary is the sanctuary for breeding colonies of aquatic birds. It also provides various natural resources and services to local population and plays a nursery ground for many species of fish and crustacean (Carmo Vaz, 2003).The estuary contributes approximately 20% of the overall shrimp catch in Maputo Bay (Anon, 2001). Macia and Menomussanga (2004) studied the flux of shrimp larvae through the Inkomati estuary and concluded that the inflow density of larvae increases with season and with tidal cycle, being higher during winter and in between neap and spring tides. Juveniles and post-larvae of shrimp are more abundant in non-degraded mangroves compared to degraded mangroves and estuarine channel. Degraded mangroves support less density and biomass than non-degraded mangroves (Macia and Menomussanga, 2004).

4.7 Potential for agriculture in the Mozambique part of the Inkomati River Basin

On the basis of the agricultural potential, the Mozambique part of the Inkomati River Basin can be divided into three major zones, which match the agro-climatic divisions of the basin; Lower Inkomati, Middle Inkomati and Upper Inkomati (Tauacale *et al.*, 2007; Kranendork, 1984; Sweco e*t al.*, 2003) and as illustrated in Figure 17.

Lower Inkomati – it comprises the area of estuary and the area immediately upstream of the estuary. In the estuary the soils are saline and barely suitable for cultivation of rice. The area immediately upstream of the estuary, covering the districts of Manhiça and Marracuene is characterised by poorly structured soils of clay sediments of river origin, suitable for cultivation of vegetables, sweet potato, rice, sugar cane and banana. The highlands adjacent to the river valley are suitable for coconut and cashew nut trees, cassava associated with peanut, and maize associated with beans. Other crops are cotton sunflower and tobacco.

Middle Inkomati - It covers almost the entire Magude district and a small portion of the northern Moamba and Manhiça districts. The altitude is less than 200 m. The soils are of riverine deposition, and suitable for cultivation of wheat, maize, sugar-cane, sweet potato and vegetables. There are two dominant systems of agricultural production practiced in the region: the rain-fed agriculture practiced by the majority of the population and growing mainly maize, cassava, peanuts and beans and irrigated agriculture practiced in the sugar cane plantations of Xinavane and Maragra. There are two different agriculture season; the summer and the wet seasons. In the summer season the main crops cultivated are maize associated with beans and rice, whereas in the winter season, the production of vegetables is most significant. The sweet potato is cultivated throughout the year. Livestock keeping is practiced and it has a significant socio-economic impact in the local community given the abundant grassland.

Upper Inkomati – The area covers most of the basin extending over the districts of Moamba and Magude, in Maputo and Gaza provinces, respectively. The altitudes vary between 200m and 500m. The river valley has soils of low texture that are deposited by floods. On the other hand, the terraces are very dry with clay soils, highly appropriate for cultivation of sweet potatoes, wheat, maize and vegetables. The higher elevation areas are suitable for cultivation of citrus, cassava, sweet potato and peanuts. The region has a good potential for rain-fed agriculture. The cultivation of maize, cassava and beans occur during the rainy season, whereas the sweet potato is cultivated throughout the year. There are also a few small-scale irrigation schemes for intensive production of vegetables, sugar-cane and fruits, particularly citrus and banana.
The main cash crops are cereals, sugar-cane, rice, sunflower, peanut, tobacco, beans and cassava.

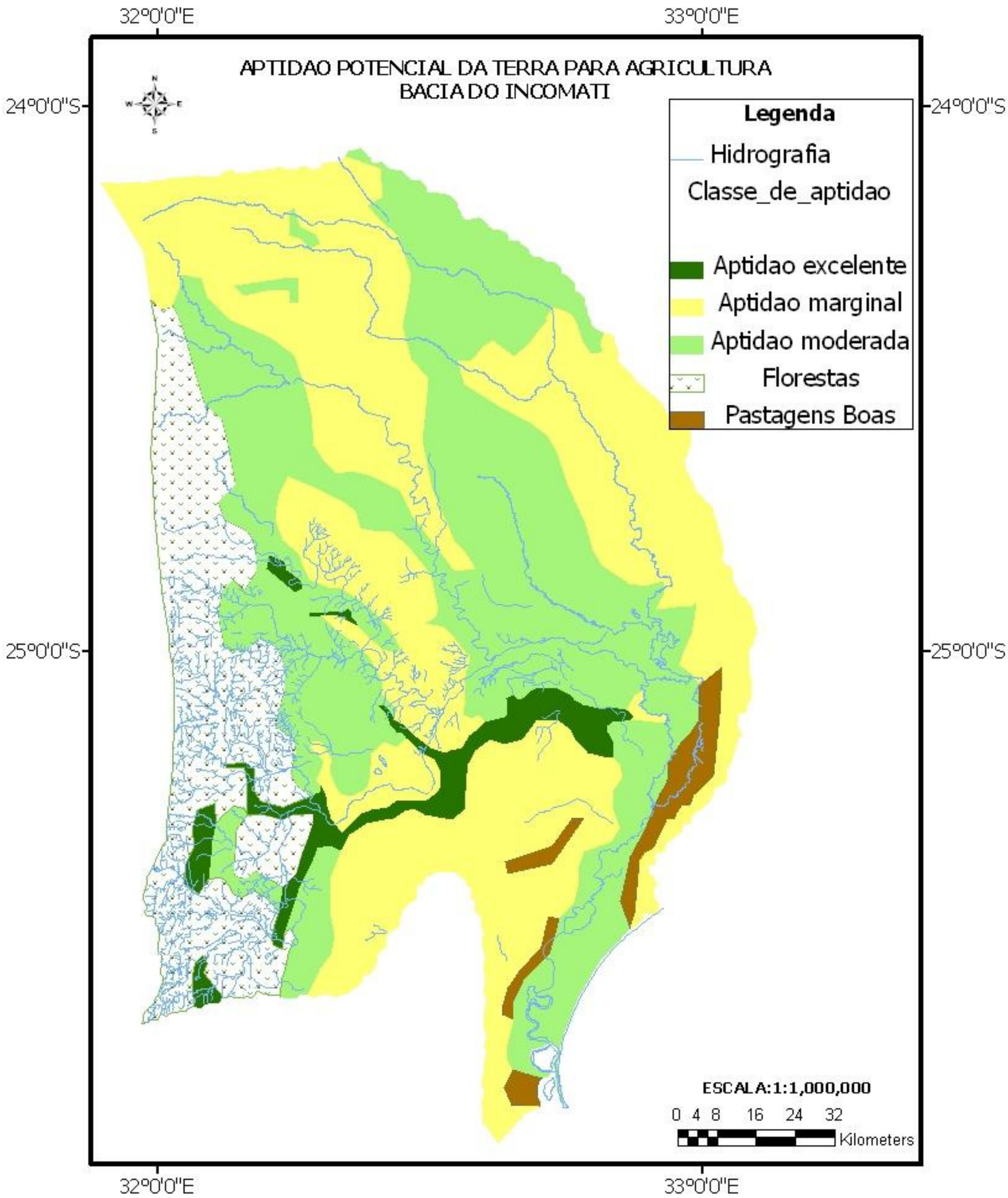


Figure 17: Potential for agriculture in the Mozambique part of the Inkomati River Basin, after Tauacale *et al.,* (2007).

5. Socio-economic characteristics of the Inkomati River Basin

5.1 Population density in the entire basin

The population of entire Inkomati River Basin is estimated at 2.3 million people; 80% of them live in South Africa and 6.6% in Swaziland (Carmo Vaz and Van der Zaag, 2003). Only about 1.7% of the total population in the basin is in Mozambique. The average population density is estimated at 50 inhabitants per square kilometer, being higher in South Africa and Swaziland with about 66 and 58 inhabitants per square kilometer, respectively. The population density is lower in Mozambique with about 17 inhabitants per square kilometer (Table 4).

Table 4: Population density in the Inkomati River Basin

Country	Basin Area (Km^2)	Proportion to overall basin %	Population	Proportion to overall basin %	Population density No. of People. km^{-2}
Mozambique	14,900	32.3	258,122	11.2	17.0
Swaziland	2,600	5.6	151,900	6.6	58.4
South Africa	28,700	62.1	1,884,520	82.0	65.6
Total	**46,200**	**100.0**	**2,294,542**	**100.0**	**49.6**

source: Carmo Vaz and Van der Zaag (2003)

5.2 Population density in the Mozambique part of the Inkomati River Basin

The distribution of the population density in the Mozambican part of the Inkomati River Basin varies from 9 inhabitants per square kilometer, in the areas with low agricultural potential, in Upper Inkomati to about 88 inhabitants per square kilometer, in the fertile agricultural lands, in Lower and Upper Inkomati or urban centers such as Moamba, Magude, Manhaiça, Marracue and Maputo (Table 5 and Figures 18 and 19) (Metier (2005).

Table 5: Distribution of population density in the Mozambican part of the Inkomati River Basin per district

Districts	**Area (Km^2)**	**Population (1997)**	**Density No. of people km^{-2}**	**Estimated for 2007**
Massingir	5,893	22,284	4.7	**25,214**
Moamba	4,628	43,396	13.6	**35,430**
Magude	7,010	42,788	9.0	**27,259**
Manhiça	2,373	130,351	82.0	**144,679**
Marracuene	703	41,677	87.0	**50,842**
Chokwe	2,466	173,277	88.0	**279,578**
Total	**23,073**	**453,773**	**47.4**	**563,002**

Fonte: INE (1997/99), Metier, (2005)-Perfis distritais

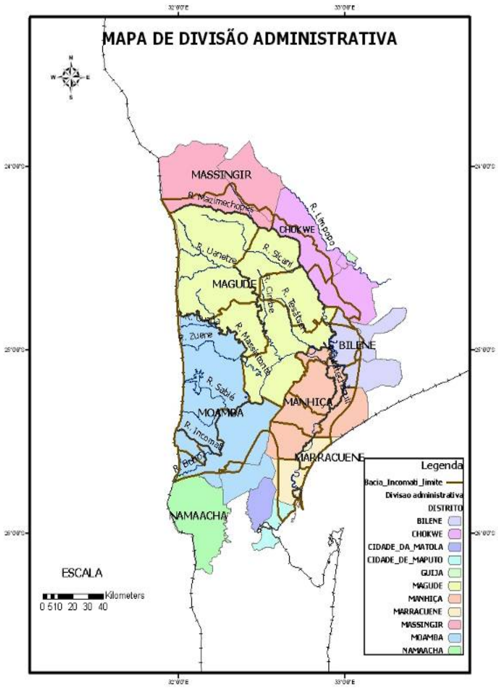


Figure 18: Administrative divisions in the Mozambique part of the Inkomati River, after Tauacale *et al.,* (2007).

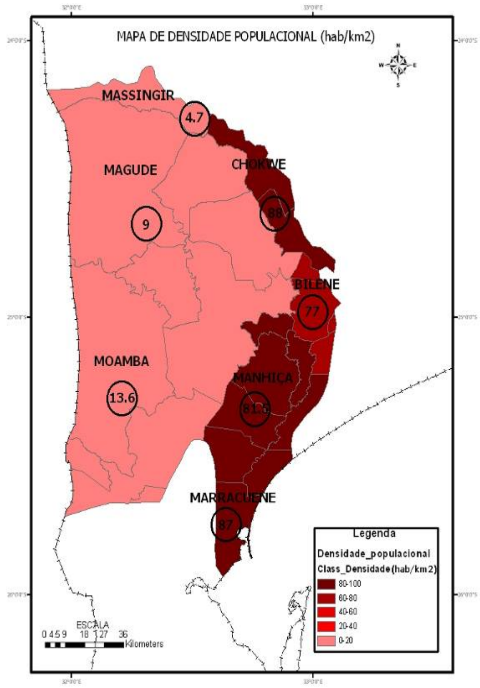


Figure 19: Distribution of population density in the Mozambique part of the Inkomati River, after Tauacale *et al.,* (2007).

5.3 Historical overview of the socio-economic activities

The Inkomati River Basin is of great socio-economic and cultural importance in parts of southern Mozambique, northern Swaziland and eastern South Africa. There are many factors that led to the current settlement patterns including urban and industrial developments within Inkomati Basin. Maputo Bay has been an important regional trading centre since the Seventeenth Century (Newitt, 1995). In the Eighteenth Century, road and railway connecting the Maputo Bay and South Africa, passing through most of the Inkomati River Basin was built (Libby, 1987). The mining activity that started in mid and late Eighteenth Century in Kimberley in the Rand area (Gauteng) and near Barberton further led to significant population migration into the basin (Nyathi, 1977). Maputo harbour became the preferred port for South Africa imports and exports (Beinart, 1994). In the Nineteenth Century a game reserve (now Kruger National Park) was established in the area between the Crocodile and Sabié rivers. In the same period farmers settled along the Upper Inkomati River Basin, cultivating mostly citrus, cotton and tobacco (Packard, 2001). In the Lower Inkomati River Basin, irrigation was developed for sugarcane plantation and sugar mill at Xinavane in Mozambique was established. In the 1960s, rice plantation was introduced in the Lower Inkomati River Basin while Swaziland started sugar plantations along the Umbeluzi River, adjacent to the Komati. A paper mill was established in the upper parts of the Crocodile River (Ngodwana) (Mather, 1992, cited in Packard, 2001).

The socio-economic activities in the Mozambican part of the Inkomati River Basin include agriculture, livestock, fisheries, tourism, trade and services. Figure 20 shows the current land-use within the Inkomati River Basin.

5.4 Agriculture activities in the Inkomati River Basin

Agriculture is the main economic activity in the Mozambique part of the Inkomati River Basin. There are three main types of land-uses: (1) non-irrigated land (2) irrigated land (3) urban and habitation land, including the tree plantations (CENACARTA, 1999). The irrigated agriculture, which currently covers about 13,789 ha, is devoted mainly for the cultivation of sugar cane in large plantations. A limited number of small-scale farmers also practice irrigation agriculture (ARASUL, 2007; Sweco *et al.*, 2003). The total area of land that is potentially suitable for irrigation is over 25,000 ha (Table 6).

Most of the land is currently used for small-scale or subsistence agriculture that is essentially rain-fed (Figure 21). Tree plantations are mainly found in the Lower Inkomati River Basin and are composed of eucalyptus trees. Livestock grazing is extensively practiced in the middle parts of the Inkomati River Basin.

Table 6: Area with irrigation infrastructures in the Inkomati Basin (ha) (Carmo Vaz and Van der Zaag, 2002)

Country	Area under irrigation in 2002	New planned irrigation land in 2000 (JIBS)	Additional irrigation land allowed by TIA (2002)
Mozambique	23,300	52,300	0
South Africa	83,000	15,100	15,100
Swaziland	4,500*	7,400	7,400
Total	**110,800**	**74,800**	**22,500**

** Excluding 10,800 ha outside the basin*

Livestock and game

The total number of livestock and game within the Inkomati Basin is about 700,000 equivalent livestock units (ELSU), of which some 520,000 and 120,000 are found in South Africa and Swaziland, respectively. Mozambique has 60,000 livestock units (Carmo Vaz and Van der Zaag, 2002). Table 7 presents the livestock population in the districts in the Mozambique part of the Inkomati River Basin in the period 1990- 2004 based on the FAO country statistics for 1990 and 2004.

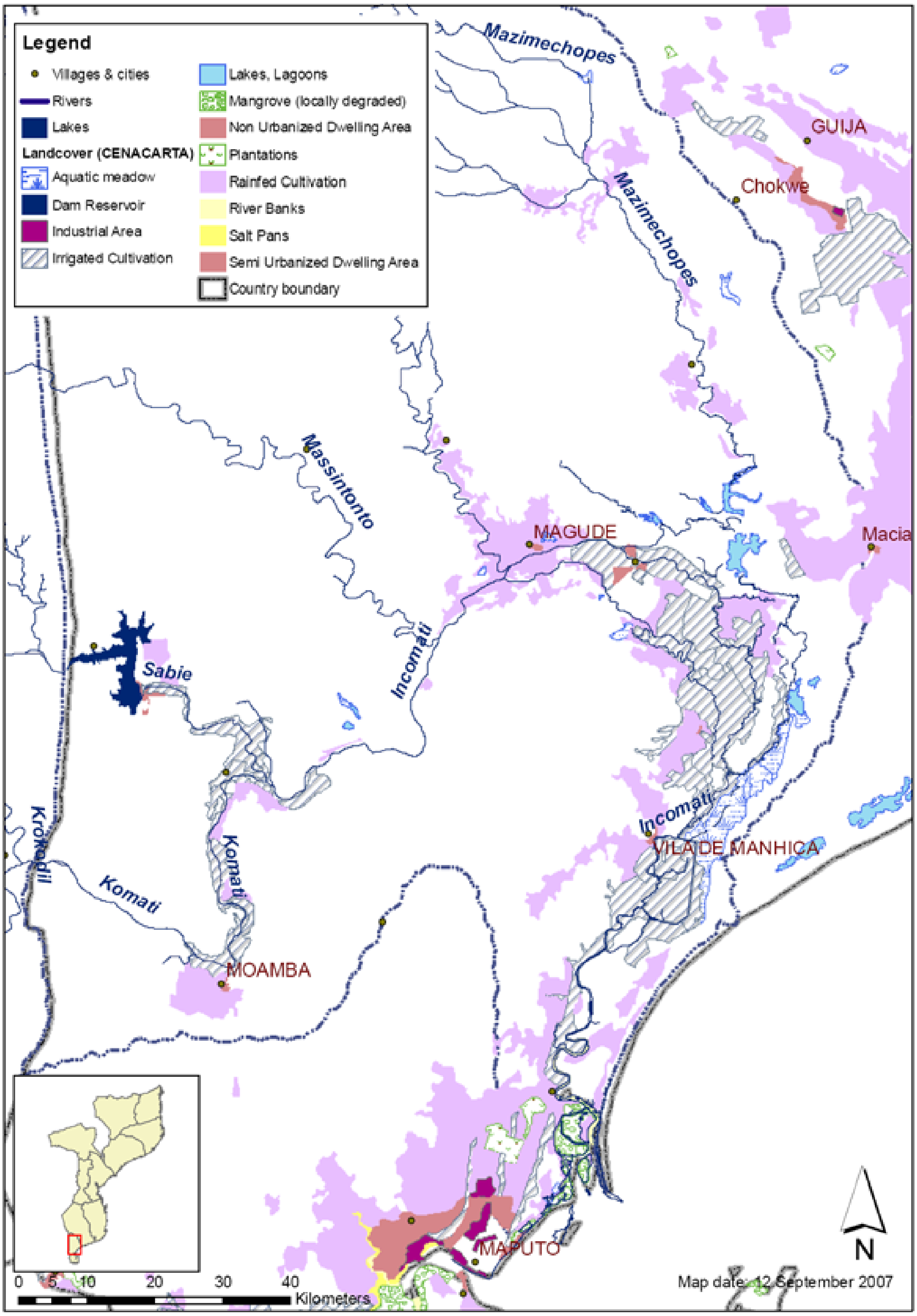


Figure 20: Vegetation cover, agricultural areas and the main urban centers in the Inkomati River Basin (Mozambique), after Bydekerke (2007).

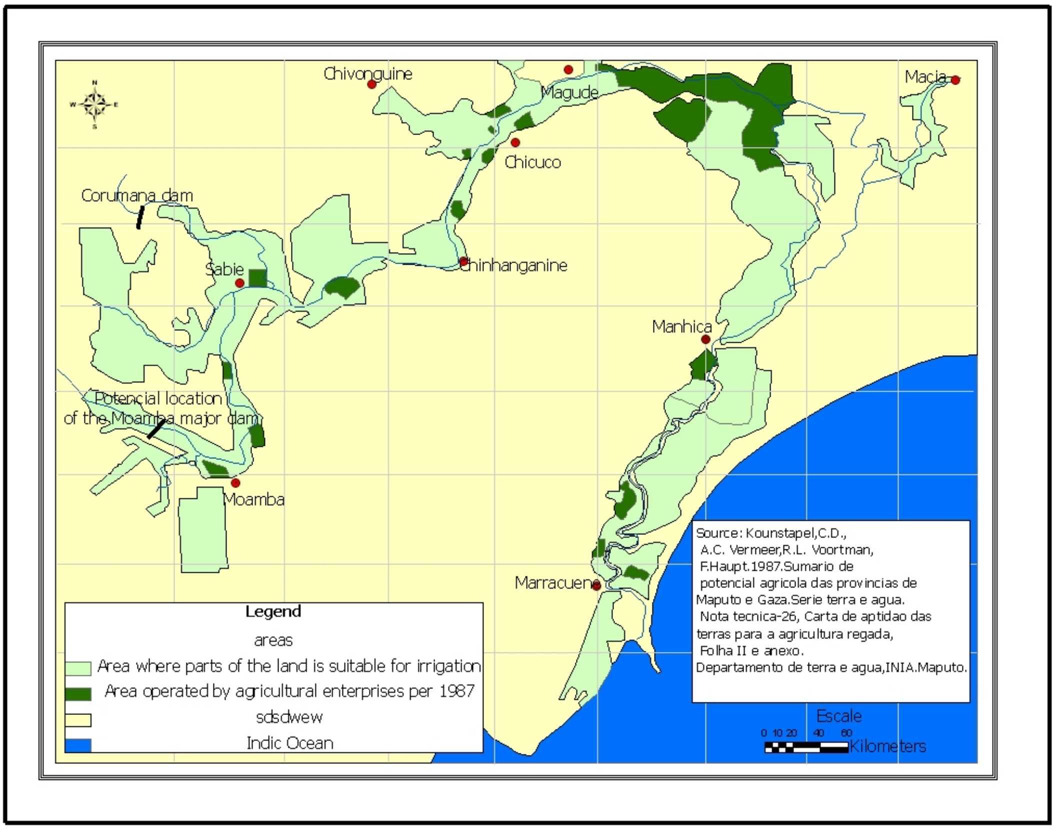


Figure 21: Potential irrigated areas in the Inkomati River Basin and land currently under irrigation (Tauacale *et al.,* 2007).

Rain-fed agriculture

The rain-fed agriculture is practiced in the entire basin with particular emphasis in Curumana, Sábiè, Magude, Chókwè, Bilene, and Manhiça. It is mainly subsistence farming with most of the crops been consumed at household level The main crops that are cultivated includes cassava, maize, groundnut, sweet potato, cowpea, pigeon pea and vegetable crops such as squashes, pumpkins, tomatoes and okra (Schouwenaars, 1988). This type of agriculture is characterized by application of low technology.

Table 7 provides data on the production of maize, sorghum and livestock in the Mozambique side of the Inkomati River Basin for the period 1990 - 2004. The overall maize production has increased from 3,000 tonnes to 11,000 tonnes, representing an increase of about 3.5 times in the period between 1990 and 2004. Higher production was experienced in the districts of Bilene and Marracuene and lower production occurred in Chokwe and Manhica. It should be noted that Boane, Chokwe, Namaacha and Bilene are only partially covered by the Inkomati River Basin, and so, maize production registered in these districts includes the production from neighbouring river basins (Bydekerke, 2007).

The rain-fed agriculture is highly dependent on climate. Given that evaporation surpasses rainfall, there is significant moisture deficit in certain periods of the year that severely stresses crops thus affecting agricultural production. The average grain yields is about 1 tonne per ha (Carmo Vaz and Van der Zaag, 2002 quoting Schouwenaars, 1988). Figure 22 shows the changes in the area planted with maize and Figure 23 shows the changes in the yield of maize in the period 1990 and 2004. Comparing these figures and the maize production presented in Table 7, it can be concluded that the observed increase in maize production was due to increase in the agricultural area and increased maize yield per ha, which may be attributed to improvements in the agricultural practices.

Table 7: Maize, sorghum and livestock statistics for 1990 and 2004, Source: FAO Country Statistics for 1990 and 2004.

District	Maize production (tonnes)		Sorghum production (tonnes)		Livestock (thousands)	
	1990	2004	1990	2004	1990	2004
Bilene	3,673	13,318	1,384	1,794	0.263	0.295
Chokwe	2,725	9,675	1,140	2,518	0.341	0.266
Massingir	3,610	12,410	1,680	2,376	0.343	0.282
Boane	3,385	11,594	1,140	2,347	0.300	0.289
Magude	3,709	13,047	1,337	2,915	0.336	0.240
Manhiça	3,802	9,232	1,210	2,796	0.241	0.333
Marracuene	3,712	13,702	1,594	2,539	0.305	0.273
Moamba	2,790	10,956	1,478	2,720	0.363	0.298
Namaacha	3,133	11,145	1,615	2,954	0.322	0.286

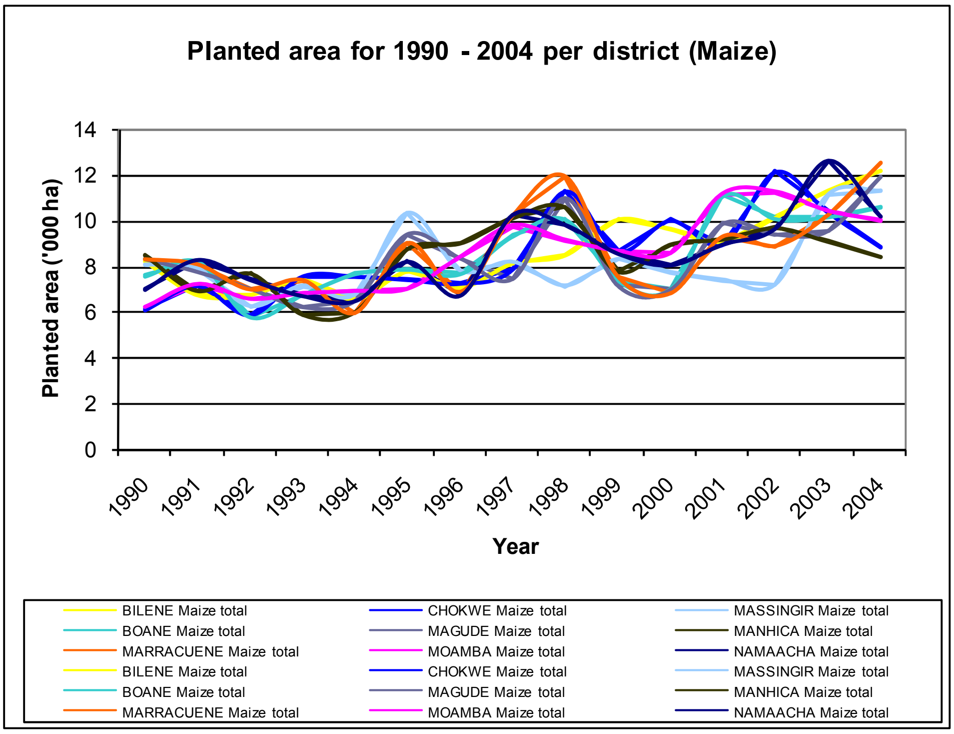


Figure 22: Changes in area under maize cultivation in the period 1990 – 2004 (Bydekerke, 2007).

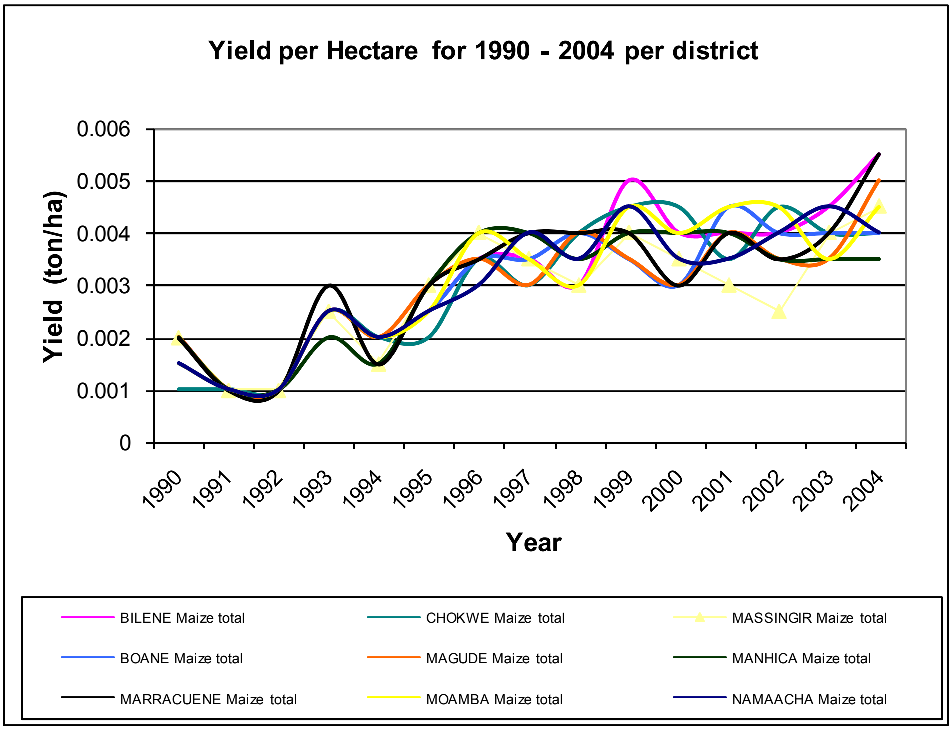


Figure 23: Changes in maize production (FAO) in the period1990 - 2004 (Bydekerke, 2007).

Exotic tree plantations

The main exotic tree plantations are composed of eucalyptus trees. These plantations are found in Swaziland and South Africa (Table 8). South Africa has 310,00ha of exotic plantations while Swaziland has 29,400ha (JIBS, 2001; Carmo Vaz and Van der Zaag, 2002). Currently Mozambique has 2,400 ha of exotic tree plantations. Other exotic tree plantations include pine trees which mostly supply building poles and firewood.

Table 8. Exotic tree plantations in the Inkomati Basin (ha)

Country	Established (1991)	Maximum allowed/planned
Mozambique	2,400	25,000
South Africa	310,000	367,300
Swaziland	29,400	32,400
Total	**341,800**	**424,700**

Source: JIBS (2001)

Irrigated agriculture

The area under irrigation in the Inkomati Basin is estimated to be 102,000 ha, mostly in South Africa (83,000 ha) and Mozambique (23,300 ha). In Swaziland, the area under irrigation is estimated to be 4,500 ha, although it also irrigates additional 10,800 ha in the Umbeluzi Basin with water pumped from the Inkomati River Basin. There are plans to expand the area under irrigation by additional 74,800 ha. However, TIA in 2002 only permitted an area equivalent to 22,500 ha to be under irrigation in South Africa and Swaziland (Table 6). The major irrigated crop includes sugar cane, representing about 42% of the entire irrigated area in the basin. Other irrigated crops include orchards, summer grains and winter vegetables (Carmo Vaz and Van de Zaag, 2002).

According to ARASUL (2007) and Sweco *et al.,* (2003), most of the irrigated area (about 13.789 ha) in the Mozambique part of the Inkomati River Basin (Table 9) is operated by sugar cane plantation and small-scale farmers. The irrigated land in the upper Inkomati mainly in Moamba and Sabié is operated by small scale farmers with a capacity to cultivate land smaller that 50 ha. These farmers use land previously owned by the government and have some irrigation infrastructures (Moamba I and II, and Sábiè Blocks I and II). The government still owns some land - about 50 ha - that is administered through the Hydraulic Development Fund under the Ministry of Agriculture (Sweco *et al.*, 2003).

In the Middle Inkomati, in Magude, there are small-scale farmers producing vegetables, tomatoes and onions, for subsistence and commerce. Sugarcane plantations in Mozambique are located in Xinavane and Maragra. In Xinavane there are about 7,149 ha of sugarcane plantations, corresponding to 51% of all the irrigated land in the Mozambican part of the Inkomati River Basin (ARASUL, 2007). This area includes small-scale farmers who operate about 200 ha of the irrigated sugarcane plantations in the eastern part of Xinavane, in Vamagogo and Taninga (Tauacala *et al.*, 2007). In Maragra, there are about 6,440 ha of sugarcane plantations corresponding to about 48% of the total irrigated land in Mozambique part of the Inkomati River Basin (Tauacale *et al.*, 2007).

Table 9: Areas under irrigation in the Mozambique part of the Inkomati River Basin in 2007 (Tauacale *et al.*, 2007).

Company	Irrigated areas (ha)	Water used for irrigation (m^3/month)
Xinavane	5,800	5,957,476.17
Maragra	5,000[1]	4,051,854.80
Small farmers		166,666.66
COFAMOSA	30,000[2]	
Total	**40,800**	**10,175,997.63**

Source: ARASUL (2007)
[1] To be developed in association with Associação Malengane
[2] In the first period, the project implementation will be on 10000 ha;
the remaining area will depend on the increase of the absorption capacity of Currumana

6. Water demand

The water demand in the Inkomati Basin is higher than water availability. This can be attributed to increased uses of water within the basin due to the increased population and the associated expansion of urban areas. The water demand is increasing as a result of industrial development in the basin (Anon, 2001). The mean annual water requirement for irrigation within the Inkomati River Basin is estimated at 1,125.9 Mm^3. The irrigation water demand is highest in South Africa (669.6 Mm^3) followed by Mozambique (280.3 Mm^3) and Swaziland (174.9 Mm^3). Because of plans to increase the area under irrigation in South Africa, Swaziland and Mozambique (Van der Zaag and Carmo Vaz, 2003; Carmo Vaz A. and Van der Zaag, 2002), it expected that the water demand for irrigation would increase considerably in the near future.

As a result of significant differences in economic development among the three countries sharing the Inkomati River water, there is no equitable use of water in the basin. In this regard, South Africa will continue to be the dominant user of waters of the Inkomati River in view of its more advanced economy as compared to Mozambique and Swaziland. This is demonstrated by existence of several large dams in the South African part of the basin while Mozambique has only one dam that was build to address the issue of water shortage (Carmo Vaz A. and Van der Zaag, 2002).

The estimated annual discharge of the Inkomati River is about, 3,587 $Mm^3 yr^{-1}$ (JIBS, 2001). The average annual evapo-transpiration and rainfall are 1,900 mm and 740 mm, respectively. Thus, the annual total evapo-transpiration is much greater than annual total rainfall in the Inkomati River Basin. This means there is a water deficit hence the need to construct dams in order to increase dry season storage. Although water demand is continuously increasing, water available in the river is not sufficient to meet the demand. For instance in the year 2002, the estimated total consumptive water use was about 1,800 $Mm^3 yr^{-1}$ (Table 10) including consumptive use by exotic forest plantations. The total consumptive water use represents 50% of the total annual river discharge. This level of consumption is relatively high and frequently leads to water shortages given the high variability of flow, both within and between years (Carmo Vaz A. and Van der Zaag, 2003).

6.1 Water demand for domestic and municipality services

The domestic and municipal water use in the entire Inkomati River Basin is about 3% of the total water use. Mozambique uses only 11 $Mm^3 yr^{-1}$ of water from Inkomati River (Table 10). The water use is of the order of 30 litres per day per capita. This can be attributed to the fact that most of the population in Mozambique live below poverty level with no access to piped water (Leestemaker, 2000, quoting Kranendonk, 1980).

Table 10: Estimated water use for different purposes in the Inkomati River Basin per country (in $Mm^3 yr^{-1}$) as per the year 2002.

Country	Water available	Water use							Water used %	Water available %
		Industry	Domestic and municipal	Livestock and sport	Exotic plant species uses	Irrigation agriculture	Inter-basin water transfer	Total		
South Africa	2,937	90	35	8	473	670	132	1,408	78	48
Swaziland	479	6	1	2	46	48	135	238	13	50
Mozambique	171	3	11	1	2	150	0	167	9	97
Total	3,587	99	47	11	521	868	267	1,813	100	51
Percentage		5	3	1	29	48	15	100		

Fonte: Carmo Vaz and Van der Zaag (2003);JIBS (2001); TIA, (2002)

6.2 Water demand for irrigation

Agriculture is the main consumer of water from the Inkomati River Basin, representing about 48% of the total use. The area under irrigation in the three countries in 1991 was about 126,000 ha of which 66% was in South Africa. The equivalent areas in Swaziland and Mozambique were 11% and 23%, respectively (Carmo Vaz A. and Van der Zaag, 2002). The mean annual water demand for areas under irrigation within the Inkomati River Basin is estimated at 1,126 $Mm^3 yr^{-1}$. South Africa (669.6) has the highest irrigation water demand followed by Mozambique (280.3) and Swaziland (174.9). There are plans to increase the irrigated areas in South Africa, Swaziland and Mozambique (Van der Zaag and Carmo Vaz, 2003; Carmo Vaz and Pereira, 2002) and this would led to increased demand for water.

In Mozambique, area under irrigation is 13,789 ha. This consumes about 122 Mm^3 annually. It is however projected that the area under irrigation would be increased to 40,800 ha which would mean that the water consumption would be 360 $Mm^3 yr^{-1}$, (ARASUL, 2007).

6.3 Water demand for exotic plants irrigation

The irrigation of large plantation of trees is the second largest water user in the Inkomati River Basin, representing about 29% of the total water use. These plantations are found mainly in South Africa and Swaziland, occupying an area of about 400,000 ha. The annual water consumption is estimated to be about 518 $Mm^3 yr^{-1}$ of water (JIBS, 2001). In Mozambique tree plantations are still in the early stages of development and represent about 2% of the total water use in the entire basin. However, there are plans to expand the total area under tree plantations to about 25,000 ha (Carmo Vaz and Van der Zaag, 2003) which means water demand will rise.

6.4 Water demand for industry

The industrial water demand in the entire basin represents only about 3% of the total water use. Most of it is used in South Africa, particularly in the paper industry (SAPPI in Ngodwana), in TSB in Malelane and Komatipoort. In Mozambique, the industries that consume water abstracted from the Inkomati are sugar factories in Xinavane and Maragra and textile factory in Marracuene.

6.5 Inter-Basin Water Transfer

Water abstracted from the Inkomati River is also transferred to other neighbouring basins. This represents the third type of water use in the basin after irrigation and water consumption by exotic tree plantations. There are two bulk water transfers in the Inkomati River Basin: South Africa exports 132 Mm^3 per year from upper Inkomati River Catchment as cooling water for thermal power generation in adjacent Olifants Catchment, and Swaziland exports 136 $Mm^3 yr^{-1}$ from Komati river, and uses about 128 $Mm^3 yr^{-1}$ for irrigating 10,800 ha on the Umbeluzi, 5 $Mm^3 yr^{-1}$ for domestic use in the three villages in the vicinity of irrigation scheme, and the remaining for Mhlume sugar mill (Carmo Vaz, 2003).

6.6 Ecological water demand

Downstream and coastal ecological systems are highly influenced by the river flow regime, both the amount and the seasonality of discharge. The river flow regime determines the water quality, sediment and nutrient load, salinity and hydraulic characteristics of the estuary. It also influences the adjacent coastal waters which may have impact on the growth and health of the downstream and coastal marine ecosystems, such as mangroves and seagrass beds that provide a habitat and feeding grounds for estuarine and coastal organisms (Monteiro & Matthews, 2003).

Mangrove swamps are common features along the coast of Mozambique. They are associated with mangrove forests, wetland vegetation adapted to wet soils, saline habitats, and periodic tidal inundation. The extent of swamps is controlled by seasonal freshwater and semidiurnal tidal water influx.

Mangrove vegetation is a primary ecological component of the coastal environment. They extract phosphates and nitrates from the sediments and synthesise carbon. By the fall of their leaves, branches and trunks, and by subsequent decomposition they provide to the adjacent seas, dissolved and particulate organic matter. In doing so, they contribute to the recycling of nutrients (Hoguane, 1996). Mangrove swamps are important nursery areas for several commercial species such as penaeid prawns. They provide a foothold for other animals. The juveniles of the penaeid prawns are nursed in mangrove swamps. Both the availability of food and protection in the mangrove swamps are the main reasons why juveniles of penaeid prawns prefer mangrove swamps (Hoguane, 1996). Large artisanal and commercial fisheries are also associated with mangrove forests. Kampetsky (1987) quoted by Hoguane (1996) has estimated that the average yield of fish, shrimps and crabs from the mangrove associated swamps and estuaries is about 9 tonnes per square kilometre per year. Pauly and Ingles (1986), quoted by Hoguane (1996) estimated catch of about 14 tonnes of prawns per square kilometre of mangrove forest each year. Therefore a healthy mangrove environment leads to high production of coastal fishery resources. Mangroves are also important to local communities as they provide timber and charcoal used in domestic and industrial activities.

Although mangrove communities develop best in the absence of strong currents or wave action, once they are settled they prevent coastal erosion. In this way they contribute to the coastal protection (Hoguane, 1996).

Although mangroves have the ability to excrete salt from the roots, some proportion of salt infiltrates into the tissues. The more saline the water, the more the salt enters the tissues. In order to keep the right salt content within the tissues, they need substantial amount of fresh water. Hence, right salt balance within the water in the estuary has to be maintained for optimum plant growth. The physical processes in the mangrove swamps act naturally in such a way as to keep the right salinity. Heavy rain and the subsequent river flow flush the creeks and swamps and dilute the water within the swamp, contributing to the maintenance of appropriate salt balance (Hoguane, 1996).

Shrimps are euryhaline species meaning that they can tolerate a wide range of salinity. Typically the juveniles are found in estuaries, lagoons or coastal areas whereas the adults move further offshore. The life history of the shrimp may be divided into six phases:

- embryo phase (planktonic/benthic) (inshore/offshore)
- larval phase (planktonic) (inshore/offshore)
- juvenile (estuarine)
- adolescent (estuarine)
- sub-adult (coastal)
- adult (inshore/offshore)

Typical life cycle of the penaeid shrimp is presented in Figure 24. The adults spawn in the open sea, often during the dry season. The eggs and the larvae drift passively to the sheltered mangrove and estuary zones, where they grow into juvenile stage. The juveniles are recruited to the coastal fishing area during the rainy season.

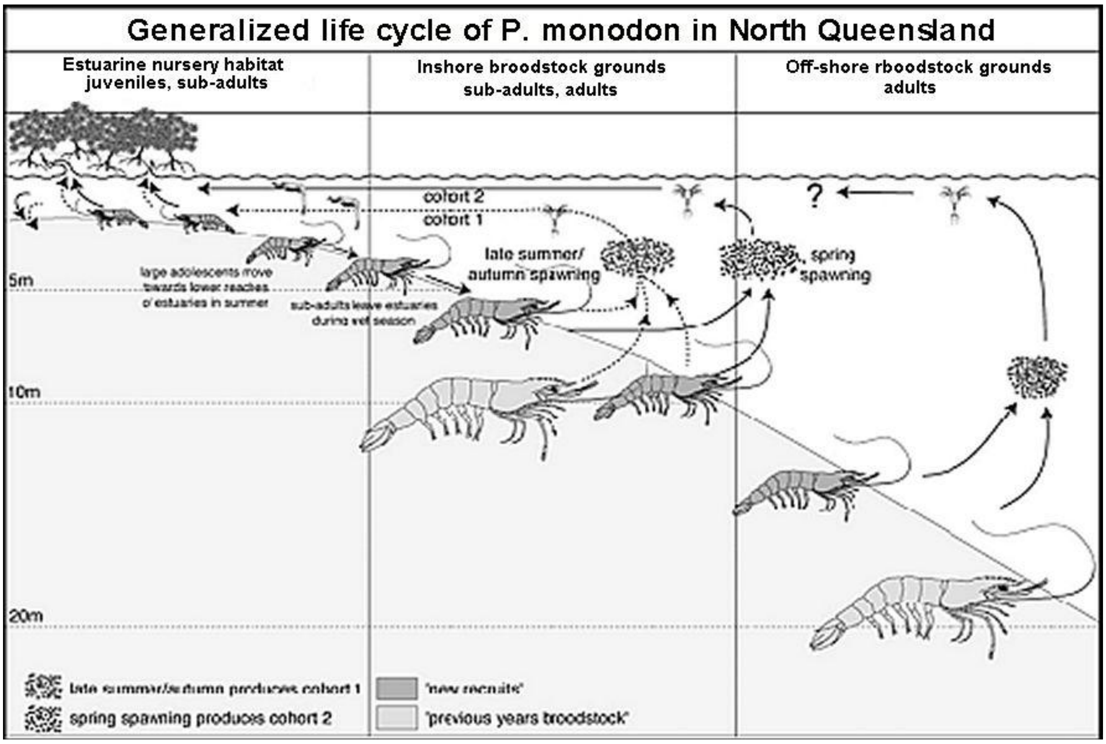


Figure 24: Schematic representation of the penaeid shrimp life cycle.

Several studies have shown that there is a good correlation between the shrimp catch and the river flow. The shallow water shrimp resources are often related to freshwater availability, both river runoff and coastal rainfall. Previous studies conducted in Sofala Bank have revealed a strong correlation between Zambezi river runoff and the shrimp abundance (Jorge da Silva, 1986; Gammelsrød, 1992a,b; Hoguane 1997). Gammelsrød (1992a,b) developed a simple linear relationship between the catch rates and Zambezi runoff during the rainy season (October to March) for the period 1977 to 1988. The coefficient of goodness of fit of his regression was about r^2=0.8. Hoguane (1997) reworked the linear regression with data from 1978 to 1993, and the coefficient of goodness of fit he found was about r^2=0.6. Further, Hoguane (1997) founded a negative correlation between the shrimp catch and the Zambezi runoff during the dry season (May to August).

The correlation between the Inkomati River runoff and the shrimp catch in Maputo Bay is however weak since the coefficient of goodness is about r^2=0.34 (Figure 25). Better correlation is found between the local rainfall and the shrimp catch. This may reflect the effect of river flow abstraction, so that river flow no longer matches the natural processes or due to the fact that shrimp fisheries in Maputo Bay depend on other river discharges such as the Umbeluzi and Maputo rivers.

The rationale behind the good correlation between the runoff and shrimp catch rate lies between two major basic assumptions (Staples, 1985; Gammelsrød, 1992a; Gammelsrød and Hoguane, 1995) that the freshwater: (i) stimulates the recruitment, (ii) provides nutrients to the coastal waters. The juveniles of the shrimp, which usually develop in mangrove swamps, would tolerate freshwater content up to a certain limit above which they migrate from the swamps (Staples, 1985). Hence, the higher the runoff, the lower the salinity in the swamps and the larger the area of the swamp flooded by freshwater; the larger the number of the juveniles released to the coastal fishing zone. Low regression coefficient may indicate that the river flow is contributing less to the availability of the shrimp, and the reduction of river influence could be both due to reduction of flow or change in the hydrological regime.

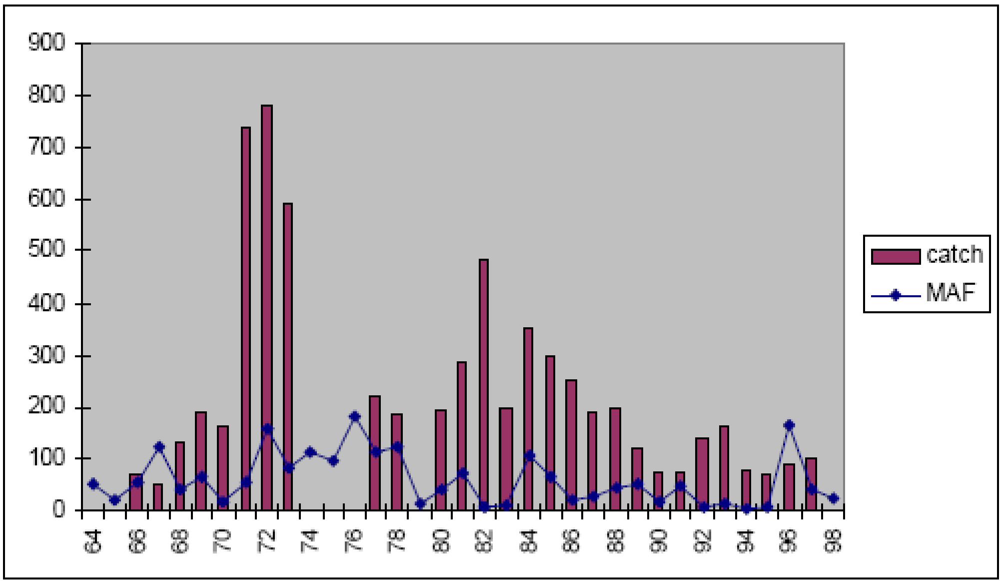


Figure 25: Mean annual Inkomati River discharge and the total annual shrimp catch in Maputo Bay (poor correlation).

7. Institutional and legal framework

7.1 Institutional framework

Each country traversed by the Inkomati Basin has its own mechanism of managing water resources within its border provided by international agreements and regulations. There are also regional mechanisms to ensure coordination and equity in water use across the countries. The following are the regional institutions involved in water resources management in the Inkomati River Basin:

- Joint Water Commission with Swaziland (Swaziland JWC)
- Joint Water Commission with Mozambique (Mozambique JWC)
- Tripartite Permanent Technical Committee with Mozambique and Swaziland (TPTC)
- Komati Basin Water Authority (KOBWA) (at regional level)
- Save-the- Sand (a Non Government Organisation)
- Irrigation Boards (at national level)
- Water Users Associations
- Bushbuckridge Water Board (in South Africa)
- District and local municipalities (at national level)
- Inkomati Reference Group (a stakeholder participation group formed as part of the CMA establishment process).
- ARA-Sul (in Mozambique)

Increasingly, the Members States are realizing that TPTC in its present form is not ideal for addressing the objectives of the IIMA. The Agreement taking into consideration the enormous challenges that the basin faces need to be revisited. The TPTC does not have legal personnel preventing it from engaging in the mobilization of financial resources from prospective donors.

Within the context of increasing competing uses, there is a need for a permanent body that would deal with management issues in a timely manner, with sufficient power to enforce its decisions. The PRIMA project is intended to address this issue by investigating different options of increasing efficiency in the decision–making process.

South Africa

The National Water Act of 1998 recognizes the need to establish Catchment Management Agencies for specific water management area (Carmo Vaz, 2003). This agency has a major role of investigating and advising on the protection, use, development, conservation, management and control of water resources in its water management area. Other roles include: development of catchment management strategies, control of all related water users activities and activities of water management institutions within its area of jurisdiction; Also, to promote community participation in the protection, use, development, conservation, management and control of the water resources. Following the enactment of the Act, the Inkomati Catchmnet Management Agency, comprising the Komati, Crocodile and Sabié Rivers was established, with each of these rivers having a sub-catchment organization (Carmo Vaz, 2003). Depending on the complexity of the water management area, a period of two to three years is allowed for the completion of the process of establishing the agency and appointing the governing board (Sengo *et al.*, 2005).

Swaziland

The Department of Water Affairs and its executive arm, the National Water Authority are the government institutions that are responsible for managing the water resources in Swaziland. Government Water Control Area may be declared if it is deemed necessary in the public interest for the purpose of controlling the abstraction, utilization, supply, or distribution of the water of any public stream within the relevant area. The Komati River and all its tributaries within Swaziland have been proclaimed a Government Water Control Area. The Water Apportionment Board has determined apportionments based on normal flow. When the flow is very low, the abstraction by irrigators must be reduced proportionally. The Water Bill of 2002 was designed to strengthen the role of the Water Apportionment Boards, and it was envisaged that they would be transformed into River Basin Authorities. The minister may, on his or her own accord or at the request of a number of proprietors of land riparian to a public stream, declare any area as an Irrigation District. An Irrigation District is administered by the River Basin Authority, and has an Irrigation Board. The Board comprises mainly of members elected by the relevant proprietors. An Irrigation Board is charged with such functions as: the protection of the water sources; preventing wastage of the water; preventing unlawful abstraction or storage of public water; exercising general supervision over all public streams within the District; recording the entitlements to any share in the use of the water and the times when such shares may be taken; and supplying water to any person or local authority for primary, urban, or industrial purposes (Carmo Vaz, 2003).

Mozambique

The Ministry of Public Works and Housing (MOPH) is in charge of managing water resources and related infrastructures. DNA (National Directorate of Water) executes the water resources activities at the national level. Regional Administration of Waters (ARA) does management at regional levels.

ARA-SUL is the authority that manages the water in the Southern part of Mozambique. The Unity of Management of Inkomati Basin (UGBI) is a sub-unit of ARA-SUL and is responsible for operational activities at Inkomati Basin (Carmo Vaz, 2003). The River Basin management Unit of Umbeluzi is also responsible for overseeing the Maputo River Basin. These units deal directly with the water users and are primarily concerned with hydrometric and pluviometric data collection as well as operation of dams.

7.2 International agreements

There are a number of agreements signed between water users and governments to protect the environment and to assure equity in water use in the Inkomati River Basin. The revised Protocol on Shared Watercourse System in SADC Region signed in 2000 by head of states of SADC countries, came into force in 2004. The main objective of this protocol is to have a "closer co-operation for judicious, sustainable and coordinated management, protection and utilization of shared water courses" (JIBS, 2001).

The number of agreements signed from 1964 to 2002 show the commitment of involved parties in the issue of water sharing. The latest agreement was signed in 2002, and is known as the Tripartite Interim Agreement between the Republic of Mozambique, the Republic of South Africa and the Kingdom of Swaziland. This agreement is concerned with the cooperation on the protection and sustainable utilization of the Inkomati and Maputo watercourses and resources. This agreement is interim in nature and is set to be replaced by a comprehensive agreement to be signed after a joint study in the Maputo River Basin has been undertaken. During the negotiation of the IncoMaputo, the Members States felt that the existing amount and confidence on the knowledge about the water resources of the Maputo River was not enough as to allow the riparian countries to engage in a more permanent agreement. It was agreed that they should commission a comprehensive study to raise the knowledge of the water resources particularly regarding the surface and groundwater resources, including a comprehensive system analysis and a yield modelling to assign flow with acceptable assurance of supply to different water users and sectors.

The Members States have developed and are currently implementing the PRIMA project. This project intends to progressively implement the objectives of the Inkomati Maputo Agreement, namely the exchange of data and information on water quality, floods and droughts, capacity building issues, operation rules of dams and other infrastructure, mechanism to deal with droughts, as well as to investigate appropriate institutional set up for a smooth management of the Inkomati and Maputo basins.

8. Water related environmental problems

Major issues of concern in the Inkomati River Basin are directly linked to water shortage which further causes water quality deterioration, saltwater intrusion, with consequent environmental and socio-economic impacts. As stated previously, 50% of the available water in Inkomati is abstracted is used in socio-economic activities. The river basin currently has over 10 dams with a total storage capacity of about 12 million cubic meter of water (Water in Southern Africa, 1996). It is estimated that South Africa and Swaziland abstract between 40% and 60% of the total flow, respectively (Hoguane *at al*., 2002).

8.1 Flow augmentation and diversion

Since the sixties, the Inkomati Basin has experienced a substantial amount of regulation as small and large dams were built to address the socio-economic needs of the riparian countries. During the period of 1972-1981, four relatively small dams were built in the Crocodile and Sabié rivers in South Africa. The Kwena dam on the Crocodile, with storage capacity of 155 Mm^3 increased the storage capacity in the basin to some 430 Mm^3 (Carmo Vaz & Van der Zaag, 2002). In the eighties, Mozambique built a large dam on the Sabié tributary with a total storage capacity of 850 Mm^3. On the nineties, Maguga and Driekopies dam were built in Swaziland and South Africa, respectively, bringing the total storage capacity to 2,060 Mm^3 in the basin.

Figure 26 illustrates the impact of the flow augmentation on flow regime and on water level in the Inkomati River Basin. The figure compares the flow regime before (1957-1980) and after heavier (1980-2001) regulation at the Chobela River gauging station E-44. It is evident that regulation has caused the reduction in the peak river discharge. Statistical analysis of discharge data from the two locations conducted by Sengo (2003) indicated that the frequency of floods exceeding 600 Mm^3 per month has reduced from one every 2 years to one every 5 years after 1980s. The immediate consequence of the reduction in the frequency of the high floods is the reduction in the flooding of the higher river banks and inundation of the flood plain, which in turn resulted in to the reduction in the size of the wetlands. Periodic high floods are required in flushing the estuary and deposition of new terrigenous sediments in the mangrove forests. Further, the reduction of the availability of freshwater may contribute to the reduction of productivity of the key downstream ecosystems such as reeds, grasslands and mangroves (Sengo *et al.,* 2005). In addition, the flow augmentation has increased saltwater intrusion in the estuary.

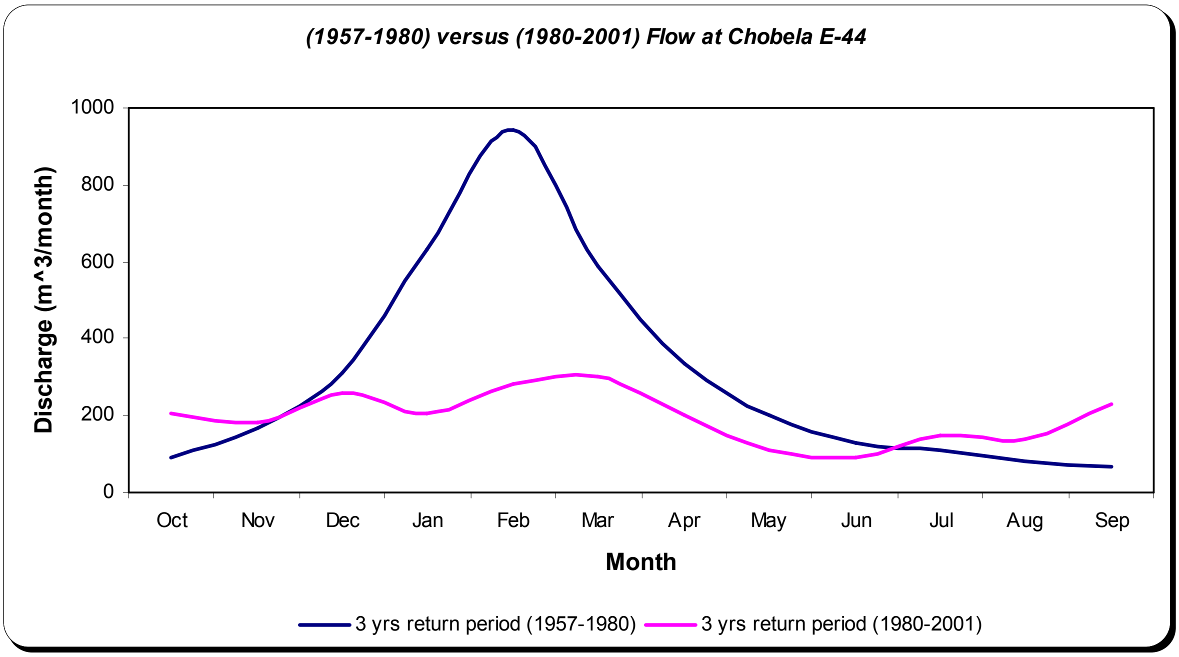


Figure 26: Flow regime before (1957-1980) and after heavier (1980-2001) regulation at the Chobela river gauging station E-44 [Source: Sengo, 2003]

8.2 Saltwater intrusion

Saltwater intrusion is a direct consequence of the reduction in river runoff in the estuary. According to Gonzalez and Serraventosa (1999) saltwater intrudes to over 80 km, and recently, Hoguane (2002) observed salt intrusion up to about 40 km upstream in the Inkomati River estuary. According to Brockway *et al.,* (2005), the river discharge required to keep the saltwater intrusion below 20km is 35 $m^3 s^{-1}$ against the 2 $m^3 s^{-1}$, set in the Piggs Peak Agreement.

The impacts of the saltwater intrusion in the estuarine environment are diverse. Species that are less tolerant to salinity are highly affected, and forced to migrate, thus changing species composition within the estuary. Increase in salinity also threatens the normal growth and survival of plants and animals living in mangrove swamps. Gundy *et al*., (1981) point out that although salt is important for growth and survival of mangrove plants, extremely high salinity retards the growth of even the most resistant species. According to Hoguane (2002), farmers found about 20 Km upstream from the mouth of the Inkomati River who cultivate and graze their livestock on the river banks are negatively impacted by the saltwater intrusion.

8.3 Chemical water pollution

The major sources of pollution of the surface water in Inkomati River Basin are from domestic, industrial and agricultural return flows; and a small fraction originates from suspended solids and sediments. These are characterised by diffuse discharges (fertilisers, pesticides and salinity through leaching), domestic and urban runoff, industrial waste and sewage discharges. According to the findings of the Department of Water Affairs in South Africa, the contaminants from sewage discharge often exceed the allowable international standards (Sengo *et al.*, 2005).

The water quality is relatively more deteriorated in the lower Komati as a consequence of the return flows from irrigated lands (Sengo *et al.*, 2005). In the Upper Komati, river water is relatively good. However, coal mining in the Upper Komati River catchment poses a very serious threat to the water quality in this sub-area. Eskom power stations receiving water from the Komati catchment were designed for use with high quality low sulphate water. Coal mining activities could increase the sulphate levels in the water, which would have major implications for Eskom, and by implication to all electricity users. In the Crocodile sub-area, there are some levels of arsenic contamination, due mainly to return flows from upstream users including irrigation, urban areas and old gold mining activities. Industrial pollution from the SAPPI paper mill at Ngodwana is the most serious cause of water quality problem. Soil has become saturated with salts (especially chlorides) and these leach out into the Elands River and then enter the Crocodile River.

There is no systematic collection of data for water quality in the Mozambique part of the Inkomati River Basin. The information that exists is based in sporadic observations. So it is difficult to draw conclusions on long-term trends. Table 11 presents some parameters of water quality as observed at the station E-23 (Ressano Garcia-Moamba). The values fit within the standards recommended by MISAU and WHO for water quality that is safe for human consumption: however, the table shows an increase in the content of chloride with time. Figure 27 shows the time series of the electrical conductivity of water along the river in the Mozambique part of the Inkomati River Basin, and it can be seen that the conductivity is higher at the station E-23 (Ressano Garcia-Moamba), suggesting an increase in the total dissolved salt content.

8.4 Eutrophication

Inkomati is prone to eutrophication because of high nutrient supply associated with agricultural activities in the basin. Eutrophication is observed mainly in the Lower Inkomati between Xinavane and Marracuene. According to Paulino (1993) quoted by Leestemaker and Tauacale (2000), the eutrophication observed in the Inkomati River results from the leaching of fertilizers used in agriculture or from the excessive dumping of garbage in the water, from sewage and from residues produced by the sugar industry at Xinavane (Sugar Society of Inkomati) and Maragra.

The nutrients enrichment promotes the phytoplankton, algal and water hyacinth blooms in water (Figure 28). The following species of algae and water hyacinth were observed in Lower Inkomati *Cladophora filamentous*, *Eichornia crassipes* and *Pontederiaceae kindred* (Leestemaker and Tauacale, 2000). The water hyacinths have further environmental impacts in the river. They block the river hampering navigation and also block the penetration of sunlight into the water preventing or limiting photosynthetic activities as well as air exchange with the atmosphere. Further, the decomposition of the organic matter consume oxygen often leading to anoxic conditions causing further deterioration of the water quality.

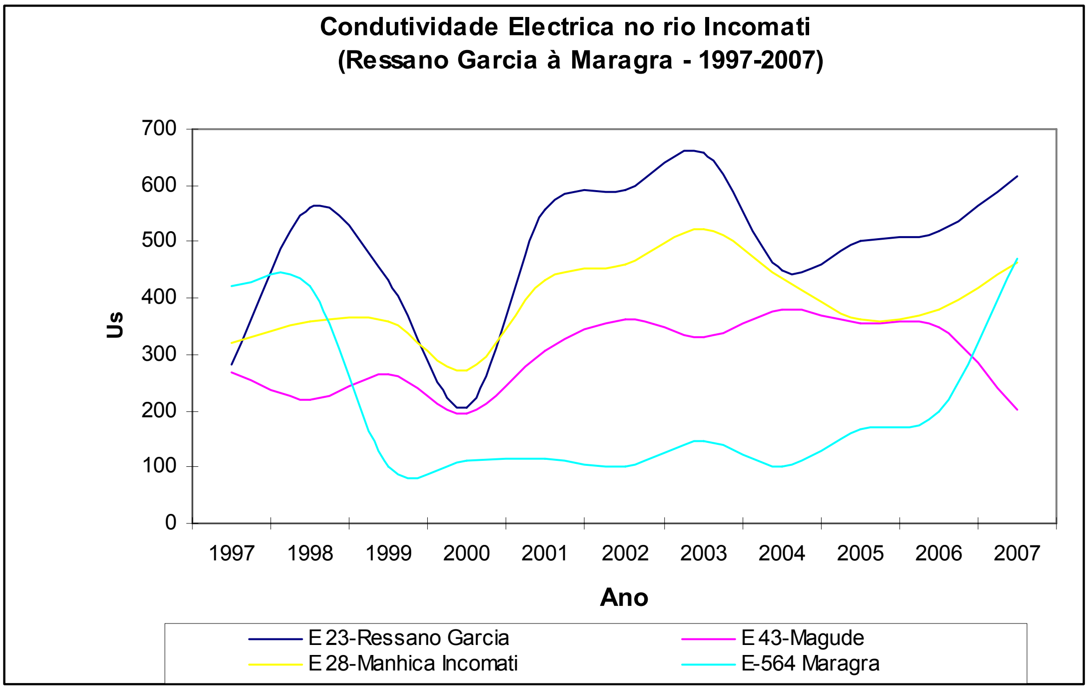


Figure 27: Electrical conductivity of water in the Inkomati River Source: ARASUL (2007)

Figure 28: Water hyacinth in the Lower Inkomati (Tauacale *et al.*, 2007)

Table 11: Water quality at the Station- E23 (Inkomati River, Ressano Garcia - Moamba)

Year	Temperature ° C	pH	Electrical Conductivity (EC) (m s /cm)	Total dissolved carbonates ($mgCaCO_3/l$)	Chlorides (mgCl/l)	Nitrates (mg N / l)
1997	21.70	7.30	281.00	110.00	24.00	2.11
1998	-	8.64	559.00	178.00	47.30	5.48
1999	25.50	7.40	431.60	155.00	40.70	6.18
2000	21.90	7.57	206.00	80.00	21.80	8.18
2001	24.00	8.13	556.00	145.00	44.88	4.41
2002	22.10	7.68	593.00	180.00	70.90	6.71
2003	24.40	7.80	658.00	325.00	92.78	5.19
2004*	-	7.70	448.00	140.00	63.94	13.17
2005	-	7.80	500.00	200.00	62.62	10.00
2006	-	7.75	520.00	215.00	61.23	8.00
2007	-	8.39	618.00	228.00	64.87	3.26

Source: Developed in accordance with water quality data ARA-SUL (2007).
*During this year there was a pesticide effusion in South Africa, from 6 to 9 April.

8.5 Microbiological - Sewage and Domestic Solid Wastes

Bacteria *Vibrio parahaemolyticus* and *Vibrio mimicus* were found in clams in the Inkomati River mouth, in the bay adjacent to Polana and near Matola in the Maputo Estuary (Fernandes, 1996; Anon, 1998). Water in some places in Maputo Bay, particularly where the discharge of sewage takes place such as Miramar at the entrance of the Maputo Estuary, is not safe for swimming. Faecal coliform content in the water within the channel adjacent to the Infulene River in Maputo is high ($4.6x10^5$ bacteria counts/100 ml). The river mouth exceeds 2,400 bacteria counts/100 ml). Faecal coliform, faecal streptococci and *E. coli* were also detected in both marine waters and shellfish tissues in other places within the Maputo Bay. The concentrations found in the shellfish were higher.

There is no record of the microbiological contamination along the entire river basin, but judging from the few records in the vicinity of Maputo City it could be considered that the situation is critical for there is no wastewater water treatment plant and most of the people use pit latrines or defecate in the open air along the river valley (Buuren and Heide, 1995).

8.6 Suspended sediment and sedimentation

Inkomati River is characterized by high suspended sediment load particularly during flood periods. High suspended sediment load is attributed to poor land use practices, deforestation, dredging operations, sand extraction (Figure 29) and river channel erosion.

Sand extraction for use in building industry is mostly common in Middle and Upper Inkomati River Basin, in Ressano Garcia and Moamba. Sand extraction results into large puddles that obstruct the normal flow of water. It also leads to the modification of the river channel topography. Changes in water flow may lead to sediment re-suspension (Lestemeeker and Tauacale, 2000). The Maputo harbour is located in an estuary with high sedimentation rates. The navigation channels needs to be dredged continuously to allow for the safe operation of the harbour. Surveys undertaken on dredging operation showed that about 1.2×10^6 m^3 of sediments are dredged annually from the Maputo ports (FAO, 1999).

As a consequence of high sediment load, accretion does occur at the river mouth. According to aerial photograph analysis conducted over the period 1965 to 1991 by Hoguane *et al.,* (2004), the Macaneta Spit located at the Inkomati estuary has been growing due to deposition of sand that may have been removed from the surrounding areas. The spit was displaced south-eastwards in an area of about 0.30 km^2 during the period 1965 to 1982 and by about 0.1 km^2 during the period 1982 to 1991. The observed displacement is a result of an accretion process (Figure 30a and 30b).

The key sectors contributing to high suspended sediment load are agriculture (soil erosion in river basin), ports and harbours through dredging operations and construction industry sector through sand extraction. Some of the impacts of the high suspended sediment load are as follows:

- Reduction of the light penetration into the water column and subsequent reduction of primary production.
- Smothering of benthic organisms (communities)
- Suffocation of marine organisms
- Mortality on marine biota e.g. sea-grasses, mangroves and corals
- Siltation of tidal channels hampering water circulation and navigation
- Modification of marine biota and fauna species composition

The socio-economic consequences of increased suspended sediment loads in coastal waters include:

- Loss of aesthetic and therefore recreational value of the environment
- Loss of commercial and/or artisanal fishery resources
- Loss of livelihood and revenue
- Loss in quality of seafood products.

Figure 29: Sand mining in the Inkomati River Basin (Tauacale *et al.*, 2007)

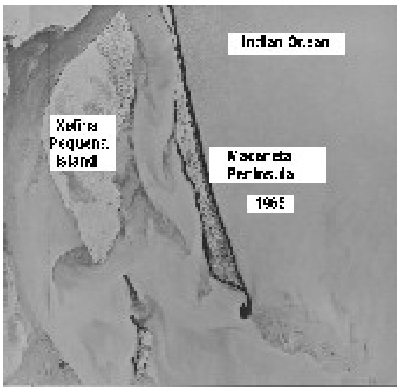


Figure 30a: Aerial photograph of the study area, May 1965.

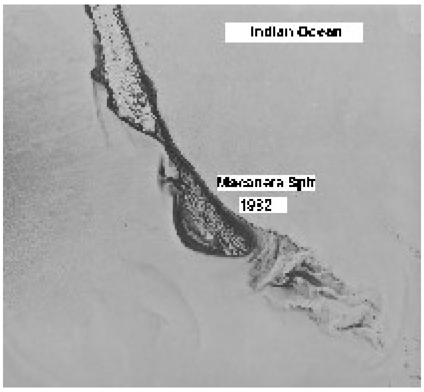


Figure 30b: Aerial photograph of Macaneta Peninsula, September 1982.

8.7 Erosion in the Estuary

The Peninsula of Macaneta located in the Inkomati estuary is rapidly eroding due to increased wave action, winds and strong Inkomati River currents. The narrowest part of the peninsula is less than 100m wide and occasionally breaks during periods of heavy storms (Hoguane *et al.*, 2004). The erosion of the peninsula is also attributable to the clearing of vegetation over the sand dunes. The complete erosion of the peninsula would lead to major environmental and socio-economic problems since seawater would flood the river valley (including the livestock grazing fields). Also, the estuary would be pushed further upstream thus increasing the intrusion of seawater upriver. The mangrove forests would be affected by increased salinity and the estuary would be invaded by marine species resulting in the modification of the estuarine ecosystem composition structure.

8.8 Human health

As a consequence of water shortage, there has been a deterioration of water quality, resulting in pollution and consequent occurrence of water borne diseases. As mentioned above, bacteria *Vibrio parahaemolyticus* and *Vibrio mimicus* were found in clams in the Inkomati River mouth, with high possibility of being introduced in the human food chain. It is important to note that *Vibrio spp*. are the main causes of gastro-intestinal illnesses (Fernandes, 1996). Table 12 presents the reported cases of waterborne diseases in Maputo and Gaza provinces both sharing the Inkomati River Basin. A total of about 210,918 cases of diarrheae, 50,356 cases of dysentery and 36 cases of cholera were recorded in the Maputo and Gaza provinces in the period 1994 - 1996. It is not clear how much of these cases are from the Inkomati River Basin, but the Inkomati is one of the major river basins and so it is expected that most of these cases originate from the basin.

The economic impact of the water-borne deseases is enormous. The medical treatment of the water born diseases in Mozambique is estimated at US$15.00 for dysentery, $10 for Cholera and US$5.00 for Diarrhea, per person. On average the annual health cost for dysentery, cholera and diarrhoea in the period 1994-1996 exceeded US$ 250,000.00, US$ 2,480.00 and US$ 350,000.00, respectively. The loss from cholera epidemic in the period 1998-99 was over US$ 100,000.00 in treatment and over 200 deaths occurred. It caused a deficit of about US$ 30,000.00 to US$ 60,000.00 in fish product export. The European Union had temporarily banned the export of Mozambican fish products due to fear of contamination by cholera (Fernandes, 1996; Anon, 1998).

Table 12: Number of cases of waterborne diseases reported in coastal provinces

Province	1994			1995		1996	
	Diarrhoea	Cholera	Dysentry	Diarrhoea	Dysentry	Diarrhoea	Dysentry
Maputo	61,750	36	19,424	50,258	9,264	50,572	7,971
Gaza	16,909		8,854	14,463	2,661	16,966	2,188
Total	**78,659**	**36**	**28,278**	**64,721**	**11,919**	**67,538**	**10,159**

Source: Anon, (1998).

8.9 Conflicts in the use of Inkomati River water resource

Water shortage in the Inkomati River Basin has the potential to cause conflicts. During the drought period 1980s, water levels in the Inkomati Basin were so low that many people in southern Mozambique who depended on the river died of starvation. Sugar companies suffered severe losses and sugar production dropped significantly. Due to the level of economic development upstream (which is sustained by Inkomati), South Africa could not afford to release water during the dry season. The situation got so bad that the flow at the Mozambique border was as low as 0.04 m^3s^{-1} against the normal minimum of 6 m^3s^{-1}. As a result, awareness was created on the need for an agreement on the use water of the Inkomati River among the three countries. The need for coordination of future water resources development projects and plans was also recognised (Carmo Vaz and Van der Zaag, 2002).

The first step towards building a common understanding and agreement on water use in the basin was recognition of the need to exchange information on water related development plans and on the data pertaining to water resources management. The next step was to ensure equitable distribution of the water resources among the countries sharing the basin, in light of the Article 5 of the Helsinki Rules, which provides a list of factors to be taken into account when establishing "a reasonable and equitable share" of the water resources of an international basin (Carmo Vaz and Van der Zaag, 2002). Further, the parties included other issues on the shared information, required for assuring human and property safety in case of the floods, such as information on the flood warning across the river.

During the negotiations between Mozambique, South Africa and Swaziland, the main disagreement was based on the fact that Mozambique demanded release of a minimum flow and would not accept further development in South Africa that would require additional abstraction of the river water. South Africa and Swaziland on the other hand have ambitious plans for urban, industrial and agricultural development that necessitate additional abstraction of water from the Inkomati River. The two countries also intended to build more dams in the Inkomati, and to transfer water from the Inkomati River basin to the adjoining basins. The negotiation have been characterised by suspicions and mistrust among the three countries. Due to lack of technical capacity, Mozambique has failed to table to the partners its water requirements based on sound scientific and technical assessment. As a result, its plan was rejected by South Africa and Swaziland (Carmo Vaz and Van der Zaag, 2002).

South Africa and Swaziland are forced to negotiate with Mozambique as they need a “no objection” from Mozambique for them to obtain necessary funding from World Bank and other international financial agencies, in order to undertake planned development projects such as dam construction. Mozambique has taken advantage of this requirement to demand for the respect of principles of shared water courses.

As a result of negotiations, the minimum flow at the Mozambique border was set at $2m^3s^{-1}$, and it was agreed that South Africa would not undertake any further development project that would require water consumption or abstraction larger than 250,000 m^3 before consult the TPTC. There was also an agreement for the three countries to conduct a joint study on the water resources demands and development potential of the entire Inkomati Basin. This joint study proved to be a powerful tool for enhancing cooperation among the three countries as it created alliances at the technical level that influenced the process all the way up to the political level. It was on this basis that the Joint Inkomati Basin Study (JIBS) was recommended in 1992. The minimum flow of 2 $m^3\ s^{-1}$ has not always been adhered to by South Africa due to the fact that in situation of serious drought, there is only limited volume of water stored in reservoirs and all consumption has to be rationed.

After the end of apartheid in 1992 and the establishment of a multi-party democratic system in Mozambique, the political environment in the Inkomati River Basin improved considerably. In 1995, the Joint Inkomati Basin Study was completed. Negotiations extended to other shared water courses such as Umbeluzi and Maputo. In July 1996, South Africa and Mozambique agreed to establish a Joint Water Commission on rivers of mutual interest, in due consideration of the interests of the other riparian countries (i.e. Swaziland on the Maputo and Inkomati, and Botswana and Zimbabwe on the Limpopo). In 1997, Mozambique and Swaziland started to hold meetings concerning the establishment of a Joint Water Commission, along similar lines of JWC between Swaziland and South Africa, and that between Mozambique and South Africa. During the floods of February 2000, when nearly 800 people died, many more were displaced from their home villages and infrastructures were severely damaged in the Limpopo and Inkomati Basins; South Africa assisted Mozambique with rescue operations (Carmo Vaz and Van der Zaag, 2002).

9. Analysis of root causes of environmental problems observed in the Inkomati Basin

9.1 Immediate and root causes

As mentioned above there are two key problems related to Inkomati River Basin, and are as follows: (a) Shortage of freshwater, (b) alteration in river flow regime. Other related problems are: Saltwater intrusion, Erosion (soil erosion or coastal erosion), Accretion (sediment deposition) and Pollution (water quality degradation)

The casual chain analysis is summarised in Table 13 and Figures 31 and 32. Shortage of freshwater is mostly caused by increased damming, diversion and high consumption of water in the upper riparian countries. This is exacerbated by the climate change that is causing an erratic rainfall distribution. Alteration of the river flow regime refers essentially to shift from the natural flow regime characterised by occurrence of extreme floods including reduction of the peak flood flows and smothering of the discharge throughout the year. For instance, due to regulation of the river, there is a reduction of the mean flow discharge from about nearly 900 m^3 per month to nearly 200 m^3 per month during the wet season (Figure 26).

Although occurrence of floods may partly be attributed to natural factors such as heavy rainfall associated with El-ñino Southern Oscillation phenomena (ENSO), there is evidence that the situation is worsened by poor management of dams that lead to sudden release of the stored water.

Saltwater intrusion is mainly caused by the reduction in river flow, as a result of the damming of the river, diversion of the river courses and high consumption at the upper riparian countries.

River channel erosion is mostly caused by the strong river currents, while coastal erosion is attributed to both the effects of waves and tidal currents. Coastal erosion is intensified due to reduction in sediment load reaching the coast due to the reduction of river flow (hence the capacity of the river to transport sediments). Dams also trap a significant volume of the sediment load preventing it from reaching the coast where it is required to replenish beaches. Accretion i.e the deposition of sediments creating or extending geomorphic features such as sand spits, mudflats, sand bars, etc is caused by excessive sediment load. High sediment load can be attributed to poor land use practices in the river basin. Floods are capable of transporting huge volume of terrigenous sediment that is usually deposited along the coast.

Water quality degradation in the Inkomati Basin is attributed to high suspended sediment concentrations that make the water very turbid, chemical and microbiological pollution mainly due to sewage discharge, solid waste, industrial and agricultural effluents discharged into the water course.

These direct root causes can further be attributed to six key underlying sectors, namely: urban and coastal development, agriculture, industry, mining, transportation and energy sectors.

9.2 Challenges and constraints

The main constraint for an effective management of the Inkomati River Basin is associated with the complexity of managing transboundary institutions in an environment where the demand for water exceeds the existing supply. Any additional allocation to one of the countries or sectors would mean a reduction in use elsewhere, and it is likely to be highly contested by the other countries (Anon, 2001). Further, there is lack of understanding of how the coupled river basin and coastal system functions. The water allocation is based in the water demand for domestic use, agriculture and power production while environmental flows is never considered during negotiations on shared water courses. This is because it is still difficult to determine environmental flows (Hoguane, 2002; Tharme, 1996). There is no standard and a clear methodology for estimating environmental flow rates.

Strong competition on the water use and development between the countries may encourage countries to hide the information and data for their own benefit. This calls for an urgent need for more effective transboundary co-operation, but also underline the political and institutional difficulties involved (Anon, 2001). Lack of an effective national capacity, particularly in Mozambique and Swaziland for monitoring river basin processes, required in the designing of management strategies, hinders the capacity for an effective management and for negotiating new management arrangements. With uncontested data it is difficult to reach to an agreement (Anon, 2001).

On the other side, there is a weak institutional capacity, which includes not only lack of infrastructures for long–term research and monitoring, but also the weak coordination between river basin management institutions and those in the adjacent coastal areas. Weak coordination often leads to duplication of efforts or to an isolated single sector or discipline approach that has limited impacts. In addition to this, sustainable exploitation of resources does require thoroughly research and long term monitoring, which is too expensive for Mozambique and Swaziland. Therefore, regional and international cooperation is essential. In other cases, existing legislation may not favour sustainable development, particularly, where there is free access to resources and absence of enforcement of resource use regulations (Hoguane *et al.*, 2002).

Table 13: Causal chain analysis of the major concerned issues in the Inkomati River Basin

ISSUES	CASUAL CHAIN			
	IMMEDIATE	SECONDARY	TERTIARY OR OVERLYING	INSTITUTIONAL
Shortage of freshwater Alteration in river flow regime.	Damming the river, diversion and high water consumption	Agriculture, urban and industry development	Population pressure Socio-economic drivers	Lack of awareness, understanding and appreciation of economic value of coastal-marine ecosystem goods and services Insufficient public and stakeholder involvement and awareness across the river basin
Saltwater intrusion	Extreme floods and droughts	Torrential rainfall and severe drought	Climate change	Inadequate implementation/enforcement of Law and legislation.
Erosion	Poor land-use, tidal currents Sediment load deficit	Extreme floods Reduction in river flow Poor land use practices	Same as above	Lack of scientific and socio-economic data and information to support policy making and monitoring and enforcement
Accretion	Increased sediment load	Extreme floods Sand extraction Dredging the bay	Same as above	Lack of standards and guidelines for water quality control in the countries across the river basin
Pollution	Increased sediment load Domestic sewage Solid wastes Agricultural runoff Industrial runoff	Extreme floods Sand extraction Agriculture, urban and industry development	Same as above	Inadequate human and financial resources and technical capacity in institutions to deal with the issues of shared river courses Lack of mechanisms for effective coordination and inter-sectoral governance across the river basin

Figure 31: Casual chain analysis of the water related environmental issues in the Inkomati Basin

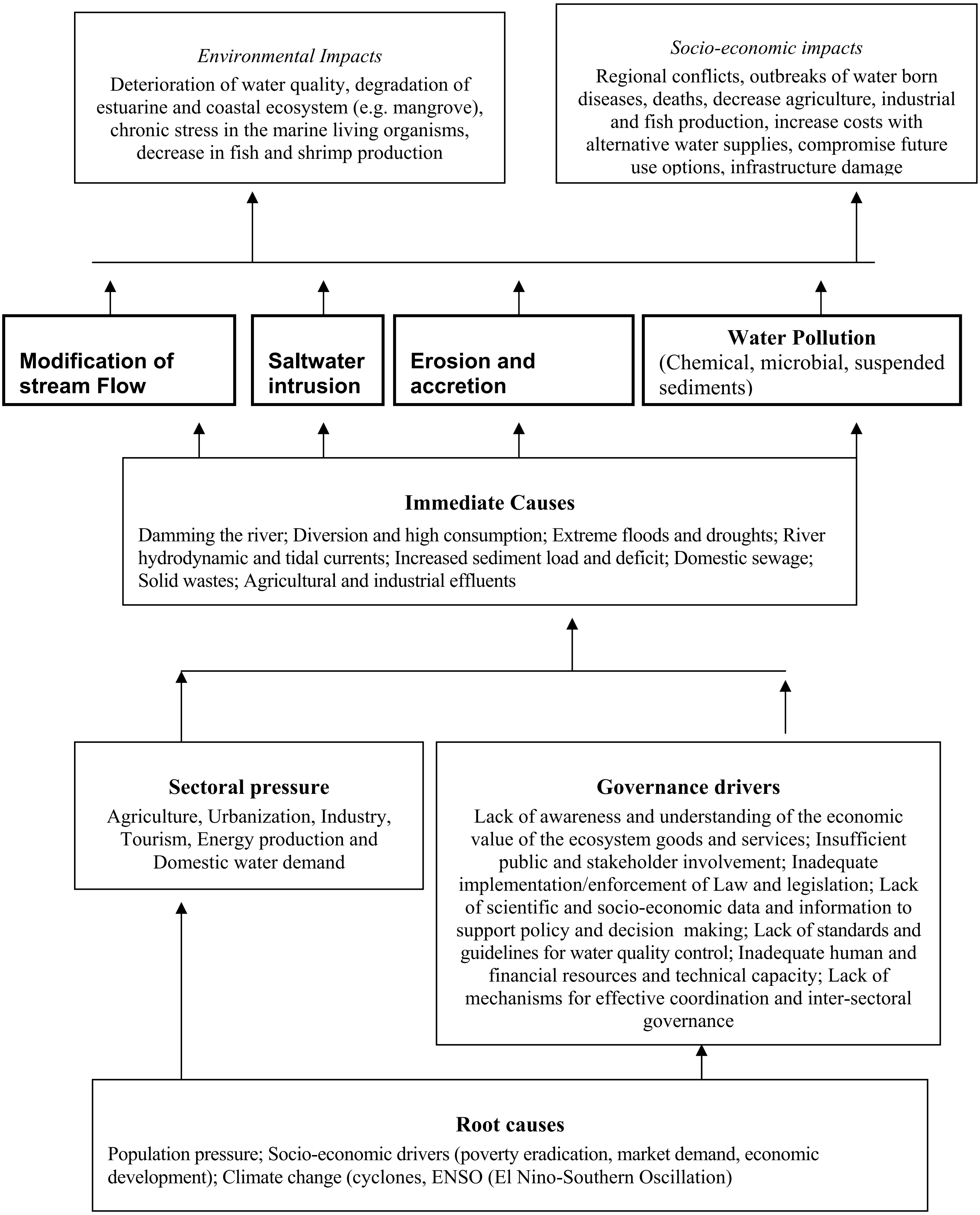
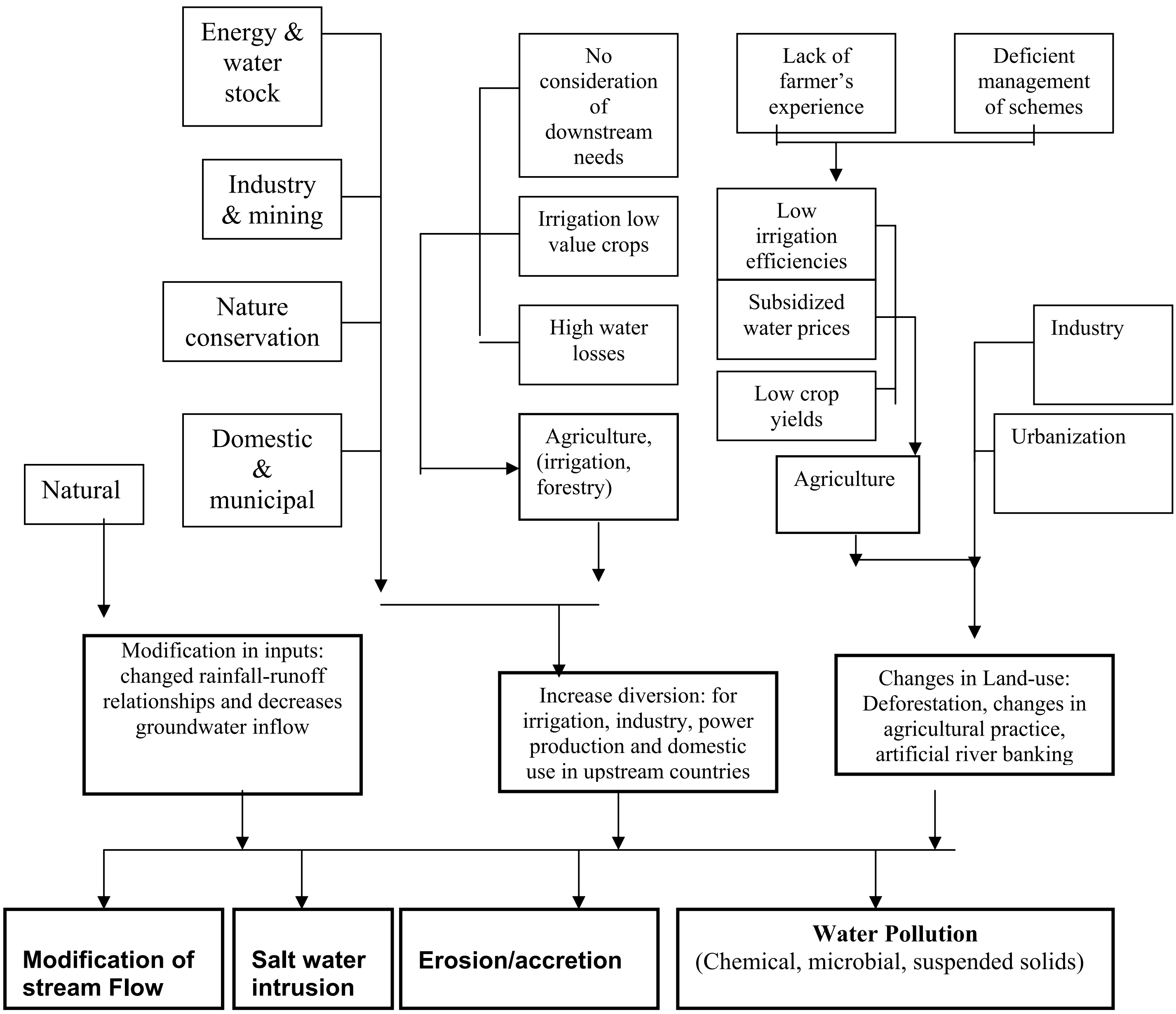


Figure 32: Analysis of the immediate causes and sector use direct pressures



9.3 Measures taken to mitigate the observed environmental issues

Given the fact that shortage of water is the main problem of the Inkomati River Basin, the major effort has been towards the management of this shared water course. For an effective integrated management of the river basin there is need to: (i) master technical and scientific knowledge from which the measures will be based (ii) establish an enabling political environment, (iii) set adequate institutional arrangements (iv) adopt wise policies and strategies.

Efforts to bring together countries sharing the Inkomati River Basin have been made since colonial era. Negotiations were held and agreement signed between the Governments of South Africa and Portugal in regard to rivers of mutual interest in 1964. In 1983 the Governments of South Africa, Swaziland and Mozambique agreed to establish a Tripartite Permanent Technical Committee (TPTC), which provided technical advice to the governments regarding management of the shared water courses. The TPTC coordinated the Joint study of the Inkomati Basin, on water resources availability, demands and development potentials. In 1991 the Piggs Peak Agreement was signed. This agreement established among others, the maintenance of a minimum runoff of 2 m^3s^{-1} , for the lower riparian country. A Treaty on the Development and Utilisation of the Water Resources of the Inkomati River Basin was signed in 1992, and in 1996 a Joint Water Commission was established. The Commission provides a forum through which issues related to the management of shared water courses are discussed, it promotes joint studies, data and information exchange and collaboration between the countries. Ultimately, the Commission provides advice to the respective Governments. Further the SADC Protocol on Shared Watercourse Systems adopted by the Heads of State in 1995 and revised in 2000, entered into force in 2003. This Protocol aims at fostering closer cooperation for judicious, sustainable and coordinated management, protection and utilization of shared watercourses and to advance the SADC agenda of regional integration and poverty alleviation (Van der Zaag and Carmo Vaz, 2003; Heyns, 2004).

In Mozambique, in particular, effort have been made towards strengthening institutions, developing policies, strategies, building technical and scientific capacity for negotiation and effective participation in the regional efforts towards management and sustainable use of the shared water courses. In 1991 a new Water Act establishing basic principles of water management was promulgated in Mozambique. The Act considers water as a scarce public resource that needs to be conserved and used in a sustainable manner (Carmo Vaz and Lopes Pereira, 2000). Another important feature introduced by the Water Act is the payment for the abstraction of water. This includes abstraction of bulk water by water supply companies, water used for irrigation and for hydropower production. The Government approved in 1995 a new National Water Policy that puts emphasis on Integrated Water Resources Management to maximise the benefits. DNA (National Water Department)- the government institution responsible for managing the water resources was strengthened. In addition, Regional Water Authorities (ARAs) were established with the view of improving the capacity and efficiency of water management. Another important change introduced by the Water Act is the creation of a National Water Commission (CNA), which functions at the ministerial level to support decision-making.

Joint Inkomati Basin Study (JIBS) has been conducted in order to build a knowledge base to support adoption of the policies and strategies for management of the Inkomati water courses (Carmo Vaz and Lopes Pereira, 2000). Various studies were conducted within the spirit of Land Ocean Interaction in Coastal Zone (LOICZ) to understand the coupling of river basin system and the coastal ecosystems. An example of these studies is the *Catchments to Coast Project* carried out during 2002-2005 with financial support from European Union (Monteiro e*t al.,* 2002).

10.Towards integrated management of shared river

10.1 Principles of Integrated Water Resource Management (IWRM)

Integrated Water Resource Management (IWRM) and Integrated River Basin Management (IRBM) are both approaches that seek to achieve more sustainable (environmental and socio-economic) use of freshwater. The Global Water Partnership (GWP, 2000) defined IWRM as:

> *"A process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."*

WWF in its 2003 publication *Managing Rivers Wisely* defines IRBM as:

> *"Integrated River Basin Management (IRBM) is the process of coordinating conservation, management and development of water, land and related resources across sectors within a given river basin, in order to maximise the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems."*

IWRM and IRBM (and other related terms such as Integrated Catchment Management) are broadly compatible approaches that have been developed as a reaction against the shortcomings of traditional supply-based water management. IWRM focuses on technical solutions, with individual and – in many cases – completely unconnected projects designed and implemented by different agencies representing different sectors (agriculture, energy, transport etc). This has typically resulted in the management of water being highly fragmented with multiple, sometimes overlapping responsibilities. This approach can be characterized as focusing on supply 'fixes', with little regard to managing demand or minimizing adverse environmental and social impacts. The IRBM focuses on conservation based on the fact that, naturally functioning river-basin ecosystems – including associated wetland and groundwater systems – provide freshwater which we all depend on. When these ecosystems are no longer able to function naturally and begin to break down, water resources – for people and wildlife alike – shrink. Therefore, effective management of a river basin's water resources must include maintenance of ecosystem functioning as a paramount goal (Jones, 2006). It should encompass:

- conservation of resources (and not only resource management and development)
- inter-sectoral cooperation at river-basin level (given that a river basin is the fundamental hydrological unit for which integrated management must be achieved, and that interventions carried out with insufficient basin-scale cooperation among key sectors and stakeholders may have adverse impacts on the whole basin)
- protection and restoration of aquatic ecosystems (given that the natural functioning of ecosystems is ultimately responsible for ensuring the continuity of the water cycle).

In managing rivers wisely, WWF set out seven general principles for successful IRBM initiatives. These are:

- A long-term vision for the river basin, which is supported by the major stakeholders
- Integration of policies, decisions and costs across major sectors such as industry, agriculture, urban development, poverty alleviation, navigation, fisheries management and conservation
- Strategic decision-making occurs at the river-basin level and is used to guide actions at sub-basin or local levels
- Great care is taken in the selection and timing of IRBM initiatives and actions; there is need for readiness to seize opportunities as they arise, provided that they will contribute towards realisation of the strategic vision
- Priority is given to maximising active stakeholder participation in decision-making processes that operate transparently and are based on provision of adequate and timely information
- Sufficient investment by governments, the private sector and civil society organisations in capacity building to ensure effective river-basin planning through participatory processes
- A solid foundation of knowledge about the river basin and the natural and socio-economic forces that influence it.

In summary these incorporate the principles of:

- integration of land- and water-use planning
- cross-sectoral cooperation
- environmental sustainability
- economic efficiency
- social equity
- stakeholder participation.

All of these principles are likewise fully compatible with poverty reduction (alleviation or eradication) initiatives, in the framework of the UN *Millennium Development Goals* (UN Millennium Project, 2005).

10.2 Potential benefits of Integrated Coastal Area and River Basin Management

Rivers and their associated ecosystems and biological diversity provide life support for a high proportion of the population and sustain economies of the countries concerned. Further, poor management of land and water resources in many river basins has led to major floods, water shortages and pollution; loss of biodiversity and lives; and destruction of infra-structures. Studies and discussions lead to a worldwide consensus on the need for an integrated approach to coastal area and river basin management (ICARM), which incorporates ecosystem functions and values.

The main goal of the ICARM is to ensure the proper management and sustainability of ecosystems and associated biodiversity within river basins and adjacent coastal areas. ICARM brings together all the stakeholders intervening in a river basin to an effective coordination allowing for the development of economic sectors without prejudice to the others; making optimum use of the water resources; ensuring sustainable development and adequate water supply for basic domestic needs in the urban centres and villages. It ensures there is water for the functioning of the downstream ecosystems. An effective implantation of ICARM would ensure: cooperation, strengthen partnership between water and land use sectors; build consensus, conserve biodiversity and wetlands; integrate development from catchments down to the coast; improve understanding of the system structure and functioning through sharing of information and knowledge among the countries. It would ensure transparency and equitability in water allocation, which in turn would contribute to conflict prevention at the national level and across the borders; It would help ensure the integrity of the downstream ecosystems and increase in the natural resources production.

Clearly, an effective implementation of the ICARM would contribute to the reduction or even prevention of potential negative impacts mentioned above, for instance: (i) the impacts of droughts and floods could be reduced through sharing of information along the river basin from upper to lower riparian countries, (ii) conflicts in water use and development could be prevented through dialogue and mutual understanding among the stakeholders; (iii) water pollution and degradation of downstream ecosystems and ecotones could be prevented through adequate river flow regime. Thus, the ICARM would benefit various economic sectors, the population and ecosystems along the river basin to the coast.

10.3 Equity in water use

Ensuring equity in water use and environmental sustainability in the river basin where water is limited against the increasing demand and where there is lack of knowledge on the ecosystem water demand, and lack of capacity for monitoring and enforcement, constitute the real challenges. The Inkomati River flow is shared by South Africa, Swaziland and Mozambique where it drains into Indian Ocean through Maputo Bay. The Tripartite Interim Agreement sets limits on water use in each of the countries and sets a target flow that is necessary for sustaining the riverine ecology as well as appropriate water quality standards (Table 14). However, the main challenge is the enforcement which is constrained by the lack of capacity in Swaziland and Mozambique.

Table 14: Interin target flow

River	Key point	Interin target in-stream flow per year	
		Mean (Million m^3)	Minimum (m^3)
Sabié	Lower Sabié	200	0.6
Crocodile	Tenbosch	245	1.2
Komati	Diepgezet	190	0.6
	Mananga	200	0.9
	Lebombo	42	1.0
Inkomati	Ressano garcia	290	2.6

10.4 Water resources monitoring programs

Article 4 of the Tripartite Interim Agreement states that, "*The parties shall establish comparable monitoring systems, methods and procedures to guarantee the agreement*." Article 12 of the Tripartite Interim Agreement states that parties within the TPTC should exchange information regarding the hydrology, geo-hydrology, water quality, meteorological and environmental conditions of the Inkomati and Maputo water courses. In line 7, it states that parties shall develop appropriate measures to ensure that information is homogeneous, compatible and comparable, as agreed by the TPTC. To fulfil this requirement, there is need to establish across the basin, multidisciplinary technical teams or joint research and monitoring teams.

South Africa is implementing different monitoring system in selected sites in the basin. The monitored parameters include; water flow measurements, water quality, groundwater, eutrophication, radioactivity and toxicity. South Africa has developed a data bank consisting of: Surface water hydrology, water quality, groundwater and Water Use Registration and Authorisation (WARMS). Mozambique has a monitoring station in Komatiport, at the boarder with South Africa.

10.5 Capacity building

There is a marked difference among the three riparian countries in terms of existing capacity -human, technical and financial - with South Africa dominating the other two countries sharing the basin (Carmo Vaz, 2003). This could jeopardize the implementation of the signed agreements. There is an urgent need to invest in capacity building in Mozambique and Swaziland. The UNESCO-IHE in the Netherlands and Coastal Zone Management Centre and the Government of Netherlands had showed interest to contribute towards building such capacity in Mozambique. The capacity building should focus, not exclusively, in the following areas:

- Data collection and analysis, including remote sensing and GIS techniques
- Modelling, prediction and mapping areas of vulnerability
- Environmental flow determination
- Socio-economic development and impacts
- Cultural and political dimensions
- ICARM and IWRM applications

Under the PRIMA Project capacity buidling aspect will be dealt with. The project seeks to implement the Interim Agreement and its appendix "the Resolution of the TPTC on Exchange of Information and Water Quality" which spells out the capacity building requirement in terms of human resources, measuring and monitoring equipments, laboratory facilities, etc. ARA SUL in Mozambique will have to allocate funds for capacity building to ensure proper monitoring and compliance with the IIMA Agreement.

10.6 The regulation of water resources and the need for transboundary response

A number of studies have been done regarding the water resources of the Inkomati Basin and a common conclusion is that the development of the Inkomati River Basin by construction of dams, irrigation schemes, inter-basin water transfer schemes, etc, has reduced the amount of water to the lower sections. Sengo (2003) has demonstrated that the regulation of Inkomati River has changed the flow regime in downstream area with impact on the peak flows, particularly small floods with 1-5 year return period. The Catchment-to–Coast Project undertook a comprehensive assessment of the effects of land and water use in the basin on the quality and quantity of water in the lower section of the river, particularly in the estuary. The change of flow regime, sediment load and the quality of water affects its capacity to support fauna and flora.

The IIMA agreement recognizes the complexity and importance of the environmental flow especially to the estuary. The IIMA has computed in-stream and estuarine flow requirements and assigned different reaches to the estuary, to meet its demand. In an increasingly regulated Inkomati River Basin, there is a challenge for member states to meet these flows and create capacity for proper monitoring.

The history of cooperation on transboundary water resources between riparian countries of Inkomati River and the ongoing collaboration, illustrated by recent joint exercises under the Maputo River Basin Study, indicate the willingness to find mechanisms for integrated and transboundary solutions.

10.7 Summary of actions required

The actions recommended are summarised in Table 15. The main underlying actions aim at alleviating the negative impacts of the modification of streamflow into the estuarine and coastal ecossystem, which in turn require knowledge on the river flow and impact on downstream ecosystems. The main action may be clustered into four cathegories as follows: (i) a better understanding of the ecosystems structure and functioning; (ii) establishment of ecological flow regime; (iii) strengthening capacity and co-operation between institutions involved in IRBM and ICZM; (iv) harmonisation of legislation related to natural resources exploitation and socio-economic aspects.

Table 15: Summary of the actions recommended addressing the major water-related environmental issues.

ISSUE	RECOMMENDED ACTIONS	RESPONSIBLE AGENCY	PRIORITY
Shortage of freshwater Alteration in river flow regime. Saltwater intrusion Erosion (in the basin and in the coastal area) Accretion (in the river mouth) Water quality degradation (pollution)	• Establish and strengthen regional water management units • Integrated the ICZM into IRBM • Establish linkages between river basin and estuarine and coastal processes • Establish environmental flow regime • Establish a network/forum for IRBM and ICZM • Improve cooperation and information sharing among riparian states and within relevant national institutions • Assessment of the extent of water pollution and its impact. • Propose techniques for waste-water treatment • Improve early warning systems for flood mitigation and rescue mission preparedness • Improve monitoring of relevant processes in the river basin • Increase efficiency of water use • Studies on impacts of the modification of water on ecosystem structure and function. • Assessment of environmental and socio-economic impacts.	Regional Water Authorities • ARA-SUL, • SADC • DNA, Universities, research institutes (INAM, INIA, etc), ARA-Sul • MICOA	High High High High

	• Development of regulation for sustainable use of waters		

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