ASSESSMENT OF THE ENVIRONMENTAL, SOCIAL AND ECONOMIC IMPACTS ON THE SERENGETI ECOSYSTEM OF THE DEVELOPMENTS IN THE MARA RIVER CATCHMENT IN KENYA

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Introduction

The Government of Kenya is proposing two development concepts, which are considered to impact on the environmental and socio-economic dynamics of the region surrounding the Mara River in particular, Tanzania and Kenya in general. Even more devastating, will be the loss of Tanzania's unique endowment and national heritage for which there is a protracted effort not only by the Tanzania Government, but also by the world community at large to conserve the ecosystem for the benefit of the present and future generations. These development concepts are described as follow:

Amala Project

The proposed Amala Project in the Ewaso Ngiro (South) River is a multipurpose project in Narok and Kajiado Districts in Kenya consisting of a cascade of development of three hydroelectric schemes on the Ewaso Ngiro (South) River with a transfer scheme from Amala River to the headwaters of the Ewaso Ngiro River. Since Amala River flows southwards into Mara River which passes through the Serengeti Ecosystem and finally into Lake Victoria, the diversion of water from Amala River catchments into the Ewaso Ngiro, will substantially reduce the volume of water available in the Mara River and may lead to complete drying of the River in times of severe drought. Scientific analysis has determined that these developments in Kenya will severely affect the Serengeti Ecosystem along with its attendant socio-economic activities.

Degazettement of the Mau Forest

The Mau Forests form very crucial water catchments for some of the large rivers in Kenya, which feed such Lakes as Nakuru and Bogoria in Kenya as well as Lakes Victoria and Natron in Tanzania. Furthermore, the Mara River originates from the forests where it has crucial water catchments. The degazettement of the Mau Forests to provide more agricultural land will, therefore, adversely affect water volumes and flows of these rivers through denudation of their critical catchments around the Mau Hills and will thus compound the problem which will be created by the diversion of water from Amala River to the head- waters of Ewaso Ngiro (South) River.

Besides the two proposed developments concepts, there is also irrigated farming which is going on along the river basins up-stream in Kenya. This activity has two main effects to Tanzania; first it reduces the amount of water that remains available down-stream in Tanzania, and second it may lead to contamination of the Mara River waters as a result of utilizing pesticides.

Migration

Prof. Sinclair, a prominent researcher with thirty (30) years of experience with Serengeti ecosystem, notes that the spectacular annual event of migration occurs because of the wildebeest, need to find permanent water during the dry season. It so happens that the Mara River, the only permanent flowing water of sufficient quantities for the large herds in the Serengeti Ecosystem. Furthermore, migration determines the large numbers of wildebeest, which in turn determines just about every other aspect of the ecosystem including the structure of the plains and the Savanna woodlands, the number of most other ungulates and the population of predators. If the wildebeest were to collapse to one fifth of their present size, then all these aspects would change and possibly there would be no migration. It should be noted further that migration is the reason that Serengeti is a world heritage site.

Previous Engineering Study

It is noted that the engineering feasibility study of the hydroelectric project (Knight Piesold, 1992) argued that for a typical year, the project would not modify the mean discharge of the Mara and the project would not impact the Serengeti ecosystem. However, this prediction flawed. Firstly, no prediction of the availability of water in the Mara River during a drought was carried out by Knight Piesold because the data used in the study spanned over the years when no severe drought occurred. Secondly, the study Knight Piesold made did not adequately calculate the availability of water in the Mara River as it flows through the Serengeti ecosystem because it neglected the impact of deforestation and irrigation in Kenya. Thirdly, the study did not include the additional impact on the availability of water resulting from likely climatic changes from enhanced green effect. Furthermore, Prof. Sinclair notes that over the past thirty years, the flow in the Mara River has been decreasing at a remarkable rate. Therefore the assertion that diverting water from the source would not interrupt the flow carries with it a high element of risk. Given that risk, it is important to invoke the precautionary principle and state that any action to increase the risk of the Mara River drying should be discouraged. Prof. Sinclair further notes that the other ecological and environmental problems where they act together will exacerbate the stresses, hence, the importance of the precautionary principle. These observations made by Sinclair tend to agree with the findings of Wolanski et al (2000).

Dislocation of Surrounding Ecosystems

Scientific studies have shown that water quantity and quality constitute the single most dominant force driving the ecosystems of the surrounding region. It is obvious that these developments in Kenya will result into serious dislocation of the ecosystems within the region. Not only will they affect the vegetation dynamics of the area and the ensuing vegetation patterns, they will also influence the degree of salinity of such lakes as Nakuru, Bogoria, Victoria and Natron and the extent to which these lakes become sodic. All these have important bearing to the flora and fauna of the region. In this study, an ecohydrology model was used to predict the likely impact of the water stress to be caused by these developments on the Serengeti ecosystem. The model was forced by observed monthly rainfall in the period 1960-2000 and calibrated against observations of the number of wildebeests and lions during the same period. It predicts that, during a drought, 20% to 80% of the migrating wildebeest might die depending on the severity and duration of the drought. Furthermore with a 50% die-off, it may take twenty (20) years for the wildebeest population to recover while with 80% die-off; there may be no recovery of the wildebeest population. A model sensitivity analysis, which was carried out, suggests that these predictions are reliable to the extent of 80%.

Serengeti – Mara Ecosystem

The combined effect of deforestation, irrigation and the Amala water diversion will result in times of drought, in a flow rate, which would be smaller than the water consumption in the Serengeti ecosystem by animals drinking and evaporation. The pools of water in the riverbed will dry out. Once the pools dry out, the wildlife will start dying at an estimated rate of 30% per week starting from the end of the first week. At this juncture it is important to note that the Serengeti ecosystem as it exists now supports the largest herds of migrating ungulates including the highest concentrations of large predators in the world. It is estimated that there are about 1.3 million wildebeest, 200,000 zebras and 440,000 Thomson gazelles. Among predators, hyenas are thought to be the most numerous estimated at about 9,000 followed by lions estimated at 3,000 and cheetahs at about 250. There is also an array of other large and small mammals and over 500 species of birds. This ecosystem is also unique because of the migration system it supports. This annual event consists of about 1.2 mill wildebeests, 250,000 zebras, 5,000 elands and 400,000 Thomson's gazelles. All these use the Mara system as their dry season refuge because the Mara River is the only permanent water source in the Masai-Mara and the Serengeti National Park. In 1993, following a severe drought experienced by the Serengeti region, about 400,000 wildebeest perished. It is, therefore, possible that a prolonged drought exacerbated with a higher extraction of water to meet power demands may lead to a loss of migratory wildebeest by about 30% during the first two weeks, and possibly leaving a negligible number at the end of one month. Furthermore, loss of drinking water for large vertebrates including lack of food in a prolonged drought, semi aquatic crocodiles and hippos as well as terrestrial large animals such as elephants, buffalo, topi, reedbuck, waterbuck, and others will be severely affected. Since, historically, drought occurs once every seven years and severe drought once every twenty years, these events may occur in the not too distant a future given that the last severe drought occurred in 1993.

Lakes Natron, Nakuru and Bogoria Ecosystems

The ecosystems of these lakes support the lifestyles of millions of flamingos. They host about 98% of the total world population of lesser flamingos, whose biomass is more than 90% of all water birds in the world. These flamingos are well adapted to walking and swimming in sodic waters and have very specialized diet, feeding as well as breeding behavior which is wholly dependent on the level of salinity of the lakes and the extent to which they are sodic. Flamingos display nomadic movements both within and between these lakes, which are associated with food availability, fresh water points as well as conditions for successful breeding. Thus while Lake Nakuru provides a feeding and display site, Lake Natron is their only successful breeding site and Lake Bogoria as their stable lake and refuge when other shallow lakes dry out. Recent studies have shown that these flamingos play very important ecological and economical roles and yet even as of now, their survival is uncertain due to influence of human activities. These developments in Kenya will only worsen the situation and will lead to reduction and ultimately the extinction of these birds.

The social and Economic Impact to Tanzania

As noted above, the implementation of these projects in Kenya will obviously affect the ecosystems of the surrounding region, and with it, the socio-economic dynamics of the people of the region. Tourism industry will also be seriously affected as described below.

Tourism Sector

- Tanzania could lose up to 125,000 (about 40%) tourists or visitors currently visiting Serengeti. Given the average annual rate of increase of 12.3%, the figure would have grown to 397,330 by the year 2011. Furthermore, the other parks of Northern Tourist Zone would get very few visitors, if any, since most of them, if not all, do come because of the famous Serengeti. In effect, therefore, Tanzania may lose about 75% of all the tourists coming to the country. This works out to be about 238,814 visitors by 2001 statistics and the figure would grow to about 510,828 by the year 2011.

- In terms of revenue generation Serengeti National Park will outright lose more than USD 6,040,290 and this is projected to increase to USD 40,636,057 by the year 2011 at an average annual rate of 21%. Considering the Northern zone aspect, the loss would be USD 13,932,938 by 2001 statistics and would grow to USD 70,488,117 by the year 2011, the average annual rate being 17.6%.

- Serengeti's existing workforce of about 385 people will lose their jobs as well as their income amounting to about TAS 836 million. This will mean suffering not only to themselves, but also to their dependants, particularly spouses and children.

- Communities living around the national park will no longer benefit from the support they have been getting in terms of community based development projects. Communities around Serengeti National Park will be losing an average of about TAS 40 million per year. The Government will lose tax revenues it has been getting from the operations of the park. Serengeti District, for example, will be losing an annual tax income of more than TAS 1.0 billion from the operations of the Serengeti National Park.

- Serengeti National Park has been getting significant amounts of donations and assistance from various countries and institutions. If the park collapses the donations and assistance will cease. As an example, the donation to Serengeti National Park from Frankfurt Zoological Society during the first half of 2000 was close to Euros 1,440,000. This amount would have been lost.

Agricultural Sector

The majority of people living in this region engage in agriculture and livestock keeping as their economic activities. The Mara River supports these activities. In the event of serious and prolonged drought, this region will lose about TAS 17bn. worth of crops, TAS 25bn. worth of livestock and annual milk production worth TAS 960 mill. Apart from these monetary values, livestock in this part of the country is associated with other intrinsic cultural and social values, which will also be lost. The fisheries sub-sector will also be affected with an expected loss of foreign earnings amounting to the equivalent of TAS 65bn.Other development projects impacting on health, water supply etc. based on Mara River will also be adversely affected.

Recommendation

It is a fact that science and technological advances, with time, will bring about solutions to the numerous problems associated with power and food production. Indeed experience has shown that human ingenuity has never failed them in their quest for survival and better living conditions. However, the story of creation has been different, and no historical data has suggested that human ingenuity can create such wonderful creatures of God as elephants, wildebeest, giraffes etc. It is no wonder, therefore, that there is redoubled effort to conserve and protect wildlife anywhere in the world. It is for this reason that it is proposed that a transboundary Mara River Management Plan be established which will take into account the cost-benefit analysis (for Kenya and Tanzania) of deforestation, irrigation and the proposed Ewaso Ngiro (South) Hydropower Project as well as to factor in the likely changes to rainfall and hence river discharge arising from climatic changes due to enhanced greenhouse effect. As it is now, with the proposed developments in Kenya, the economic benefits will go to Kenya while most of the environmental and socio-economic costs such as loss of national heritage; negative impact on tourism industry etc would be borne by Tanzania. The idea here is to request the Government of Kenya in the spirit of East African Community and Regional Co-operation, not to take unilateral decision and go ahead with the projects. It is further recommended that the Government of Tanzania should set aside adequate funding for a more detailed study on how to avert possible collapse of the said ecosystems even without those projects going ahead; considering, for example, the effects of the evolving climatic changes associated with greenhouse effects.

CHAPTER 1

INTRODUCTION AND BACKGROUND

Introduction

The government of Kenya is proposing to develop a hydroelectric power scheme named AMALA PROJECT and DEGAZETTMENT of the MAU FOREST to provide power and more agricultural land respectively. There are concerns and fears that the implementation of these developments will affect the ecosystem of the surrounding areas in a way, which will have consequences environmentally, socially and economically. More specifically, Serengeti National Park, with the only intact big mammal migration in their thousands is likely to collapse and with it all the socio-economic activities related to the ecosystem of the surrounding region.

The proposed AMALA PROJECT in the Ewaso Ngiro (South) River based in Kajiado and Narok Districts in Kenya consists of a cascade development of three hydroelectric schemes at Oletukat (36 MW), Leshota (54 MW) and Oldorko (96 MW). Altogether, this project along the Ewaso Ngiro River will have the capacity to produce 186 MW of electric power with the support scheme to transfer water from the Amala River to the headwaters of Ewaso Ngiro River. The Amala River flows southwards into Mara River, which originates from the southern slopes of the Mau escarpment in Kenya and flows through the Masai-Mara Game Reserve, the Serengeti National Park in Tanzania and eventually drains into Lake Victoria. Diversion of water from the Amala River will lead to the possible decline of water flow in the Mara River. Furthermore, Ewaso Ngiro River flows into Lake Natron, the main breeding ground for flamingos in East Africa. It is expected that implementation of the said project will lead to possible increase of water flow in the Ewaso Ngiro River and will subsequently impact on the ecosystem of the Lake Natron. Excessive water flow will, for instance, lower pH levels in Lake Natron leading to decreased production of the algae which constitutes the major food of the lesser flamingos.

The Mau Forest in Kenya forms very crucial water catchments for some of the largest rivers in Kenya that feed such lakes as Nakuru, Bogoria, Victoria and Natron. Again the Mara River, the only permanent water source in the Masai-Mara Game Reserve and Serengeti National Park, originates in the Mau Forest. The forest also supports the flamingos not only directly through Lake Nakuru in Kenya, which is a very important feeding site; but also indirectly through Lake Natron in Tanzania, the only known breeding habitat for the flamingos. The degazettement of the Mau Forest in Kenya, will, therefore, pose a threat to these affected areas and their environments.

It is obvious that the 25,000 Km^2, which forms the Serengeti Ecosystem covering Serengeti National Park, Maswa, Grumeti and Ikorongo Game Reserves, Ngorongoro Conservation Area and Loliondo Game Controlled Area in Tanzania and the Masai-Mara Game Reserve in Kenya will be impacted by the proposed developments in Kenya.

It is noted that the engineering feasibility study of the hydroelectric project (Knight Piesold 1992) argued that for a typical year, the project would not modify the mean discharge of the Mara River and therefore the project would not impact the Serengeti ecosystem. However, this prediction is flawed. Firstly, no prediction of the availability of water in the Mara River during a drought was carried out by Knight Piesold because the data used in the study spanned over the years when no severe drought occurred. Secondly, the study by Knight Piesold did not adequately calculate the availability of water in the Mara River as it flows through the Serengeti ecosystem because the study neglected the impact of deforestation and irrigation in Kenya. Thirdly, the study did not include the additional impact on the availability of water resulting from the likely climate changes from the enhanced greenhouse effect.

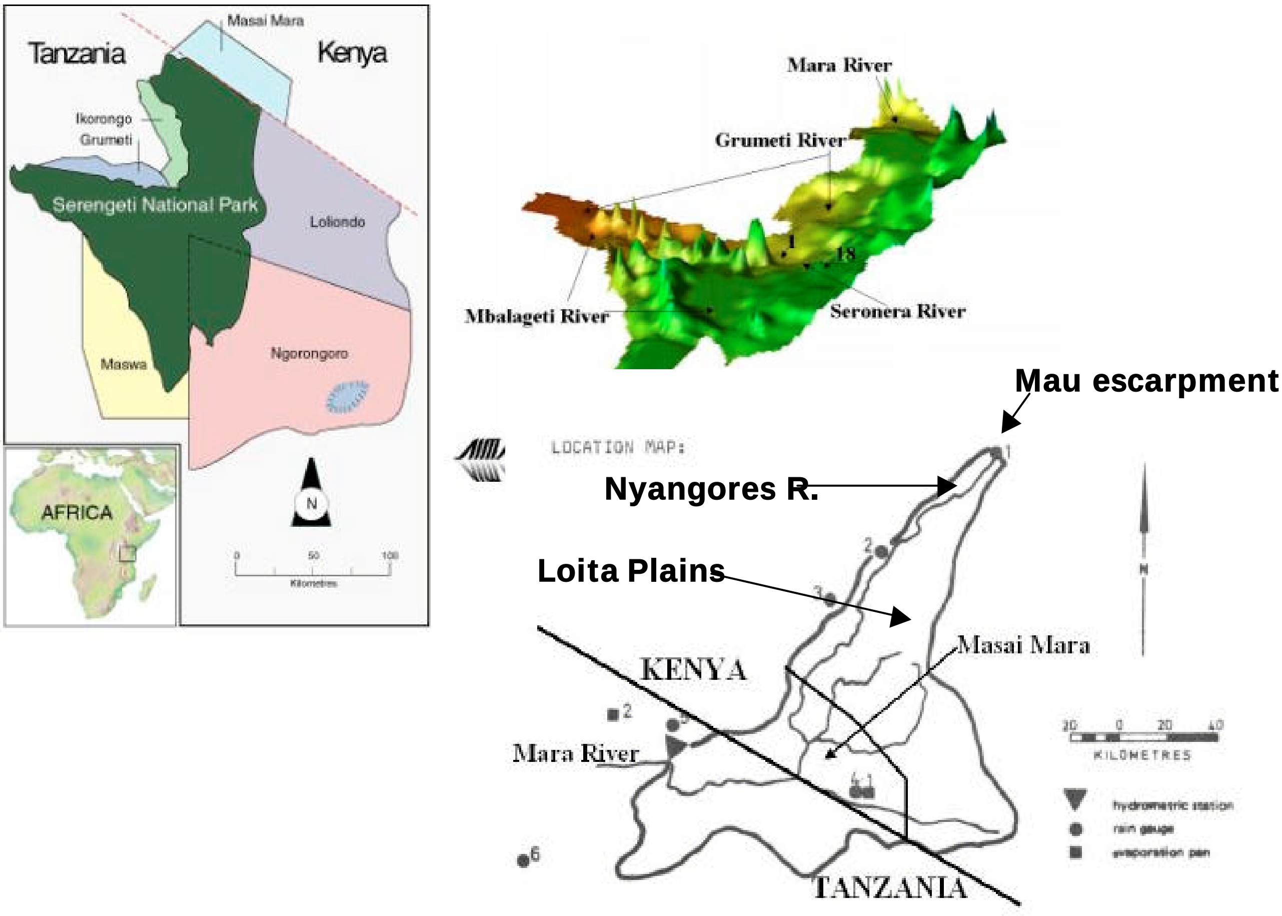

Fig. 1. (a)
Map of the Serengeti National Park and surrounding game reserves, game controlled areas and the Ngorongoro Conservation Area in Tanzania, and the Masai Mara Reserve in Kenya. (b) Three-dimensional rendering of the topography of the Serengeti National Park showing the major rivers. Stations 1-18 are key water quality sampling sites along the Seronera River, a tributary of the Grumeti River. (c) Map of the Mara River catchment showing the river gauging station and the meteorological stations (Brown *et al.* 1981). The river flows through the Masai Mara Reserve in Kenya, see location map in (a). The catchment of the Nyangores and Amala rivers extend into the forested Mau escarpment. Mechanised agriculture is prevalent in Loita Plains. X and ∇ indicate the sites of, respectively, the proposed Amala water diversion weir and the Mara River gaging station at Mara Mine.

The objective of this study therefore is to assess the potential environmental, social and economic impacts of the impending developments in Kenya especially as they relate to the following activities:

- The diversion and transfer of some water from Amala River to the Ewaso Ngiro River bearing in mind that the migration of the wildebeests in the Serengeti National Park depends on the water flow in the Mara River.
- The degazettement and subsequent excision of some forest in the Mau escarpment bearing in mind that it is an important source of rains and hence water catchment of the Mara River.
- Irrigated farming that extracts water from the Mara River upstream from the Kenyan side.

The methodology used in this study includes literature search and reviews, field surveys, interviews, field observations and the use of ecohydrology model in assessing and predicting the likely impact on the Serengeti ecosystem of deforestation, irrigation, the proposed AMALA project and the likely climate changes from the enhanced "Greenhouse effect".

Background Information

Tanzania's General Characteristics

Tanzania covers a total area of 945,000 km^2, approximately three times the size of Finland or Norway, or four times the size of Japan. The country is bordered by Kenya and Uganda to the north, by Rwanda, Burundi and Democratic Republic of Congo to the west, Zambia, Malawi and Mozambique to the south. Tanzania has a coastline of about 800 km along the Indian Ocean with a continental shelf of about 30,000 km^2. Inland water bodies cover an area of 52,000 km^2 mainly comprising of territorial waters of Lake Victoria, Lake Tanganyika and Lake Nyasa.

Tanzania lies immediately south of the equator, on the East Coast of Africa, between latitudes 1^0 and 11^0 South and longitudes 30^0 and 40^0 East. The country enjoys a warm tropical climate. In the coastal areas, the weather is hot and humid with temperatures rarely dropping below 25^0 C. In the higher inland areas the climate is semi temperate.

Based on the estimated population of about 24.5 million people and a growth rate of approximately 2.5 % per annum, as per 1988 National Population Census, the country's population was projected at about 33.82 million people by the year 2001. It is expected that the population census conducted this year will come up with a more exact figure.

Tanzania's Economic Overview

Tanzania's economy is currently steadily on course towards accelerated and sustainable growth, thanks to the ongoing radical economic reforms initiated and undertaken by the Government since mid 1980's. The thrust of the reforms has been to reverse and translate the previous poorly performing socialist oriented economy into a vibrant and dynamic market driven economy, with the private sector taking its rightful place and role as the engine of economic growth, while the Government retains its traditional role as the regulator and facilitator of the economic activities, implying an '' eyes on – hands off'' situation.

With all major economic indicators depicting favourable trends, it can be said that Tanzania's quest for macro economic stability will be achieved. Again, thanks to prudent and firm fiscal and monetary policies instituted and pursued by the Government in the course of implementing the economic reforms.

Real Gross Domestic Product (GDP), for instance, accelerated to 4.7% in 1999 from 4.0% recorded in 1998. The target growth rate for the year 2001 was set at 5.1%. According to the Economic Survey, 2000, the major contributing sectors to the overall GDP were Agriculture (45.1%), Financial and Business Services (13.7%) and Trade, Hotels and Restaurants (12.4%). As far as inflation rate is concerned, this has been currently tamed at a unitary figure of about 5.5% for the year ending December 2000, down from 33.1% in 1994, 12.9% in 1998 and 7.7% in 1999.

The balance of payment performance has also been improving steadily over the recent years. In June 1999 gross foreign reserves stood at USD 604.9 million, while in June 2000 the situation had improved to USD 751.7 million. Further improvement was recorded in December 2000 whereby the figure went up to USD 974.0 million. While the export sector remained weak, foreign exchange reserves continued to build up strongly, following foreign exchange receipts from tourism that continued to rise, augmented by large inflows from foreign direct investment as well as external loans and grants.

Along with the macro economic adjustments, the Government has also initiated and implemented a series of structural reforms covering the entire spectrum of the economy, the thrust of which being to put in place a conducive and favourable investment climate in the country. In this regard appropriate sectoral policies and strategies as well as corresponding institutional, legal and regulatory frameworks have been put in place.

Notable legislation and institutional frameworks include the following:

- The National Investment Act, 1990, repealed and replaced by the Tanzania Investment Act, which led to the creation of the Investment Promotion Centre (IPC) under the former Act and later on the Tanzania Investment Centre (TIC), corresponding to the latter Act. The Centre was created to facilitate and promote investment activities in the country.

- The Public Corporation Act (1992) which provided the legal framework for divestiture of public organizations and the creation of the Presidential Parastatal Sector Reform Commission (PSRC) to implement the program.

- The Banking and Financial Institutions Act (1991), which provided the legal framework for the establishment of private banks and financial institutions in the country.

Under the ongoing prudent economic and financial management strategies as well as the existing political and social tranquillity, most of the economic activities have been recording significant growth. It is worth noting that Tourism, among others, has benefited tremendously from this favourable social economic environment. Under the circumstances, Tanzania's economic future outlook can be described as highly promising and bright.

Government Plans and Priorities

The major thrust of the macro-economic and sectoral policies so far have been to debottleneck structural impediments and to establish a self-sustaining economy in the long-term development perspective. Along with improvement of the physical infrastructure in support of directly productive sectors and restoration of the internal and external imbalances in the economy by pursuing prudent and appropriate fiscal, monetary and trade adjustments, increasing foreign exchange earnings by export trade have been key issues addressed by the Government. It is worth noting, again, that Tourism is among the top foreign exchange earners in the country. Currently, Government plans are focused on consolidation of the economic gains so far achieved, poverty alleviation, good governance as well as institutional and administrative structure improvements.

CHAPTER 2

USE OF AN ECOHYDROLOGY MODEL TO PREDICT THE IMPACT ON THE SERENGETI ECOSYSTEM OF DEVELOPMENTS IN THE MARA RIVER CATCHMENT IN KENYA, INCLUDING DEFORESTATION, IRRIGATION AND THE PROPOSED AMALA WEIR WATER DIVERSION PROJECT

Site Description

The 25,000 km^2 Serengeti ecosystem includes a national park, game reserves, game controlled areas, Ngorongoro Conservation area and the Masai-Mara Game Reserve in Kenya (Fig. 1). At the centre of the ecosystem is Tanzania's 14,763 km^2 Serengeti National Park. The Mara, Grumeti and Mbalageti Rivers, all of which flow westward to Lake Victoria, drain the park. The park is listed as a UNESCO World Heritage Site and is made spectacular by the annual migration of more than 1 million wildebeest and 200,000 zebras. As described by Sinclair and Arcese (1995), these animals disperse into the treeless southern grasslands (dotted lines in Fig. 1) of the park and the western region of the Ngorongoro Conservation Area during the rainy season (December through April). This area is the driest region of the park and is arid in the dry season. At the end of the wet season, these animals migrate towards the lower Grumeti River and thence to the northern region of the Serengeti National Park and the Masai-Mara Reserve in Kenya; there they take refuge during the dry season (July to October).

This ecosystem may be impacted by (1) deforestation in the Mau escarpment in Kenya, (2) irrigation for mechanised wheat farming in Kenya's Loita Plains, and (3) the proposed Ewaso Ngiro (South) Hydropower Project, also in Kenya. This scheme would divert water from the Amala River in the Mara River catchment at a site shown in Fig. 1, and divert this water to another catchment, the Ewaso Ngiro River (Fig. 2a). This water would be used to generate on the average about 180 MW of hydroelectricity for Kenya using a three dam cascade (Oletukat, Leshota and Oldorko). The water diversion rate would vary with the river discharge, peaking at 6 $m^3\ s^{-1}$ during high flows, and being smaller when the river discharge is smaller ensuring a remaining discharge of at least 0.25 $m^3\ s^{-1}$ at full-scale operation of the project (EAC 2000). The engineering feasibility report of this hydro-electric project (Knight Piesold 1992) argued that for a typical year the project would not modify the mean discharge of the Mara River, and therefore the project would not impact the Serengeti ecosystem.

The Knight Piesold (1992) prediction is flawed. Firstly, no prediction of the availability of water in the Mara River during a drought was carried out by Knight Piesold (1992). The reason for that is that the data used in that study spanned years when no severe drought occurred. Secondly, the Knight Piesold study did not adequately calculate the availability of water in the Mara River as it flows through the Serengeti ecosystem, because the study neglected the impact of deforestation and of irrigation in Kenya. Thirdly, the study did not include the additional impact on the availability of water resulting from likely climate changes from the enhanced "Greenhouse effect".

In this study, an ecohydrology model is used to assess the likely impact on the Serengeti ecosystem of deforestation, irrigation, the proposed Amala weir and likely climate changes from the enhanced "Greenhouse effect". The model predicts that the Serengeti ecosystem will be severely affected during a drought, and may even collapse during a severe drought.

It is suggested that a Mara River Transboundary Management Plan needs to be established, where the governments of Kenya and Tanzania will have equal voices as they both have much to lose if the Mara River ecosystem is excessively stressed. This management plan must be compatible with ecohydrology principles for the sustainable use of the water resources by both countries.

Hydrology Of the Serengeti Ecosystem

The main dry-season source of drinking water for migrating wildlife in the Serengeti ecosystem is the Mara River, especially in a drought. This river passes through the Masai-Mara Reserve in Kenya (Fig. 1) and the far north of the Serengeti National Park, at 1,300 to 1,500 m elevation, and drains a total of 10,300 km^2, most of which is in Kenya. The other main rivers in the Serengeti ecosystem are the Grumeti and Mbalageti Rivers. The Grumeti River has a total catchment area of 11,600 km^2 and drains the wooded savannah of the central and northern hills, much inside the park's boundaries. Further south, the Mbalageti drains an area of 2,680 km^2 of treeless grasslands and hills lying between 1,600 and 1,660 m elevation, nearly all within the park (Wolanski, Gereta, 2001).

Reliable rainfall data are available from 1960 onwards. Rainfall is generally greatest in the north-western corner of the park and in the Masai-Mara, exceeding 110 cm $year^{-1}$; it is smallest in the southeast at about 50 cm $year^{-1}$. Rainfall varies inter-annually by a factor of about four between extreme wet and dry years. This rainfall variability generates wide seasonal and inter-annual fluctuations in river runoff (Brown et al. 1981).

Potential evaporation is about 173 cm $year^{-1}$, the maximum monthly evaporation is 16.9 cm in October in the dry season (Woodhead 1968). From a water balance study, Brown et al. (1981) estimated that potential evapotranspiration was equal to about 71% of free water evaporation on an annual basis.

The Mara, Grumeti and Mbalageti Rivers were gauged daily from 1970 to 1974 (Brown et al. 1981), all near the point where they leave the Serengeti National Park. Mara Mine, the location of the hydrographic station in the Mara River, is shown in Fig. 1. In peak flows, these three rivers all carried a large amount of water; the peak observed flood of the Mara, Grumeti and Mbalageti rivers was, respectively, about 1,000 m^3 s^{-1}, 200 m^3 s^{-1} and 40 m^3 s^{-1}. After the rains, discharges decreased exponentially to base flows. The Mara River in recorded history has always kept flowing even in drought years, whereas the Grumeti and Mbalageti Rivers declined to zero flow in 1973, which was a dry year.

In a typical dry season in a non-drought year, the Grumeti and Mbalageti Rivers consist of a series of stagnant, shallow, muddy pools tens of meters long in the dry season. The Mara River and these stagnant pools along the Grumeti and Mbalageti Rivers are the only source of drinking water for wildlife during the dry season. However most of these pools dry out during a drought year, defined as a year when the yearly rainfall is at least 25% below average. In the period 1960-2000, this occurred 6 times, i.e. once every 7 years or so (Wolanski *et* al., 1999; Wolanski, Gereta, 2001). However drought years can follow each other. At such times the Mara River, because so far it always has had water, is the last refuge for migrating wildlife of the Serengeti ecosystem (Gereta, Wolanski 1998).

The main reason that in recorded history the Mara River has always kept flowing, while the other rivers have all dried out during a drought, is that (Dwasi, 2002) the river is fed by the Nyangores and the Amala rivers that drain the forested Mau escarpment where their catchment area constitute respectively 60% and 40%.

For the period 1970-1974, the mean annual flow rate of the Mara River at Mara Mine was about 36 m^3 s^{-1}, and this varied markedly from year to year. Reliable river gauging data (Brown et al. 1981) during 1970-1974 showed a minimum mean annual flow rate of 18 m^3 s^{-1} in 1973 and a maximum mean annual flow rate of 67 m^3s^{-1} in 1974. In the period 1970-1974, a mean daily flow less than 6 m^3 s^{-1} occurred during 350 days, a mean daily flow less than 2 m^3 s^{-1} occurred 115 days in total or about 23 days per year. A mean monthly discharge less than 5 m^3 s^{-1} was observed during four months in the period 1970-1974. The observed daily river discharge was calculated from daily measurements of the water level and a rating curve comprising 73 points. This rating curve has a maximum observed discharge of 216 m^3 s^{-1} and a minimum discharge of 1.9 m^3 s^{-1}. There were two months during the 1973 dry season where the Mara River flow was smaller than this minimum gauging. Based on daily observations of river height during these months in 1973, using an extrapolation of the river rating curve, the Mara River discharge at Mara months was estimated to be about 0.9 m^3 s^{-1} during two consecutive months. 1973 was a dry year but not a drought year, thus the Mara River discharge at Mara Mine can be expected to be smaller than about 0.9 m^3 s^{-1} during a drought year. There are no data on the Mara River discharge during a severe drought. Drought years in the period 1960-1999 when rainfall gauges were maintained in the Serengeti ecosystem included 1966, 1969, 1993, 1994, 1995; in those years rainfall was below the long-term mean by, respectively, 28%, 33%, 41%, 35% and 32%. 1993 was the worst drought on record.

Impact Of Deforestation, Irrigation And The Amala Weir On The Water Budget: Hydrologic Predictions

For the period 1970-1974, a comparison of the flow rates upstream, at the entrance of the Masai-Mara Reserve (Knight Piesold 1992), with those downstream, at Mara Mine (Brown et al. 1981) reveals that water was lost at rate the of 1.2 $m^3 s^{-1}$ in the dry season. This loss is due to evaporation over the 100 km length of the river between those two points, and wildlife drinking. When forage is dry, wildebeest and zebra drink about 20 litres day^{-1} $animal^{-1}$ (Church, Pond 1988).

Figure (2a)

Aerial photograph of a small lot in the process of being deforested in the middle of the Amala forest catchment in the Mau escarpment during an aerial survey in April 2002. Such lots were found to be numerous throughout the Amala forest.

The main forested area is located in the Amala and Nyangores catchments in the Mau escarpment. As revealed by Landsat images (Fig. 2b), this forested area was 752 km^2 in 1973, 650 km^2 in 1985, and 493 km^2 in 2000. The actual forested area at present is even smaller because of a large number of small artisanal clearings in the forest (Fig. 2a) that Landsat cannot detect. If the 1973 meteorological conditions were repeated, and without irrigation, the flow rate of the Mara River entering the Masai-Mara Reserve would probably be reduced from 2.1 to 1.3 $m^3 s^{-1}$ (Dwasi 2002).

At present water permits have been issued to pump water for the Mara up to a maximum rate of 0.1-45 $m^3 s^{-1}$ to irrigate 520 hectares of mechanised farms in Loita Plains (see location map in Fig. 1). This represents up to 25% of dry weather flows in the Mara River. In addition there are several illegal water abstractors who are not registered in Kenya due to lack of monitoring of activities on this river (J. Anakeya, pers. com.). These farms need 600 mm of water for a crop but the amounts pumped vary depending upon rainfall. Most pumping is done when it is dry and the river flow small. Irrigation pumping may increase markedly in the future because the Water Act (Chapter 372) of Kenya allow abstractions of up to 70% of the total flow, with only 30% of the water remaining in the river. Possibly as a result of deforestation and irrigation in Kenya, much smaller Mara River flows in the dry season have been observed in recent years by park wardens in the Serengeti National Park (J. Nyamhanga, pers. com.).

Thus, with deforestation, irrigation and water diversion at Amala weir, the discharge of the Mara River may cease along its 100 km long course in the Serengeti ecosystem during a severe drought. The Amala weir water diversion project would worsen the situation by ensuring that, as the drought begins, the river will already be reduced to a series of small pools connected by a sluggish flow. By contrast, during the 1993 drought, when there was negligible abstraction of water for irrigation and no Amala weir water diversion, this situation occurred only at the end of the drought. The combined effect of deforestation, irrigation and the Amala water diversion will result, in times of drought, in a flow rate less than 0.5 $m^3 s^{-1}$ for 60 days at the entrance of the Masai Mara Reserve. The flow rate would be about 0.25 $m^3 s^{-1}$ if the Amala weir blocks all the flow. In both cases the flow rate of the Mara River will thus be smaller than the water consumption in the Serengeti ecosystem by (1) the animals drinking and (2) evaporation. The pools of water in the Mara River bed will then dry out. Once the pools dry out, which would take about two weeks after cessation of runoff, the wildlife will start dying at a rate estimated in the model (see below) to be 30% per week starting from the end of the first week.

Impact Of The Amala Weir On The Serengeti Ecosystem: Ecohydrology Model Predictions

The effect of the deforestation, irrigation and the Amala weir water diversion scheme on the Serengeti ecosystem was quantified using two models run in parallel. The food availability was calculated by an improved version of the ecohydrology model of Gereta and Wolanski (2002). The water availability was controlled by the hydrologic model of Brown et al. (1981), and only kicks in during a drought to estimate if the animals have insufficient water for drinking, this did not happen in historical conditions 1960-2000 for which data are available.

The ecohydrology model has three trophic layers. The bottom trophic layer is the grass, which grows when watered and withers in the absence of rainfall. The grass is grazed by herbivores. The herbivores calve once a year. The herbivores can die from poaching (for which data are available from the park warden), starvation (in the dry seasons) and disease (mainly in the dry season; Mduma et al. 1999). The carnivores prey upon the herbivores. The model ecosystem is divided in two areas. Area A (the southern grasslands) is used by the herbivores in the wet season. Area B (the northern region along the Mara River in the park and in the Masai-Mara Reserve) is the dry season refuge for the herbivores. The herbivores migrate from area A to area B, many transiting through the lower Grumeti River, when salinity is excessive in area A (Wolanski, Gereta 2001); they return to area A at the start of the wet season. The migration results in an additional mortality of the herbivores. The model bulks together all herbivores and all carnivores. It is necessary for model calibration to scale the herbivore population by that of the wildebeest, and the carnivore population by that of the lions, because data are available on the number of wildebeest and lions. It is thus assumed that the wildebeest form a constant proportion of the herbivore population, and the lions a constant proportion of the carnivore population. In this way, other carnivores, such as hyenas, are also implicitly included.

The model equations are of the Lotka-Volterra type for biomass at each trophic level, they express mass conservation. The model considers separately zones A and B and the migration pathways. The equations are:

1. ZONE A

GRASS (G)

$$dG/dt = \begin{Bmatrix} g\ G\ R/20, & \text{if } R > 20 \\ -2\ g\ G\ (5-R)/20, & \text{if } R < 5 \end{Bmatrix} - h\ G_o\ H/H_o$$

ADULT HERBIVORES (H)

$$dH/dt = \begin{Bmatrix} s_A\ H\ (G - G_o)/\ G_o, & (\text{if } G < G_o) \\ 0 & , (\text{if } G > Go) \end{Bmatrix} - d_1\ H - p\ H\ C/C_o$$

YOUNG HERBIVORES (Y)

Before calving $Y = 0$

In the calving month $Y = 0.5\ r\ H$

Thereafter $dY/dt = \{ s_Y Y(G - G_0)/ G_0$, (if $G < G_0$) $\}$ - $d_Y Y - p Y C/C_o$
$\{ 0$, (if G >Go) $\}$

CARNIVORES (C)

$dC/dt = \{ 0$, (if $H > H_{01}$) $\}$ + ($b - d_3$) C
$\{- d_4 C (H_{01} - H) / H_{01}$, (if $H < H_{01}$) $\}$

2. MIGRATION

When migrating A ⇒B H (new) = q (H (old) + Y / r)
Y (new) = 0

When migration B ⇒A H (new) = q H (old)
Y (new) = 0

3. ZONE B

GRASS:

$dG/dt = \{g G R/20$, if R >20 $\}$ – $h G_0 H/H_0$
$\{-2 g G (5-R)/20$, if R<5 $\}$

ADULT HERBIVORES:

$dH/dt = \{s_B H(G - G_0)/ G_0$, (if $G < G_0$) $\}$ - $d_2 H (1+H/H_s) - p H C/C_o$
$\{ 0$, (if G >Go) $\}$

YOUNG HERBIVORES

Y = 0

CARNIVORES

$dC/dt = \{ 0$, (if $H > H_{01}$) $\}$ + ($b - d_3$) C
$\{- d_4 (H_{01} - H) C / H_{01}$, (if $H < H_{01}$) $\}$

Where R = rainfall (mm/month), G = biomass of grass, H= biomass of adult herbivores, Y= biomass of young herbivores, r = calf to adult herbivore weight ratio in April, C = biomass of carnivores, G_0 = equilibrium G preventing starvation of herbivores when $H=H_o$, s_A = starvation rate of herbivores in zone A if $G<G_o$, $s_B = s_A(1+H/H_0)$ = starvation rate of herbivores in zone B if $G<G_o$, h = rate of removal of grass by herbivores at equilibrium, g = growth rate of G, p =predation rate of the herbivores at equilibrium, q = fraction of herbivores that survive the migration, d_1 = death rate of herbivores in region A, d_2 = death rate of herbivores in region B, b = birth rate of carnivores, d_3 = death rate of carnivores (excluding starvation), C_o = equilibrium carnivore biomass, H_0 = equilibrium herbivore biomass when $C= C_o$, $H_{01}=0.3H_0$, H_s = saturation capacity in zone B; d_4 = death rate of carnivores at equilibrium, t = time (starting from January 1960 when monthly rainfall data are available), dt = model time step. The list of the various rates used parameters, is shown below

Value of the rates ($month^{-1}$) used in the model.

s	0.05
r	0.7
g	0.6
h	0.05
s_A	1.2s
p	0.003
d_1	0.01

d_Y	$3d_1$
s_Y	$3s_A$
d_2	0.01
s_B	1.3s
b	0.01608
d_3	0.0016
d_4	0.0016
q	0.9
dt	1 month

It is to be noted that the equations are non-linear, reflecting basic ecologic modeling principles. Also to be noted, the model reflects Mduma (1996) observations that the population biomass is controlled by processes in zone B, these processes are parameterised by taking (see the equations) different values of G_o and d in zones A and B, by adopting a saturation term H_s in zone B, and by introducing the parameter H_{o1} in zone B.

Observed monthly rainfall data from 1960 to 1999 were used to drive the model. Data are available on the number of wildebeest and lions between 1960 and 1999 (C. Packer and E. Gereta, unpubl. data; Wolanski et al., 1999; Serneels, Lambin, 2001). The model was successful (Fig. 3) in reproducing these observations. The model was also successful in reproducing the 20% die-off of wildebeest during the 1993 drought (Mduma et al. 1999). Predation by lions is predicted to be of secondary importance for the herbivore population dynamics in the Serengeti ecosystem. The model reproduces Mduma et al. (1999) observations that the population of herbivores is limited by the availability of water and forage, and thus fluctuates inter-annually as a result of rainfall. It is apparent that the population of wildebeest did not reach a quasi-steady state (i.e. a population > 1 million animals) until 1976.

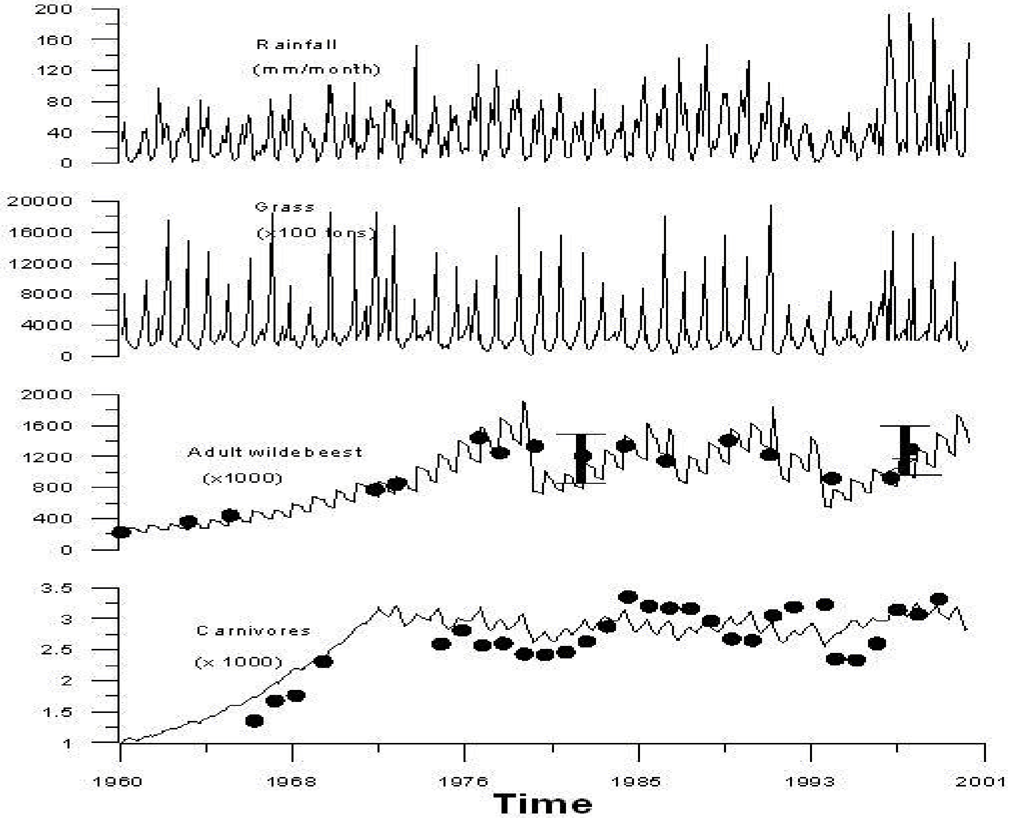

Fig. 3:

Serengeti ecohydrology model calibration. Time-series plot in the period 1960-1999 of the observed monthly rainfall, predicted biomass of grass and predicted number (thousands) of adult wildebeest and lions. For wildebeest and lions, the dots are observations and the lines are the model predictions. The error bars indicate possible observational errors. Monthly rainfall data were the forcing function for the model.

While the model appears to be verified against observations, it is important to note that, like all ecosystem models, it should be used with caution. Like all ecosystem models based on Lotka-Voltera equations, it simplifies the system and is based on a number of assumptions on the key processes governing ecosystem functioning. Some of these processes are still subject to research. The model predictions are very sensitive to the exact values of the parameters, these were chosen based on the best available data of Mduma (1996) and Gereta (unpubl. data), however some of these parameters are still subject to research.

To help predict the likely effects of deforestation and water diversion in Kenya, the model requires 100 years of rainfall data. The rainfall data from 1960 to 1999 were used. To fulfil the data set length, a further 60 years of data is required. These were simulated using the rainfall conditions from 1900 to 1959, for which data are available for Lake Victoria catchment (Mnaya, Wolanski 2002; Hulme *et al.* 2001). In order to apply these basin-wide data to the Serengeti ecosystem, which is located in a dry belt of the Lake Victoria catchment, the data were multiplied by a constant. This constant was calculated so as to reproduce the mean Serengeti rainfall data from 1960 to 1999. In addition, likely climate change effects were taken into account as they may influence both seasonal rainfall distribution (Hulme *et al.* 2001), and inter-annual fluctuations as a result of changes of the El-Nino/La Nina fluctuations (Tudhope *et al.*, 2001; J. Lough, personal communication).

Two scenarios were considered. In scenario No. 1, the simulated rainfall distribution for years 2001 to 2060 repeats the historical conditions (1900 to 1959) adjusted for likely climate changes. In scenario

No. 2, the rainfall data was calculated as in scenario 1 except that the rainfall for the years 2040-2060 was then transposed with that from 2005-2025.

Fig. 4 shows the model predictions. Without irrigation and Amala weir, the wildebeest population is predicted to fluctuate and to always recover after a die-off during a drought year (Fig. 4, top). This suggests that, if left alone, the Serengeti ecosystem is viable in the long-term.

With irrigation, at 70% of the river flow, and Amala weir, both assumed operational from the year 2002, the wildebeest population is predicted to fluctuate quite differently (Fig. 4, middle and bottom). In both scenarios 1 and 2, for the first few years after construction of the weir, near normal rainfall prevailed and water diversion had no impact on the wildebeest population. Thereafter, in scenario 1, a severe drought occurred and resulted in a 50% collapse of the wildebeest population. The wildebeest population was able to recover in twenty years, the recovery being slowed by further droughts (Fig. 4, middle). The wildebeest population was unable to recover substantially from a 70% population collapse near the end of the simulation period for scenario 1 (Fig. 4, middle), and at the beginning of the simulation period for scenario 2 (Fig. 4, bottom). The key parameters were thus

- the severity of a drought,
  and
- the occurrence of further droughts during the wildebeest population recovery period.

Further, the model predicts (not shown) that the worst case scenario is that of the Kenyan operator not shutting down the scheme during a severe drought, in order to maximise hydro-electricity production. In that the wildebeest numbers may collapse by 80%, at which time the population would not recover due to regulation by predators.

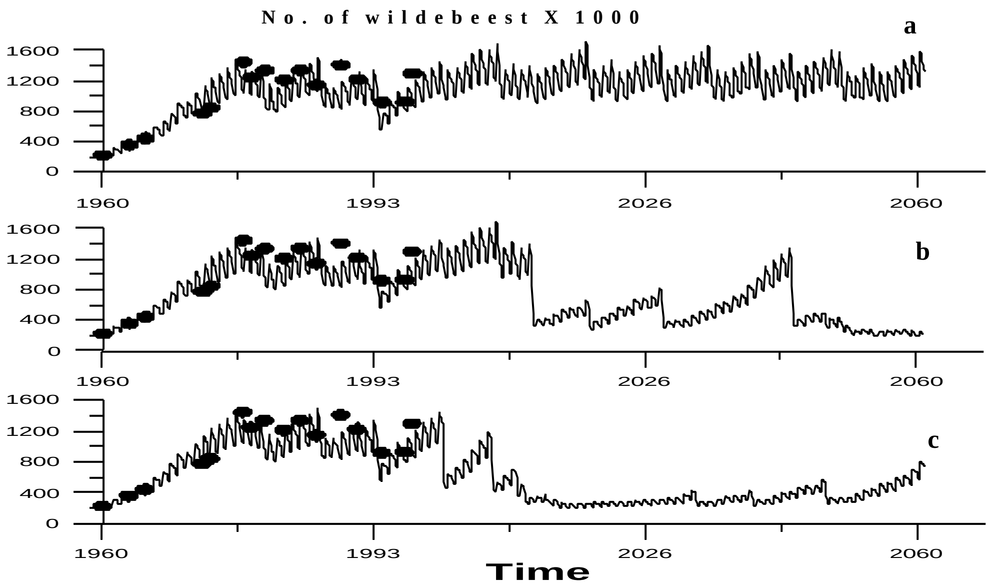

Fig. 4

Time-series plot of the predicted number of wildebeest. After the year 2000, present conditions of deforestation in the Mau escarpment are assumed unchanged. The likely climate change impact on seasonal and inter-annual rainfall distribution is included. The top figure (a) shows the prediction assuming no irrigation and no Amala weir. (b). The middle (b) and bottom figures (c) show the predictions assuming irrigation in Kenya extracting 70% of the Mara River water as well as the Amala water diversion scheme being operational from 2002, for future rainfall scenarios No. 1 and 2, respectively (see text for details).

The model was also run to predict the impact of various assumptions. It was found (not shown) that

- a further deforestation in the Mau escarpment by 30% would increase the wildebeest die-off in a moderate drought by about 20%, this makes the ecosystem collapse faster.

- if the predicted impact on rainfall from climate change from the enhanced Greenhouse effect did not eventuate, the wildebeest die-off in a severe drought will decrease by about 12% in a moderate drought but the ecosystem would still collapse during a severe drought.
- if there was no further deforestation in the Mau escarpment and no Mara River water extraction for irrigation in Kenya, but if the Amala weir was still constructed, there may be no mass die-off of the wildebeest population.
- the wildebeest die-off is largely independent of the order that the various rainfall years occur in scenarios No. 1 and 2. For instance running the rainfall scenarios backward (ie the last years in scenarios No. 1 and 2 occurring first) lead the much the same wildebeest die-off.
- The reliability of the prediction was estimated by varying within reasonable assumptions (Mduma 1996) the various model parameters. The maximum departure was ± 20% of the wildebeest population. In all cases varying these parameters degraded the goodness of fit (Fig. 3) between observed and predicted wildebeest population in the period 1960-2000.

Discussion

A rainfall-runoff model for the Mara River suggests that the Mara River may dry out in the Serengeti ecosystem as a result of evaporation and animals drinking, if the water is diverted for large-scale irrigation and for hydro-electric production in the proposed Ewaso Ngiro project in Kenya. The lack of water may worsen if deforestation continues in the Mau escarpment.

An ecohydrology model suggests that this will significantly impact the Serengeti ecosystem. This impact is predicted to worsen as a result of the likely climate change from the enhanced “Greenhouse effect”.

Under the combined effects of irrigation, present levels of deforestation, the proposed Amala weir water diversion scheme, and changes in rainfall brought upon by climate change from the enhanced “Greenhouse effect”, the model suggests that in a severe drought, the Serengeti ecosystem would collapse. More precisely, the wildebeest population would drop 80% from about 1,000,000 to about 200,000 animals, from which the population would remain depressed forever.

Sensitivity tests suggest that (1) the Serengeti ecosystem collapse would be further accelerated if the upper Mara River catchment is further deforested, (2) the exact sequence of dry and wet years will not prevent an ecosystem collapse, (3) the ecosystem would still collapse if the predicted climate change from the enhanced “Greenhouse effect” do not eventuate, (4) the ecosystem will only collapse if both irrigation and the Amala weir water diversion scheme occur.

Unfortunately there may be some realism to this prediction of ecosystem collapse. Indeed, on purely socio-economic grounds, it is possible that in a drought Kenya, which already suffers power shortage in a drought (such as happened in 2000), may not necessarily stop irrigating as well as shutting down the proposed hydro-electric scheme, at great economic costs to Kenya, in order to minimise possible environmental and economic costs in Tanzania. Both these schemes may be kept operational. Kenya could choose to install a monitoring programme in the Serengeti ecosystem. However no remedial measures would be available in case of a water shortage in the Serengeti ecosystem, because there are no other water sources. Thus the key question for the survival of the Serengeti ecosystem will be a decision by Kenya in a drought year whether to keep irrigate and to generate hydroelectricity, or to shut down these schemes for typically 60 days and possibly up to 110 days. Kenya economic needs would be satisfied in the first case, while the environmental and economical costs would be borne by Tanzania.

A word of caution is necessary because hydrologic and ecosystem modeling remains an art rather than an exact science. The hydrologic model is the most robust, it says there is simply not enough water in the Mara River to support large-scale irrigation in Kenya, water diversion for hydro-electricity production, as well as evaporation along the river and drinking of water by the vast herds of animals in the Serengeti ecosystem in a drought. This is a simple, fairly robust water budget. While the prediction of a lack of water is robust, there are uncertainties in the details of the predictions of the collapse of the Serengeti ecosystem when water will run short. These uncertainties are common to all ecosystem models. We cannot tell reliably thus if, in a drought and with the developments in Kenya, the Serengeti wildebeest population will collapse by 60%, 70% or 90%. But we can predict that the wildebeest population will collapse. Because the Mara River has always had water in recorded history, there is no historical precedent to verify the model prediction of the impact on the Serengeti ecosystem if the Mara River dries out under the combined effects of climate change, irrigation, deforestation and water diversion in Kenya. However, it is worth noting that removing all drinking water in a drought may be conceptually similar to building fences that prevent the wildebeest migrating in search for water and forage. This happened in Kenya's Masai-Mara ecosystem and in Botswana; in both systems the wildebeest population decreased by 75-90% (Keen-Young 1999; Serneels, Lambin 2001).

A transboundary Mara River management plan is thus needed, compatible with ecohydrology principles. The plan must take into account the cost-benefit analysis for Kenya and Tanzania of deforestation, irrigation and the proposed Ewaso Ngiro (South) Hydropower Project, it must also factor in the likely changes to rainfall and hence river discharge, arising from climate changes due to the enhanced "Greenhouse effect". With the proposed developments in Kenya, the economic benefits presently go to Kenya while most of the environmental and socio-economic costs, e.g. the negative impact on the tourism industry, would be borne by Tanzania.

CHAPTER 3

THE SERENGETI ECOSYSTEM AS IT EXISTS NOW

The Serengeti ecosystem supports the largest herds of migrating ungulates including the highest concentrations of large predators in the world. It is estimated that there are about 1.3 million wildebeest, 200,000 zebras and 440,000 Thomson gazelles. Among predators, hyenas are thought to be the most numerous estimated at about 9,000 followed by lions estimated at 3,000 and cheetahs at about 250. There is also an array of other large and small mammals and over 500 species of birds (Sinclair & Arcese 1995).

Historically, a viral disease called *Rinderpest* at one time attacked Serengeti. The disease, which occurs naturally in Asia, was introduced in Africa in the 1880s and by the 1890s it got into the Serengeti. Rinderpest remained in the Serengeti until the early 1960s when it disappeared from the wildlife populations as a result of cattle vaccination campaign. The vaccination programme had the effect of protecting wildlife from infectious yearling cattle, so that the disease died out among wildlife. The disease affects ruminants closely related to cattle such as buffaloes followed by wildebeest.

Within a period of 15 years following the disappearance of rinderpest in 1963 there was a six fold and five fold increase of wildebeest and buffaloes respectively. The wildebeest population increased from 0.25 million and reached its peak of 1.4 million in 1977. Thereafter it levelled off and has remained at approximately 1.3 million animals since then. Aerial censuses conducted since 1977 showed little variations except in 1994 when the population dropped to about 900,000 following a severe drought that occurred in 1993 (TWCM 1994). However, the population has since then recovered to 1.3 million following good rains in the subsequent years. Available evidence suggests that the migrants barely crossed the border into the Masai-Mara Reserve in the 1950s and 1960s most probably because of its small population size but by the 1970s when numbers were high, a large proportion were using the Masai-Mara as a dry season refuge area.

The population dynamics of the Serengeti predators have been documented by Schaller (1972), Hanby and Bygott (1979), and Bertram (1979). These studies suggested that the increase of lions on the Serengeti plains was not as a result of the increase of the wildebeest population, but because of the increase of the resident prey populations. Apparently predators cannot follow the long distance wildebeest migration because they have to take care of their underdeveloped young and maintain their territories. Thus, the lion population is limited by the availability of the resident prey populations. Studies have shown that the lion population responds to changes of the resident prey biomass, which in turn depends on the amount of rainfall. (Schaller 1972, Hanby and Bygott 1979, and Bertram 1979 Packer et al (1988). This relationship caused the lion numbers in the Serengeti Plains to level off in the 1980s. Studies conducted on lions that live in the woodlands suggested that these populations depend on the biomass of resident prey species, particularly buffalo, and are buffered by annual changes in food availability caused by wildebeest movements. The woodland populations are, therefore, net exporters of dispersers, and thus are source populations. In contrast, plains populations subjected to the vagaries of weather and wildebeest movements, cannot maintain themselves on the low resident prey numbers, hence they are sink populations. Thus, woodland populations supply lions to the rest of the Serengeti ecosystem.

Hyenas, on the other hand, form another group of important large predators in the Serengeti ecosystem and were first studied by Kruuk (1972) followed by Hofer and East (1993). Hyenas are the most abundant large predator, with a population of about 9,000 in the Serengeti ecosystem as compared to 3,000 lions. It appears their population increased in the Serengeti plains. Hofer and East (1993) demonstrated that hyenas are tied to the migrating populations than are lions because of their ability to commute long distances of up to 40 kms or more. They also have a social system that allows commuters to pass through adjacent territories. Because of these adaptations hyena numbers may have increased in response to higher numbers of wildebeest. Poaching in the Serengeti also has its implications. Since the 1960s there has been a six-fold increase in the number of arrested poachers. Although the actual number of illegal hunters is not known, a rough extrapolation suggests that up to 30,000 illegal hunters could be servicing about 1 million people within a radius of 45 km of the western boundary of Serengeti National Park (Campbell and Hofer, 1993). A very crude estimate of illegal harvest off-take is 200,000 animals per year, of which about 75,000 is of resident large herbivores both inside and outside the park. This harvest is very unsustainable and some areas within the park are already devoid of animals.

Vegetation dynamics in the Serengeti has shown a lot of spatial and temporal variations. The Serengeti-Mara ecosystem has experienced major vegetation changes in its recent history, alternating between open grassland and dense woodland over the past century. These patterns of vegetation change suggest that the Serengeti-Mara ecosystem is dynamic and may be subject to long-term vegetation cycles or transitions between stable states following ecological perturbations (Caughley, 1976; Carson and Abbiw, 1990; Dublin, Sinclair, and McGlade, 1990). In the 1930s and 1940s the area was densely wooded. The land set aside as Serengeti National Park and the Masai-Mara Game Reserve was characterized by dense woody vegetation for over 20 years. In the 1950s, however, the woodlands and thickets declined rapidly and reverted to grasslands. Earlier in the 1890s following the introduction of rinderpest epidemic it is thought both human and animal populations declined to relatively negligible numbers in the Serengeti-Mara ecosystem. Fires decreased as a result of low human population density. Elephant were low because of intense ivory poaching in the previous decade. This scenario caused the Serengeti-Mara region to be characterized by broad, open expanses of grassland punctuated with scattered Acacia trees similar to the present Masai-Mara. Over the next 30 to 50 years the conditions favoured establishment of dense woodlands and thickets. The dense, woody vegetation provided suitable habitat for heavy infestations of the tsetse fly, which in-turn prevented significant human settlements within the Serengeti and Mara. It was for this reason that the areas were set aside for wildlife protection in the 1930s (Sinclair and Norton-Griffiths 1979, Spinage, 1973, Dublin, 1986).

In the late 1950s and early 1960s the woodlands began to decline (Lamprey et al, 1967; Watson and Bell, 1969; Glover and Trump, 1970) and human populations started to recover from the effects of rinderpest epidemic (Morgan and Shaffer, 1966; Kurji, 1976). The human population increase initiated the decline of woodlands through the use of fire. The decline of wildlife populations as a result of rinderpest epidemic created a vacuum in terms of animal dispersal in the area. This was compounded by the heavy rains, which occurred in the late 1950s and early 1960s. Heavy rains caused higher production of forage that could not be fully utilized by animals. Thus hot fires became widespread during the dry season. Fires were set for various reasons. Maasai set fires to improve pastures for their grazing animals and to reduce the populations of tick, tsetse fly and bush. Honey gatherers used fire to collect honey. Poachers used fire to improve visibility and attract animals to lush grass for ease of hunting. Park authorities also used fire for management purposes. Fire activities contributed to the decline of woodlands and encouraged the establishment of grasslands. Likewise, under normal rainfall regime woodland regeneration would have been impeded by the increase of fires.

The increase of human settlements outside protected areas also caused the decline of woodland to grassland. These settlements forced the elephants to leave areas such as Loliondo, the Isuria Escarpment (Oloololo or Siria), the Chepalunga Forest and the Lambwe Valley and went to the protected area. Elephants were concentrated in protected areas and caused damage to woody vegetation opening the area into grassland.

Grassland Stable State

From the 1960s to 1980s the Serengeti-Mara ecosystem witnessed dramatic changes. By mid-1970s the wildebeest population, increased by a factor of five, and remained at approximately 1.3 million with slight variations. Each year the wildebeest travel to the northern Serengeti and Mara in search of dry season forages and remove the majority of the available standing crop, which would otherwise burn (Sinclair and Norton-Griffiths, 1979; Dublin et al, 1990; Onyeanusi, 1989).

Elephant Numbers and Distribution

The Serengeti elephant population declined by 81% from 2,460 in 1970 to 467 in 1986. The major cause of mortality was poaching and about 400 to 500 sought safe refuge in the Masai-Mara Reserve in Kenya. A combination of high tourist exposure and increased anti-poaching efforts provided a secure home in the Mara (Dublin and Douglas-Hamilton, 1987) and Serengeti National Park, and numbers increased significantly since mid 1980s. Today over 2,015 elephants move back and forth between the Masai-Mara and Serengeti National Park. The elephant numbers in the Serengeti National Park increased from 467 in 1986 to 2,015 in 1998 (TWCM, 1999). The impact of elephants on the maintenance of grassland in the Serengeti has not been felt so far despite the population increase. Through casual observations the feeding habits of the Serengeti elephants show that they spend most of their time on woody vegetation but still the woody vegetation seem to be on the increase. The cause for the recent increase of woody vegetation could be attributed to annual prescribed burning instituted by the park management to protect some sensitive vegetation and avoid hot fires during the dry season coming from outside the park. Another reason could be that the use of cool fire tends to scarify the acacia seeds on the ground and this encourages fast growth of the *Acacia* seedlings. Prescribed burning remove dry grass material and reduce competition for nutrients and water with the woody growth, hence, the coming of the woodlands in the Serengeti (personal observations). Considering this scenario, it suggests that the elephant population in the park is relatively small to reduce the existing woody vegetation and maintain grassland as is happening in the Masai-Mara.

The Importance of Water Quality in Driving the Serengeti-Mara Wildebeest Migration

Many mechanisms have been proposed as triggers for the onset of the migration. Biomass models based on forage and nutrients and the effect of carnivores have been suggested, but none has explicitly included rainfall, and the models' predictive power has proved to be low. They all fail to consider the unused forage, do not explain why animals migrate and cannot predict the timing of the migration, which may vary by as much as three months. Curiously, although hydrological data have been collected for the park for many years, for example, rainfall for 38 years and river discharges for four years in the 1970s, this information seems to have been ignored when searching for causes for migrations. To look deeper into the driving forces of the Serengeti ecosystem, water quality data were collected and merged with the available hydrological data. The analysed data were to reveal any correlations between water quantity and quality, timing of migration and vegetation types and availability. This study proposed that water quality, as well as quantity, makes up the dominant force driving the Serengeti ecosystem. Not only do these factors explain the timing of the wildebeest migration, but they also suggest why vegetation occurs in the patterns that it does (Wolanski et al, 1999).

Although the Serengeti ecosystem includes areas outside Serengeti National Park, the park covers about 14,763 Km^2 and is drained by the Mara, Grumeti and Mbalageti Rivers all flowing westward into Lake Victoria. The Mara River passes through the park in the far north, at 1,300 to 1,500 meters of elevation, and drains a total of 10,300 Km^2, most of which is in Kenya. The Grumeti, with a total catchment area of 11,600 Km^2, drains much of the wooded savannah of the central and northern hills much inside the park's boundaries. To the south, in an area of treeless grasslands and hills lying between 1,600 and 1,660 meters in elevation, the Mbalageti drains 2,680 Km^2, nearly all within the park. The Mara River that was gauged at its entrance to the park had a peak flow of 1,000 cubic Meters per second. The Grumeti, with a similar drainage area, saw a maximum of 200 cub. Meters/sec. at its exit to the park. To the south, the Mbalageti peaked at only 40 cub. Meters/sec where it left the park. These flows vary greatly with the seasons. After the rains, discharges decrease exponentially to base flows maintained by ground water seepage. The Mara reaches its base flow a few months after the rains end, whereas the Grumeti and Mbalageti decline to essentially zero flow within weeks and days, respectively. Thus during much of the year, the Grumeti and Mbalageti consist of a series of stagnant pools tens to hundreds of meters long and less than a meter deep, except where hippos constantly stir them and prevent siltation. The stagnant pools are the only source of water for wildlife during the dry season. Rainfall data analysis on a monthly basis from January, 1960 to June, 1989 from 232 stations, not all of which were operational continuously, have indicated that there is a great variation in rainfall. In general, rainfall is greatest in the north-western and extreme south-eastern corners of the park, exceeding 110 cm/year in the northwest, and least in the east, at about 50 cm/year. A rain shadow downwind of the Ngorongoro Mountains makes the southern grasslands the driest area of the park. On an interannual basis, the south-eastern rainfall dominates in very wet years (top 10%), whereas the northern rains dominate in dry years. These rainfall patterns are clearly reflected in vegetation, with the boundary between wooded savannah and grassland moving southward during the wetter decades. Nonetheless, other factors may influence this boundary shift, including the discouragement of man-made fires and poaching of elephants as described earlier (Wolanski et al, 1999).

The biodiversity of flora and fauna in the Serengeti National Park river systems has remained largely unexplored. Recent discoveries by Farm (2000) revealed a new species of BARBUS fish that was named *Barbus serengetiensis* (TELEOSTEI: CYPRINIDAE). The fish is found in shallow streams and rivers with gravel or sand substrata. The streams are in open woodlands or wooded savannas having pronounced wet and dry seasons. The specimens were collected in streams where turbidity was very high, visibility of less than 10 cm, although a visibility of more than a meter was also possible and in stagnant pools of water at the beginning of the dry season. At present the distribution of the new species is only known from the Orangi River (a tributary of the Grumeti River) and some of its tributaries: the Pololeti, Seronera, Ngarenanyuki and Nyabogati Rivers, all of which are located in the centre of Serengeti National Park.

Lesser Flamingos (Phoeniconaias minor)

The Lesser Flamingo (*Phoeniconaias minor*) is one of five (or six) species of flamingos in the family Phoenicopteridae, the only one in the order Phoenicopteroides that stands alone as a group of birds not closely related to others. The Lesser Flamingo life is in groups of very large numbers. They have a very specialized diet, feeding and breeding behaviour. They are distributed across the equator where they are entirely without influence from the usual seasons that define the life history and activity of most other birds. They are well adapted to walking and swimming in sodic waters and they are entirely tied to sodic and salty lakes by their diet. Thus, their distribution coincides with the soda and salty lakes of some parts of Africa and western Asia and their range is never far from these lakes, which are the only reliable food sources.

Distribution of Flamingos

Flamingos are widely distributed in alkaline saline lakes especially those found in the Great Eastern Africa Rift Valley. They constitute the greatest numbers and biomass of life in the lakes, which are known for their low species diversity due to hostile ecological conditions to many aquatic species and high productivity of especially *Spirulina platensis,* the main food of lesser flamingo. Located in arid and semi-arid areas, the Rift Valley lakes undergo annual cyclic changes in water levels mostly in response to precipitation, which is unreliable and unpredictable. Thus the lakes show high variability in water levels, food availability and species composition (KWS, 2001).

Lesser flamingos are algivorous filter feeders subsisting mainly on *Spirulina platensis* with occasional resource to diatoms. *Spiriluna* is the most common type of algae in the saline lakes and constitute the major food of the lesser flamingo. The quantity of other algae species found in the lakes is too small to sufficiently provide food supplies to flamingos. The ecology of flamingos is finely tuned to the variable food supply, quality and quantity. They show nomadic movements between the various lakes associated with food availability and fresh water points. Thus, the birds disperse throughout East Africa, including Ethiopia and Uganda, but mainly to Kenya's Lake Nakuru and Bogoria and Tanzania's Lake Manyara and Natron, both of which have fewer numbers than the Kenyan lakes at most times. (Njaga and Githaiga, 1999).

Flamingo movements are aimed at tracking highly productive food patches both within and between saline lakes. Any ecological process affecting these two major factors triggers off their movement instincts. Thus flamingos are non-resident in any saline lake, but exploit various lakes in their home range. Despite this kind of utilization, some lakes are of special importance to flamingos such as Lake Nakuru as a feeding and display site; Lake Natron as the only safe and successful breeding site; and Lake Bogoria as a stable lake and refuge when other relatively shallow lakes dry out. Other important dispersal lakes like Elmenteita, Simbi, Amboseli, Turkana, Sonachi and Magadi and other small lakes in the East African region are important for occasional conditions when the main lakes deteriorate simultaneously (KWS, 2001).

Flamingos Food and Feeding Behaviour

The main food of the Lesser Flamingo in Eastern Africa is the microscopic blue-green alga *Spirulina platensis* as explained above. This algae is capable of extraordinary biomass production when it has optimum conditions of water quality, water depth, water temperature and sunlight which has been suggested to be in excess of the production of a tropical rain forest or papyrus wetland. Much of the behaviour of the Lesser Flamingo seems related to finding this food source when it is in abundance and in good quality – with high levels of protein and carbohydrate contents.

The flamingos feed by filtering water through specialized bill and tongue. The head is held up-side-down and swept from side to side below the water surface at the ideal depth to capture the best growth of the algae. The pink colour in the flamingo feathers is developed from pigments derived from algae. There is likely to be some correlation between food quality and the amount of pinkness in the plumage. This in turn affects the development of conditions for reproduction within the Lesser Flamingo population. The Eastern Africa Lesser Flamingo population become reproductively active as a result of some changes in food quality, which affect both their plumage and hormonal condition. In most cases the true nesting occurs at Lake Natron.

Conditions for successful nest-building, incubation and fledging seem to be a strict combination of a remote place that can accommodate hundreds of thousands of nests and remain free from disturbances that could cause the birds to abandon their nests, the appropriate water depth with underlying mud, trona, salt or a combination, which allows the birds to mound nests that are surrounded by water. However, the water depth does not increase during incubation to the point of flooding the nests, and availability of fresh water for the adults and within walking distance for the chicks once they leave the nests. The combination of required conditions occurs from time to time at Lake Natron. Also, these conditions have to coincide with the timing of the reproductive condition of the large flocks of birds.

Nesting at Lake Natron can occur in many months but is most often seen in the months of August to December. Thus the necessary conditions need to persist until the young birds are able to leave the nesting lake in flight. This may take up to eight weeks before the entire group is able to fly to a more suitable feeding site if conditions become difficult. Incubation takes around four weeks during which adults endure very high temperatures on the soda or salt flats. The chicks stay on the nest for a week or so and then gradually form groups or crèches which are herded and guarded by a few adults and which may end up containing hundreds of thousands of individuals. Initially the chicks return to their nests for food and water but eventually they stay and move together in groups as fledging takes place.

Tanzania mainland covers a total area of 945,000 km^2 of which 61,500 km^2 is covered by water. It is estimated that about 6 – 10% of the country is covered by wetland ecosystems, including large lakes, small fresh water and sodic lakes, man-made lakes, riverine systems, estuaries, irrigated land, floodplains, etc. One of the remarkable feature of the country's topography is the Rift Valley of which many wetlands within it support flamingos. The Lesser flamingos (*Phoeniconaias minor*) are the most numerous of all flamingos in the world (Katondo and Mwasaga, 1997). East Africa's Rift Valley lakes host about 98% of the total world population of lesser flamingos, whose biomass is more than 90% of all water birds in the world. Yet only Lake Natron is suitable for breeding (Njaga and Githaiga, 1999). Recently, it has been learnt that lesser flamingos play important ecological and economic roles, yet their survival is uncertain due to influence of human activities (Katondo and Mwasaga, 1997). For instance, flamingos are estimated to harvest, under optimum conditions, up to 10,000 tons of algae per month in Lake Nakuru alone, meaning they are useful in eliminating excess nutrients, which would otherwise cause severe imbalance, as is happening with the hyacinth in Lake Victoria.

Flamingos are very sensitive to disturbances especially by visitors in their breeding grounds. Also their choice of nesting sites has very stringent requirements of soil and water chemistry, all of which have been interfered with in most other saline lakes either by industrial pollution or heavy siltation. The success of maintaining the ecological integrity of Lake Natron to flamingos lies on its remoteness, marginal infrastructure, low visitor numbers and an undisturbed lakeshore where nesting takes place (Njaga and Githaiga 1999).

The Impact of Amala project to Flamingos

Any additional flow of fresh water from the Amala Project as a result of diverting water flow will change the ecology of the system. Predicted effects:

1) Reduced food (algae) production as a result of declining alkalinity (pH)
2) Increased water volume will affect wading behaviour of flamingos (not swimmers) *e.g.,* Lake Manyara following El-Nino rains in 1997-98.
3) Change of shore vegetation as (influenced by fresh water) will reduce breeding grounds and allow predators to reach flamingo nests.
4) Increased water depth and turbidity will affect photosynthesis processes of aquatic flora.
5) Increased pollution as a result of upstream irrigation program.
6) The reduction and/or absence of flamingos in the lake will cause the lake to be over-fertilized as a result of affluent from agricultural areas. Flamingos reduce this problem by feeding on algae.
7) Invasion of new species favouring fresh water including predators and competitors.

The Mau Forests

The Mau Forests lie on the western highlands of Kenya, which are located on the south-western part of the country and include the South-west Mau, West Mau, East Mau, Transmara and Ol Posimoru forests. The forests form part of the Forest complex, that is, gazetted forests. These forests were reserved specifically for the protection and conservation of water catchment areas. South-west Mau, West Mau and Transmara forests lie on the steep slope of the Mau escarpment which forms part of the western slope of the Rift Valley. To the east, the slope of the Mau escarpment falls sharply to the floor of the Rift Valley and to the west, it slopes less sharply south-westwards and southwards onto the Lake Victoria plateau. This implies that the forests play a role of preventing soil erosion and downstream siltation and sedimentation.

The Mau Forest complex is dissected by numerous rivers, river tributaries, and streams. The rivers flow almost in a parallel pattern from north-east to south-west and southwards down the steep slope of the escarpment and either in the Mara and Sondu Rivers basins, which finally drain into Lake Victoria. Mara River passes through north-western Tanzania, or southwards into Ewaso Ng'iro River that flows into Lake Natron. The rivers are important economically and ecologically to the whole of East Africa region especially to Kenya and Tanzania. The Mara River has been noted to be the only permanent water source in the Maasai-Mara Game Reserve and the northern part of the Serengeti National Park in Tanzania. The Ewaso Ng'iro River is the only permanent water source on the whole of northern front of Lake Natron that flows into the lake, while Sondu River, which is not trans-boundary, flows through major agricultural areas in Kenya before emptying its waters into Lake Victoria.

The preservation of the Mau Forests was noted by the colonial government, hence, its gazettment as early as 1902. The forests play an important role in preserving and maintaining the water balance of the rivers, especially Mara and Ewaso Ng'iro by regulating infiltration and run-off. In turn, this controls downstream water availability especially dry season water flows in the rivers. Regulation of water run-off prevents soil erosion and thereby limit river bank erosion; thus limiting downstream siltation and sedimentation; and prevent flooding (Dwasi, 2002).

The catchment for Mara River is formed by the Mau Escarpment, which runs from north-west to south-east across the central highlands. Two tributaries of the Mara, rivers Nyangores and Amala originate from the western side of the Mau Escarpment, a high rainfall area (1400 mm/year) of high elevation (3000 m asl) and flow from a north-east to south-west direction down the steep slope of the escarpment for some kilometres and then merge to form the Mara River. The Mara River which is about 290 km long flows south-westwards for about 100 km with altitude decreasing to below 2000 m asl, passes through the Maasai-Mara Game Reserve in Kenya and into northern Tanzania where it flows south-westwards through the Serengeti National Park, the Masarua Swamp, to Lake Victoria where it empties its waters at Musoma in Tanzania. The lower portion of the Mara River in Tanzania is a dry plain of lower elevation of about 1300 m asl. receiving between 700 mm and 1200 mm of rainfall per year with high evapo-transpiration and considerable water loss. The Mara River catchment is a trans-boundary catchment with 65% of it in Kenya and the remaining lower portion in Tanzania.

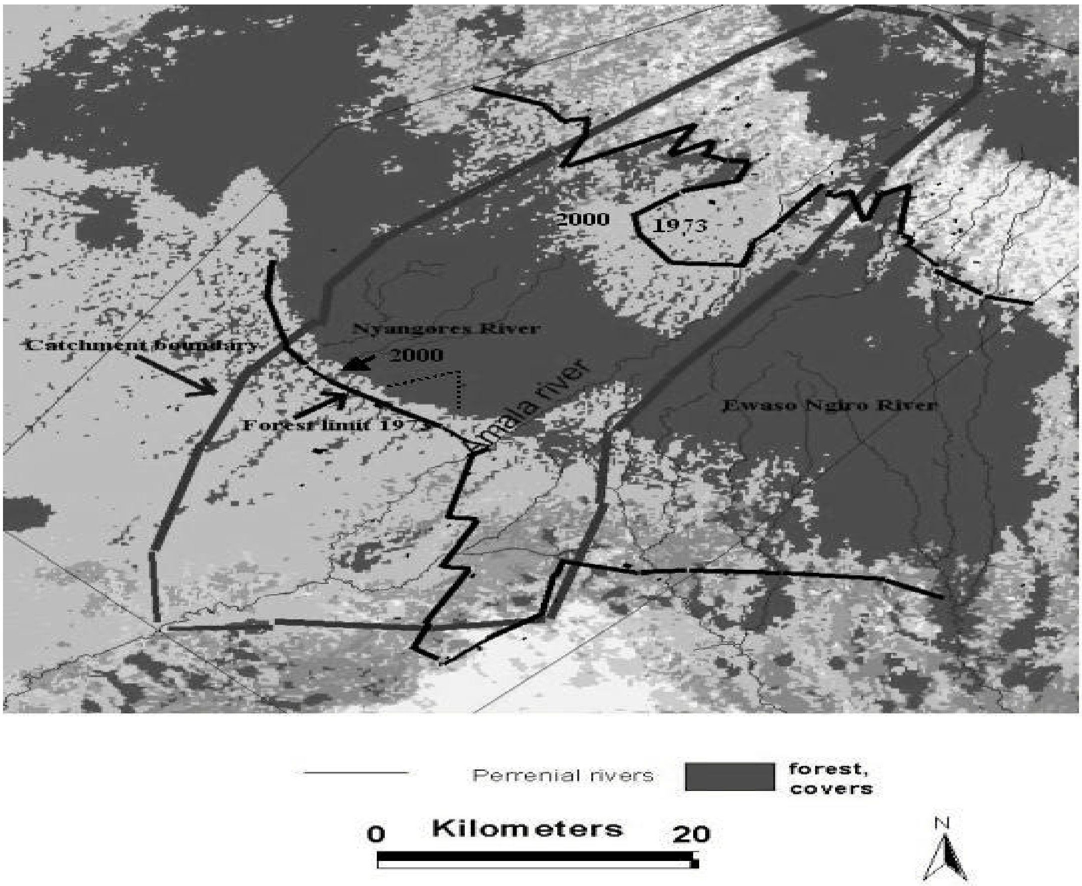

Figure (2b) February 12, 2000,
Landsat photograph showing the catchment boundary of the Amala and Nyangores rivers and, in grey, the forested area. This includes natural and regrowth forest. This catchment area is surrounded to the east by the Ewaso Ngiro River that flows south-eastward to Lake Natron, and to the west by the Gucha Migori River (not shown) that flows westward towards Lake Victoria. The forest boundaries in 1973 are also shown. The dots indicate areas proposed by the Kenya government for forest excision in 2001. This Landsat photograph does not reveal the small lots deforested within the main body of the forest.

Most of the lower catchment in Tanzania is occupied by subsistence farmers who engage in cultivation of a variety of crops and livestock production. It is the most important river entering Lake Victoria since it runs through both the Maasai-Mara and Serengeti National Park, which are unique wildlife habitats and important sources of tourist income for both Tanzania and Kenya. There are also a number of large farms producing cash crops and towns with industries along the Mara River downstream in Tanzania. Most importantly, the Mara River is the only permanent water source in the whole of the Mara region in Tanzania, supporting millions of people, wildlife and agricultural activities.

The Mau Forest is one of the few remaining moist forests in Kenya. About 60,000 ha (148,000 acres) of the forest have been set to be degazetted and used for human settlements instead. The forest consists of the Western Mau, the South-western, the Trans-Mara and the Ol Pusimoru, all forming a continuous ecosystem that harbours unique plant and animal species. It is home to elephants, endangered bongos, giant forest hogs, and an array of rare primates such as colobus and blue monkeys.

Besides harbouring various animal and plant species, the forests also form catchment for some of the largest rivers in Kenya, which feed key lakes such as Nakuru, Bogoria and Lake Victoria in Kenya and Lake Natron in Tanzania. The Mara River, the only permanent water source in the Maasai-Mara and the Serengeti National Park, originates in the Mau Forest.

The gradual shrinking of the Mau Forest started with land fragmentation and settlement programme in the 1970s. During the 1970s the forest covered nearly half of the entire Lake Nakuru catchment basin. In 1990s the forest underwent severe degazettement and erratic settlements as a result only about 10% of the Lake Nakuru catchment remained. In the past six years alone, about 200 km² (77 mile^2) have been lost to settlements. (Environment News Service, 2000).

The forest supports the flamingos, not only directly through feeding site in Lake Nakuru, but also indirectly through the Lake Natron, the only known suitable breeding site for the lesser flamingos.

Reduced Wildebeest Population: Predictions of Impacts in the Serengeti Ecosystem

Reconstruction of 100 years of the vegetation dynamics in the Serengeti Ecosystem gives an insight of what might happen if the wildebeest population is reduced to about 200,000, as it is believed to have been following the rinderpest epidemic in the early 1900s (Dublin 1995). A small wildebeest population encourages hot fires because of less removal of grass (fuel). Hot fires kill woody vegetation leading to open grasslands.

Uniqueness of the Serengeti Ecosystem

The Serengeti ecosystem is unique because of the migration system that it supports. This annual event consists of about 1.2 million wildebeest, 250,000 zebras, 5000 elands and 400,000 Thomson's gazelles. Except for the later species the rest use the Mara system as the dry season refuge.

The Serengeti migration system is the only big mammal migration system remaining in Africa after the collapse of the kob (Sudan Uganda, Ethiopia). It is a natural process that takes place on a large landscape with different vegetation types and ecological conditions.

Experiences of the 1993 Severe Drought

In 1993, the Serengeti region experienced a severe drought not recorded before. In northern Serengeti the average annual rainfall dropped to 620 mm from 1200 mm/yr. The long rains that typically span from March through June failed altogether. Although lakes, ponds and most of the rivers dried up, the Mara River maintained a small flow probably sustained by underground seepage from the Mau Forest. However, the large migrating animals moved out of the protected areas into the villages in search of food and drinking water. About 400,000 wildebeest died of starvation and slaughtering by humans most mortality happened in the western Mara. Prolonged severe drought exacerbated with a higher extraction of water to meet power demands will lead to the loss of migratory wildebeest by about 30% in the first two weeks and the entire population in one month.

Wildebeest Water Requirements

Studies on cattle have shown that zebu cow of 250 kg live weight can drink about 30 lts of water per day (Church and Pond, 1976). In the same context it is assumed that wildebeest might require about 20 lts per day on average taking into considerations of all stresses that go along with life in the wild. Assuming a population of 1 million wildebeest this translates 20,000 cubic meters of water per day.

Lack of drinking water sources plus lack of food in a prolonged drought will cause a total collapse of the wildebeest migration. Serengeti will lose its unique value, one of the reasons for its nomination into a Biosphere Reserve by UNESCO and World Heritage Site by IUCN.

Impact on Other Large Vertebrates

The Mara River is the only source of drinking water for large vertebrates during the peak of the dry season. Diversion of the water will cause the river to stop flowing. Waterborne fishes will be confined in pools and therefore exposed to increased predation, especially fish larvae (Wolanski & Mnaya 2001). Habitat for amphibians will be severely affected. In the event of a drought the riverbed may dry up altogether which will have serious consequences to the ecology of the area. Fishes and amphibians dependent on the river system will perish. The semi-aquatic crocodiles and hippos will be denied an important component of their habitat with unknown consequences. Similarly, all other large vertebrates that depend on the river as a source of drinking water will be severely affected. These include, for example, large herds of elephant, buffalo, topi, reedbuck, waterbuck, buffalo and hartebeest.

CHAPTER 4

ECONOMIC AND SOCIAL IMPACTS TO TANZANIA OF IMPLEMENTING THE PROPOSED AMALA WEIR WATER PROJECT IN KENYA

Economic and Social Impacts of the Amala Project on Tourism

Tourism Industry: a Global Perspective

Tourist Arrivals and Tourism Receipts

International tourism and business travelling are among the world's largest and most rapidly expanding economic activities. As an earner of foreign exchange, tourism and travelling have become increasingly important when compared to other exports in developing countries. In 1998, for example, international tourism arrivals attained a growth rate of 2.4 percent to reach a level of 625 million tourists. The corresponding tourism receipts amounted to US $ 436 billion. In the ten years (1989 – 1998) period, arrivals worldwide grew by an average annual rate of 4.3 percent. International tourism receipts (excluding transport) increased by a corresponding 8.1 percent per annum over a 10 year period as shown below:

Table 1: International Tourist Arrivals and Receipts World-wide: 1989 – 1998

Year	Arrivals (million)	% Arrival Change	Receipts US $ billion	% Annual change
1989	426	8.02	221	8.31
1990	458	7.47	269	21.54
1991	464	1.25	278	3.21
1992	503	8.49	315	13.52
1993	519	3.12	324	2.85
1994	550	6.05	354	9.23
1995	565	2.73	405	14.44
1996	597	5.49	436	7.52
1997	611	2.39	436	0.09
1998	625	2.37	436	2.01

Source: World Tourism Organization (WTO) A Report on "Tourism Market Trends in Africa."

World Hotel Capacity

Between 1980 and 1997 the world accommodation capacity expressed in number of beds increased at an average annual rate of 3.5 percent or by 80 percent from 16 millions to 29 million beds, as indicated in table 2 below.

Table 2: Hotel and Similar Establishments: Accommodation Capacity

	Bed – Places '000'			Market Share		
	1980	**1985**	**1997**	**1980**	**1985**	**1997**
Europe	8,542	8,637	11,731	52.5	47.5	40.0
Americas	6,436	6,933	9,345	39.5	38.0	31.8
East Asia/Pacific	763	1,694	6,725	4.7	9.3	22.9
Africa	269	525	834	1.7	2.9	2.8
Middle east	141	254	400	0.9	1.4	1.4
South Asia	126	198	310	0.8	1.1	1.1
TOTAL	**16,277**	**18,241**	**29,344**	**100**	**100**	**100**

Source: World Tourism Organisation (WTO): A Report on 'Tourism Market Trends in Africa 1999.'

Despite the reported growth in tourism activities, Africa as a whole lagged behind when compared to other regions. For example tourist arrivals in Africa stood at about 25.0 million tourists in 1998 while those visiting the Americas were 120.0 million in the same year. On the other hand, tourism performance in the Eastern Africa region in 1998 was quite impressive registering a growth rate of 7.7%.

The Tourism Industry in Tanzania

An Overview

According to available documentation by the World Tourism Organization (WTO), international tourism and business travelling are among the world's largest and most rapidly expanding industries. In Tanzania, and indeed else where in the developing countries, tourism sector has become one of the main drivers of economic growth, particularly because of its strategic significance and capacity to earn foreign exchange.

The strategic significance of the tourism sector in the country's economy is based on the following facts:

- It generates hard currency (foreign exchange) for the economy
- It creates employment opportunities.
- It generates tax revenue for the Government.
- It has an important impact on regional economic activity.
- It enhances enterprise economy because it attracts establishment of small and medium scale enterprises.
- It brings about significant economic and social benefits to local communities.
- It has considerable potential for expansion and increased value added.
- It has extensive forward and backward linkages.

In terms of the general policy objectives, Tanzania's National Tourism Policy seeks to assist in efforts to promote the economy and livelihood of the people, essentially poverty alleviation, through encouraging the development of sustainable and quality tourism that is culturally and socially acceptable, ecologically friendly, environmentally sustainable, and economically viable. It also seeks to market Tanzania as a favoured tourist destination for touring and adventure (wildlife safari) in a country renowned for its cultural diversity and numerous beaches.

Tanzania envisages that the number of tourists will be in the one million range by the year 2010, and that the proceeds of the tourism are projected to increase from the current average of 8.1% to an annual average growth rate of 10% by the year 2005. It is recognised that the private sector will play a major role in the industry's development, with the Government playing the catalytic role of providing and improving the infrastructure as well as providing a conducive climate for investment.

The Performance of the Tourism Industry in Tanzania

The performance of the tourism industry in Tanzania, particularly in the light of the above mentioned key industry characteristics, has generally been impressive over the past ten years. The total number of tourist visitors grew four fold in ten years, from 153,000 in 1990 to 627,325 in 1999 before decreasing to 502,000 in the year 2000. This implies an annual growth rate in the number of tourists of 13.56%. Total tourist bed nights in hotels rose from 1.03 millions in 1991 to 3.38 million in 1999.

During the period under consideration the foreign exchange earnings went up more than ten times, from USD 65 million (1990) to USD 739.1 million (2000); giving an average rate of increase, in foreign exchange earnings, of 28.12%. During this period the average daily expenditure per tourist increased from USD 72.42 (1991) to USD 152.00 (1999). In the year 2000, the foreign exchange earnings increased to USD 739.1 million, from USD 733.3 million in 1999, despite the decrease in the number of tourists as indicated above.

Tourism activities in the country contributed 13.15% to the Gross Domestic Product in 2000, and 12.25% in 2001. In terms of foreign exchange generation, tourism accounts for over 50% of the total foreign exchange earnings in the country. On the other hand, employment in the industry, through its chain of actors, rose from 45,000 people in 1991 to 148,000 in 1999. The table below presents a detailed scenario of the performance of the tourism industry in Tanzania.

Table 3: Tourism Industry Performance

Item	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	153.0	186.8	201.7	230.2	261.6	295.3	326.2	360.0	482.3	627.3	502.0
2		171.8	187.6	216.3	238.5	268.2	296.2	345.0	457.3	564.6	
3	65.0	94.73	120.04	146.84	192.10	259.44	322.37	392.41	570.00	733.3	739.1
4		507.0	595.0	637.9	734.3	878.5	1090.0	1181.8	1169.0		
5		7.0	7.0	7.1	7.1	7.2	7.3	7.5	7.6	7.7	
6		72.42	85.00	89.80	103.40	122.00	135.00	145.00	155.50	152.00	
7		205	207	198	208	210	212	213	215	321	
8		5484	6150	6100	6335	6935	6970	7470	7500	9575	
9		1.03	1.13	1.32	1.45	1.67	1.87	2.25	2.94	3.38	
10		9878	10963	10860	11335	12145	12348	13248	13400	17235	
11		56	56	56	56	57	56	56	60	64	
12		45.0	50.0	66.0	86.0	96.0	100.0	110.0	132.0	148.0	

Source: The Economic Survey 2000. The Planning Commission.
Key:
1 = Total number of tourists (thouisands)
2 = Number of tourists in hotels (thousands)
3 = Total earnings (in USD millions)
4 = Average earnings per tourist (in USD)
5 = Average number of bed nights per visit (in days)
6 = Average daily expenditure per tourist (in USD)
7 = Number of hotels (number)
8 = Number of hotel rooms (number)
9 = Tourist bednights in hotels (millions)
10 =Number of hotel beds (Number)
11 = Average hotel occupancy rate per year
12 = Number of employees in the tourist industry (thousands)

The contribution of tourism to the Gross Domestic Product is by no means mean. It stands at an annual average of about 15%, being second only to the mining industry in terms of its rapid growth rate as documented in the National Economic Survey for the year 2000. There is no doubt therefore that the industry is one of the key drivers of the country's economy.

Through its strategic forward and backward linkage effects, the industry accounts for the existence of a relatively significant number of visitor facilities; in particular, hospitality and tourism related establishments. These include accommodation, Air Charter, Balloon Safaris, Cultural Centres, Car Hire, Hunting Safaris, Mountain Climbing, Photographic Safaris, Travel Agents, Tour Operators, Financial and Business Services and others to be added as more tourism opportunities are being considered such as canoeing. Details are given in the table below.

Table 4: Selected Hospitality and Tourism Related Facilities

Category	Number
Accommodation	227
Air Charter	27
Balloon Safaris	1
Cultural Centre	10
Car Hire	8
Handling Agents	1
Hunting Safaris	38
Mountain Climbing	16
Photographic Safaris	3
Sea Safaris	6
Travel Agents	24
Tour Operators	118

Source: Tourism Statistical Bulletin 2000. Ministry of Natural Resources and Tourism

In terms of visitor number by purpose of visit over the past few years, the scenario is as shown in the table below.

Table 5: Visitor Number by Purpose

Purpose	No./ %	1995	1996	1997	1998	1999	2000
Holiday/Recreation	No.	198,499	219,292	246,000	299,946	383,155	339,596
	%	67	67	68	61	61	68
Business	No.	58,602	64,505	80,982	127,994	132,802	130,201
	%	20	20	22	27	21	26
Transit	No.	10,196	11,457	13,000	31,788	62,732	10,956
	%	4	4	4	7	10	2
Others	No.	28,015	30,944	20,018	22,603	48,636	20,916
	%	9	9	6	5	8	4
TOTAL		295,312	326,188	360,000	482,331	627,325	501,669

Source: Tourism Statistical Bulletin for 2000, Ministry of Natural Resources and Tourism.

According to industry estimates, over 75% of tourists visiting Tanzania are Northern Tourist Circuit bound, where Serengeti, Ngorongoro Conservation Area, Tarangire, Arusha and Lake Manyara national parks are the major tourist attractions. It is worth noting at this juncture that Tanzania offers a very limited tourist product, based on a limited resource, that is, wildlife, which is concentrated in the Northern circuit. This implies that Tanzania's tourist industry is dominated by the safari element as neither the beach nor the sight seeing tourist products are yet to be well developed. The country's tourist industry is thus highly dependent on wildlife.

The major market sources for the Tanzania's tourist industry is shown in the table below.

Table 6: Market Sources

Source/Year	1995	1996	1997	1998	1999	2000
Europe	106,012	117,098	128,912	175,031	200,585	153,958
Americas	37,425	41,038	45,219	61,930	61,918	49,513
East Asia & Pacific	8,500	9,382	11,232	14,600	35614	38,299
South Asia	13,466	14,916	16,093	18,808	31,705	22,626
Middle East	14,909	16,727	17,798	24,962	31,944	27,339
Africa	115,000	127,027	139,842	187,000	265,559	209,934
Total	**295,312**	**326,188**	**359,096**	**482,231**	**627,325**	**501,669**

Source: Tourism Statistical Bulletin for 2000, Ministry of Natural Resources and Tourism.

In view of the strategic importance of the tourist industry in the national economy, the Government gives it the attention and focus it deserves. The recently revised tourism policy (1999) and The Integrated Tourism Master plan (1996) is a clear testimony to this effect.

The Role of the Serengeti to the Tourism Sector

Overview

The Serengeti is one of the greatest wildlife wonders in the world and indeed a key endowment to Tanzania and the tourism industry. Covering an area of 14,763 km2 Serengeti is the home of a variety of animals and birds. The annual animal migration is yet another spectacular aspect of this renowned game park, thus offering a unique wildlife viewing experience. The Serengeti National Park is among the 12 parks managed by the Tanzania National Park.

Socio-economic Significance of the Serengeti

The socio-economic importance of the Serengeti National Park (SENAPA) cannot be over-emphasized. The following points elucidate this fact:

Tourist Visitors

About 75% of the tourist visitors in the country go to the Northern Tourist Circuit, which comprises of Serengeti, Lake Manyara, Tarangire, Ngorongoro, Kilimanjaro and Arusha national parks. Available documentation reveals that Serengeti is the dominant player in the Northern circuit accounting for about 40% of the tourist activities in the country. This is largely explained by its international fame, as it is one of the best known in the world.

Going by the available statistics as shown in table 7 below, the total visits to the national parks in 1995 were 431506. Serengeti's share by then was 104672 visits, which is 24% of the total visits. In the year 2000 the total figure for all parks was 777533, with Serengeti's share rising to 309517 visits, which is about 40%. On the average the number of the visits were increasing at an annual rate of 26.7%. In terms of the visitors to Serengeti, the average annual rate of increase for the period 1987/88 to 2000/01 was 12.3%. Details are given in table 7.

Table 7: Visits to the National Parks

Park/ Years	No./ %	1995	1996	1997	1998	1999	2000
Serengeti	No.	104,672	110,334	116,993	123,652	202,858	309,317
	%	24.3	24.4	24.5	24.7	32.3	39.8
Manyara	No.	56,825	58,780	60,735	62,690	73,820	85,775
	%	13.2	13.0	12.7	12.5	11.8	11.0
Ngorongoro	No.	172,091	178,020	185,468	192,917	200,800	208,249
	%	39.9	39.3	38.9	38.5	32.0	26.8
Arusha	No.	22,153	24,276	26,821	29,366	45,880	48,425
	%	5.13	5.36	5.62	5.86	7.31	6.23
Mikumi	No.	11,843	10,431	7,031	3,630	12,784	10,609
	%	2.74	2.3	1.47	0.75	2.04	1.36
Ruaha	No.	4,269	5,098	5,683	6,268	10,936	11,523
	%	0.99	1.13	1.19	1.25	1.74	1.48
Tarangire	No.	44,755	49,880	57,097	64,315	56,724	67,720
	%	10.4	11.0	12.0	12.8	9.04	8.71
Kilimanjaro	No.	14,468	15,423	16,378	17,333	22,560	33,515
	%	3.35	3.41	3.43	3.46	3.60	4.31
Gombe	No.	430	670	910	1,150	961	2,201
	%	0.1	0.15	0.19	0.23	0.15	0.28
TOTAL	No.	431,506	452,912	477,116	501,321	627,325	777,534

Source: The Economic Survey, 2000. The Planning Commission.

Revenue Generation

The Serengeti National Park generated a total of USD 3,547,778 in the year 1995/96 and this figure increased to USD 6,040,291 in the year 2000/01. These figures when compared to the TANAPA totals of USD 10,270,002 for 1995/96 and USD 18,577,250 for 2000/01 show that the average performance of Serengeti Park, over the years, was over 30% of the totals. Additionally, it will be noted that revenues for Serengeti National Park and TANAPA were increasing at an annual rate of 21.0% and 17.6% respectively. The table below shows the visitor and revenue Statistics for TANAPA and Serengeti National Park for the period 1987/88 to 2000/01.

Table 8: Visitor and Revenue Statistics for Serengeti National Park and TANAPA

Years	SENAPA		TANAPA	
	Visitors	Revenue (USD)	Visitors	Revenue (USD)
1987/88	47,625	647,984	132,876	2,534,481
1988/89	55,176	598,887	152,867	2,157,795
1989/90	59,069	1,194,472	177,941	2,898,975
1990/91	66,380	1,241,982	182,868	4,383,555
1991/92	79,713	1,620,477	209,447	4,872,814
1992/93	80,804	1,848,421	212,479	5,545,418
1993/94	105,751	2,129,450	263,527	6,624,330
1994/95	91,234	3,097,655	237,326	8,903,140
1995/96	98,501	3,547,778	259,905	10,270,002
1996/97	96,886	3,831,727	284,656	12,215,304
1997/98	90,793	4,631,247	268,902	14,218,208
1998/99	198,934	4,521,690	367,022	14,465,553
1999/00	113,867	5,119,417	293,036	16,787,204
2000/01	124,553	6,040,291	318,419	18,577,250

Source: TANAPA – Planning Unit. (1987/88 figures were only for Arusha and Gombe Parks)

It is worth noting, at this stage, that in terms of revenue generation Serengeti National Park is second to only Kilimanjaro National Park, and the two parks account for about 77% of the TANAPA's total revenue. Actually the two parks do support the operations of the other parks financially. The table below gives a comparison of the revenues generated by the various parks during the year 2000/2001.

Table 9: Park wise Revenue Records for 2000/2001

Park	Revenue in USD
Arusha	648,889
Gombe	85,478
Katavi	21,703
Kilimanjaro	8,164,945
Manyara	1,460,782
Mahale	57,862
Mikumi	154,924
Ruaha	209,922
Rubondo	13,784
Serengeti	6,040,291
Tarangire	1,486,040
Udzungwa	20,614
TOTAL	**18,365,234**

Source: TANAPA Planning Unit Data Survey, 2001

Employment

In terms of direct employment Serengeti National Park has the largest permanent work force of all the parks. The Park's work force, by 2000/01 statistics, consists of 351 males and 34 females, a total of 385 staff. The Park's work force constitutes 29.3% of TANAPA's total workforce, which is 1313 employees. The Park's annual wage bill including related allowances is about TAS 820.8 million for permanent employees and TAS 15.0 million for casual labourers. It is obvious from these statistics that Serengeti is the biggest employer of all the parks. Table 10 below provides statistics on employment on a park-by-park basis.

Table 10: TANAPA'S Manpower Record

Park	Male Staff	Female Staff	Total Staff	% of total Staff
Arusha	98	12	110	8.4
Gombe	33	5	38	2.9
Katavi	60	1	61	4.6
Kilimanjaro	132	24	156	11.8
Manyara	93	15	108	8.1
Mahale	50	4	54	4.2
Mikumi	103	18	121	9.2
Ruaha	106	13	119	9.1
Rubondo	49	5	54	4.2
Serengeti	351	34	385	29.3
Tarangire	95	15	110	8.4
Udzungwa	52	6	58	4.4
TOTAL	**1,162**	**151**	**1,313**	**100**

Source: TANAPA Planning Unit Data Survey, 2001

Apart from the actual Park employees, the Park also supports employees and casual labourers of other establishments/visitor facilities within the park. Currently there are a total of eleven permanent visitor facilities with a total bed of capacity of 836. In addition to the permanent facilities, there are twenty-seven special campsites and ten public campsites, making a total of 720 non-permanent beds in the park.

Table 11: Establishments/Facilities within Serengeti National Park

Category	Units	No. of Beds
Hotels/ Lodges	5	650
Permanent Tented Camps	6	186
Non-Permanent Tented Camps	37	720

Source: Management Zone Plan. Planning Unit. Tanzania National Parks.

Assistance to Communities

Inline with the existing TANAPA policy, communities living around the National parks are generously supported through the main community based development projects such as construction of school facilities, health facilities, water facilities and village feeder roads, in terms of materials and finance. The major objective of the support is to ensure that the communities fully enjoy and gain from the resources with which they have some entitlement. Also to create awareness on the importance of conservation of wildlife and the benefits accrued from it.

During the past 10 years, Serengeti National park was able to contribute a total of TAS 370.95 million to surrounding communities for implementation of various community based projects as shown below:

Table 12: Assistance to Local Communities (TAS Millions)

District	Education	Health	Roads	Water	Total
Tarime	40.39	13.17		18.49	72.05
Ngorongoro	63.04	10.66			73.7
Meatu	1.83				1.83
Bariadi	19.28				19.28
Magu	15.77				15.77
Serengeti	118.03	17.37	27.02	6.67	169.09
Bunda	19.23				19.23
Total	**277.57**	**41.2**	**27.02**	**25.16**	**370.95**

Source: SENAPA/TANAPA

The Government is another important beneficiary of the operations of Serengeti National Park or activities related operations of the park, particularly in the form of tax revenues and other levies. For example, records at the Serengeti district authorities show that tax collections from five hotels/camps operating within the park area are on average about TAS 1.1 billion per annum. Tourist shops, including the Sopa Lodge tourist shop generate about TAS 4.0 million per annum in terms of taxes.

Assistance to Tourism

The donor community has over the years been significantly and generously contributing to the development of the tourism and wildlife sectors. Massive financial, material and human resources have been channelled through the government, or directly to TANAPA and or Serengeti National park or related institutions for purposes of wildlife conservation management and development. For example, assistance given to Serengeti National Park by the Frankfurt Zoological Society for the period beginning 1997 to 2002 amounts to Euros 8,214,277 (see table below).

Table 13: Donor Assistance to Serengeti National Park (USD)

Donor	1997	1998	1999	2000	2001	2002	Total
FZS	78.84	1,491.45	1,431.18	1,219.48	1,356.97	1,436.36	8,214.28

Source: Frankfurt Zoological Society

Besides the Frankfurt Zoological Society, there are other donnor agencies that have assisted the Park in various ways. Serengeti National Park is, thus, a national pride and has greatly contributed in advertising Tanzania world-wide, to say the least. Thus to Tanzanians, the park significance transcends the economic boundaries to encompass a sense of national pride.

What Will Happen If Serengeti National Park Disappeared From The Tanzanian Map Following Drying Of The Mara River? What If This Catastrophe Happened In Ten Years To Come?

The answer to this question is simple and straightforward! It will entail a disaster to the tourism industry, a disaster to the national economy, and disaster in many other dimensions. In short all the benefits to the national economy and society in general as presented above will simply perish, resulting into detrimental social, economic as well as political implications.

- Tanzania will outright lose close to 125,000 (about 40%) tourist visitors currently visiting Serengeti. Given the average annual rate of increase of 12.3%, the figure will have grown to 397,330 by the year 2011. Furthermore, the other parks of Northern Tourist Zone would get very few visitors, if any, since most of them, if not all, do come because of the famous Serengeti. In effect, therefore, Tanzania may lose about 75% of all the tourists coming to the country. This works out to be about 238,814 visitors by 2001 statistics and the figure would grow to about 510,828 by the year 2011.

- In terms of revenue generation Serengeti National Park will outright lose more than USD 6,040,290 and this is projected to increase to USD 40,636,057 by the year 2011 at an average annual rate of 21%. Considering the Northern zone aspect, the loss would be USD 13,932,938 by 2001 statistics and would grow to USD 70,488,117 by the year 2011, the average annual rate being 17.6%.

- Serengeti's existing workforce of about 385 people will lose their jobs as well as their income amounts to about TAS 836 million. This will mean suffering not only to themselves, but also to their dependants, particularly spouses and children. In addition, the employment of the staff in the other parks of the Northern zone, as well as that of the staff in the various visitor facilities, will be at stake, as there would be no visitors and therefore no revenue to support them.

- Communities living around the national parks will no longer benefit from the support they have been getting in terms of community based development projects. Communities around Serengeti National Park will be losing an average of about TAS 40 million per year. The Government will lose tax revenues it has been getting from the operations of the parks. Serengeti district for example, will be loosing an annual tax income of more than TAS 1.0 billion from the operations of the Serengeti National Park.

- Serengeti National Park has been getting significant amounts of donations and assistance from various countries and institutions. If the park collapses the donations and assistance will cease. As an example, the donation to Serengeti National Park by the Frankfurt Zoological Society during the first half of 2000 was close to Euros 1440 thousand. This amount would have been lost.

- Serengeti National Park, along with Kilimanjaro National Park, is the major financial supporter of the operations of the other parks. Collapse of Serengeti will therefore seriously weaken the other parks.

Economic and Social Impacts of Amala Project on Agriculture

The Importance of Agriculture in Tanzania

Agriculture in this context refers to crop and livestock production as well as related agribusiness activities. Fisheries and hunting/wildlife that are normally included in the formal definition of agriculture will be considered separately. The importance of agriculture to Tanzania's economic and social development is clearly manifested by the following points:

- Studies by the World Bank and others indicate that over 50% of Tanzanians can be defined as poor, that is, they have a per capita income of less than USD 1.00 per day. The studies have also shown that well over 80% of the poor are in rural areas and depend on agriculture for their livelihood. Additionally, about 82% of the Tanzanian population live and earn their living in rural areas where agriculture is the mainstay of their living. This implies, therefore, that improvement of farm incomes of the majority of the rural population is a precondition for reduction of rural poverty in Tanzania.

- Recent estimates show that about 42% of households regularly have inadequate food. Food insecurity is often a manifestation of poverty. Localized food insecurity and hunger are common and reflect inadequate resource endowments at the household level. This implies that any effort to address food security must involve actions to improve agriculture so as to ensure availability and access to food.

- Over the years, agriculture has been the single dominant contributor to GDP and foreign exchange earnings. During the year 2000, for instance, agricultural sector contributed 48% to the GDP, and 65% of foreign exchange earnings (FEE). Furthermore, recent studies by the World Bank have shown that agriculture's growth linkages (multipliers) in Tanzania were higher than those of the other sectors and they are felt in both rural and urban areas. As such, agriculture remains the engine of economic growth in the country.

Table 14: Agriculture's contribution to real GDP and FEE.

	1987-1990	1990-1993	1994-1998
Contribution to GDP (%)	48.2	48.4	50.0
Contribution to FEE (%)	55.0	56.0	56.2

Source: Agricultural Sector Development Strategy

Key: GDP = Gross Domestic Product
FEE = Foreign Exchange Earnings

Features of Agricultural Sector

Land Area

Tanzania is endowed with a total land area of 94.5 million hactres, out of which 44.0 million hactres are classified as arable. Again, only 10.1 million hacters or 23% of the arable land is under cultivation. It is also estimated that about 50 million hactres of land is suitable for livestock production, but out of this only 26 million hactres or 50% of the rangeland is currently being used. Some of the reasons that render part of the available land area unutilized for crop or livestock production include soil leaching, drought proneness, tsetse infestation and lack of appropriate physical infrastructures.

Table 15: Selected Main Features of the Agricultural Sector

Feature	Quantity
Land Resource (in million ha.)	
Total Land	95.5
Arable Land	44.0
Rangeland	50.0
Land under Livestock	24.0
Tsetse infested area	26.0
Cultivated Land	10.1
Area suitable for Irrigation	1.0
Area under Irrigation	0.2
Land under medium & large scale farming	1.5
Per capita holding	0.1
Livestock population (millions)	
Cattle	15.6
Goats	10.7
Sheep	3.5
Poultry	27.0

Source: Agricultural Sector Development Strategy. Ministry of Agriculture and Food Security, 2001.

Farm Size

Smallholders who operate 0.2 to 2.0 ha farms and traditional agro-pastoralists that keep an average of 50 heads of cattle use about 85% of the arable land. It is estimated that average per capita land holding is only 0.12 ha, the limiting factor on land holding and utilization being heavy reliance on hand hoe.

Assets and Productivity

According to the Agricultural Sector Development Strategy, poor farmers have had limited access to, or use of, modern inputs and technology than the overall rural population. Such inputs/technologies include fertilizers, pesticides, ploughs, carts, mixed farming etc.

Livestock (water and pasture)

The total number of livestock is shown in table 15 above. It has been shown in the Agricultural Sector Development Strategy that the majority of households in rural areas (over 63%) own some livestock. The contribution of livestock production to agriculture in recent years has been about 15%. There is tremendous potential to increase the contribution of livestock to agricultural out put and rural incomes.

Available Technologies (Irrigation)

With no serious land constraint in most parts, efforts to increase small holder production will depend on expansion of utilized area and or intensification of the existing cultivated area. However, natural resource management practices focus first on environmentally friendly and sustainable intensification.

Agricultural Labour Force

Growth of agricultural labour force will remain one of the major factors determining the growth of agricultural out put, since Tanzania's agriculture is dominantly labour based. The agricultural labour force size is probably close to 11 million. The most active age group is that between 15 and 59 years, which accounts for about 89% the agricultural labour supply. Women account for 70% of this supply. The agriculture labour force is growing at a maximum of 2.8% p.a. while the total labour force is growing at around 3.1%. This disparity is due to rural – urban migration and the growth of non-agricultural informal sector activities in rural areas.

Literacy Rates (Education)

The literacy rate in the rural areas is about 61% for ages above 10 years. It is believed that literacy rates have increased in recent years due to deterioration of the quality of adult education and basic education in primary schools, along with fall in enrolment rates. Empirical evidence in Tanzania and elsewhere in developing countries suggests a correlation between literacy among farmers and improvements in farm productivity.

Performance of the Agricultural Sector

Food Crops

Food assessment in year 2000 showed food deficits in some regions of the country. Maize production, for instance, declined from 2,451,750 tonnes in 1999 to 2,128,000 tonnes in 20000, equivalent to a decline of 13.2% likewise, wheat production declined by 61.2%, cassava by 19.7% and bananas by 13.3. In general, therefore, the national goal of attaining food security for all people was not attained. The table below shows food production levels in 1999 and 2000.

Table 16: Food Crop Production (Tonnes)

Crop	Year	
	1999	**2000**
Maize	1,451.75	2,126
Paddy	576.19	576
Millet	576.03	576
Finger millet	194.37	195
Cassava	1,795.38	1440
Bananas	751.6	652
Potatoes	569.59	587
Wheat	82.37	32
Beans	528.2	584

Source: The Economic Survey 2000. The Planning Commission

Cash Crops

With the exception of sugar, sisal and pyrethrum, other cash crops recorded declined production between 1999-2000. For example, coffee production declined by 0.39%, cashewnut production by 6% and tea production by 1.5%. The table below shows the production levels of various cash crops for the years 1999 and 2000.

Table 17: Cash Crops Production (Tonnes)

Crop	Year	
	1999	2000
Coffee	48,000	47,811
Cotton (bales)	192,730	188,643
Cashew nuts	130,000	121,207
Tobacco	26,670	26,488
Tea	24,7928	24,430
Sisal	23,229	20,584
Sugar	113,622	132,000
Pyrethrum	1,000	1,500

Source: The Economic Survey 2000, The Planning Commission

Non-Traditional Crops

The volume of exports for non-traditional crops for the year 2000 were as follows:
Vegetables 6,706 tonnes
Flowers 2,000 tonnes
Spices 1,241 tonnes
Fruits 3,888 tonnes
These crops earned the nation over TAS 10.3 billion in foreign exchange.

Livestock and its Products

The population estimates, at national level, for the various categories of livestock has been given in table 15 above. Table 18 shows the trend of production of livestock products over seven years period ending 2000/01.

Table 18: Production of Livestock Products

Production /Year	Unit	1994/5	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01
Meat								
Beef	Ton	137,000	148,000	152,000	151,000	155,000	176,000	177,000
Mutton	Ton	45,000	58,000	61,000	62,000	70,000	70,900	72,100
Pork	Ton	10,500	8,000	9,000	9,000	9,500	14,700	16,700
Chicken	Ton	34,500	31,500	35,000	38,000	42,200	45,400	47,000
Milk								
Traditional Diary Cattle	Lts (000)	390,000	390,000	370,000	430,000	440,000	448,500	451,000
Graded Diary Cattle	Lts (000)	200,000	195,000	230,000	240,000	260,000	252,000	255,000
Eggs								
Poultry	Qty (000)	390,000	3,960.000	400,000	400,000	430,000	-	-
HIDES & SKINS							-	-
Cattle	Qty (000)	1,523	1,323	1,000	1,000	1,400	-	-
Goats	Qty (000)	1,829	1,611	1,000	800	650	-	-
Sheep	Qty (000)	561	587	560	500	350	-	-

Source: The Economic Survey 2000, The Planning Commission.

Agricultural and Livestock Policy Objectives

The Agricultural and livestock policy (1997) aims at ensuring that the direction and pattern of development in the agricultural sector meets social objectives and outputs. The policy emphasizes the importance of competitive markets, with the Government providing priority public goods and services and the conservation of the environment as a rational basis for agricultural development. The Policy has the following major objectives.

- Assure food security for the nation, including improvement of national standards of nutrition.
- Improve standards of living in rural areas
- Increase foreign exchange earnings
- Production and supply raw materials and expansion of the role of the sector as a market for industrial output.
- Develop and introduce new technologies for land and labour productivity
- Promote integrated and sustainable use and management of natural resources (environmental sustainability).
- Develop human resources
- Provide support services
- Promote access of women and youth to land, credit, education and information

Agricultural Sector Development Strategy

According to the Tanzania Development Vision 2005, the Government and agricultural stakeholders envisage an agricultural sector that is modernized and commercial as well as highly productive and profitable. In additional, they expect the sector to utilize natural resources in an overall sustainable manner and to act as an effective basis for inter-sectoral linkages.

The primary objectives of the Agricultural Sector Development Strategy are to create an enabling and conducive environment for improving the productivity and profitability of the sector. This will, in turn, serve as a basis for improving farm incomes and reduction of rural poverty in the long term. The strategy, therefore, focuses on the following main issues.

- Strengthening the institutional framework for managing agricultural development in the country. Of particular importance is defining the roles of the Government versus those of the private sector.

- Creation of a favourable climate for commercial activities so as to increase private sector participation and agricultural development in general. This includes a stable macroeconomic environment and appropriate changes to the administrative and legal framework.

- Clarifying, public and private roles in improving support services including agricultural research extension, training regulation, information and technical services as well as finance. Improved delivery of these services is critical to increasing agricultural production and productivity.
- Pay attention to marketing of inputs and outputs in order to improve net farm returns and to commercialize agriculture.

- Working out mechanisms for mainstreaming planning for agricultural development in other sectors so that due attention is paid to issues such as rural infrastructure development, the impact of HIV/AIDS and malaria, gender issues, youth migration, environmental management, etc.

What Will Happen to Agriculture In The Mara Basin Areas If Drought Occurs And The Mara Dries Off?

A Review of the Mara Region

Mara Region is the habitat of the direct beneficiaries of the Mara River. The region comprises five administrative districts, namely, Tarime, Musoma rural, Musoma urban, Serengeti and Bunda. Out of the five districts the River traverses through Tarime, Musoma Rural and Serengeti districts. As such, the effect of any interference with the Mara River waters will be most felt in these areas, and hence this review.

The Mara region has a total surface area of about 30,150 km2 of which the lake Victoria occupies 7,750 km2 and 7,000 km2 is part of the famous Serengeti National Park. Hence the area available for agricultural activities is only about 14,799 km2, out of which only about 3,000 km2 are utilized for agriculture. With the limited availability of suitable land for agriculture, it appears there is struggle for land in the region taking into account the current population standing at about one million people. Thus any intervention in the land utilization efforts would mean disaster to the people.

People in the three vulnerable districts together with their livestock depend on the waters of the River Mara for their daily living. The table below shows the population by district in the region.

Table 19: Human Population

District	Population Census (1978 to 1988)						
	1967	1978	1988	Estimate 1995	Estimate 1998	estimate 2000	Growt h %
Tarime	188,596	252,513	333,888	402,616	436,116	459,984	2.7
Musoma-Rural	340,177	219,127	248,268	295,114	317,805	333,894	2.5
Musoma-Urban	15,412	43,980	68,364	93,034	106,167	115,936	4.5
Serengeti		207,675	111,710	195,206	247,958	290,827	8.3
Bunda			190,386	198,527	202,121	204,554	0.6
Total	**544,185**	**723,295**	**952,295**	**1,184,497**	**1,310,167**	**1,405,195**	**2.6**

Source: Population Census Report of 1967& 1988, Planning Commission.

The majority of the people in these districts live in rural villages where agriculture and livestock keeping are the major economic activities on which they depend for their living. The table below shows the population distribution between rural and urban areas in the districts.

Table 20: Population Distribution

District	Formal Jobs	Agriculture	Industry & Trade	Unemployed	Total
Males					
Tarime	3,996	57,246	2,332	32,063	97,293
Serengeti	1,223	19,057	897	11,470	32,768
Musoma Rural	2,659	41,528	1,132	24,040	69,587
Musoma Urban	4,843	4,395	4,022	7,468	20,967
Bunda	2,625	38,324	1,574	18,298	61,324
Total	15346	160,550	9,957	93,339	279,192
Females					
Tarime	1,667	84,302	1,010	30,637	118,632
Serengeti	504	27,280	312	11,417	39,618
Musoma Rural	965	56,950	316	24,154	82,659
Musoma Urban	3,395	8,069	2,674	10,928	25,234
Bunda	957	49,729	665	19138	70,956
Total	7,488	226,330	4,977	96,278	335,099

Source: Planning Commission; Compiled Data on Mara Regional Statistical Abstract, 1993.

The table shows that the major economic activity employing a large number of people is agriculture, which absorbs over 80% of the population in the region and utilizing between 30% and 50% of the total arable land available.

Crop Production

Most of the people engage in subsistence agriculture producing only enough food crops for home use and selling the marginal surplus to meet financial requirements for the home. The areas bordering the River Mara have relatively fertile soils where production of food and cash crops is at optimum levels. The plains bordering the Serengeti National Park are largely used for livestock. Agriculture production is practised on small acreage ranging between 4 and 5 acres. Both food and cash crops are produced. Food crops include maize, sorghum, millets, cassava, groundnuts etc. Cash crops include Cotton, Coffee (in Tarime), Paddy and Beans. Some Sugarcane is also produced along the banks of The River Mara. It is worth emphasising here that one of the major constraints facing agricultural sector is inadequate and unreliable rainfall. Hence the importance of the Mara River. The table below gives the estimates of crop production in the districts of Musoma rural, Tarime and Serengeti (areas influenced by the river).

Table 21: Crop Production in Metric Tons, and Values (in TAS million)

Crop	1996/97		1997/98		1998/99		1999/2000	
	Ton	Value	Ton	Value	Ton	Value	Ton	Value
Maize	45,300	3,624.0	48,200	3,856.0	48,200.0	3,856.0	43,600	3,488.0
Sorghum	61,460	3,687.6	44,110	2,646.6	51,000.0	3,060.0	39,380	2,362.8
Paddy	2,480	372.0	2,270	340.5	5,310.0	796.5	2,000	300.0
Millets	22,000	2,640.0	180,000	2,160.0	10,510.0	1,261.2	18,900	2,268.0
Beans	2,700	675.0	3,000	750.0	2,150.0	537.5	3,150	787.5
Cassava	57,740	1,732.2	77,000	2,310.0	51570.0	1,547.1	62,000	1,860.0
Sweet Potatoes	47,630	1,428.9	650,050	1,951.5	51570.0	1,547.1	50,000	1,500.0
Total	**239,310**	**14,159.7**	**257,630**	**14,014.6**	**220,310**	**12,605.4**	**219,030**	**12,566.3**

Source: Extract from Mara Region Economic Profile and from Regional Agriculture Statistical Reports; 2000.

The table below shows the cash crop production for the same period.

Table 22: Cash Crop Production in Metric Tons, and Values (in TAS million)

Crop	1996/97		1997/98		1998/99		1999/2000	
	Ton	Value	Ton	Value	Ton	Value	Ton	Value
Cotton	29140	5828.0	26860	5372.0	22480	4496.0	18100	3620.0
Coffee	1370	822.0	1300	780.0	1110	666.0	1410	846.0
Sunflower	10	32.7	-	-	-	-	4	0.64
Groundnuts	2310	369.6	90	14.4	110	17.6	230	36.8
Sesame	240	28.8	20	2.4	15	1.8	30	3.6
Yellow gram	1110	33.3	830	24.9	150	4.5	267	8.0
Total	**33940**	**7114.4**	**28920**	**6133.7**	**23865**	**5185.9**	**20041**	**4515.0**

Source: Extract from Mara Region Economic Profile and from Regional Agriculture Statistical Reports; 2000.

In an event that drought occurs and the Mara River dries off, there would be insignificant crop production, if any, in the three districts endowed with the river. As a result, the three districts would loose about TAS 17 billion worth of crops and there would be hunger and starvation. Declined production of food and cash crops as well as the resulting hunger and starvation are known to be closely associated with increased poverty and illiteracy levels among the rural communities.

Irrigation and Hydro-electric Power Generation

The Tanzanian Government realized, long ago, the great potential of the Mara River and its basin in terms of irrigated agriculture and hydroelectric power generation. In this context the Government with some foreign assistance commissioned a study on the possible development of the Mara river basin. The study came up with the following findings:

- About 65% of the Mara river basin surface is in Kenya and 35% of the basin surface is in Tanzania. Specifically the basin covers 8,030 Km2 in Tanzania and 16,320 Km2 in Kenya, a total of 24,350 Km2.

- About 75-85% of the Mara River waters and their regime comes from the larger upper reaches of the Mara River.

- An estimated 70 – 90,000 ha of land are good soils in the Mara River valley, especially the riparian zone of the Lake Victoria.

The study also established that the river basin area had the following investment potentials:

- Production of sugar cane on an irrigated area of about 10,000 ha at Ikongo valley, along with a sugar factory capable of producing about 75,000 tonnes of sugar per annum valued at about TAS 22 billion.

- Generation of hydroelectric power at the Mara mine taking advantage of the 304.8 m head between the Kenyan border and the Mara mines. This could produce an estimated 380 million kWh of electric power. Valued at current prices this is worth.

- Production of paddy by irrigation on 20,000 ha using 2 sequences harvested during a year, the valued of which would about TAS 12 billion.

- Possibility to employ about 1,600 people at the sugar estate/factory.

If the Mara River dries, all these investment opportunities, worth more than TAS 34 billion along with the employment opportunity, would be forfeited. However, these investment potentials would not be exploited without assessing their possible impact on the environment.

Livestock Production

The Mara River basin currently supports the life of about 167,670 cattle, 46,265 goats and 23,042 sheep, valued at TAS 25.15 billion, 416.4 million and 172.8 million respectively. The livestock depend on the Mara River for drinking water and pasture production. The cattle population in this area has the capacity to produce about 9,557,190 litres of milk per annum, valued at TAS 955.7 million. If the Mara River dries off, most of these livestock if not all will die and all the associated benefits will be foregone.

Apart from the monetary values, livestock in this part of the country are associated with some intrinsic cultural and social values. Cattle, for instance, are associated with prestige and respect on the part of the owners. Cattle are also used as dowry, and marriages are respected and valued if cattle are used as dowry.

Economic And Social Impacts Of Amala Project On Wildlife

In the management for sustainable utilization of wildlife, activities that are undertaken include tourist hunting, traditional hunting, marketing of live animals and trophies as well as wildlife farming. In the year 2000 there were 893 tourist hunters, 130 hunting blocks and 407 tourist companies. Hunting activities amounted to USD 8.5 million. The sale of live animals and trophies earned TAS 136.2 million. Income from penalized poachers was TAS 13.8 million. Details of the extent and earnings of the activities are given in the following four tables:

Table 23: Export of Government Trophies, Live Animals and Birds (In TAS'000)

Type of Trophy	1993		1994		1995		1996		1997		1998	
	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value	No.	Value
Live animals and birds	100,255	26,013	56,553	16,672	43,735	18,120	50,100	16,934	55,000	22,672	86,812	22,900
Hippo teeth (kg)	6,243	18,729	2,440	7,319	1,502.9	4,509	533	1,600	400	1,200	-	-
Tortoises	-	-	74	523	15	106	-	-	-	-	-	-
Crocodile skins	240	1,200	134	660	1,000	5,000	1,000	5,000	1,000	5,000	1,000	5,000
Other products	435	340	NA	1,185	NA	1,990	NA	NA	NA	NA	NA	NA

Source: The Economic Survey, 2000. The Planning Commission.

Table 24: Export of Live Animals and Animal Tusks/Teeth (In TAS,000)

Type of animal	Jan-June 1999		July-Dec. 1999		Total 1999	
	Qty/Wt	Value	Qty/Wt.	Value	Qty/Wt.	Value
Primates	612	3,448.0	482	2,768.0	1,094	6,216.0
Other mammals	665	671.8	614	620.1	1,279	1,291.9
Birds	81,300	9,888.5	85,305	10,374.8	1,66,605	20,263.3
Amphibians	10,878	894.6	15,022	1,235.6	25,900	2,130.2
	30,009	1,444.1	33,841	1,628.3	63,850	3,072
Insects	8,088	357.0	10,295	454.4	18,383	811.3
Animal Tusks and Teeth	516	1,548.8	1,223	3,669.0	1,739	5,217.8
Cropping problem animals		-	-	-	-	-
Miscellaneous e.g. export certificates		-	-	-	-	-
Total		**1,825.7**		**20,750.3**		**39,003.0**

Source: The Economic Survey 2000. The Planning Commission.

If the Mara River dries off, most of the migrating ungulates in the Serengeti and Masai Mara ecosystem will simply perish. Following this most of the tourist visiting Serengeti National Park will disappear, since the Park supports the largest herds of migrating ungulates in the World.

Economic And Social Impacts Of Amala Project On Fisheries

The Fisheries Sub-sector

The fisheries sub-sector in the country is important because of the following attributes:

- Contributes to the provision of nutritional food
- Contributes to the provision of employment
- Generates substantial foreign exchange earnings

The contribution of the sub-sector to the GDP during the year 2000 was 2.7%, compared to 2.6% in 1999. The sector grew by 7.2% in 2000 compared to a growth rate of 3.2% in 1999.

A total of 320,900 tons of fish, valued at TAS 77.68 million, were caught in 2000. The total amount of foreign exchange earnings from export of 41,725.22 tons fish was USD 64.5 million. Details of production and sale of fisheries are given in the two tables below:

Table25: Production in the Fisheries (quantity in Tonnes '00 & Value in TAS' millions)

Years	No. of Artisans	No. of Boats			Fish Catch and Revenues					
		Fresh Water	Sea Waters	Total	Fresh Waters		Marine Waters		Total	
					Qty	Value	Qty	Value	Qty	Value
1993	61,943	-	-	20,976	294.8	31.2	36.7	10.2	331.5	41.4
1994	61,943	-	-	19,361	228.0	30.9	40.8	14.2	268.8	45.2
1995	62,486	18,696	3,768	22,464	207.1	45.8	51.1	28.6	258.2	74.4
1996	62,486	18,696	3,768	22,464	308.6	38.2	48.2	24.1	356.8	62.3
1997	62,486	18,696	3,768	22,464	306.8	42.3	50.2	25.4	357.0	67.6
1998	62,486	18,696	3,768	22,464	300.0	47.5	48.0	29.3	348.0	76.8
1999	62,486	18,696	3,768	22,464	260.0	44.0	50.0	33.5	310.0	77.5
2000	62,486	18,696	3,768	22,464	271.0	45.5	49.9	32.2	320.9	77.7

Source: The Economic Survey, 2000. The Planning Commission.

Table 26: Summary of Fish Export Products – 2000

Year	Quantity	Values		Duties
	Tonnes	TAS' millions	US $ '000	TAS' millions
1996	25,544.9	2,483.77	61,782.88	1,513.45
1997	32,098.1	41,879.81	70,165.11	2,512.74
1998	46,661.0	54,836.80	83,523.09	3,290.22
1999	28,928.8	44,712.63	61,789.86	2,687.06
2000	4,172,521.6	51,173.64	64,535.11	3,071.39
Total	**4,305,574.3**	**217,440.20**	**341,716.05**	**1,3074.86**

Source: The Economic Survey, 2000. The Planning Commission.

Fisheries in Mara River

The current level of fish stock in the Mara River is not established, but research work by TAFIRI shows that most of the fish species that have disappeared from Lake Victoria are now found in Mara River. Such species include Oreochronis and Esculenta. Some rare species like ctenopoma murici are also found in this river. Apart from being a good habitat for rare species, the river is an important breeding ground for fish.

Despite the fact that the Mara River has a wide range of fish species, the fishing activities in the three districts of Serengeti, Musoma and Tarime are only at subsistence level. People use local fishing gear to catch fish for food and to earn some money. Average income from fishing is about TAS 10,000 per head per day. If the Mara River dries the fishing community will denied of this income. Additionally, the inhabitants of this area will be denied of the food that is very rich in nutrients. And above all, the potential for improved fish production is immense.

Tree cutting at the catchment area or along the riverbanks can have several probable effects that may include flooding of the river, erosion and widening of the river, changing of the cause of the river and siltation. All these can result into destruction of the breeding areas or habitats for some fish species.

Gardening or farming along the river banks can accelerate erosion of the river banks. If pesticides are applied to the gardens or farms this may allow organophosphates or organochlorides to find their way into the river. Excessive application of the pesticides may cause the river and oxbow lakes to be devoid of fish. Construction of a dam in the river can have devastating effects on the natural aquatic ecosystem. A change from a river ecosystem to a dam ecosystem is likely create changes in the dominance and abundance of fish and fish food. There is likely to be temporary drought of the river, down stream, until the crest of the dam is saturated with water. During the temporary drought the aquatic life in the river is likely to disappear.

Economic And Social Impacts Of Amala Project On Health

General Health Status in the Country

The Tanzania government has been implementing reforms in the delivery of primary health care to all Tanzanians particularly the vulnerable and risky groups. Various guidelines are being prepared and the existing ones are being reviewed in order to provide better services. The policy guidelines are intended to meet the current demands and challenges such as control of HIV/AIDS as well as monitoring of activities such as traditional medicine, family health care, food and nutrition. The Government has continued to emphasize on establishment of a better health system that will ensure increased capacity and better services. Private institutions and individuals are encouraged to participate in this move. According to the Economic Survey, 2000 there has been a little change in the number of patients reporting and admitted in hospitals between 1996 and 1999. The rate of increase was higher in 2000 compared to previous five years.

Malaria, Diarrhoea and acute respiratory diseases remained major causes and leading diseases for admission to hospitals and for death of people. Preventable diseases by vaccines, malnutrition and reproduction complications which are preventable as well as HIV/AIDS continued to be problematic.

The Mara River Basin Health Status

According to the survey that covered the three districts through which the Mara River traverses, the most common water related diseases and their average levels of incidence are as follows:

Malaria 40%
Schistomiasis 17%
Diarrhoea 16%
Dysentery 8%
Typhoid 5%
Skin infections 2%

Malaria (water-related), Schistomiasis (water-based) and diarrhoea (water-borne) are thus the most threatening diseases in this area. Mortality rates of malaria and diarrhoea, as given in the Serengeti District Health Profile Report of 2001, are as follows:

Disease 5 years	5 years
Malaria 19%	23%
Diarrhoea 5%	10%

Severe drought or formation of water pockets in the Mara River is likely to increase the incidence and mortality rates of some diseases and thereby necessitating the utilization of the TAS 50,000 per household. This is the amount that is estimated to be required for control/treatment of these various diseases. Diseases such as diarrhoea, dysentery and skin infections would increase because they are associated with personal and general hygiene. The formation/creation water pockets, instead of water flowing in the river, would provide a favourable environment for the spread of diseases like malaria and Schistomiasis.

Economic And Social Impacts Of Amala Project On Water

General

The Government's water policy is intended to ensure proper protection and equitable use of water sources for both social and economic development for the benefit of all communities. The Government has been involving various communities in the processes of planning, selection of appropriate technology, construction, contribution and management of water projects. In addition, the Government has been encouraging the participation of institutions, non-governmental organizations, private institutions, religious organizations and the public in improving the provision of water services in the country.

Rural Water Supply

According to projections, services were expected to increase from 48.5% in 1999 to 50% in 2003. According to available statistics, provision of safe and clean water has reached 50% of rural population and 73% of urban population. Rural water supply efforts that have been taken of the Government in this connection include construction, expansion and rehabilitation of existing water projects as well as exploration of new water projects in some regions. Efforts have also been made to promote rainwater-harvesting technology as an extra source of water in some areas. In addition, communities have been sensitized to manage and rehabilitate their water projects through training, seminars and workshops.

Among the major problems facing the water sector is environmental degradation particularly at water sources a s a result of human activities such as deforestation, irrigated farming, human settlement and bush fires. Other problems include

- ❖ Deterioration of water distribution systems
- ❖ Limited investment in water sector
- ❖ Drought in some areas
- ❖ Lack or inferior technology in rainwater harvesting and distribution.

Utilization of International Waters

Currently, there are efforts to establish an authority that will manage and ensure sustainable utilization of Nile basin waters. Along with this, a project on development and utilization of water resources has been prepared by the Nile basin Initiative in order to source funding.

In February 2002 a meeting of Ministers responsible for water sector was held in Cairo to discuss a draft on institutional and legal system to oversee the utilization and development of the Nile Basin waters.

During the year 2002/2003, the Government through the Ministry of Water and Livestock will continue to follow-up on efforts to establish the Nile Basin Authority. Furthermore, the Ministry will establish a legal institution for the development of the Mara river basin.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Conclusion

The Government of Kenya envisages undertaking two development concepts, that is, Amala Project for hydro-electric power generation and Degazettement of the Mau Forest to open up more land for agriculture. This study has shown that the two development concepts, along with irrigated farming, are going to have serious detrimental impacts on the Serengeti and Masai-Mara ecosystems, both in terms of environmental sustainability as well as social- economic stability.

The study has revealed that the proposed diversion of the Amala River waters into the Ewaso Ngiro River, deforestation of the Mau forest as well as irrigated farming will have negative effects on the quantity and quality of the waters of the Mara and Ewaso Ngiro Rivers. These rivers form a major stabilising factor of the ecosystem in this region. One obvious effect of the combined developments in Kenya will be the reduced quantities of water in the Mara River. In fact, it is predicted that during severe drought the River may dry off completely. If this happens, the entire wildebeest population of 1.3 million will be wiped out in matter of four weeks. And as one would expect, the lives of other fauna and flora in the ecosystem will also be jeopardised.

According to this study, another impact of the proposed developments in Kenya will be on the life a yet another unique feature of the ecosystem, the lesser flamingos. The ecosystems of Lakes Natron, Nakuru and Bogoria support about 98% of the world's total population of the flamingos. The proposed developments will disturb the normal alkalinity of the lakes, particularly Lake Natron which is their only known breeding site in the world. It is feared, therefore, that if the alkalinity of the lakes is disturbed significantly, the entire population of the lesser flamingos will disappear. As it is, the survival of the flamingos is already threatened by the on-going human activities. The proposed developments will only help to worsen the situation.

It has been shown in the study that if the proposed developments in Kenya are left to continue unabated, the effects will not be limited to the collapse of the Serengeti and Masai-Mara ecosystems only. The collapse of this unique natural feature and one of the wonders of the world will also lead to far reaching social and economic dimensions. In terms of tourism, the cost to Tanzania will be as follows:

- Tanzania could lose close to 125,000 (about 40%) tourist visitors currently visiting Serengeti. Given the average annual rate of increase of 12.3%, the figure would have grown to 397,330 by the year 2011. Furthermore, the other parks of Northern Tourist Zone would get very few visitors, if any, since most of them, if not all, do come because of the famous Serengeti. In effect, therefore, Tanzania may lose about 75% of all the tourists coming to the country. This works out to be about 238,814 visitors by 2001 statistics and the figure would grow to about 510,828 by the year 2011.

- In terms of revenue generation Serengeti National Park will outright lose more than USD 6,040,290 and this is projected to increase to USD 40,636,057 by the year 2011 at an average annual rate of 21%. Considering the Northern zone aspect, the loss would be USD 13,932,938 by 2001 statistics and would grow to USD 70,488,117 by the year 2011, the average annual rate being 17.6%.

- Serengeti's existing workforce of about 385 people will lose their jobs as well as their income amounts to about TAS 836 million. This will mean suffering not only to themselves, but also to their dependents, particularly spouses and children. In addition, the employment of the staff in the other parks of the Northern zone, as well as that of the staff in the various visitor facilities, will be at stake, as there would be no visitors and therefore no revenue to support them.

- Communities living around the national parks will no longer benefit from the support they have been getting in terms of community based development projects. Communities around Serengeti National Park will be losing an average of about TAS 40 million per year. The Government will lose tax revenues it has been getting from the operations of the parks. Serengeti district for example, will be loosing an annual tax income of more than TAS 1.0 billion from the operations of the Serengeti National Park.

- Serengeti National Park has been getting significant amounts of donations and assistance from various countries and institutions. If the park collapses the donations and assistance will cease. As an example, the donation to Serengeti National Park from the Frankfurt Zoological Society during the first half of 2000 was close to Euros 1440thousand. This amount would have been lost.

Other costs that Tanzanians that Tanzanians are likely to suffer if the proposed developments in Kenya are implemented are as follows:

- In the event of serious and prolonged drought, this region will loose about TAS 17bn worth of food and cash crops per annum, TAS 25bn worth of livestock and annual milk production worth TAS 960 mill. Apart from these monetary values, livestock in this part of the country is associated with other intrinsic cultural and social values, which will also be lost. The fisheries sub-sector will also be affected, leading to loss of this nutritive food as well as an expected loss of earnings amounting to about TAS 10,000.0 per day per fisherman. The overall effect of drought in this regard will be starvation, malnutrition and eventually death of the most vulnerable categories of the population of this region.

- Wildlife activities such as tourist hunting, marketing of live animals and trophies will be reduced significantly and so will the income accruable from the activities.

- It is predicted that the incidence and mortality rates of the water related diseases would increase. The diseases include diarrhoea, dysentery, skin diseases, malaria and schistomiasis. The cost of controlling the water-related diseases is estimated at TAS 50,000 per household.

- Deforestation and irrigated farming are to be among the major problems facing the water supply sector. Diversion of the Amala River water will only worsen the situation. If the proposed developments are allowed to continue, there will be acute shortage of water for domestic purposes as well as for agricultural and livestock production. The effects of such a situation have already been explained, but furthermore, additional funds will be required for construction of more wells to meet the people's water requirements.

Recommendations

The financial cost that Tanzanians are likely to suffer as a result of implementing the proposed developments in Kenya, as presented in this study is actually the least that can be predicted. Actual costs are likely to be much higher than it has been projected here. Some cost elements have not been analysed in the study. Furthermore, it has been observed that some of cost elements related to this study can not be easily determined. Loss of unique national heritage like Serengeti Park along with wonderful migration, for example, can hardly be valued.

It is a fact that science and technological advances, with time, will bring about solutions to the numerous problems associated with power and food production. Indeed experience has shown that human ingenuity has never failed them in their quest for survival and better living conditions. However the story of creation has been different, and no historical data has suggested that human ingenuity can create such wonderful creatures of God as elephants, wildebeest, giraffes etc. It is no wonder therefore that there is redoubled effort to conserve and protect wildlife anywhere in the world. It is for this reason that it is proposed that a transboundary Mara river management plan/authority be established which will take into account the cost-benefit analysis (for Kenya and Tanzania) of deforestation, irrigation and the proposed Ewaso Ngiro (south) hydropower project as well as to factor in the likely changes to rainfall and hence river discharge arising from climatic changes due to enhanced greenhouse effect. As it is now, with the proposed developments in Kenya, the economic benefits will go to Kenya while most of the environmental and social-economic costs such as loss of national heritage; negative impact on tourism industry etc would be borne by Tanzania. The idea here is to request the Government of Kenya in the spirit of East African Community and regional cooperation, not to take unilateral decision and go ahead with the projects. It is further recommended that the Government of Tanzania should set aside adequate funding for a more detailed study. The study should involve not only the impact of the proposed developments in Kenya, but also, how to avert possible collapse of the said ecosystems even without the Kenyan projects going ahead; considering for example the effects of the evolving climatic changes associated with greenhouse effects. Participation of stakeholders of the Serengeti-Masai Mara ecosystem is strongly emphasised.

The composition of the Mara River transboundary authority is a subject of separate discussion, but it is deemed imperative to have relevant expertise from all the beneficiary countries.

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