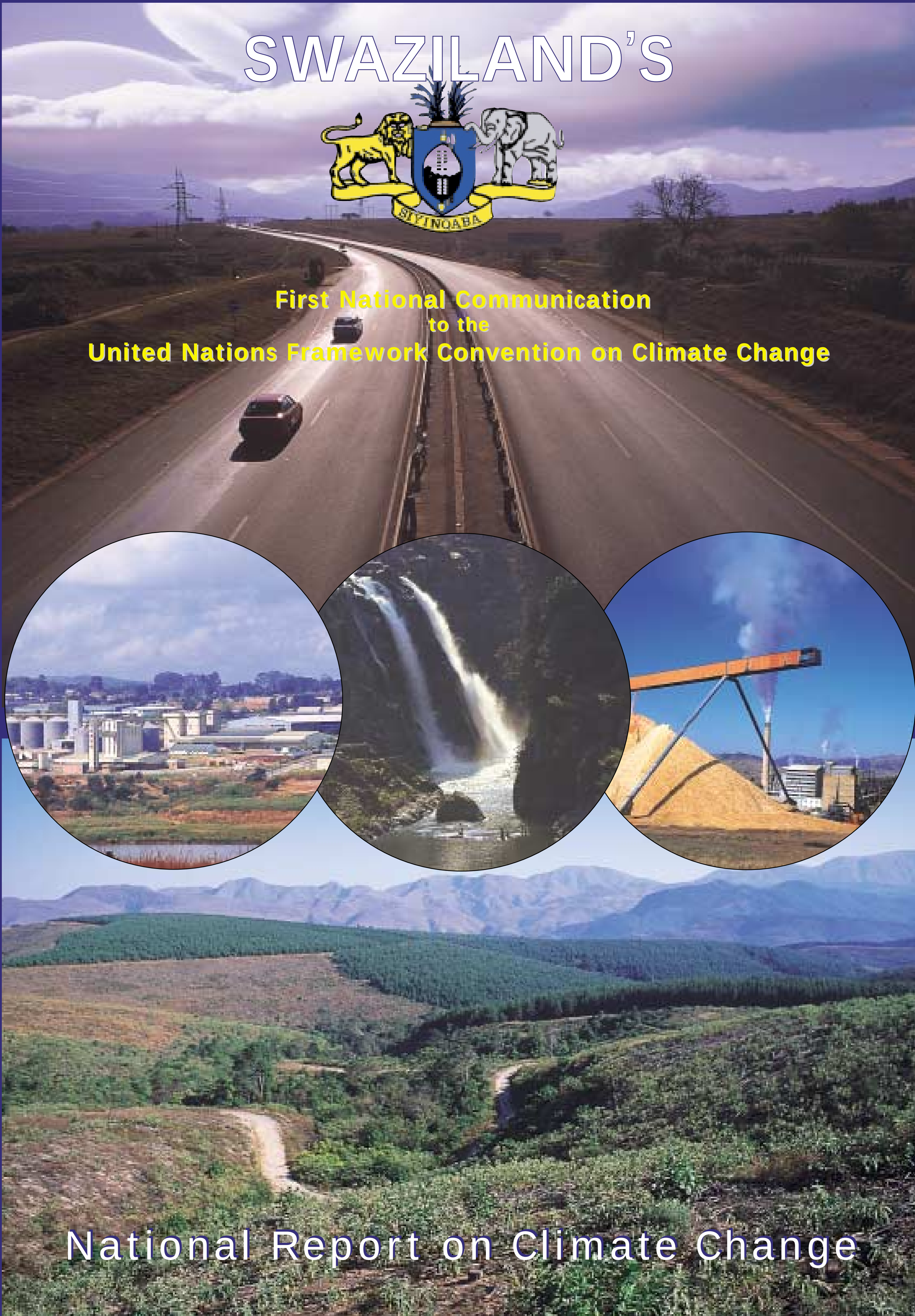

SWAZILAND'S

First National Communication
to the
United Nations Framework Convention on Climate Change

National Report on Climate Change

FOREWORD

The Kingdom of Swaziland has accepted the mounting scientific evidence that human activities are interfering with natural systems, particularly global climate change. The country has joined other nations of the world in the Intergovernmental Panel on Climate Change (IPCC's) coordinated effort to better understand, not only aspects related to causes of this change, but also the likely extent of its impacts on various aspects of our livelihood, how we may contend with it and how we can help curb its exacerbation by limiting the emissions from the sources of these gases.

It is well understood that the climate system is vast and that human interactions with it present complexities that are not yet fully understandable. These uncertainties notwithstanding, no country can justify reason for inactivity especially in the light of the high stakes involved and the reality that damage caused today may turn out to be irreversible should the assumptions hold. Policymakers in Swaziland are keen to accept expert advice based on objective scientific, technical and socio-economic information available on climate change in general and how Swaziland will fair in it, particularly in future years.

The study presented in this report attempts to quantitatively expound on the country's current as well as future position as pertains to issues and effects of global warming and climate change. This has been done in the context of several of Swaziland's unique national circumstances and capabilities in playing an effective role in international cooperation towards the fulfilment of commitments outlined in articles of the Convention on Climate Change of which we are Party.

The highlights of this study show that whilst Swaziland's emission of Greenhouse Gases (GHGs) in per-capita Carbon Dioxide (CO_2) equivalents is modest, the country also commands a rather large CO_2 sink owing to its man-made forests which are amongst the largest in the world. We can proudly declare that this huge sink capacity we have, already by far outweighs our gross annual emission of CO_2 as revealed in results of the inventories undertaken in this study.

The country has not stopped at this positive development alone. In its pursuit to thrive as an environmentally conscious nation, the country has over the past few years developed and enacted several policies aimed at ensuring that environmental issues in general and climate in particular are taken into consideration in all planning and developmental efforts. This we do with a commitment to finding "win-win" solutions that address not only the concerns of global climate change and its impacts, but also the country's requirement for development in all sectors of its economy so as to lift the standard of life of the populace. The nation's customs and developmental priorities are thus enshrined in peaceful co-existence with our environment and achieving for the country an acceptable level of sustainable development for all in this the Twenty First Century and beyond.

The Hon. T.M. Mlangeni
Minister for Public Works and Transport

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List of Abbreviations and Acronyms

AEEI	Autonomous Energy Efficiency Improvements
CCCM	Canadian Climate Centre Model
CDM	Clean Development Mechanism
CEST	Condensing Extraction Steam Turbines
CFCs	Chlorofluorocarbons
CGEs	Computable General Equilibrium models
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COMAP	Comprehensive Mitigation Analysis Process
CRC	Constitutional Review Commission
CSO	Central Statistics Office
DANCED	Danish Cooperation for Environment and Development
DSSAT	Decision Support System for Agrotechnical Transfer
E	Emalangeni
ESKOM	South African Electricity Company
EU	European Union
FDI	Foreign Direct Investment
GCM	Global Circulation Model
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFDL	Geophysical Fluid Dynamics Laboratory model
Gg	Gigagrammes
GHG	Greenhouse Gas
GNP	Gross National Product
GWP	Global Warming Potential
Ha	Hectare
HFCs	Hydrofluorocarbons
ITF	Individual Tenure Farm
IPCC	Intergovernmental Panel on Climate Change
Km^2	Square kilometres
Kt	Kilotonne
LEAP	Long Range Energy Alternative Planning
LPG	Liquid Petroleum Gas
M^3	Cubic Metres
MAGICC	Model for the Assessment of Greenhouse-gas Induced Climate Change
MCM	Million Cubic Metres
MOAC	Ministry of Agriculture and Cooperatives
MT	Metric Tonne
NDS	National Development Strategy
NDPs	National Development Plans
NGO	Non-Governmental Organizations
NMVOCs	Non-Methane Volatile Organic Compounds
N_2O	Nitrous Oxide
NO_X	Oxides of Nitrogen
PCFs	Perfluorocarbons
PET	Potential Evapotranspiration
RDAPs	Rural Development Area Programmes
SACU	Southern African Customs Union
SADC	Southern African Development Community
SCENGEN	Scenario GENerator
SEA	Swaziland Environment Authority
SEAP	Swaziland Environment Action Plan
SEI-B	Stockholm Environmental Institute in Boston
SNEP	Swaziland National Energy Policy
SNL	Swazi Nation Land
TDL	Title Deed Land
UKTR	United Kingdom Meteorological Office Hardley Centre Transient model
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WatBal	Water Balance model

Chapter 1

The Executive Summary

1.1 BACKGROUND

Swaziland was amongst the 150 nations that signed the UN Framework Convention on Climate Change during the convening of the United Nations Conference on Environment and Development (Earth Summit) in Rio de Janeiro in June 1992. The country subsequently ratified the Convention, becoming Party to it in 1996.

The Convention process was the culmination of international concern on the global increase of greenhouse gas (GHG) emissions mainly due to human activities since the industrial revolution. This increase his been directly linked to the threat of global climate change and its associated impacts of increase in temperatures, rise in sea levels, changes in precipitation, extreme weather events and other weather-related effects. As an objective of the Convention therefore, a concerted global effort is amassed to achieve a stabilisation of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Swaziland, as are most developing countries, is a minor contributor of GHG emissions. The total African share of carbon emissions for example accounted for only 3.2% of the world's total in 1992. Inspite of this fact, according to the Intergovernmental Panel on Climate Change (IPCC) report, Africa has been described as the continent most vulnerable to the likely impacts of climate change. It is in the country's interest therefore to pursue all intervention options that can contribute to limiting effects of these impacts with similar results of achieving more efficient use of resources and of the systems employed.

In compiling her National Communication, Swaziland seeks to comply with provisions of Articles 4 and 12 of the Convention which enumerate commitments and implementation issues. In the country's willingness to contribute to the protection of the climate system it's intervention is to follow after the Convention's guiding principles, namely the consideration of Swaziland as a developing country Party with special circumstances, the extent of its capabilities, regards for the common but differentiated responsibilities, and equity.

The National Communication is therefore the country's preliminary attempt to present an overview, with respect of the base year 1994, of:

- Its national social and economic context on the basis of which it will address climate change and its adverse effects and within which various interventions could be made;
- A national inventory of anthropogenic emissions by sources and removals by sinks of greenhouse gases using the IPCC 1996 Revised Guidelines;
- An assessment of the country's potential vulnerability to climate change and approaches for adapting to such change; and
- A general description of steps taken or envisaged by the country to implement the Convention.

1.2 SWAZILAND IN CONTEXT

Swaziland is a small country covering an area of 17 360 in southeastern Africa. Within the limited area of about 193 kilometres north to south, and 145 kilometres east to west, every feature of Africa's terrain, with the exception of the desert, is to be found. Great variation in landform characterises the country's cross-section ranging from steep hills and an escarpment in the west to gentle undulating plains and basins in the eastern interior.

The Climate

The country enjoys a climate which is generally subtropical with summer rains (75 percent) falling in the period from October to March. Further variations in climate occur along the cross section of the country following the topological features of the landform. Marked variations in the climate system do occur from year to year giving rise to extreme events that sometimes impact negatively on the country's natural and socio-economic environments.

Events of prolonged drought spells in some years and of significant flooding by tropical storms in others are features of the region's climate that have constantly been witnessed. The types of human activities have mainly been dictated by both the prevalent climate and the topology of each respective area.

Population

The population of Swaziland was in 1994 standing at 870,000, with a corresponding annual growth rate of 3.2% which has since been on decline. The demographic distribution is such that 25% of the population lives in urban areas and urban migration occurs at 3 to 5% per annum. Life expectancy is 60 for men and 53 years for women.

It is expected that by the year 2030, approximately 70% of the population will be living in urban or peri-urban areas. The population has a high dependency ratio owing to the fact that 60% is composed of people under the age of 21 years. These are some of the issues the country has to contend with in mobilising support for its development priorities of accelerating economic growth, alleviating poverty, improving social services, and ensuring sustainable use of scarce natural resources.

The Economy

Being the smallest country in the sub-region, Swaziland's economy is closely tied to that of its larger neighbour, the Republic of South Africa. It is strongly export-oriented with limited domestic markets. Over the period 1968-96, the country's economy saw growth averaging 6.5% annually. Total GDP at cost factor in 1994 was E 3047 million (about $ 900 million) and the corresponding per-capita GDP was E 4308 ($ 1240). The impressive economic growth slowed down as from the 1980's, a trend attributed to several factors amongst which are declining foreign direct investment inflows, uncertainty over the recent political developments in the sub-region, and most notably effects of the unusually long drought conditions spanning the period 1989-92.

Swaziland, together with South Africa, Botswana, Lesotho and Namibia belong to a regional agreement named the Southern African Customs Union (SACU). This pool has historically supplied for Swaziland, 50% of her public revenues hence the single most important source supporting GDP. The agreement is currently under negotiation and it is yet unclear how its future management will affect share proportions of member states.

Apart from the SACU, agriculture has traditionally been the cornerstone of country's economy, an attribute that renders the latter particularly vulnerable to impacts of climate change on this sector. The post-independence era has however seen a shift of the economy out of agriculture into industry and services with the associated increases in energy demand and related resource inputs.

Nevertheless, to the extent that a large portion of the manufacturing sector is agro-based (mainly sugar, wood pulp and citrus canning), the base of the economy is therefore still agricultural. A meaningful diversification of economic activity areas is necessarily desirable if the country is to reduce its level of vulnerability due to over reliance on climate-sensitive sectors.

The highly regulated sugar industry is one leading export earner for Swaziland. Three major estates operate mills with a combined output of over 450 000 metric tonnes (MT) and bring in earnings of over E 520 million ($150 million) (1994). Next are citrus fruits whose production averages some 70 000 MT mainly for export markets. In the forest sector, the country's vast pine growing areas make up one of the largest man-made forests in the world and cover some 66 000 hectares (6% of the country's total land area). The trees grown here are mainly used to produce unbleached kraft pulp for world markets too. Other export commodities include beverages, coal, cotton, meat and timber.

The Convention provides for special considerations to developing country Parties with specific needs and concerns arising from the adverse effects of climate change and/or the implementation of response measures where certain circumstances apply. Some of these circumstances of concern that apply in the context of Swaziland as listed in Article 4.8 are the following five:

- Countries with arid and semi arid areas, forested areas and areas liable to forest decay;
- Countries prone to natural disasters;
- Countries with areas liable to drought and desertification;
- Countries whose economies are highly dependent on income generated from the production, processing and export, and/or on consumption of fossil fuels and associated energyintensive products; and
- Land-locked and transit countries.

Swaziland's small per-capita GHG emissions and it's disadvantaged position due to the preceding national characteristics will be important factors to consider in the formulation of strategies to fulfil the country's developmental objectives while satisfying the Convention's requirements.

1.3 SWAZILAND'S GREENHOUSE GAS INVENTORY

A national inventory of anthropogenic emissions by sources and removals by sinks of the main greenhouse gases was compiled for the country for the base year 1994 in accordance with Article 4.1(a). The Revised 1996 IPCC Guidelines were used for this task.

The major source categories considered as provided in the guidelines are energy, industrial processes, agriculture, landuse and forestry, and waste. The inventory results reveal that the country's total emission of carbon dioxide (CO_2) amounted to 874 kilotonnes (Kt). For the other two direct GHGs, methane (CH_4) and nitrous oxide (N_2O), the amounts were even lower at 64 and 1 Kt respectively.

Information on emissions of precursors (gases which have an indirect effect on climate) and some of the fully fluorinated compounds, was also quantified in the inventory.

Emissions of Carbon Dioxide

The 874 Kt energy sector CO_2 emission accounted to virtually all the country's CO_2 production. This represents a comparatively small per-capita CO_2 value of 0.87 tonnes. This emission was predominately derived from fuel combustion from these sectors in the following order: transport (50%), manufacturing (32%), household (15%) and commercial (3%).

Within energy, the transport sub-sector which accounts for half of all emissions is itself dominated by fuel combustion by modes of road transportation. On households, the emissions emanate from the predominant use of coal liquefied petroleum gas (LPG) and to some extent kerosene for heating and cooking especially in rural areas where about two thirds of the population reside.

In manufacturing, the emissions are mostly from the traditional reliance on coal for steam generation especially in the sugar, pulp, food and beverages industries. When applying global warming potentials, the country's contribution in terms of carbon dioxide equivalents amounted to 6.33 million tonnes. The share of carbon dioxide is therefore 13.8% of the total carbon dioxide equivalent.

Emissions of methane

Of the total 64.4 Kt methane ($CH_{4)}$ emissions from sources in the country, the agriculture sector was the largest contributor with 40.5 Kt (66.9%). Enteric fermentation from domestic livestock (substantial herds of cattle and goats) accounted for most of these emissions. The waste sector followed with 16.5 Kt (27.3%), which came from industrial waste out of the production of beer, pulp and paper.

Emissions derived from the all energy sector were 7.2 Kt (5.5%). This resulted from fugitive fuel emissions in coal mining operations and the combustion of firewood for cooking and heating. Insignificant emissions were derived from on-site burning within the land-use change and forestry sectors. The methane carbon dioxide equivalent accounted to 0.13 million tonnes, making up 2.1% of the country's total.

Emissions of Nitrous Oxide

The country's N_2O emissions were a paltry 1.3 Kt. Most of this amount (93%) resulted from the liming of agricultural soils, agricultural waste burning and savannah burning within the agriculture sector.

There were minute emissions in the all energy sectors of manufacturing and households arising from firewood combustion. This gas had a carbon dioxide equivalent figure of 0.42 million tonnes and thus accounting for 6.6 % of the country's total.

Emissions of Precursors and Flourinated Compounds

Emissions of oxides of nitrogen (NO_X), carbon monoxides (CO) and non-methane volatile compounds (NMVOCs) were estimated at 19.9, 523 and 80 kilotonnes respectively. The largest contribution of NO_X came from agriculture (60%) and fuel combustion of firewood under the residential sector (38%). CO emissions emanated from similar sources whilst NMVOC emissions largely came from industrial processes.

The country's single largest contribution in terms of carbon dioxide equivalent was observed in the hydrofloucarbons HFCs category. This yielded some 4.9 million tonnes amounting to 77.5% of the country's total. Such a level is attributed to the fact that the country has a significant refrigerator production plant for export markets. The gases were therefore used in the refrigerator units as well as in air conditioners, fire extinguishers and to a lesser extent on solvents and aerosols.

Carbon dioxide removals

The inventory revealed GHG sinks in the country's land-use change and forestry sector. As mentioned, the managed forest plantations are significantly large, hence providing for substantial removals for a country the size of Swaziland. On the emissions side, this sector produced some 2 910 Kt CO_2, 60% of which were from commercial harvests, 25% from off-site burning through firewood combustion, and lesser amounts from liming of soils and other activities.

In contrast to the emission state of this sector, the sink capacity amounted to 6 168 Kt carbon dioxide removal. The predominant carbon uptake offering 99.5% of the removals was by trees from commercial plantations including non-forest trees in towns. The remainder was from abandoned areas.

On aggregate therefore, taking into account the amounts of emissions and sinks in all sectors the country's final GHG budget is of a net CO_2 sink.
CO_2 emissions totalled some 3 784 Kt whilst the sink capacity was 6 168 Kt. The net balance in favour of sinks was a substantial 2 384 Kt. Such an achievement in GHG removal terms by the country is considered significant in fulfiling the objectives of the Convention to tackle the very cause of climate change.

1.4 IMPACTS AND ADAPTATION

The high vulnerability of Africa to various manifestations of climate change has been confirmed in reports of the IPCC and other publications. In the context of Swaziland, the sectors that are climate sensitive and hence highly at risk are:

- Water resources, especially in international shared basins;
- Agriculture, in issues of food security at risk from declines in production in an uncertain climate;
- Natural resources and biodiversity, on future types of ecosystems, tree growth, distribution and mortality of species; and
- Health, on vector-borne diseases as they relate to anticipated changes in climate parameters, notably precipitation and temperature.

Climate Change

Swaziland does not have sufficiently long instrumental climate data to reliably construct past climates. As a result the wider temperature record for Africa south of the equator is used to present the climate of the twentieth century for the sub-region. Such an analysis shows a warming of almost 1°C having occurred between 1900 and the 1980s and an average warming of 0.05 °C per decade over the almost 100 year period.

According to projections by the IIPCC, if current trends of GHG emissions remain unchanged, GHG concentrations in the atmosphere will double by the year 2075 with the result of global temperatures increasing by about 2.5 °C. Any future climate change will most certainly have some form of impacts, not only on conditions of the physical environment, but also on the overall socio-economic aspects of life.

As a first step to assess the extent of changes in the future climate of the country, a current climate baseline was established from available meteorological records. This was based on a thirty-year period (1961-1990) of data obtained from meteorological instruments. The current climate classification for the country is therefore a humid and subtropical one.

In determining future climate scenarios, a simple climate model called MAGICC combined with a regional climate database called SCENGEN was used. A choice of some three General Circulation Models (GCMs) were employed in running the simulations based on how well they represent the current climate, their age and their resolution. These were the UKTR, GFDL and CCC-EQ.

The projections from all the models point to temperature increases in future years though with varying magnitudes. Precipitation projections on the other hand give mixed results. In general, the models project total annual rainfall amounts by 2075 falling below those received under current climate by single digit percentages. The monthly situation projects amounts that are higher than those under current climate in the late spring to mid summer period (October to January) For the rest of the months of the year projections give future rainfall amounts that are lower than under current climate.

As most of the country's annual rainfall is received over the summer period, an increase in precipitation over this period is likely to result in flooding conditions. The projections of winter rainfall reduction also pose the problem of higher possibilities of drought occurrences. Other meteorological conditions that are related to either temperature or rainfall are likely to be equally affected. These are the initial risks that the country is likely to face in a climate change situation.

Impacts on forests and woodland resources

Forests are an important resource in Swaziland because of their value in a variety of applications. Some of the value derived from the different tree species (exotic and indigenous) are as follows: commercially as a source of revenue, culturally for ceremonial use, health-wise in medicinal requirements, and nutritionally in providing food supplements to rural communities. It is on the basis of these that an assessment of climate change impacts on this sector was considered important to undertake.

The forest species selected for the assessment were two exotic ones (pinus and eucalyptus) and four indigenous ones (combretum, syzygium cordatum, sclerocarya birrea and pterocarpus angolensis).

Ecosystems
It was established that Swaziland is currently characterised by two ecosystem types. One is the subtropical moist forest which occurs on the high lying western parts, and the other is the subtropical dry forest covering the rest of the eastern half of country.

To assess the impacts of climate change on these ecosystems, future climate scenarios for the country were used as generated from the selected three global climate models. These scenarios in general point to a future climate featuring country wide increases in temperatures and some varying patterns in seasonal rainfall.

The current and projected ecosystem types were assessed by applying the Holdridge Life Zone Classification Model on the climate scenarios obtained thus giving the potential land cover for each location. The results show a westward shift and shrinking in size of both the areas covered by the subtropical moist and subtropical dry forests in the future. Furthermore the country is projected to see the introduction of a tropical very dry forest type of ecosystem in the eastern flanks taking as much as up to one fifth of the total land area.

Tree growth
The vulnerability of tree species to climate change was assessed with applying the Forest GAP model on the climate scenarios. Simulations of future distributions, tree growth and mortality of species were made based on environmental conditions.
The general conclusion is that for both exotic tree species biomass production is likely to increases in the future compared to those being realised under current climate. In terms of stem sizes, projections are that these will be slightly smaller under climate change and as expected, more individuals will fall under the smallest diameter ranges (0-10cm).

As for the four indigenous species, the biomass performance shows mixed results but with more tendency towards a general reduction. This fact may be attributed to the expected increase in future temperatures in the areas where these species strive coupled with the already low rainfall amounts which would cause high evapotranspiration and hence low overall water availability for the plants. The sclerocarya species is also likely to dominate over the three others whilst syzigium is likely to be compromised by climate change.

Impacts on Water Resources
The future performance of climate will most certainly have a primary effect on water resources and as such make this sector key in impact assessment studies.The study was made to focus on one river, the Great Usutu mainly because of the great socio-economic significance of this basin, being one within which about three quarters of the country's population lives.

The response of the Usutu river to climate change was evaluated using outputs of the three GCMs (GFDL, UKTR, and CCC-EQ) The results obtained were then used as inputs to the WatBall model which is an integrated rainfall-runoff model for forecasting stream flow.

The model runs gave projections up to the year 2075 for this river. In summary, the model projects stream flows that are higher than those under current climate in the late spring to mid summer period (October to January). For the rest of the months of the year projections give future flows that are substantially lower than those of corresponding months under the current climate.

In terms of total annual runoff, the GCMs give an overall average reduction in runoff ranging from 2 to 6% in a normal year and even higher for dry years. Such changes will translate to increased possibilities of flooding in the rainy season due to higher flows and drought-related conditions in winter due to low flows. As the projections depict an overall reduction in annual runoff, the drought conditions are expected to be more pronounced and frequent features of future climate than shall be the floods. Effects of this will likely find its way into groundwater recharges and salinity as well as dam capacities.

Impacts on Agriculture
Agricultural production, which is one of the country's leading contributor to GDP is very sensitive to weather variations. To assess the performance of three major crops under the present climate as well as under projected future conditions (2025), the

Decision Support System for Agrotechnical Transfer (DSSAT3) was employed.

The general observation was that for the maize crop, most of the country could be unsuitable for its growth since yields are estimated to decrease considerably. In the other regions yields could be improved by changing the planting season from the traditional second week of October to the second week of August. For sorghum and beans, yields are also projected to decrease in general with the exception of the western parts where these are currently not grown extensively.

1.5 GENERAL DESCRIPTION OF STEPS

Mitigation Options

An attempt was made to elaborate on steps that have either been taken or envisaged by the country to implement the Convention. The mitigation options considered were mainly centred in the Energy and Forestry sectors as these are where most opportunities for intervention are.

In energy, mitigation would be meaningful on both the supply and end-use.

The supply side:
Electricity generation through cogeneration by the use of high-pressure steam turbines burning bagasse and wood-pulp residue as input fuel.
End-use side:

- Energy efficient boilers, and electric motors
- Matching electric supply to demand
- Improved maintenance and inspection of motor vehicles
- Gasoline/ethanol blending
- Efficient lighting systems
- Use of solar geysers
- Improved wood stoves
- Switching from the use of wood and kerosene to LPG and electric stoves

In Forestry, the mitigation intervention could include the following:

- Increasing area under forest cover and reducing degraded areas
- Establishment of additional woodlots
- Introducing agro-forestry activities

Policies and other measures

The country has in the past spelled out its development objectives through various frameworks and set strategies to achieve these. As the significance of environmental issues began to emerge, there has been a move to model such policies and actions to embrace this domain more comprehensively. Notably, the government's environment legislation has been strengthened to require both the public and private sectors to ensure that all their future policies and strategies take environmental considerations into account. This is considered a strength to supporting the requirements of the Convention as inherent climate change considerations can be covered to some degree. Supporting policy interventions and strategies are either already in place or in the process of being promulgated in other areas including Energy, Forestry, Water resources, Transport, Agriculture and Land.

Financial and Technological needs and constraints

Through undertaking the process of compiling the National Communication, the country has identified several areas with constraints that need to be attended to. Firstly institutional infrastructures for facilitating a continuous process of undertaking such assessments and related activities was identified as weak. There therefore is need for the structures to be strengthened for more efficient coordination and execution of processes and activities for purposes of future National Communications.

There also is the element of inadequate local technological capacity to expedite in an effective manner the tasks of undertaking the assessments. Capacity building is therefore required in the human resource domain to ensure availability of a pool of experts that the process can draw from. Similarly technology transfer is increasingly more desirable if more efficient and environmentally friendly systems and technologies are to be introduced. Together with these, is the lack of comprehensive local data and country-specific information to support the studies. The physical recording network requires strengthening to ensure systematic observations, as do the related information collection and management systems.

As a developing country with many priority issues to consider, Swaziland's financial resources are not adequate for use in making a meaningful intervention in the Convention's implementation. The many good measures identified in this study are not possible to undertake without some form of financial support. The country can certainly join the international effort to protect the global climate system with the support and assistance from other partners.

Chapter
2
National Circumstances

2.1 GEOGRAPHY

The Kingdom of Swaziland, is situated in South Eastern Africa between the 25th and 28th parallels and longitudes 31° and 32° East. It lies some 48 to 225 kilometres inland of the Indian Ocean littoral and hence physically landlocked, meaning all traffic in and out of the country has to be routed via one of its neighbours, South Africa or Mozambique.The country has a total surface area of 17,360 km^2 and as such, the smallest country in the southern hemisphere.

It is bounded by the Republic of South Africa in the north, west and south, and by Mozambique on the east (Figure 2.1). Although small in size, Swaziland is characterized by a great variation in landscape, geology and climate. It also lies within the Maputoland Centre, an area reported to have the greatest biodiversity in Southern Africa.

There are four distinct physiographic regions within the country (highveld, middleveld, lowveld and lubombo) which are clearly distinguished by elevation and relief (Murdoch, 1970).

Figure 2.1 *Swaziland*

Source: National Meteorological Service

Major landforms featuring mountains, hills and plains characterize the east to west cross-section of the country, giving rise to valleys, plateaux and basins.

Although the country has historically been divided into the four physiographic zones, it has now been more appropriately reclassified into six , taking into account climate, elevation, landforms, geology, soils and vegetation. Characteristics of these physiographic zones including landforms and altitudes (representing the common ranges, not extremes), are given in Table 2.1.

The Highveld (33%) of the country's total land area, is the upper part of an overall escarpment. It consists of a complex of steep slopes between low and high levels, dissected plateaux, plateau remnants and associated hills, valleys and basins.

The Upper Middleveld (14%) consists of strongly eroded plateau remnants and hills at an intermediate level of overall escarpment. It also contains structurally defined basins in relatively protected positions, which are only weakly eroded.

The Lower Middleveld (14%) is basically the piedmont zone of the escarpment, characterized by generally strongly eroded foot slopes. The overall slopes are predominantly moderate and the zone classifies at the first level as a plain.

The Lowveld plain consists of sedimentary and volcanic Karro beds versus the igneous and metamorphic rocks of the Highveld and Middleveld.

The Lowveld is subdivided into the higher Western Lowveld (20%) on sandstone or clay stone, and the lower Eastern Lowveld (11%) on basalt.

The sixth zone is the Lubombo Range (8%), a cuesta with a steep escarpment bordering the Eastern Lowveld and a gradual dip slope of about 1:20 descending east. As a major landform the Lebombo qualifies as a plateau.

The Lowveld plain consists of sedimentary and volcanic Karro beds versus the igneous and metaphorphic rocks of the Highveld and Middleveld.

Fog capped interlocking hills of the highveld with Ngwenya mountains behind

Photograph Dirk Schwager Cape Town

Table 2.1 *Physiographic regions of Swaziland*

REGION (area)	ALTITUDE (m) (min - max)	LANDFORM	TOPOGRAPHY	SLOPE (%)
Highveld (5 680 ha)	900 - 1 400 (600 - 1 850) upper medium	Medium Hills associated high hills and plateaux	Steeply Dissected escarpment, transitions to undulating plateaux	18
Upper Middleveld (2 420 ha)	600 – 800 (400 – 1000) lower medium	Medium Hills associated low hills and basins	Hilly plateau remnants and undulating basins	12
Lower Middleveld (2 420 ha)	400 – 600 (250 - 800) low	Plain associated low hills	Rolling piedmont, undulating basins, isolated hills	12
Western Lowveld (3 410 ha)	250 – 400 (200 - 500) very low	Plain	Undulating, part rolling	5
Eastern Lowveld (1 960 ha)	200 – 300 (200 - 500) low	Plain	Gently Undulating, part rolling	3
Lubombo Range (1 480 ha)	250 – 600 (100 - 750) low	Plateau dissected	Undulating cuesta, part hilly and steeply dissected	5

Source: *Remmenzwaal (1993)*

2.2 CLIMATE

Swaziland enjoys a climate which is generally sub-tropical, with hot and wet summers and cold and dry winters. Further variations in climatic conditions occur within the different physiographic regions giving rise to three clearly distinguishable climate types.

The highveld and upper middleveld are characterised by a Cwb climate. The lower middleveld and lubombo range have a Cwa climate whilst the western and eastern lowveld have a Bsh climate (Murdoch, 1970).

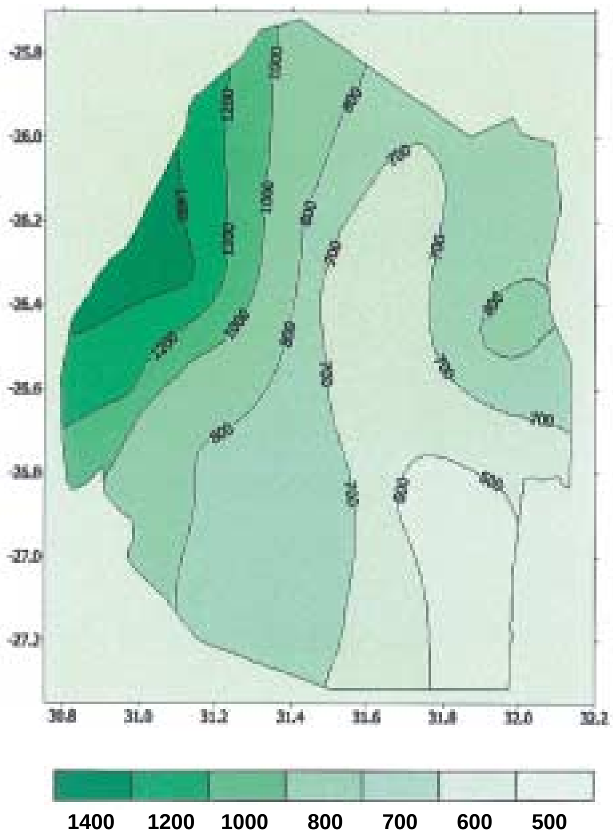
Mean annual rainfall ranges from about 1500 millimetres in the highveld to a little less than 500 millimetres in the southern lowveld. Figure 2.2 gives the distribution of mean annual rainfall within the country.

Little Usutu river waterfall at Mantenga

Photograph Dirk Schwager Cape Town

The Highveld's temperate climate is characterised by wet summers and dry winters, and annual rainfall averaging 1500 millimetres. Temperatures vary between a maximum of about 33 ˚C in mid-summer and 0 ˚C at night in mid-winter. On the other extreme end is the Lowveld which experiences a sub-tropical climate. This region receives the lowest annual rainfall of about 450 mm. There is also a large diurnal temperature range experienced here with maximum temperatures reaching the upper 30's not uncommon. Semi-arid pockets of areas are found in this region, which is also liable to desertification. The frequency of heavy downpours is more uniform across Swaziland than is total rainfall. Between 75% and 83% of precipitation (summed mean monthly amounts) comes in summer (October - March).

***Figure 2.2** Mean annual rainfall distribution*



Source: *National Meteorological Service*

The country is prone to occurencies of natural disasters, such as tropical cyclones on one end and drought on the other. The latest and longest drought experienced occurred during the period of 1989 -1994. Climate change is therefore likely to have a bearing on the frequency and magnitude of these events and their associated impacts.

Table 2.2 Average annual temperature and rainfall by physiographic region

Physiographic Region	Annual Rainfall (mm)	Annual Temperature (ºC)
Highveld	1 500 – 900	17.6 -16.3
Middleveld	810 – 580	20.5 - 19.3
Lowveld	> 500	22.4 - 21.3
Lubombo	710	19.2

2.3 Population

Swaziland's population in 1994 was estimated at 870 000 with an annual growth rate of 3.2%. High rates of fertility (5.6 lifetime births per woman) also prevail accompanied by high, albeit decelerating mortality rates (compared to other countries with similar per capita GDP).

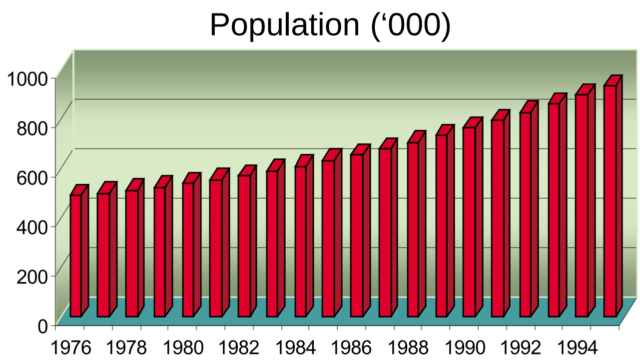
The population is fairly evenly distributed across the four administrative regions, reflecting the fact that the country is devoid of natural barriers inhibiting human settlements.

The country's population, which may be divided into 76% rural and 25% urban is a young one. The country's age-sex pyramid is broad-based with a 60% of the population under the age of 21 years.

The de-facto population for the period 1976-1995 is presented in Figure 2.3 and the projections of population growth rates are given in Table 2.6.

The high incidence of HIV/AIDS could have an impact on future population projections and related socio-economic performances. Life expectancy is currently estimated at 52,8 years for men and 59,8 years for women.

Figure 2.3 *Swaziland's de facto Population (1976-1995)*



Source: *Central Statistics Office*

Swaziland people at a national ceremony

Photograph Dirk Schwager Cape Town

2.4 THE ECONOMY

Swaziland has a small, but strongly export-oriented economy. In the 1993/94 fiscal period, the country realized exports that were 70% of the gross domestic product and imports of 80%. Economic activity, which is vibrant in the country, is an important source of Green house gas (GHG) emissions.

The main economic sectors in Swaziland include agriculture, forestry, mining, manufacturing, construction, electricity and water, transport and communications, and government services.

Emissions of GHG stem from a variety of human activities. The agriculture and forestry sectors are among the most active active in the Swaziland economy and are responsible for large amounts of GHG emissions as levels of consumer demand increase.

Similarly, the nature of the economy, as well as the physical circumstances display the country's particular vulnerability to climate change and its related adverse effects.

In considering economic activity and its contribution to climate change, several macroeconomic variables have been examined. These include, amongst others, growth trends of Gross Domestic Product (GDP) and demographic information.

2.4.1 Economic Performance

Over the years since 1968 when Swaziland obtained her independence, the country's economy has experienced remarkable economic growth, social progress, political stability and human development. The historical economic environment of the country up to the 1980s was hence characterized by positive growth and a notable surplus position.

The upward trend however slowed down around the 1980s impacting on several important features of the nation's development, including the per capita income growth. The major causes of the declining trend were the decline in foreign investment inflows (particularly since the 1990s), recurring drought conditions (spanning the period 1989-1994), high population growth rates and other contributing factors including the poor overall performance of economies of the subregion. The recent decline in economic growth saw a low of -0.1% in 1991/92 and a slight recovery thereafter reaching about 3% in 1994.

Official statistics indicate that real gross domestic product at factor cost grew at an average 2.8% per annum during the period 1989/90-1993/94. Table 2.3 presents the important indicators of the country's national situation for the base year 1994. The total GDP at factor cost and at current prices for that year stood at 3 047 million Emalangeni (US$ 878 million). The corresponding GDP per capita was E 4 308 (US$1 240).

Table 2.3 *Swaziland's National Circumstances*

Criteria	1994
Population	800 000
Relevant areas (square kilometers)	17 360 km^2
GDP (1994 US$)	878
GDP per capita (1994 US$)	1240
Estimated share of the informal sector in the economy in GDP	-
Share of industry in GDP (manufacturing, Electricity, construction)	32.7%
Share of services in GDP	35.5%
Share of agriculture in GDP	10.2%
Land area used for agricultural purposes	1950 km^2
Urban population as percentage of total population	24.5%
Livestock population	1 830 000
Forest area	6 300 km^2 (36% of total land area)
Population in absolute poverty	-
Life expectancy at birth	61 years
Literacy rate	76.7%

Source: Central Statistics

Mbabane, capital of Swaziland

Photograph Dirk Schwager Cape Town

2.4.2 Sectors of the Economy

An analysis of the share of each sector on the overall country's GDP shows the category of services assuming the lion's share at about 35.5% in 1994. This includes, in descending order, government services, wholesale and retail, transport, banking, financial and other related services.

A summary of the country's GDP by sector of origin and their relative share is presented on table 2.4. Secondary production is the second largest category making up the GDP with a total contribution of 32.7%.

The activities under this category are manufacturing, electricity and water and construction.Manufacturing growth is largely attributed to the increase in production of drink processing and sugar based production activities.

The share of manufacturing alone is 27.5%. The rest of the other sectors, namely agriculture, mining and forestry account for 10.2%, 1.4% and 0.7% of GDP respectively. This shows a level of diversification of the country's economy from heavy reliance on any one particular sector.

Within the agricultural and forest sectors, sugar and wood pulp have been the main contributors to the Swaziland economy. Production of sugar and wood pulp is directly derived from the agricultural and forestry sectors respectively.

Processing of raw materials in the production of these two involve complex industrial processes, which add to the emissions of GHG.These processes therefore need to be considered when determining adaptation and mitigation strategies for the country.

Table 2.4 Gross Domestic Product by Sector of Origin at Current Prices

Sector	GDP (millions of Emalangeni)	GDP (millions of US$)	Percentage shares of GDP
Primary Production	**464.3**	**133.7**	**12.3%**
Agriculture	384.6	110.8	10.2%
Forestry	28.2	8.1	0.7%
Mining	51.5	14.8	1.4%
Secondary Production	**1239.3**	**356.9**	**32.7%**
Manufacturing	1042	300.1	27.5%
Electricity & Water	67.5	19.4	1.8%
Construction	129.2	37.2	3.4%
Services	**1343.7**	**387.0**	**35.5%**
Wholesale and retail			
GDP at factor cost	**3047.3**	**877.6**	**80.5%**
GDP per capita	**4308.5**	**1240.8**	

Source: Central Statistics Office

Swaziland is one of the leading producers of soft drink concentrate and a supplier of the majority of African countries and beyond.This has lead to an increase in the production of miscellaneous edibles.The type of energy used is worth investigation for their contribution to GHG levels.

With regard to exchange rates, the Lilangeni is recorded to have been steady at 2:1 US$ in the mid 1980s and a relatively small drop to an average of about 3.4:1 US$ in 1994. The Lilangeni is pegged to the South African Rand at par.

Swaziland also belongs together with South Africa, to a common monetary area agreement. It is also a member of the Southern African Customs Union (SACU) of which South Africa is a dominant partner.

2.4.3 Country Developmental Strategies

The country's development objectives outlining national priority issues have been central in structuring Swaziland's anticipated intervention in commitments of the Climate Convention and others. To attempt an initial assessment of climate change impacts and identification of mitigation options, baseline projections have been developed using sets of assumptions depicting the expected pattern of economic development. In particular, country objectives as presented in the National Development Strategy (NDS), were considered when making sector projections and overall country projections.

It is important to note that the country continues to use the three-year rolling National Development Plans (NDPs). These are now designed in the context of the long term plan NDS (twenty five year). The NDS, NDPs and annual budgets jointly, are designed to ensure that aspirations of the Government of Swaziland for the welfare of its people are translated into actionable policies and programmes to ensure optimization of resource allocation.

Before making the baseline projections, it is important to provide a summary of Government's objectives regarding Swaziland's development and the welfare of its citizens. The Government of Swaziland has as part of its main objective endeavoured to address three main areas: good governance, a vibrant economy, and human and social development.

Good governance encompasses such issues as constitutionalism, the role of the State, and tradition and culture. One of the initiatives, which came up, as a direct consequence was the setting up of the Constitutional Review Commission (CRC), aimed at soliciting views of the nation on areas that warrant inclusion into the country's constitution. This process, when completed, is expected to help assess various elements of good governance, which include, inter alia, legitimacy, accountability transparency and popular participation.

Strategies aimed at improving human and social development include ensuring high levels of food security, provision of proper human settlements and shelter, initiatives aimed at human resource development and improvements in health amenities. Provision of safe water and sanitation as well as programmes aimed at containing the population growth rate are paramount for improvement of the nation's standards of living.

Before we turn to our model for the development of the baseline scenario it is important to state the country's vision encapsulated in the NDS document, which reads as follows:

"By the year 2022, the Kingdom of Swaziland will be in the top 10% of the medium human development group of countries founded on sustainable economic development."

In essence what the country determines is to speed up the pace at which it bids for enhancement of human capabilities.

Parliament buildings at Lobamba in the middleveld

Photograph Dirk Schwager Cape Town

2.4.4 System of National Accounts: GDP Projections.

In developing the baseline for impact assessments and mitigation analysis a model referred to as the Simplified Macroeconomic Analysis of GHG (SMAG) has been used in the quantification of changes in the economic sectors deemed important in relation to GHG limitation.

This simplified assessment involves the use of existing statistics in which all projections for GDP (Table 2.5) are based on national accounts data. These projections were computed using simple moving averages. Had there been an advanced method of compiling national statistics capable of providing detailed multi sectoral information then it would have been possible to engage Computable General Equilibrium Models (CGE models) when analysing climate change mitigation.

Table 2.5 Projection for average growth rates of the GDP by sector 1994-2030

GDP per Sector	1994-2000	2001-2010	2011-2020	2021-2030
Agriculture	11%	15.2%	14.9%	13.7%
Forestry	1.3%	1.4%	1.3%	1.3%
Mining	1.7%	2.3%	2.29%	2.12%
Industry/Manufacturing	37.57%	29.28%	29.6%	32.15%
Construction	3.7%	3.6%	3.8%	3.7%
Transport & Communication	6.5%	6.3%	6.4%	6.4%
Government Services	17.7%	17.5%	17.5%	17.6%
Overall GDP as well	3.2%	4.66%	5.29%	5.00%

CGE models consist of a number of complex equations, which places great demand on data and other resources. Projections of population growth rates for the period 1994-2030 were also computed for this assessment (Table 2.6).

Since Swaziland has relatively good statistics and development plans it has been possible to carry out assessment such as the SMAG, which provides a deeper mitigation analysis than a purely descriptive approach. The analysis contained in this report, therefore, offers a superior decision framework for GHG limitation compared to a purely descriptive approach.

The background information provided on the various economic sectors associated with GHG emissions and an in-depth look into the country's developmental objectives provided a good base for application of SMAG.

Table 2.6 Projections of Population Growth Rates (1994-2030)

Periods of growth	*1994-2010*	*2000-2001*	*2010-2020*	*2020-2030*
Average population growth rates	2.3%	2.3%	2.3%	3.0%

2.5 AGRICULTURE

Swaziland commands two agriculture production systems. One is on Swazi Nation Land (SNL) where there is communal ownership of land and the other is on Individual Tenure Farms (ITFs) where there is private ownership of land. Production of crops and livestock on SNL is mainly subsistence whilst production on ITFs is commercial and consist of huge farms under irrigation. Agricultural production on SNL has remained low and technology used has remained rudimentary.

In spite of its poor performance, agriculture remains the mainstay of the Swaziland economy. Projections in Table 2.5 indicate that this sector is possibly expected to continue to account for, at least, 13% of GDP over the next 30 years. Should the country succeed in its endeavour to develop and promote agricultural technologies that are cost effective, acceptable to all stakeholders and environmentally friendly, the objective of self-reliance shall not always remain elusive.

Sugar crop under irrigation at Simunye

Photograph Dirk Schwager Cape Town

Although Swaziland has succeeded in achieving self-sufficiency in agriculture, she has failed to achieve self-reliance and as such remains a net importer of agricultural produce. In spite of the various agriculture promotion programmes the country has failed to exploit its comparative advantage in the production of several types of crops.

Attempts to encourage maize production have been hampered by unfavourable soil and climate conditions. Even in those cases where agricultural production responded positively to initiatives by the public sector, cooperatives and NGOs, the lack of markets posed a serious obstacle to the advancement of the sector.

Use of advanced technologies in the production of high value crop such as sugar, citrus, cotton and tobacco can be expected to increase yield and commercial value and thus improve the status of the agricultural sector as a foreign exchange earner.

Climate change mitigation policies have the primary responsibility of addressing themselves to changes aimed at ensuring improved yields on both SNL and ITF. Swaziland is capable of realizing both its goals of self-sufficiency and self-reliance in agricultural production.

2.6 FORESTRY

Forestry is an important economic activity, on average this sector accounts for 1.3% of the country's GDP. As a foreign exchange earner wood pulp is second only to sugar. Presently this sector accounts for, approximately, 10% export value.

Despite the country's small size, Swaziland has one of the largest man-made forests in the world. These man made forests account for 6% of the total land mass. These vast plantations of pine trees have been well managed and continue to be an important source of input for the pulp industry. Favourable climatic conditions and appropriate irrigation practices give Swaziland a competitive advantage in this resource.

Indigenous woodlands and wattle plantations account for 25% and 2% respectively, of the total land mass. These two types of forests have not been well managed and have suffered from deforestation as a result of the rapid increase in the country's population. Large amounts of forest area have had to be cleared in order to put up buildings both for domestic and commercial use.

These forests also serve as the main sources of wood fuel and raw material for wood products and homestead construction. Deforestation has led to serious land degradation and loss of biodiversity.

This is a clear indication that Swaziland has a very big challenge to ensure that afforestation campaigns are effective for the goal of sustainable development to be realized. Restoration of indigenous forest shall definitely require sound rural development programmes.

So far, Rural Development Area Programmes (RDAPs) have mainly addressed themselves to the improvement of agricultural programmes to, almost, a total neglect of the forestry sector save for a few tree planting campaigns undertaken in a selected number of areas in the country.

Indigenous and exotic forests against the backdrop of the Bulembu mountains in Piggs peak

Photograph Dirk Schwager Cape Town

2.7 INDUSTRY / MANUFACTURING

The manufacturing sector has always been the country's main contributor to GDP. Projections for GDP over the 30-year period indicate that this sector is likely to continue as the leading source of national income.

Successful environmental degradation abatement actions also have a direct positive socio-economic impact. As was alluded to earlier on, the private formal sector is one of the main employers of the labour force, maintaining high levels of productivity in this sector guarantees employment of large segments of the population, particularly, if production is kept relatively labour intensive.

Industries at Matsapa - the country's main manufacturing site.

Photograph Dirk Schwager Cape Town

The impetus to growth in this sector is attributable to Foreign Direct Investment (FDI) attracted in the past, mainly by a favourable industrial climate characterized by the abundance of trainable labour at competitive wages, a poorly unionised labour resource and a relatively stable political situation.

The manufacturing sector consists mainly of agro-based processing industries, which have survived because of good soils and climatic conditions. Sustainability of these industries depends on, among other things, the extent to which climate change mitigation policies are effectively implemented.

Reduction of GHG emissions is therefore key in the strategies to sustain the agro-based industry.

It is important to note that the manufacturing sector in Swaziland has recently been seriously challenged by changes taking place in neighbouring countries, particularly those of a political nature. The new democratic and thus favourable political climate in the Republic of South Africa led to a relocation of large amounts of foreign capital. Political and economic improvements in the Republic of Mozambique are also likely to display similar behaviour.

The challenge for Swaziland therefore is to find a possible and long lasting solution to foster sound domestic macroeconomic development in the context of regional cooperation and maintenance of healthy competition with her neighbours.

Various land use types at the Ezulwini valley

Photograph Dirk Schwager Cape Town

2.8 MAJOR LAND USE ACTIVITIES

Grazing occupies about 63% of the country's total land area and most of the grazing is restricted to the SNL. In 1989/90, natural veld comprised 95% of the land available for grazing (Swaziland Government 1994), with the remaining 5% being improved pasture used mainly for dairy production. However considerable portions of the grazing land exist in arable,grazing,settlement mosaics and have been dramatically modified by cultivation, heavy grazing, and human and livestock population increases over the past two to three decades such that they are no longer true rangelands supporting predominantly natural vegetation.

This is attributed to the fact that cattle are intimately involved in Swazi custom and culture, and are regarded as a store of wealth. They are important as sources of meat, milk, manure, and draught power for ploughing and transport. About 65% of rural homesteads keep cattle, which make a significant contribution to income from farming activities, perhaps between 30% and 50% of annual income (Swaziland Government 1983).

There are no restrictions on the number of livestock that an individual can own, and those without livestock have a right to grazing for any they eventually acquire. Cattle are put out to graze during the day, and returned to the kraal at night, when calves are separated from the cows, which are milked in the morning.

The practice of fallowing in the croplands has been decreasing due to the increase in population leading to higher demands for cropped land. A large part of the SNL is under maize production, which is the staple food of Swaziland.

Sugarcane is the leading crop in TDL and it is the main source of foreign exchange for the country. The value of export of sugar was 25% of the total national export in 1992 (Swaziland Government 1994b).

Commercial forest is the third most common land use in Swaziland. This activity is predominantly based on large plantations operated by the private sector. (6%)

The remaining 20% of land in the country is either residential, held in the form of natural reserves, water reservoirs and their catchments, or is used by a wide variety of land uses in small areas such as quarrying, orchards, market gardening, etc.

2.9 TRANSPORT

The efficient functioning of the economy is dependent upon a good network of transport and communication infrastructure and the availability of transport services. The Swaziland Government and its either wholly or partially owned parastatal organisations have a direct role to play in the provision and maintenance of an infrastructure network which is adequate to satisfy all effective demand. In addition, government provides a number of transport services and is responsible for regulating services provided by private enterprises in order to ensure fair competition and adherence to basic safety standards.

Government strives to promote a balanced multi modal split which facilitates the development and growth of all transport modes, the enhancement of telecommunications and to coordinate all activities within the sector.

Swaziland's transport services are well developed and cover the spectrum of requirements for the movement of goods and people. Several operations specialising in a diversity of services operate within the country and are professionally run to high standards. However, public transport by bus is an area, which continues to need improvement.

Air links to regional and international destinations are facilitated through commercial carriers, including the national airline; (charter companies operate to complement these services.)

2.9.1 Road Transport

The road network has subsequently undergone expensive upgrading and today ranks among the best in the continent, while effective rail links also ensure the prompt, efficient movement of import and export commodities.

New classification of roads adopted in 1970, has accounted for the decrease in length of main roads.

2.9.2 Air Transport

There is only one airport in Swaziland, Manzini, situated at Matsapa, 37 kilometres from Mbabane. Until 1971 no air transport statistics were available, so the data were collected retrospectively from the files of the Ministry of Transport and Communications together with those of the Matsapa Airport Authorities.

2.9.3 Rail Transport

The Swaziland Railway is 220,4 kilometres inside Swaziland and continues a further 74,0 kilometres to connect with the port of Maputo. The line was originally built for the transport of iron ore from Ngwenya to Maputo, but with the growth of the economy, other traffic, consisting mainly of sugar, pulp and citrus, is being supported.

Transnational autobahn linking the Mbabane and Manzini cities.

Photograph Dirk Schwager Cape Town

Chapter
3

Greenhouse Gas Inventories

3.1 INTRODUCTION

IN accordance with article 4.1 (a) of the United Nations Framework Convention on Climate Change (UNFCCC), all parties to the Convention are requested to update and report periodically on their national inventory of anthropogenic emissions and removal of greenhouse gases (GHG). This section of the national communication of Swaziland gives an outline of anthropogenic greenhouse (GHG) emissions and removals for the year 1994.

The inventory focuses on direct GHG emissions; carbon dioxide (CO_2), methane (CH_4), and Nitrous Oxide (N_20). Other Non-CO_2 emissions gases which have been considered and have an indirect effect on climate change through their influence on other greenhouse gases, especially ozone are precursors e.g. oxides of Nitrogen (NO_X), carbon monoxide (CO), and non methane volatile compounds (NMVOCs). In keeping with the IPCC guidelines, emissions from international bunkers are treated separately. Information is also available for emissions of perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphurhexafluoride (SF_6).

3.2 METHODOLOGY

The calculated emissions and removals of greenhouse gases for 1994 were based on the Revised 1996 IPCC Inventory Guidelines for National Greenhouse Gas Inventories. The source categories; energy (fuel combustion and fugitive emissions); industrial processes; agriculture; land-use change and forestry, and waste. were adopted with IPCC default emissions factors used and with the exception of waste, where the regional default factors for Tanzania were used. The methodology used for CO_2 and non-CO_2 emissions in the energy category was IPCC bottom -up sectoral approach. Energy activity data (total quantities of solid and liquid fossil fuels produced, imported, exported and consumed) was obtained from the Energy Section of the Ministry of Natural Resources and Energy. Conversion factors for various fuels used were IPCC default.

CO_2 and non-CO_2 emissions from industrial activities were determined from various activities and included are road paving, food and drink and chemical products use. The general methodology used involves knowledge of the product of activity level e.g. amount of material produced or consumed, and an associated emission factor per unit consumption/production. Activity data on quantities consumed/produced was obtained from various industries.

Also provided is data on consumption of HFCs, PFCs and SF_6 associated with application of refrigeration and air conditioning, fire suppression and, gas insulated switch gear and circuit breakers.

Emissions from agriculture namely CH_4, N_20, CO and NO_X were determined from five sources: domestic livestock (enteric fermentation and manure management), rice cultivation, prescribed burning of savannas, field burning of agricultural residuals and agricultural soils. Activity data, on number and type of animals, annual harvested area cultivated under continuously flooded conditions, area of savanna and grassland burnt annually, and fraction of agricultural residuals that are annually burnt, was obtained from general statistics of the Government of Swaziland.

The methodology for determining CO_2 and non-CO_2 emissions from land-use change and forestry and removals was in accordance with 1996 IPCC methodology modified to include sources of emissions and removal which covered agriculture, firewood, timber, settlements and plantations. Activity data such as abandoned area during and over 20-year periods was obtained from central statistics office.

CH_4 is the predominant greenhouse gas from waste. Using IPCC methodology, CH_4 was determined from solid waste disposal sites, domestic/commercial wastewater and sludge, and industrial waste and sludge. Activity data was obtained from the following industries: Non-alcoholic and alcoholic beverages, meet and poultry, dairy products, sugar, and pulp and paper.

Table 3.1 *Swaziland's greenhouse gas inventories overview in kilotonnes (Gigagramms per year) 1994*

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs
TOTAL (Net) NATIONAL EMISSIONS	**873.871**	**64.367**	**1.339**	**19.981**	**523.048**	**80.011**	**1.974**	**3.7713**
1. ALL ENERGY	**873.871**	**7.217**	**0.09845**	**7.4973**	**123.102**	**11.0811**		
Fuel Combustion								
Household	131.243	2.847	0.0346	0.9512	43.55	5.174		
Agriculture	0	0	0	0	0	0		
Manufacturing	278.333	0.428	0.0573	2.222	52.05	0.723		
Commercial	25.441	0.0034	0.00025	0.0341	0.112	0.0121		
Transport	438.854	0.0758	0.0063	4.29	27.39	5.172		
Fugitive Fuel Emissions								
Coal Mining		3.863						
2. INDUSTRIAL PROCESSES				**0.423**	**1.579**	**68.9294**	**1.974**	**3.7713**
Pulp and Paper				0.423	1.579	1.0434	1.974	0
Food and Drink						6.886	0	0
Air conditioning and refrigeration						0	0	0.1533
Fire extinguishers, solvents and aerosols						0	0	3.618
Road Paving						61	0	0
3. AGRICULTURE		**40.45**	**1.23885**	**11.96**	**396.6**			
Domestic Livestock		24.10	0	0	0			
Animal Wastes		0	0.00085	0	0			
Rice Cultivation		0.010	0	0	0			
Savannah Burning		10.12	0.126	4.54	265.9			
Agricultural Waste Burning		6.22	0.21	7.42	130.7			
Agricultural Soils		0	0.902	0	0			
4. LAND-USE CHANGE AND FORESTRY	**2910.028**	**0.201**						
On site Burning	46.27	0.2011	0.0013	0.0503				
On site Decay	68.65							
Off site Burning	748.958							
Commercial Harvest	1792.96							
Liming of Soils	253.19							
SINKS	**(6167.71)**							
Carbon uptake by trees	(6138.67)							
Carbon uptake in abandoned areas	(29.047)							
BALANCE	**(3257.35)**							
5. WASTE		**16.499**						
Solid Waste Disposal Sites		1.07						
Domestic/commercial waste water & sludge		0.029	0.00019					
Industrial waste water and sludge		15.4						

3.3 NATIONAL GREENHOUSE GAS EMISSIONS OVERVIEW

The national inventory has been organised into five parts corresponding to five of the six major source activities described in the 1996 IPCC Guidelines as follows:

(i) Energy

(Fuel Combustion Activities)

a) Household
b) Agriculture
c) Manufacturing
d) Commercial
e) Transport

(Fugitive Emissions)

a) Coal mining

(ii) Industrial Processes

a) Pulp and paper
b) Food and drink
c) Air conditioning and refrigeration
d) Fire extinguishers- solvents and aerosols
e) Road paving

(iii) Agriculture

a) Domestic livestock
b) Animal waste
c) Rice cultivation
d) Savannah burning
e) Agricultural waste burning
f) Agricultural soils

(iv) Land Use and Forestry

(Emissions)

a) On-site burning
b) On-site decay
c) Off-site burning
d) Commercial harvest
e) Liming of soils

(Sinks)

a) Carbon uptake by tress
b) Carbon uptake in abandoned areas

(v) Waste

a) Solid waste disposal sites
b) Domestic/Commercial waste water and sludge
c) Industrial waste water and sludge

Table 3.1 gives an overview of greenhouse gas emissions and removals in Swaziland for the year 1994.

Table 3.2: *Global warming potentials (GWPs)*

GAS	CO_2	CF_4	C_2F_6	SF_6	HFC-125	HFC-134a	HFC-143a	HFC-152a	CH_4	N_2O
GWP	1	6500	9200	23900	28000	1300	3800	140	21	310

3.4 GWP EFFECTS ON TOTAL EMISSIONS

An overall picture of Swaziland's contribution to radioactive forcing from greenhouse gas emissions is given using Global Warming Potentials (GWPs) from Table 3.2. The GWPs are calculated for a time horizon of 100 years are direct and indirect for gases and for methane respectively.

3.5 Emissions of CO_2 CH_4 and N_2O

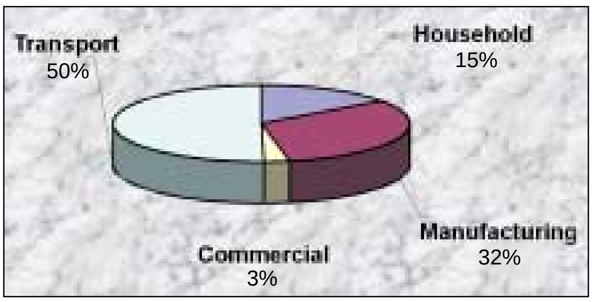
3.5.1 Emissions of CO_2

Swaziland's contribution of CO_2 amounted to 873 870 tonnes in the year 1994, (representing 0.873 tonnes CO_2 per capita).Virtually all CO_2 emissions emanated from fuel combustion (energy) characterised by household, manufacturing, commercial and transport sectors.

There were no CO_2 emissions from industrial processes. The largest single source of CO_2 in Swaziland is the transport sector, which accounted for 50% of energy CO_2 emissions in 1994. The manufacturing, household and commercial sectors accounted for 32.0%, 15.0% and 3.0% respectively.

The relatively high contribution of CO_2 from the residential sector is due to use of coal, liquefied petroleum gas (LPG) and to some extent kerosene for heating purposes in households. The largest contribution of CO_2 from the manufacturing sector comes from the use of coal for steam generation in the pulp and paper, and food processing and beverages industries. Given on Figure 3.1 is the ratio of CO_2 emission per sector.

Figure 3.1 Ratio of CO_2 emissions per category



3.5.2 Emissions of CH_4

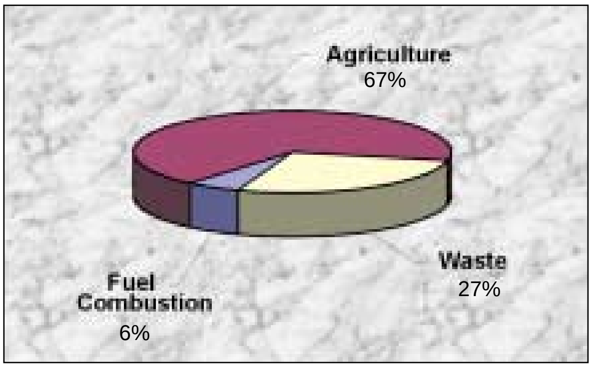
Total methane emissions in Swaziland for 1994 amounted to 64 370 tonnes. The dominant sources of CH_4 emissions are agriculture (66.9%) and waste (27.3%). Fuel combustion and coal mining contribute 5.5% of total CH_4 emissions (Figure 3.2).

Within the agriculture sector, the largest contribution (60%) comes from domestic livestock influenced by enteric fermentation.

In 1994, there were 642,000 and 435,000 of non-dairy cattle and goats; respectively which both contributed 97.0% of total CH_4 emissions from the domestic livestock.

Under fuel combustion, the largest contribution (85.0%) derives from the residential sector involving combustion of firewood for cooking and heating purposes.

Figure 3.2 *Ratio of CH_4 emissions per category*

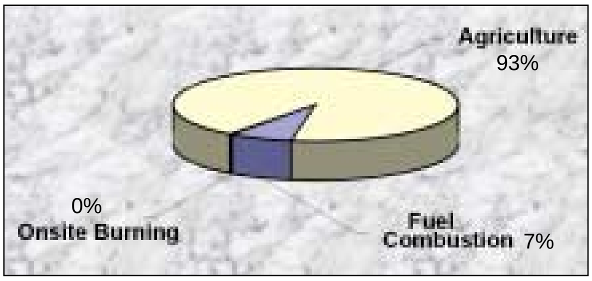


In waste, the largest contribution (93.0%) comes from industrial waste dominated by the beer and pulp and paper industries.

3.5.3 Emissions of N_2O

Swaziland's total anthropogenic emission of N_2O in 1994 is estimated at 1 337 tonnes. The major contributor was agriculture (93.0%) predominantly from liming of agricultural soils followed by fuel combustion (7.4%). Within the fuel combustion category, 35% of the N_2O emissions were attributed to the residential sector, mainly from combustion of firewood for cooking and heating purposes. Given on Figure 3.3 is the ratio of N_2O emissions per category in 1994.

Figure 3.3*: Ratio of N_2O emissions per category*



3.6 EMISSIONS OF OTHER GHGs (PCFs, SF_6 AND HFCs)

In view of the nature of Swaziland's manufacturing industries notably the assembling of air conditioning and refrigeration systems, direct data was collected on consumptions of HFCs.

For the year 1994, 153.3 tonnes of HFCs were estimated to have been discharged into the atmosphere. In addition, 3 361 tonnes of HFCs were estimated to have been discharged from fire extinguishers, solvent and aerosols, making a total of 3 771 tonnes from the two sources.

3.7 EMISSIONS OF PRECURSORS (CO, NO_X AND NMVOCs)

Precursors are gases such as NO_X, CO and NMVOCs, which have an indirect effect on the climate through their influence on other GHGs, especially ozone. Emissions for NO_X, CO and NMVOCs for the year 1994 were estimated at 19 930, 523 048, and 80 011 tonnes respectively. The largest contribution of NO_X comes from agriculture (60%) and fuel combustion (38.0%), again mainly from combustion of firewood under the residential sector. The same trends was noted for CO, whilst NMVOC emissions' largest contributions emanated from industrial processes (86.0%).

3.8 EMISSIONS OF CO_2 EQUIVALENTS

Total emissions of GHGs given as CO_2 equivalents for the year 1994 using the GWP values quoted in Tables 3.2 are given in Table 3.3.

Table 3.3 *Total Emissions of Greenhouse Gases for the year 1994*

YEAR	CO_2 (M.T.)	CH_4 (K.T.)	N_2O (K.T.)	CF_4 (T.)	C_2F_6 (T.)	SF_6 (T.)	HFC-134a (M.T.)	HFC-152a (T.)	HFC-125a (T.)	HFC-143a (T.)	CO2 Equivalent (M.T.)
1994	0.874	134.170	415.090				4.9027				6.33

GWP taken account of, altogether 6.33 million tonnes of CO_2 equivalent is estimated. The largest contribution (77.5%) emanates from consumption of HFC's in air conditioning and refrigeration systems, and fire extinguishers on one hand, and the use of solvents and aerosols on the other.

The second largest source of CO_2 equivalents is CO_2 (13.8%). The Contribution of N_2O and CH_4 emissions to CO_2 equivalents were estimated at 6.6% and 2.1%, respectively.

3.9 CO_2 REMOVALS

The main sources of CO_2 emissions in Swaziland under land-use change and forestry are commercial harvests (60.0%), and offsite burning through firewood combustion (25.0%).

Liming of agricultural soils, on-site burning and on-site decay contributions were estimated at 8.5%, 3.4% and 3.1% respectively. Given on Table 3.4 are CO_2 emissions from identified sources above.

Table 3.4 *Annual Balance in Carbon Dioxide in Land Use change and Forestry*

	SOURCES	Annual Emissions (CO_2 Kt)	Annual Uptake (CO_2 Kt)	Balance (Kt CO_2)
1.	On-site Burning	46.27		
	On-site Decay	68.65		
2.	Off-site Burning	748.958		
3.	Commercial Harvest	1,792.96		
4.	Liming of Agric. Soils	253.19		
	Sub-Total	2,910.028		
	SINKS			
1.	Carbon Uptake by Trees		6,138.67	
2.	Carbon Uptake in Abandoned area		29.047	
	Sub-Total		6,167.71	
	Balance			3,257.35

Swaziland possesses a comparatively large GHG sink capacity, owing to the very large man made and indigenous forest cover in the country, the former ranking amongst the largest such in the world. The major sinks therefore are carbon up-take by trees predominantly from commercial plantations including non-forest trees planted in major cities. These all together account for 99.5% of the country's overall uptake. A small fraction is carbon uptake in abandoned areas (0.5%).

Table 3.5 shows the final GHG budget for Swaziland for the year 1994. Results from this table indicate that the balance which takes account of emissions and sinks is a net sink for the year 1994 by 2.383 million tonnes carbon dioxide up-take.

3.10 INTERNATIONAL BUNKERS

As in accordance with IPCC guidelines emissions from international bunkers were reported separately. In the year 1994, 3,640 tonnes of carbon dioxide were emitted into the atmosphere under international bunkers. The fuels used in international transport is jet kerosene.

3.11 UNCERTAINTIES AND FURTHER WORK

In undertaking this study, in all respects, default emission factors were used as a result of absence of country-specific emissions factors and ratios particularly in firewood combustion, agriculture, land-use change and forestry, and waste. There is need to have further work to develop local specific emission factors and ratios.

Another area of concern is the source and availability of activity data in energy particularly biomass and in the other sectors; agriculture, land-use change and waste. For example, activity data availability, variability and reliability under land-use change (in particular, area converted annually, area converted under different periods of time, area of abandoned land, net change in biomass density, fraction of biomass burned on site etc), caused immense difficulties.

Furthermore, work under land-use change and forestry requires generation of activity data through social and corresponding forest survey, forest inventories and studies and experimental related research to generate emission and conversion factors. Accessibility, to satellite imagery and capacity building in all these areas remains necessary to move the work forward.

Table 3.5 *Swaziland's 1994 final GHG budget (tonnes)*

EMISSION SOURCE / SINK	CO_2 (Kt) 1994
EMISSIONS	
All Energy sources	873 871
Land-use	2 910.028
Sub-Total	3 783.899
SINKS	
Carbon up-take by trees	6 138.67
Carbon uptake in abandoned areas	29 047
Sub-Total	6 167.71
Balance	2 383.811

Chapter 4

Vulnerability and Adaptation

4.1 INTRODUCTION

The biosphere is characterised by a diversity of ecosystems, which have irregular and asymmetric distribution patterns. Changes in climatic conditions and soil characteristics are responsible for the irregularity in the distribution patterns and floristic composition of ecosystems over time. There is a close relationship between the distribution of organisms, particularly plants and climatic conditions.

Climatic conditions generally vary with latitude and altitude. Of particular importance are the spatial variations in temperature conditions and quantity of precipitation. Authors such as Woodward (1988) note that there is an abundance of evidence that extremes in climate such as drought, low and high temperatures and high winds have an influence on plant distribution. Such evidence is illustrated in studies of pollen records that suggest that the geographical distribution and range of plants have been subject to change with changing climatic conditions over time.

4.2 FORESTRY

4.2.1 Background

This study examines the extent to which managed forests and other ecosystems in Swaziland are vulnerability to climate change and thereafter, feasible adaptation options available to the country. Table 4.1 presents a panaromic listing of possible impacts due to climate change on forests.

Of particular concern are the variation in temperature conditions and changes in the distribution and amount of rainfall. Other factors that are likely to influence the composition, structure and distribution of ecosystems include increasing carbon dioxide levels, ultra-violet radiation, and outbreaks of pests and diseases.

Apart from the climatic processes occurring within the natural environment, human activities also have an influence on the spatial distribution of patterns of ecosystems. Man's cultural practices such as deforestation, grazing and fire serve as short-term effects on the distribution and composition of ecosystems.

Table 4.1: *Some possible climate change impacts on forests and other ecosystems*

• Changes in the location and optimum growing size of species and shifts in species composition and size of forest estate
• Increases or decrease in production of wood or non-timber products per unit area
• Changes in the type, location and intensity of pest and disease outbreaks and fires
• Increase or decrease in amount of carbon stored in forest ecosystem
• Disturbance of ecosystem functions such as nutrient retention, litter decay, flowering and leaf-fall.
• Changes in biodiversity
• Invasion of alien species into natural ecosystems

Source: Freenstra et al (1998)

Managed forests and woodlands are the main sources of timber for construction, energy and pulp hence contribute to the economy of many countries in the world (Feenstra et al., 1998). Changes in the composition, structure and productivity of ecosystems will not only affect the sustainability of organisms that are associated with the ecosystems but may also lead to effects on the national economy which they support. This is particularly true in the case of managed forests.

Medicinal plants also occur within natural ecosystems. Therefore the impacts of climate change on ecosystems will not only affect the socio-economic status of the nation but it will also have serious effects on health. Swaziland is highly diversified in terms of relief, climate, land-use systems and associated ecosystems.

SNL covers 74.2% (1 287 300ha), while the TDL makes up 25.6% (444 100 ha) of the total area (Remmelzwaal and Vilakati, 1994).

Swazi Nation Land comprises of communal (948 000ha) or non-communal (14 200ha) land under the control of chiefs. Part of the land under SNL is controlled by Tibiyo (49 500ha), the Ministry of Agriculture and Co-operatives (117 300ha), the Swaziland National Trust Commission (46 000ha) or leased (112 300ha).

TDL constitutes land owned by companies (estates and commercial forests) and individuals in rural areas (43 1600ha). Urban areas make up a small portion (125 00ha) of TDL.

Generally, access to land is limited on SNL compared to TDL. Most settlements on SNL are less than 2 hectares in size, and only 2% of the total holdings (63 583) are larger than 5 hectares (Central Statistical Office report, 1993).

Pine forest plantations of the pulp company at Bhunya in the highveld.

4.2.2 Land Tenure and Land-use

Swaziland has a dual system of land tenure instituted when the country was still under British protection. The system comprises of Swazi Nation Land (SNL) and Title Deed Land (TDL). Overall,

Land-use practices and the exploitation of natural resources in the country vary according to the land tenure system in each area. According to

Remmelzwaal and Dlamini (1994), the main land uses in the country are small-scale subsistence crop agriculture, large-scale crop agriculture, extensive communal grazing, ranching, plantation forestry and others.

Table 4.2 *Coverage of the main land uses in each physiographic region of Swaziland*

Land use system	Highveld		Middleveld		Lowveld		Lubombo		Country	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
SA	39 100	6.9	74 000	15.4	84 200	15.1	16 100	10.9	213 400	12.3
LA	1 100	0.2	18 400	3.8	81 400	16.9	2 800	1.9	103 700	6.0
CH	320 600	56.7	291 00	60.3	173 800	30.5	80 400	54.3	865 800	50.0
RH	49 500	8.7	85 800	17.8	164 300	31.0	32 700	22.1	332 300	19.2
F	132 300	23.4	7 500	1.6	0	0	0	0	139 800	8.1
E	0	0	0	0	8 400	1.3	0	0	8 400	0.5
P	20 100	3.5	900	0.4	21 100	4.7	16 100	10.9	58 200	3.4
W	400	0.1	0	0	3 800	0.7	0	0	4 200	0.2

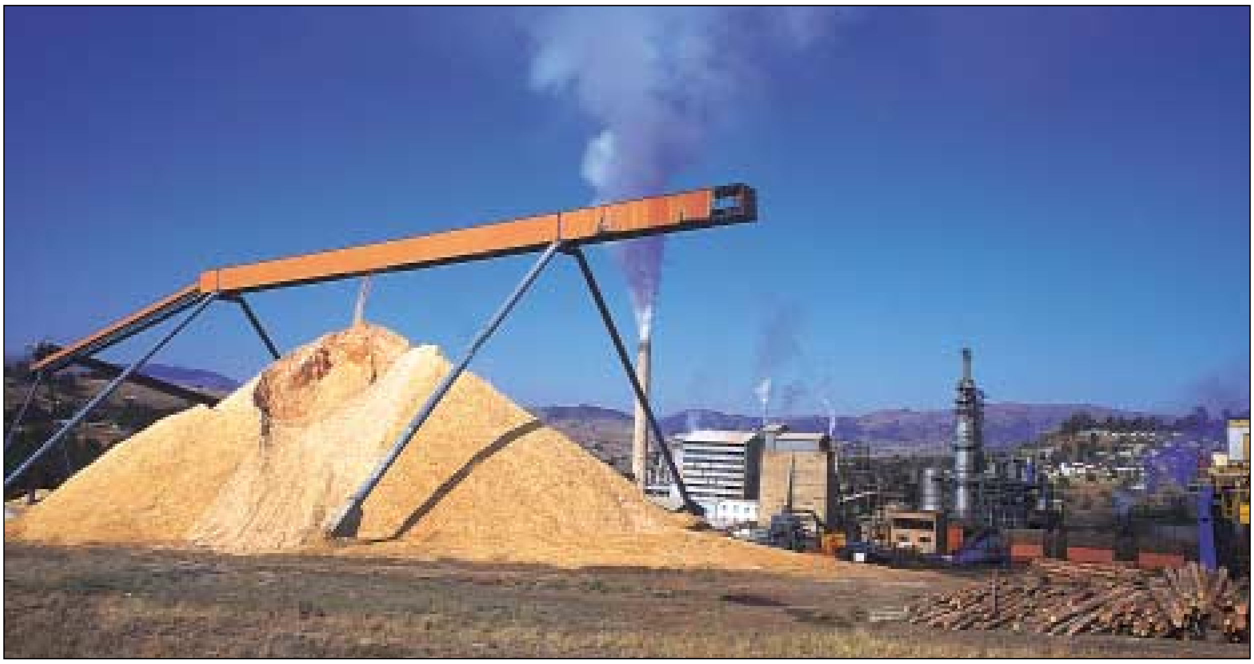
The other land uses include hunting, parks and reserves, water reservoirs and areas that are used for settlements, industry and recreation. Table 4.2 shows the areal coverage of the main land uses in the country per physiographic region. Small-scale crop agriculture (SA), extensive communal grazing (CH) and some extraction and collection (E) occur on SNL.

Land-uses that are associated with TDL include large-scale crop agriculture (LA), ranching (RH), plantation forestry (F). Parks and reserves (P) are either under SNTC or TDL. Although water reservoirs (W) mostly serve TDL, they are found on SNL.

4.2.3 Ecosystems

Swaziland has quite a high diversity of ecosystems for a small country. Generally, each physiographic region is associated with specific ecosystems (veld types) with a number of units. I'ons and Kidner (1967) subdivided the veld types of Swaziland into eleven (11) units on the basis of climate and composition of the communities.

Pulp mill at Bhunya with wood chip stockpile



Sweet and Khumalo (1994) recognise five vegetation units in the highveld, which are associated with short sour grassland. Patches of montane and riparian forests occur along river valleys and interfluves in the highveld. The middleveld is characterised by tall grasses, hillside bush and broadleaf savanna. Five vegetation units are recognised in the lowveld consisting of broadleaf, microphyllous or acacia savanna. Lubombo is characterised by bush or broadleaf savanna and has three vegetation units.

Table 4.3: *Physiographic regions and Ecological Zones of Swaziland.*

Physiographic region	Ecological Zone
Highveld	Mountain Sourveld
	Highland sourveld
Upper Middleveld	Moist tall grassveld
	Tall grassveld
Lower Middleveld	Dry tall grassveld
	Upper broad -leaved tree savanna and hillside bush
	Upland tall grassveld
Western Lowveld	Lower broad-leaved tree savanna
Eastern Lowveld	Acacia savanna
	Dry acacia savanna
Lubombo	Mixed bush and savanna

Table 4.4: *Areal extent of forests in Swazland*

TYPE OF FOREST	AREAL EXTENT (ha)
Montane and Highland	11 930
Riparian	2 344
Moister Savanna	112 720
Acacia Savanna	150 590
Dry Acacia Savanna	34 025
Bushveld	151 890
Total	463 499

Source: Hesse et al. (1997)

Each of the six physiographic regions of the country is associated with at least one ecological zone. These zones and the associated physiographic regions are shown on Table 4.3. Table 4.4 gives the areal extent of indigenous forests.

4.2.4 Climatic requirements for forests

The mountain sourveld is located within an area of rainfall exceeding 1 250 mm a year. This zone is associated with fairly light or severe (especially in the valleys) winter frost. The highland sourveld occurs in a slightly drier zone where the annual rainfall does not exceed 1 000 mm.

Within the moist tall grassveld rainfall is about 1 000 mm a year or more. Winters in this zone are usually frost-free. The tall grassveld receives an annual average of about 900 mm. The dry tall grassveld on the other hand receives about 750 mm of rainfall a year. It is also characterised by slightly higher temperatures than the tall grassveld. The upper broad-leaved tree savanna is characterised by hot summer temperatures. The amount of rainfall in this zone is about 1 000 mm a year. Though cooler than the rest of the middleveld, the upland tall grassveld receives between 800 and 900 mm of rainfall per year.

Associated with the lowveld regions are the lower broad-leaved tree savanna, the acacia savanna and the dry acacia savanna. The occurrence of these ecological zones is partly influenced by climatic conditions and soil types.

The broad-leaved tree savanna found in the western lowveld, occurs on granites soils. In the eastern lowveld is the acacia savanna, which is associated with fertile soils derived from basalt. The dry acacia savanna occurs along the southern Lubombo foothills where that annual rainfall varies between 500 and 625 mm per year. On the Lebombo mountain is the mixed bush and savanna.

Managed (plantation) forests in Swaziland consist of soft and hardwoods such as pine, eucalyptus and wattle. Table 4.5 shows the area of land under managed and natural forests in some of the companies in Swaziland. Each of the species found within plantation forests strives within specific tolerance ranges in terms of climatic conditions.

Table 4.5: *Area under Forestry in various companies in Swaziland.*

COMPANY	Area (ha)				
	Pinus spp.	Eucalyptus spp.	Acacia Mersnii	Natural Forest	TOTAL
Mondi forest	17 841	3 745	0	2 196	23 782
SAPPI Usutu	54 244	118	194	-	54 556
Shiselweni Forestry	17 470	9 296	158	800	27 724
TOTAL	89 555	13 159	352	2 996	106 062

Most plantations are found in the highveld region of Swaziland with a few wattle forests found in the upper middleveld.

Table 4.6: *Mean annual temperature and rainfall requirements for some forest species.*

SPECIES	ANNUAL TEMPERATURE REQUIREMENTS (°C)	ANNUAL PRECIPITATION REQUIREMENTS (mm)
Acacia Mernsii	>14	850 – 750
Eucalyptus grandis	14 – 23	900
Pinus patula	12 – 19	950
Pinus elliottii	12 – 14	850
Eucalyptus saligna	15.5 – 19	850

Managed forests in the country consist of eucalyptus trees *(Eucalyptus saligna and E. grandis)*, Pine trees *(Pinus elliottii,, P. patula and P. sylvestris)* and wattle *(Acacia mernsii)*.

Each of the species has a specific tolerance to climatic conditions. The mean annual temperature and rainfall requirements for some of the species are shown on Table 4.6.

Changes in these climatic conditions may also cause an increase in the susceptibility of these species to pests and disease outbreaks.

Acacia mernsii, for example, is susceptible to bag worm and mirid attacks whose incidences increase when the mean annual temperature is above 1 200mm.

4.2.5 Methodology

Assessment of the vulnerability of the country's forests and ecosystems was conducted on the basis of three Global Circulation Models (GCMs) recommended for the country; GFDL, CCCEQ and UKTR. Results presented in this report are based on these models and on the country's observed climatological data supplied by the meteorological service, and serving as inputs to the GCMs.

4.2.5.1 Types of Ecosystems

The current and projected ecosystem types in Swaziland were assessed using the *Holdridge Life Zone Classification Model*. Using data on annual biotemperature and precipitation to classify ecosystems, the model gives the potential land cover for each study site (Hartshort, 1992).

The potential land cover is assessed on the basis of the various life zones shown on the life zone chart and on the basis of both latitudinal and altitudinal differences. The assessment was conducted for the current (baseline) situation and the GCM scenario projections.

4.2.5.2 Tree growth

In assessing the vulnerability of tree species to climate change, the *Forest GAP mode*l was used. This model simulates the distribution of plant populations as well as the growth and mortality of individual species. The performance centres on environmental conditions and interactions between the species found on the plot. The growth of individual plant species is indicated by variations in the diameters and changes in biomass production and basal area.

4.2.5.3 Forest Species Assessed

This model was run using two exotic species and four indigenous species. The exotic species used in the assessment were *Pinus and Eucalyptus.* The indigenous trees were *Combretum sps, Syzygium cordatum, Sclerocarya birrea and Pterocarpus angolensis.* Choice of the species used in the assessment was based on the occurrence, commercial value and social value of each of the tree species.

In terms of occurrence, most of the selected indigenous trees are found in all the physiographic regions. The only exception is Syzygium cordatum, which occurs mainly in the highveld and lubombo regions. The exotics are also generally confined to the highveld and middlevled regions of the country.

(i) Exotic Trees

Forest plantations are an important source of revenue in the country. Pinus and Eucalyptus cover a large area of the plantations. For example, Mondi forest had about 17 345 ha and 3 745 ha under pine and eucalyptus respectively. The tree species are grown for timber and pulpwood for paper and non- paper products.

(ii) Indigenous Trees

Combretum spp are used as timber and fuelwood. According to Mtetwa and Vilakati (1992), Combretum species are amongst the trees whose wood has high calorific value.

Some species of the genus also have cultural value in that they are used during Incwala (Dlamini, 1981). As such these species are amongst the protected in the country. Syzygium produces edible fruits, which are sold by members of communities where the species occurs.

The bark is used in the treatment of diarrhoea. This species plays an important role in hydrological processes and is also used as timber. *Sclerocarya birrea* bears fruits that are used by rural communities to brew a highly potent drink rich in calcium.

The nuts are used both as relish and as an important food supplement to rural communities whilst the bark is used for medicinal purposes (Dlamini, 1982). *Pterocarpus angolensis* on the other hand is an important source of timber and carving material.

Any negative impact of climate change on these tree species would have not only an effect on the natural environmental processes of their habitat, but also an impact on the income generation and other cultural and social activities that they support.

4.2.5.4 Representative study sites

The vulnerability assessment of the selected species was based on climatic data from four representative sites of the main physiographic regions. In the assessment of exotics, climatic data from Bulembu was used. This study site represents the highveld where most exotics are grown. For the vulnerability assessment of indigenous trees, the representative sites are Mpisi (middleveld), Big Bend (Lowveld) and Siteki (Lubombo).

Table 4.7: *Current Vegetation zones in globally selected grids within Swaziland*

Latitude	Longitude	Area represented by grid reference and (region)	Vegetation zone
-26.0	31.5	Mzimnene: Hhohho (Highveld)	Sub-tropical dry forest
-26.0	32.0	Lomahasha (Lubombo)	Sub-tropical dry forest
-26.5	31.0	Bhunya (Highveld)	Sub-tropical moist forest
-26.5	31.5	Hhelehhele: Manzini (Middleveld)	Sub-tropical dry forest
-26.5	32.0	Siteki (Lubombo)	Sub-tropical dry forest
-27.0	31.0	Mahamba (Highveld)	Sub-tropical moist forest
-27.0	31.5	Mbulungwane (Highveld)	Sub-tropical dry forest

4.2.6 Results and outputs.

4.2.6.1 Holdrigde.

All the model runs suggest that Swaziland is currently predominantly characterised by two types of ecosystems. These are the *Subtropical moist forest* and the *Subtropical dry forest*. The south eastern corner of the country is also observed to support a *tropical very dry forest* (Table 4.7 and Figure 4.1).The results provide an indication of the current potential ecosystem types in the country.

There is a relationship between the current potential ecosystem types and the existing ecological zones in the country. Theories on the evolution of grasslands suggest that areas within the highveld

Table 4.8: *Current forest ecosystems associated within specific sites in Swaziland*

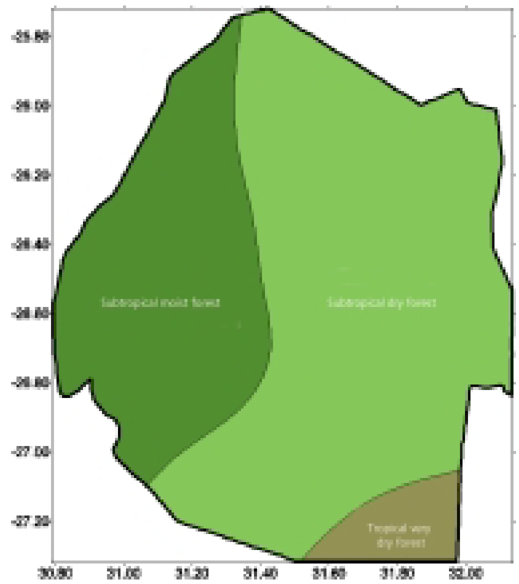
STATION	LATITUDE	LONGITUDE	TYPE OF FOREST
Big Bend	26.85	31.87	Subtropical dry forest forest
Bulembu	25.95	31.13	Subtropical moist forest forest
Lavumisa	27.30	31.88	Tropical very dry forest forest
Mananga	26.00	31.75	Subtropical dry forest forest
Malkerns	26.55	31.15	Subtropical dry forest forest
Mbabane	26.55	31.15	Warm temperate moist forest
Mpisi	26.38	31.53	Subtropical dry forest forest
Nhlangano	27.12	31.20	Subtropical dry forest forest
Siteki	26.47	31.95	Subtropical dry forest forest

and upper middleveld regions are ideally suited for growth of sub-tropical forests.

Considering that the model was run using the global data that uses grids, an attempt was made to correlate the results with specific areas in the country. This was achieved by running the model using local weater data from nine sites. Almost similar results to the global data were obtained from the country specific data (Table 4.8). The only exceptions are Mbabane and Lavumisa, which the model suggests, are capable of supporting warm temperate moist forest and a Tropical very dry forest forest respectively.

With Mbabane characterised by summer rainfall and severe winters, the type of temperate forest suggested by the model is the deciduous.

Figure 4.1: Currrent ecological zones in the country



(Chapman and Reiss, 1999). As such, areas in the highveld and upper Middleveld regions of Swaziland (Bulembu and Mbabane) have a potential to support a sub-tropical moist forest. The Lower middleveld, Lowveld and Lubombo regions have a potential to support a sub-tropical dry forest.

Figure 4.2: Potential future scenario of ecological zones.

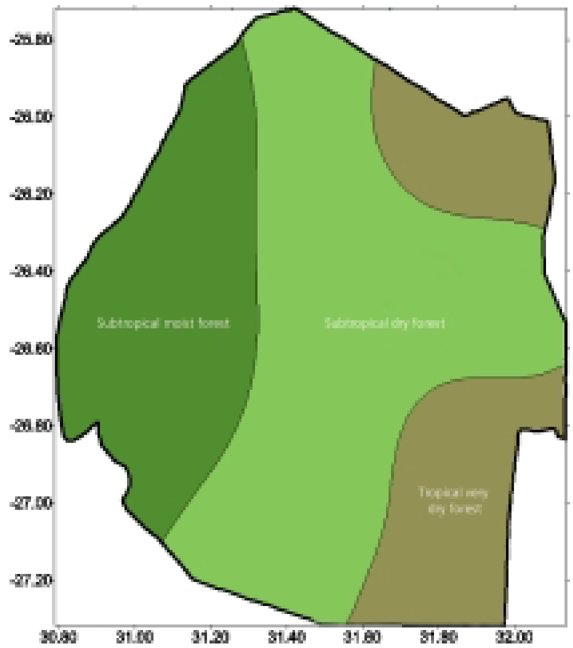


Table 4.9: *Projected changes in ecosystems in Swaziland for each of the GCMs*

SITE	LAT.	LON.	CCCEQ	GFDL	UKTR
Big Bend	26.9	31.9	Subtropical thorn	Tropical very dry forest	-
Bulembu	26.0	31.1	Subtropical moist forest	Subtropical moist forest	Subtropical moist forest
Lavumisa	27.3	31.9	Tropical very dry forest	Tropical very dry forest	Subtropical dry forest
Mananga	26.0	31.8	Subtropical dry forest	Subtropical dry forest	Subtropical dry forest
Malkerns	26.6	31.2	-	-	-
Mbabane	26.3	31.2	Subtropical moist forest	Subtropical moist forest	Subtropical moist forest
Mpisi	26.4	31.5	Subtropical dry forest	Subtropical dry forest	Subtropical dry forest
Nhlangano	27.1	31.2	Subtropical dry forest	Subtropical dry forest	Subtropical dry forest
Siteki	26.5	32.0	Subtropical dry forest	Subtropical dry forest	Subtropical dry forest

Model projections suggest changes in forest ecosystems in Big Bend, Mananga and Mbabane (Figure 4.1). All the model scenarios suggest an ecosystem in Mbabane changing from the current warm temperate moist forest to a Subtropical moist forest forest.

There are some variations in the case of Big Bend and Mananga. Big Bend is likely to be covered by a subtropical thorn woodland (CCCEQ) or a Tropical very dry forest forest (GFDL) whilst Mananga is likely to have a Tropical very dry forest forest (CCCEQ-high) or subtropical desert scrub (GFDL- low). Table 4.9 and Figure 4.2 present future scenarios of forest cover in the country.

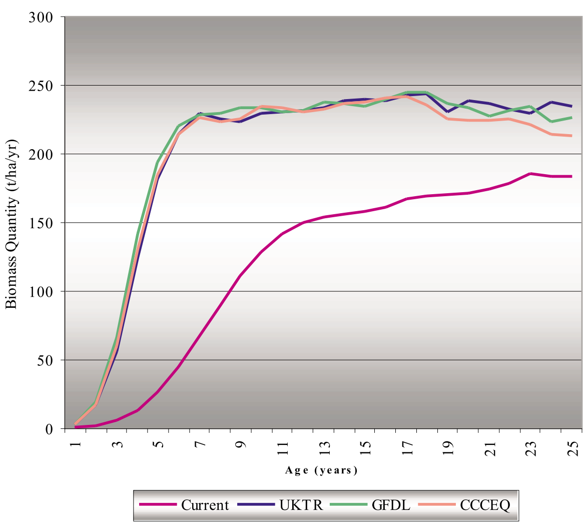
These possible changes are due to the estimated slight decrease in precipitation and increase in temperature in the country. This suggests a possible change not only in species composition but also in the geographical areas that they support.

Regarding species composition, the results imply that xerophytes such as the Acacia species are likely to flourish in the country with changing climate. This will have implications on the availability of medicinal plants. Secondly, the conversion of ecosystems is likely to have implications on the overall structure of and nutrient cycles within the ecosystem. Such would therefore require changes in lifestyles and resource use in the affected areas.

4.2.6.2 Pine biomas distribution and growth

A general slight increase in biomass production in pine trees is projected with respect to the GCM models compared to the current climatic scenario. With the current climate scenario, biomass production in pine trees is estimated at an average of 22.55/ha/yr. The GCMs used in the study however give lower average estimates of biomass at Bulembu. Figure 4.3 shows the projected biomass production in pine trees at Bulembu.

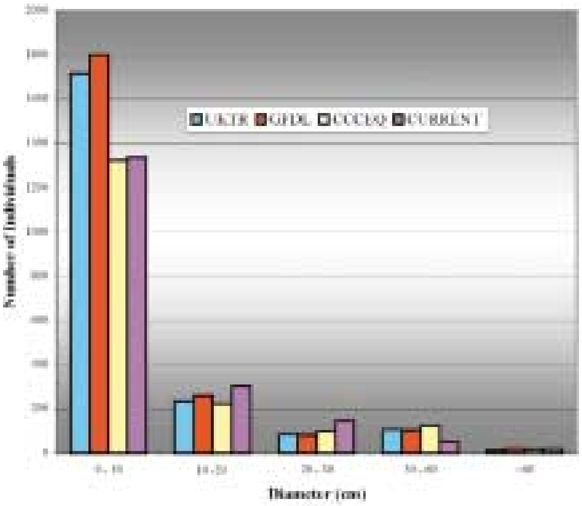
Figure 4.3: *Projected Eucalyptus tree Biomass Production at Bulembu*



4.2.6.3 Eucalyptus biomas distribution and growth

The assessment of biomass production in eucalyptus indicates a change in climate change will increase the biomass. On the basis of the current climate scenario, the average annual biomass production in Eucalyptus is projected at 159.67 t/ha/yr at Bulembu. The GCMs used in the study give biomass values of over 200 at Bulembu as indicated on Figure 4.3. In summary, both the biomass and basal

Figure 4.4: *Projected Size class distribution of eucalyptus at Bulembu in 2075*



area of exotic trees in plantations are projected to increase under climate change compared to the current climate scenario

4.2.6.4 Stem size

For all the exotic species used in the study it is projected that the stem size will be slightly lower under climate change compared to the present climate scenario. As expected, there will be a large number of individuals with a diameter that ranges between 0 and 10 cm followed by those with a diameter of 10 - 20 cm. Very few individuals with the larger diameter classes are expected in 2075.

4.2.6.5 Distribution and Growth of Indigenous trees

a)Biomass

The Global Change models indicate variations in biomass productivity in the four indigenous species assessed in the study. Also noted are the differences in the performance of the species in the different regions that are represented by the selected study areas.

In the case of *Combretum* the projections indicate the highest biomass at Mpisi followed by Mananga where the difference between the business as usual scenario and the scenario under climate change is highest. Projected biomass quantity for *Sclerocarya and Syzygium* are highest at Mananga. General indications from the projections are that *Pterocarpus and Combretum* will be the most negatively affected of all four species. This is particularly true at Siteki than Mpisi and Mananga.

The general reduction in biomass production in the four species could be attributed to the general increase in temperature, which could also cause an increase in potential evapotranspiration. Although climate change is likely to increase the amount of rainfall recieved, available water for plant growth will be low. Overall, *Combretum* seems to have the lowest biomass of all the four species assessed.

Examining the performance of each species, it is observed that *Sclerocarya* is likely to dominate over the other three species in all the regions. The effects of climate change on *Syzygium* are also not as pronounced whilst *Combretum and Pterocarpus* indicate a general decline in biomass production under both the business as usual and climatic change scenarios. This observation highlights the need for sustainable use and protection of the species whose future is uncertain.

Overall biomass production in indigenous forests is projected to decline under climate change with the highest decline at Mpisi and the lowest at Siteki. The only exception is the UKTR model which suggests an increase in biomass under climate change. The same applies with regard to the basal area of indigenous trees in the three study areas.

b) Stem size

The Global Climatic Models are projecting a general decline is stem sizes for *Syzygium and Sclerocarya* at Siteki compared to the current climatic scenario. This is particularly true for the 10 - 20 cm diameter class. At Mpisi, the GCMs are projecting a slight increase in the stem sizes of *Syzygium and Pterocarpus.*. At Mananga, there is no major difference between the current climatic scenario and the predictions of the GCMs in the number of *Combretum and Sclerocarya* trees in almost all the diameter classes, particularly in the classes 0 to 10 cm and 10 - 20 cm. Regarding *Combretum*, the pattern is not quite clear, especially when comparing the data from the three study areas.

Based on the results on indigenous trees, it appears that the existence of *Syzygium and Sclerocarya* trees is likely to be compromised by climate change, except at Mpisi or in the middleveld region. On the other hand *Sclerocarya and Syzygium* will be the least affected, particularly in the Lubombo region.

4.2.7 Adaptation

Apart from the effects of climate, managed forests and other ecosystems in the country are threatened by agricultural activities. Of major concern are small-scale (SNL) and large scale crop (TDL), extensive communal grazing (SNL), ranching (TDL) and some extraction and collection on SNL.

The expansion of settlements is another threat to ecosystems in the country. This is particularly true for the indigenous forests in the lowveld and lubombo regions and other ecosystems such as wetlands in the middleveld and highveld regions. Indigenous forests and wattle plantations are used as sources of firewood and construction timber both in the rural and urban areas. As such deforestation is another serious threat in the country.

Frequent, uncontrolled fires are also major threats to the maintenance of managed forests and other ecosystems in the country. In a study of indigenous knowledge practices in the country (Fakudze, 1998) forty five percent (45%) of the respondents attested to the frequent use of fire due to the opinion that fire has a positive impact on land in that it encourages regeneration of grass, increases in soil fertility and destroys pests such as ticks and mice.

Increased frequency of fires will contribute to a paucity of fire prone species such as grasses and trees whilst encouraging the growth of fire tolerant species. Policy guidance, amongst other controls, is a necessary tool to enable adequate preventative and adaptive actions that are key to sustaining the country's forest resource, especially in the light of an impending climate change.

Considering the paucity of information on the key parameters of indigenous trees in the country, there is need for research on these parameters in the country. This will enhance understanding of the impacts of climate change on the ecosystems in the country. Changes in plant distribution also need to be monitored on a periodic basis, especially in the protected areas where anthropogenic impacts are controlled.

4.3 HYDROLOGY AND WATER RESOURCES

4.3.1 Introduction

Water Resources constitute a major sector for climate change impact assessment for Swaziland due to the sector's importance in supporting the country's socio-economic development.

The objective of this study is to assess the extent and magnitude of impacts due to climate change on the country's water resources with a view to identifying viable measures for adaptation in order to minimize the anticipated impacts.

The study examines the performance of surface water, ground water and water quality under climate change conditions.

4.3.2 Baseline Scenario

4.3.2.1 Surface Water

Komati and Mbuluzi are the major basins that contribute to sugar cane irrigation The third basin of economic significance is the Usutu, which also supports sugar cane irrigation and hydro power generation. The two southern basins (Pongola and Lubombo) are smaller and relatively underutilised. All the rivers, with the exception of the Komati, Usutu and Lomati basins originate within Swaziland. Figure 4.5 shows the drainage basins in Swaziland.

Figure 4.5: Swaziland's Major Drainage Basins.

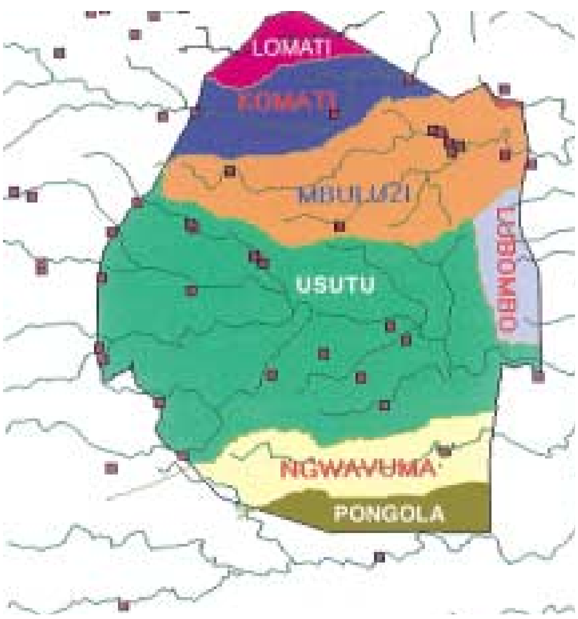


Table 4.10 illustrates the country's major drainage basins and their capacities. All the rivers, save the Lubombo flow from the west to the east and hence traverse the four physiological regions of the country. The catchment areas for the Usutu, Lomati and Komati basins include portions of the basins in the Republic of South Africa.

Table 4.10: *Major drainage basins of Swaziland and their corresponding hydrologic variables*

RIVER SYSTEM	AREA [km^2]	RAINFALL [mm]	INFLOW (naturalised) [x 10^6 m^3/a]	OUTFLOW (naturalised) [x 10^6 m^3/a]
Pongola		400 – 600	Nil	59
Ngwavuma	1305	600 – 900	Nil	156
Usutu	12903	600 – 1000	896(386)	2357(1356)
Mbuluzi	3065	700 – 1200	Nil	460(208)
Lomati[1]	931	900 – 1400	74(40)	249(118)
Komati[1]	7423	800 – 1400	688(515)	1239(520)
Lubombo		800 – 900	Nil	31
TOTAL		Mean =850	1809	4551(2448)

The inflows and outflows show that the runoff generated within Swazilnd is about **2706 million m³** of water per annum while the mean annual precipitation (MAP) is **850 mm** which is equivalent to **14800 million m³** of water per annum. This means only **18%** of the rain water is tranformed to runoff whilst the remainder could be lost through evaporation and to aquifer recharge.

4.3.2.2 Ground-Water

The country's ground water is an important resource that is of use especially in communities with very low water availability. There is an increase in demand and use of the ground water resource by communities in the rural and peri-urban areas particularly in the dry periods. Groundwater is also a source of stream flow especially during the dry winter months.

It is estimated that groundwater recharge ranges between 5 to 20 % of the average rainfall in Swaziland. It is also estimated that the ground water resource potential is equivalent to a sustained flow of about 21 m³/s.

The potential for groundwater resource is highest in the Highveld and Middleveld regions. Of this potential, only 6% of the ground water has been

Usutu river flowing through the highveld

tapped through existing boreholes which number about 1500. Average yield from the boreholes is about 1.4m/s, with others giving rates as high as 20 l/s. Most of the springs are concentrated in the Highveld and Middleveld regions.

4.3.3 Water Resources Development

Water resources development in the country has been enhanced by the construction of dams. The seven main dams in the country have a total capacity in excess of 230 million cubic metres (MCM). The Mnjoli dam is the largest man made lake in Swaziland with a capacity of 135 MCM. The ministry of Agriculture and Co-operatives is involved in small dams construction country wide to curb water shortages during dry periods.

To-date, about 500 small dams have been constructed impounding a total of about 130 MCM (Murdoch, 1997). The Maguga dam is currently under construction. Water from the dams is mainly to be used for power generation and irrigation. The major dams in the country are listed on table 4.11.

4.3.4 Current Water Demand

The demands for water in Swaziland are mainly for domestic, industrial and agricultural activities. Domestic and industrial water demand does not vary much with season. Since most of irrigated agriculture is practiced in the Lowveld where rainfall is generally low it follows that demands are high in this area particularly during the winter months. Table 4.12 illustrates summarised sectoral water demand.

Table 4.11: *Major dams and their storage capacities in the country*

Dam	*Capacity*	*Year*	*Purpose*
Mkikomo Weir	2.0	1963	Power Generation
Sand River	50.0	1965	Irrigation
Hendrick Van Eck	10.4	1969	Irrigation
Sivunga	6.9	1972	Irrigation
Mnjoli	135	1980	Irrigation
Nyetane	6.0	1983	Irrigation
Luphohlo	23.6	1984	Power Generation
Maguga (under construction)	332	2001	Irrigation

4.3.5 Irrigation Water Demand

The crops that are grown under irrigation are sugar cane, citrus fruits, pineapples, vegetables and corn. It has been established that about 70 000 ha of land is under irrigation in the country. Most of the irrigation activities are located in the Lomati catchment (Ngonini Estates), the Lowveld part of the Komati river (sugar cane), the Lowveld part of the Mbuluzi river (Simunye, Mhlume, Tambankulu sugar estates), Middleveld and Lowveld part of the Usutu river (Ubombo Sugar, Big Bend, Malkerns) and the lower part of the Ngwavuma river.

It is estimated that the irrigation water demand is about 1734×10^6 m^3/year compared to amount of 4270×10^6 m^3 of water leaving Swaziland per annum. After some allowance for use by South Africa and Mozambique it is estimated that some 2670×10^6 m^3/year could still be retained in storage facilities. This could mean that there is enough water to meet current and future irrigation water demand. However, it should be noted that the flow in most rivers is low during the winter months and it is during these months that water is critically required to sustain crop growth.

The need to expand the irrigation acreage is also there as crop production expands. However, due to water scarcity especially in the Mbuluzi catchment, the demand cannot be met. As a result some companies like Simunye sugar company are changing their irrigation water application method from sprinkler to sub-surface irrigation. It is anticipated that this will increase water use efficiency and the saved water could then be used for irrigating new areas ,or be made available for downstream users as well as for the sustainability of the river environment.

The current Maguga dam construction came about as a result of water scarcity in the Komati river. It is anticipated that the dam will stabilize the flow regime down stream the reservoir. Various other water development activities are also proposed for the Usutu river.

Dam construction site over the Komati River (Maguga Dam)

4.3.6 Industrial And Domestic Water Demand

Urbanization and industrial growth is rapidly taking place in Swaziland with major industrial activities in Matsapha and Mbabane. Population growth is creating an increase in domestic and industrial water demand. Migration of rural population to urban centers is also putting pressure on the water demand. It should however be noted that most of the urban centres are served with clean portable water in contrast to only 40% of the rural population.

Rainfall, and hence the water resource, is naturally unevenly distributed in both time and space and this is the case with Swaziland. While the Highveld and Middleveld including Lubombo regions enjoy enough water especially during the rainy season the Lowveld faces water scarcity related problems. This situation calls for proper water resources planning in future in order to adequately meet demands of all the regions.

Table 4.12: *Current Sectoral Water Demand in Swaziland*

PURPOSE	DEMAND ($x 10^6$ m^3/a)	% of TOTAL DEMAND
1. DOMESTIC	30	1.7
2. STOCK FARMING	14	0.8
3. INDUSTRIAL	17	0.9
4. IRRIGATION	1734	96.6
TOTAL	1795	100.0

4.3.7 Water Quality

Industrial activities in major cities and in sugar cane estates are a major concern as far as water pollution in the country is concerned. Leachate from improperly managed solid waste disposal sites in urban and industrial sites do find its way into natural water courses.

Accidental spillages of toxic substances like phenol liquors at times do occur. This pollution threatens biodiversity and is also a health hazard to human beings downstream. Due to intensive agricultural activities the sediment yield is affected in the catchments resulting in poor water quality.

Water pollution monitoring is being conducted by the water resources branch at all major rivers and at all industrial and municipal effluents. It has been established that the agro-industrial and industrial effluents from some industries in Matsapha area have shown an increase in COD and phenol. Cross-border effluent pollution from the Republic of South Africa has on occasions been witnessed, especially on the Ndlotane river.

The lowest concentration of dissolved solids is found in the rivers of the Highveld and the concentration increases to about 150mg/l in the Lowveld.

Best quality water is found in the basement aquifers of the highveld while the worst is in the Lowveld. This is because of the groundwater stagnant conditions in the Lowveld while there is groundwater movement in the Highveld and Middleveld due to gradients resulting from the mountainous topography towards discharge points by springs.

On the average groundwater quality meets the WHO recommended drinking water guidelines. However, there are isolated areas with high concentrations of fluorides and nitrates. Groundwater with high concentration of salts are found in the Lowveld where evapotranspiration rates are high and the rate of ground water recharge is low due to low rainfall in this region. Fluoride concentration ranges from 0.1 mg/l to 18.4 mg/l and nitrate concentrations are up to 45 mg/l.

4.3.8 Usutu Drainage Basin

This study focuses on assessing climate change impacts on the Great Usutu river. This basin is of great socio-economic importance to the country because about three quarters of the population of Swaziland living within and being supported through it.

Apart from this fact this catchment was selected for the impact assessment because it is fairly representative of a large part of the country. The current water demand in the catchment is estimated to be 266400 m^3 per day which is equivalent to 0.0222 mm/day.

4.3.8.1 Data Requirement

The assessment of the impact of climate change in water resources requires the utilisation of a various data types. The required input data are hydrological (streamflow, sediment load discharge etc.) and meteorological (precipitation, air temperature, windspeed, evaporation, humidity, air pressure, solar radiation, sunshine hours etc.)

Stream flow data are available for a period more than 30 years in many of the gauging stations. The data series is not continuous throughout the base period due to data gaps arising from siltation of the stilling well and as a result of destruction in 1984 by tropical cyclone domonia. Likewise gaps also exist in the Meteorological data series. The Hydrological and Meteorological data were obtained from the Water Resources Branch and the Department of Meteorological Services respectively.

The streamflow gauging station at Siphofaneni (GS 6) was selected as the catchment outlet for the Usutu river basin. Data from this station covers the period 1958 to 1982 with two years discontinuity after cyclone domonia. The other data (precipitation and potential evapotranspiration) were made to cover the same period.

The rainfall information that was used in this project was from the following stations: Siphofaneni, Mankayane, Malkerns and Mbabane. A representative station for the Usutu catchment was developed using the arithmetic mean method.

Potential Evapotranspiration Data from Malkerns weather station was used as a representative station for the Usutu catchment. Data, gaps were patched using the method of interpolation. A regression analysis between potential evapotranspiration and average temperature was developed (1964 to 1982). The regression equation that was obtained was used to determine the potential evapotraspiration values for the period from 1963 to 1969. This was done in order to increase the data record length (1963 to 1982). Potential evapotranspiration values could not be extended to 1958 due missing average temperatures.

4.3.9 Methodology

The greenhouse gases effect is expected to cause global warming which in turn will cause changes in average annual precipitation. Generally it is expected that floods now considered rare would occur more frequently in certain regions while drought related and competing water use issues will intensify in other regions (Miller, 1989; Schaake, 1989).

General circulation models provide physically based predictions of the way climate might change as a result of increasing concentrations of atmospheric carbon dioxide and other trace gasses. The GCM's are mathematical representatives of the earth's climate system, and they simulate atmospheric processes at a field of grid points that cover the surface of the earth. The outputs of these models are: temperatures and precipitation values.

4.3.9.1 Hydrologic Models

A model is a conceptualization of a real system that retains the essence of that system for a particular purpose. Every model is an attempt to capture the essence of the complex nature in hydrologic modelling in a manageable way but it is important to recognise that this conceptualization also involves a considerable degree of simplification. Anderson and Burt (1990) contend that, "all models seek to simplify the complexity of the real aspects of a system at the expense of incidental detail"

A model must remain simple enough to understand and use , but complex enough to be representative of the system being studied. There are many hydrologic models in the literature (Singh, 1995; Anderson and Burt, 1990; Schulze, 1984; Hughes and Sami, 1994; Pitman, 1973).

For the purpose of evaluating the impact of climate change on water resources, the models that are in use usually operate in simulation mode. A river-basin-monthly water balance model is recommended as the primary approach for assessing climate change impacts on river runoff (IPCC, 1996).

The CLIRUN set of models is the standard water balance tool selected for Country Studies Programme (IPCC, 1996). The WATBALL model developed by Yates (1994) is one of the CLIRUN sets of models and was used in this study.

4.3.9.2 Watball Model

WatBall is a lumped conceptual integrated rainfall runoff model. It has two major components which are: (i) A water balance which describes the water movement into and out of a basin (ii) The computation of potential evapotranspiration (however, potential evapotranspiration can be input directly).

The water balance is written as a differential equation involving input and output, where storage is lumped as a single conceptualised bucket with the components of discharge and infiltration being dependent on the relative storage which is expressed as follows:

$$S_{max} [dz(t)/dt] = P_e(t) - R_s(z,P_e,t) - R_g(z,t) - R_b - E_v(z,PET,t)$$

Where, S_{max} is maximum water holding capacity (mm); P_e is effective rainfall (mm/day); R_s is surface runoff described in terms of storage, precipitation over time; R_g is the ground water flow (mm/day); R_b is baseflow (mm/day); E_v is actual evaporation which is a function of potential evapotranspiration (PET), relative catchment storage (z) and time (t in days).

The model contains five parameters which are: direct runoff; surface runoff; subsurface runoff, maximum catchment water holding capacity and base flows.

WatBall accounts for changes in the soil moisture by taking into account precipitation, runoff, actual evapotranspiration while using potential evapotranspiration to derive the extraction of water from the soil strata. It has been established that, any estimate of climate change impacts on water resources depends on the ability of the model to relate changes in actual evapotranspiration to predict changes in the runoff in the stream.

WatBall has been found appropriate for the estimates of the impact of climate change on water resources because it meets the above criteria. Secondly it requires less input parameters compared to other hydrologic models.

4.3.9.3 Application of Watball Model to the Usutu Catchment

The WatBall model has been applied to the Usutu river for the evaluation of the effect of climate change on the water resources in the basin. There are two stages in the application of a rainfall runoff model, that is calibration and verification.

During the calibration stage the model parameters are adjusted by trial and error process till the model closely reproduces the observed stream flow. Ten years of monthly flow data was used during the calibration stage (January 1963 to December 1972).

Figure 4.6: *Simulated and observed stream flow at GS6 during calibration (1963-1972)*

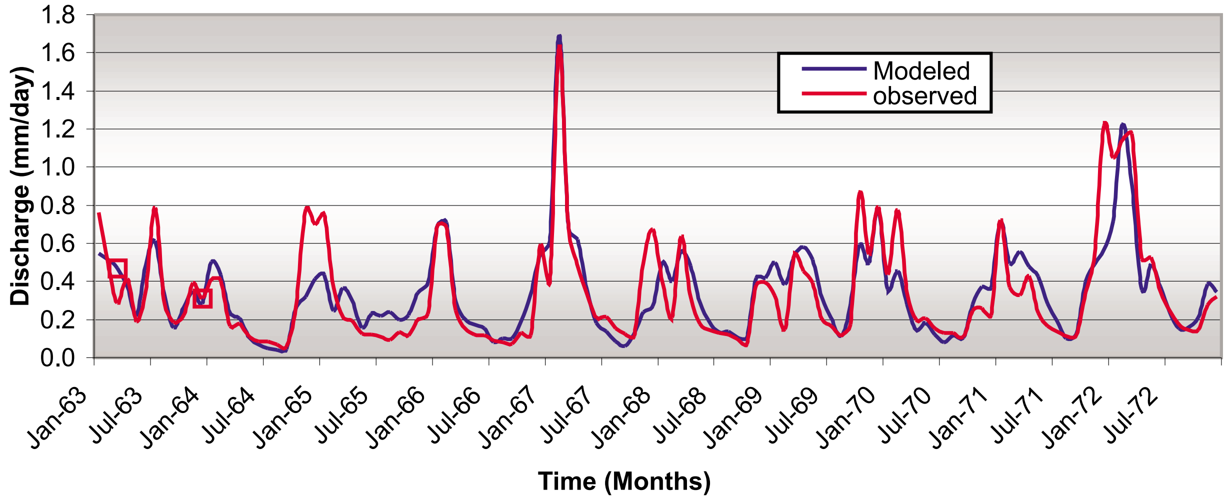
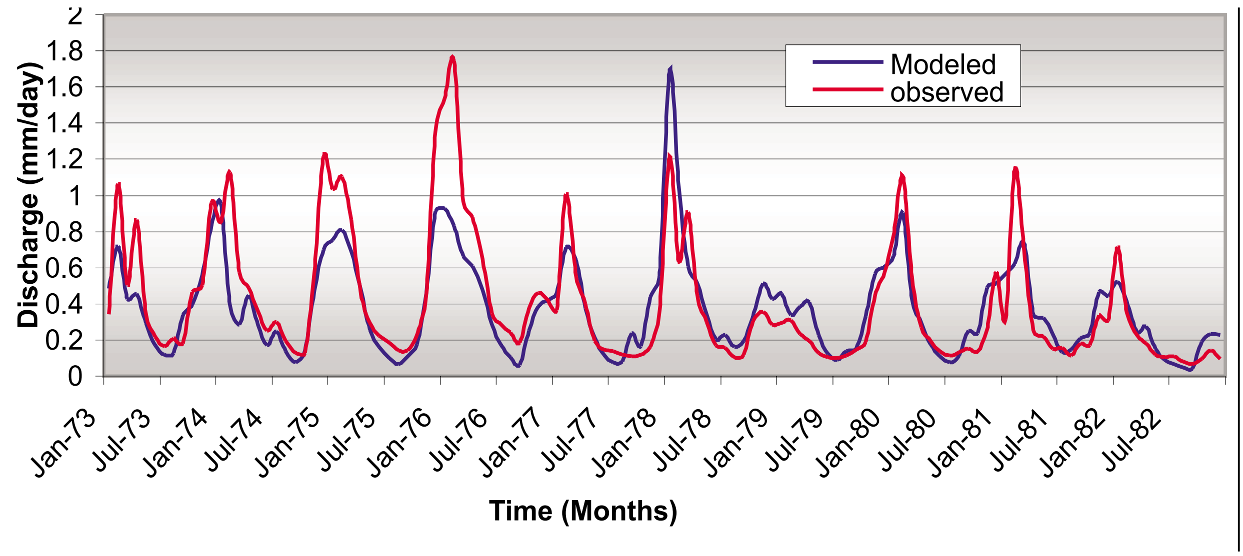


Figure 4.7: *Simulated and observed stream-flow at GS6 during Validation (1973 to 1982)*



Model verification on the Usutu drainage basin was performed using monthly stream flow data for the years from January 1973 to December 1982. Other input variables such as rainfall and potential evapotranspiration also covered the same period. Figures 4.6 and 4.7 show the hydrographs of simulated and observed stream flow for calibration and validation respectively.

The WatBall model was also calibrated for the wettest years, driest years and average years. That is, average daily monthly values were used in this exercise. Table 4.13 shows the optimal model parameters for wet years, dry years and the average or normal year.

The above model parameters for the wet years (1969, 1971, 1972, 1973, 1976 and 1978), dry years (1964, 1965, 1968, 1970 and 1982) and the average year were used to simulate the flow given the results of the GCM models (that is predicted precipitation, temperature and thus potential evapo-transpiration).

The developed regression equation between temperature and potential evapo-transpiration was used to predict the potential evapo-tanspiration for year 2075 given the predicted temperatures by GCM models.

4.3.10 Results of the effect of climate change on water resources

The response of the Usutu river to climate change has been evaluated using GCM models which are; the Geophysical Fluid Dynamics Laboratory (GFDL), the United Kingdom Transient Resalient (UKTR), and the Canadian Climate Change Equilibrium (CCC-EQ).

The selected models were used to simulate the temperatures for Swaziland. All the models well simulated the observed temperature values. They therefore, have been found the ideal choice for simulating future climate scenarios for the country.

Results of these GCM models (temperature, rainfall changes and potential evapotranspiration for year 2075) were used as input to the calibrated WatBall model to forecast stream flow for Usutu for the wet years, dry years and the average years forthe year 2075 without taking into consideration water abstractions.

The results of the runoff simulations are shown in Figures 4.8, 4.9 and 4.10 for dry , normal and wet years respectively. It can be seen from Figure 4.8 that the forecasted flows with inputs derived from the GCMs for the months of October to December are higher than the current observed flows. There after all the forecasted flows are lower than the current observed stream flows for the rest of the months.

The three simulation results show that the forecasted flows are higher during the early summer months (October to January) and lower during the late summer and winter months (February to September). This implies that the country could experience high flows during the early summer months and low flows thereafter. This is due to the fact that the expected climate change will bring high temperatures and therefore, high evapotranspiration and thus low flows during the late summer and winter months.

Figure 4.8: *Simulated and observed stream flow for Usutu river (Dry years)*

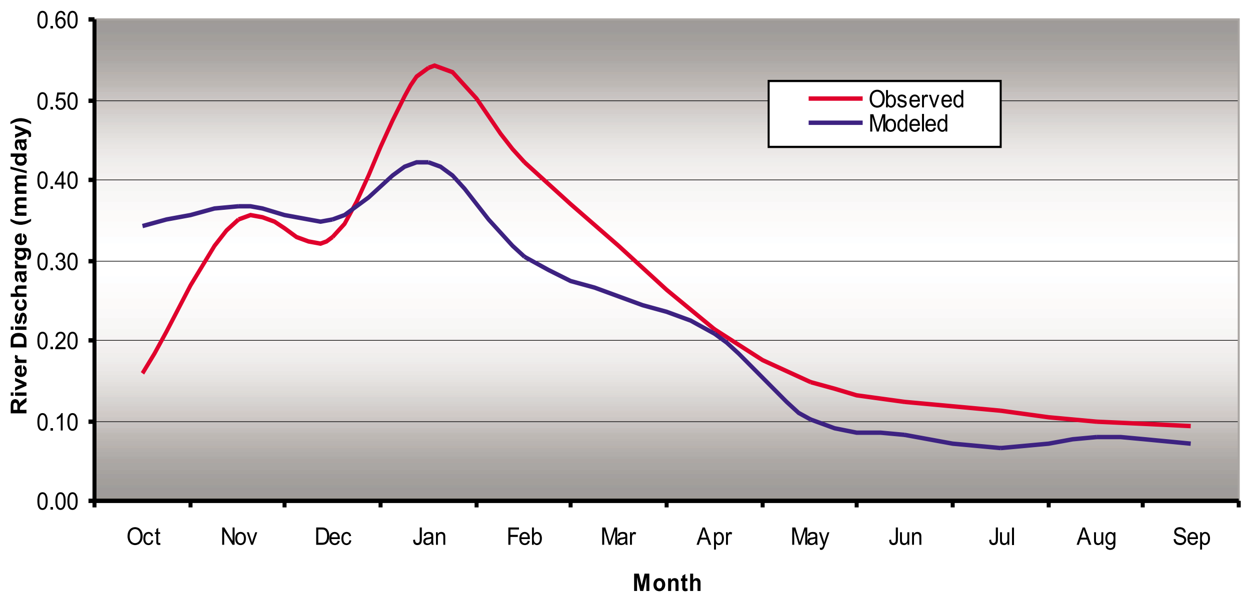


Figure 4.9: *Simulated and observed stream flow for Usutu river (Normal years)*

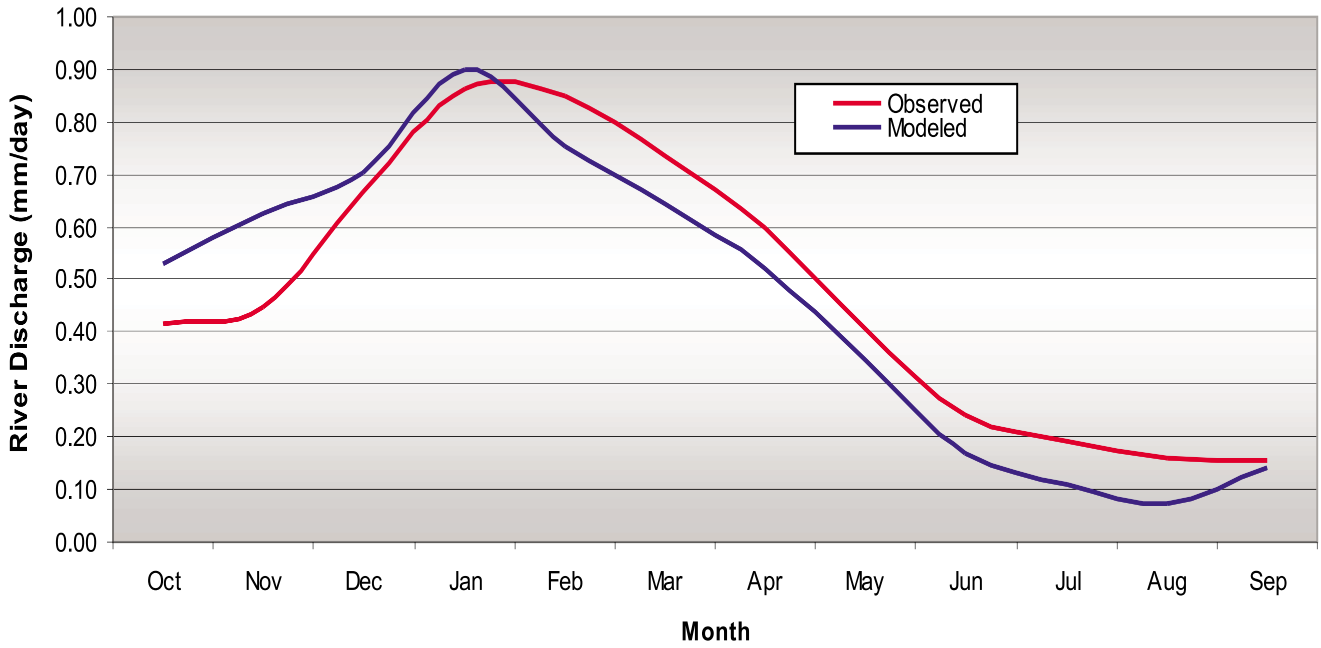


Figure 4.10: *Simulated and observed stream flow for Usutu river (Wet years)*

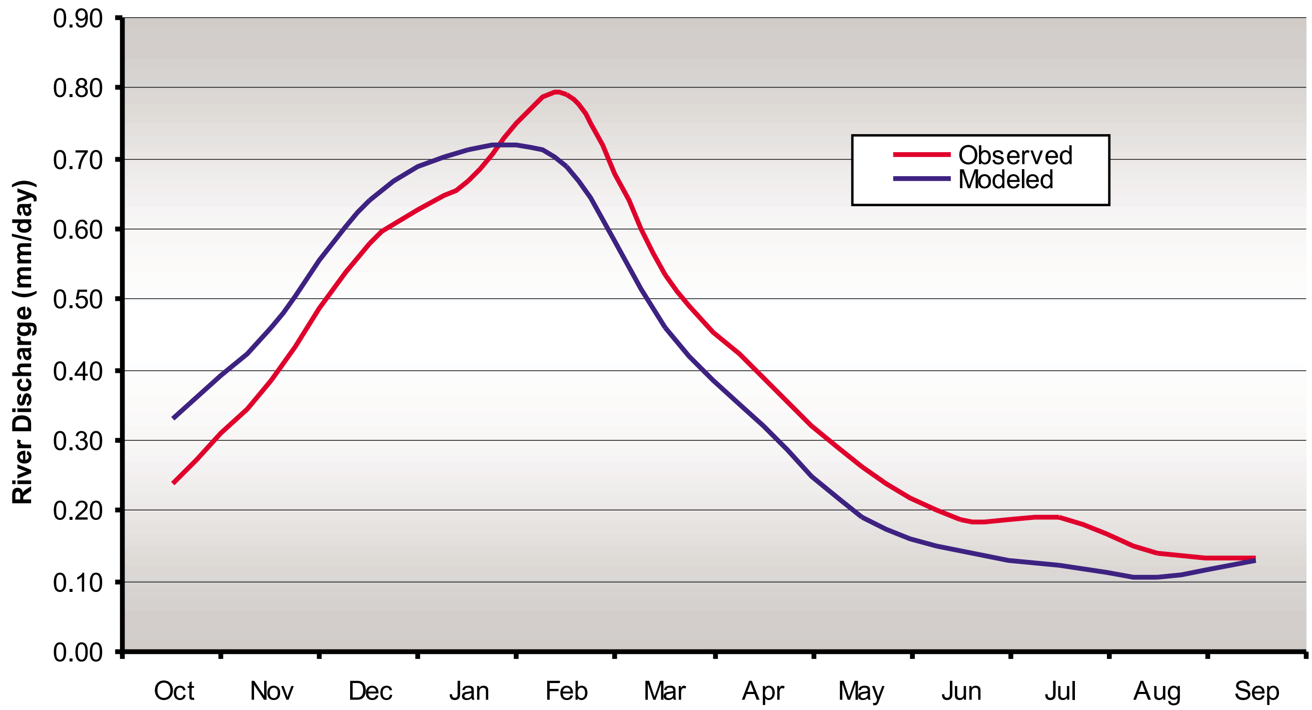


Figure 4.11 shows the % annual runoff change for all the GCMs under dry, normal and wet scenarios for all of the climate change scenarios (Low, Medium and High). The interpretation is that the high annual runoff change (Reduction) occurs during the dry scenario under almost all the climate change scenarios (Low, Medium and High) followed by the normal and the wet scenario.

Figure 4.11: *Average Annual runoff change for Usutu river under different scenarios (%)*

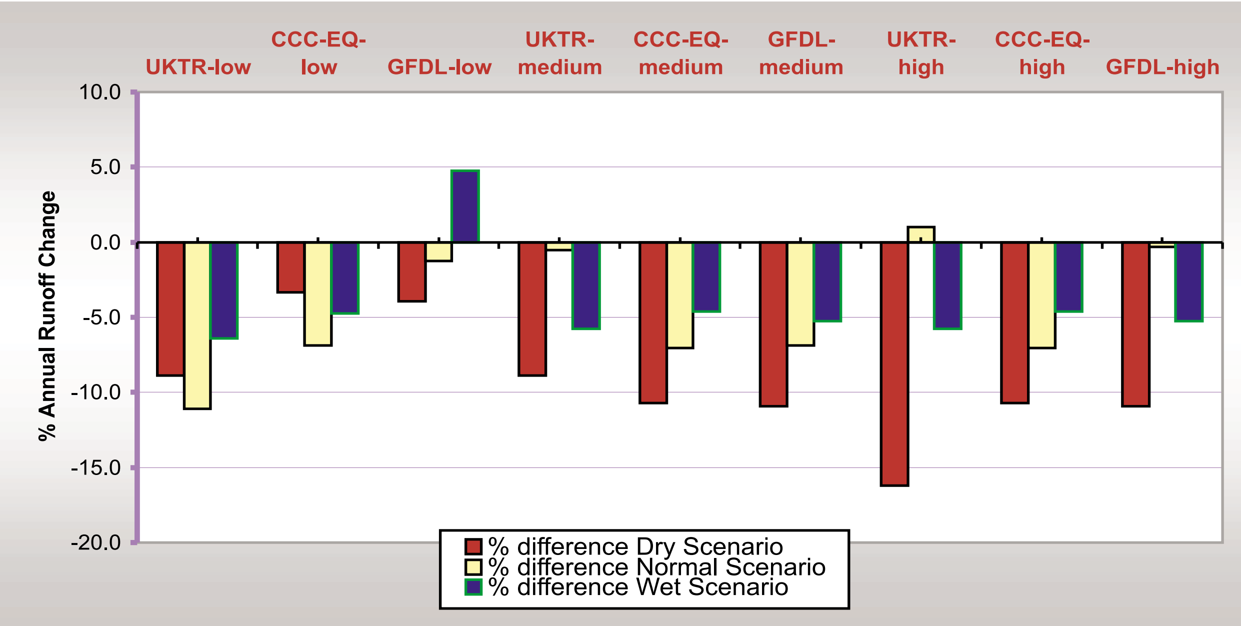


Figure 4.12 shows the average of GCMs % annual runoff change for dry, normal and wet scenario for all the climate change scenarios (Low, Medium and High).

The projection therefore, shows a maximum reduction in annual runoff of 12.6% in the Usutu river under climate change conditions which is equivalent to 133.6 million cubic meters (11.35 mm per year).

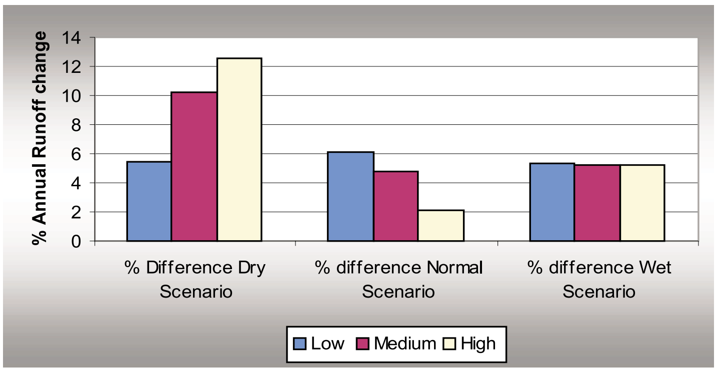
When this maximum % annual runoff reduction is applied to all the catchments in the country, the predicted annual runoff reduction becomes 350 million cubic meters which is approximately the size of Maguga reservoir.

4.3.11 Interpretation of Results

The models' stream flow future projections point to highs and lows during the summer and winter months respectively under climate change conditions. Currently the country is experiencing flooding related problems during summer months of wettest years and drought related problems during years with low flows. Therefore, flooding and drought related problems are likely to prevail during the summer and winter months respectively.

The combined effect of high temperatures and low runoff especially during the winter months could adversely affect groundwater recharge particularly in the Lowveld. Therefore, the present salinity of groundwater could be worsened due to the reduced groundwater recharge and high evaporation rate. The low flows during the winter months have the potential to affect negatively the riverine ecological system.

Figure 4.12: *Average GCMs annual runoff change for Usutu river (%)*



Simulation results have shown a possible water reduction of 12.6% which is equivalent to 133.6 million cubic meters. Therefore, if nothing is planned for the development and management of the water resource, water shortage related problems could prevail by year 2075.

The economy of the country is based on agricultural activities (agro-based economy). The enumerated changes could negatively impact on rain fed and irrigated agriculture, hydropower generation, livestock and other social economic water uses. The water shortage for domestic use will cause poor sanitation conditions and thus the outbreak of diseases. The country therefore could be forced to import food and medicine. The drought conditions will also impact negatively on the biodiversity of the country.

4.3.12 Adaptation options

The flow regime of any river is greatly influenced by human activities particularly land use. Overgrazing which leads to land degradation is emerging as a problem in the country. Poor farming practices also lead to land degradation.

The time horizon of the change that might occur (increased or reduced precipitation) is similar to the time required for planning, approval, funding, construction and economic life of water resource projects (dams, irrigation canals, drainage systems etc, (Schaake, 1989)). Therefore, mitigation strategies should make sense regardless of the direction and magnitude of change.

It has been established that Swaziland could experience a reduction in stream flows under all scenarios (wet, dry and average year) given climate change. Therefore, in view this the vision for water resources planning, development, operation and management demands the development of policies and strategies that will promote for the growth of water in the future. Adaptation strategies should be directed at developing robust water resource systems as well as techniques to incorporate climate change uncertainties into the long-term planning.

A reduction in annual runoff of the order of 134 million cubic meters has been established in this study for the Usutu catchments and 350 million cubic meters for the whole country. Inter-basin water transfers in the country is not a viable option due to over commitment of the available water resource within each basin.

4.3.12.1 Water Conservation

It has been established that there could be a reduction in runoff under climate change conditions. Therefore, water use sectors will have to adapt to the meagre resource that will be available. It has been assumed here that there will be no significant water savings from industrial and domestic water use, currently at 4% of the total water demand. The major consumer of water in the country is irrigation and at 96%. It is expected that large savings in water will come from efficient use of irrigation water.

Currently the land that is under irrigation in the Usutu catchment is estimated at 15000 hectares. The acreage that is under furrow, centre pivot and drip system presently is assumed to average to sprinkler system. The water demand for sugar cane under sprinkler irrigation system is 1400mm per year per hectare.

With technological advancement there might be more efficient irrigation systems in the future. A 20% water saving could be realised by switching from sprinkler to drip irrigation system. This water saving translates to 280mm per hectare per year. Water that will be conserved in the Usutu catchment by the use of drip irrigation system therefore amounts to 42 million m^3 per year. This will leave a water deficit of 92 million m^3 per year. This water deficit will have to be provided for by the construction of a water storage facilities and other related means.

4.3.12.2 Dam Construction Cost Estimates

The cost estimates for construction of a dam in Usutu catchment in order to meet water demand due to anticipated climatic changes has been derived from the cost estimates for the construction of Maguga dam. The cost for the construction of the Maguga dam is currently at 1.2 billion Emalangeni (US $ 150 million). The Maguga dam will impound 330 million m^3 of water. The cost of a Dam in the Usutu catchment that will impound 90million m^3 could therefore cost 327 million Emalangeni ($ 40 million) today.

Other water resources adaptation options that are possible for Swaziland in order to deal with the effects of expected climatic changes are as follows:

4.3.12.3 Modification of the existing infrastructure

i. Supply adaptation (installing canal linings, changing location of water intakes, using grating separate reservoirs into a single system,using artificial recharge to reduce evaporation)

ii Construction of new infrastructure (reservoirs, hydroplants, delivery systems.

iii Alternative management of existing water supply systems (change operating rules, use conjunctive surface/groundwater sup ply, change priority of releases, physically integrate reservoir operation system, co-ordinate supply/demand)

4.3.12.4 Demand adaptation

i. Conservation and improved efficiency

ii. Domestic (low-flow toilets, low-flow showers, re-use of cooking water, more efficient appliance use leak repair, commercial car washing where recycling takes place, rainwater collection for non-potable uses)

iii. Agricultural (night time irrigation, lining canals, closed conduits, improvements in measurements to find losses and apply water efficiently, drainage re-use, use of wastewater effluent, better control and management of supply network.

iv. Industrial (re-use of acceptable water quality, recycling)

4.3.12.5 Technological change

i. Domestic (water efficient toilets , water efficient appliances, landscape changes, dual supply systems, recycled water for non-potable uses)

ii. Agricultural (low water use crops, high value per water use crops, drip, micro-spray, low-energy, precision application irrigation systems, salt tolerant crops that can use drain water, drainage water mixing stations)

iii. Industrial (dry cleaning technologies, closed cycle and/or air cooling, plant design with reuse and recycling of water imbedded, shift the type of products manufactured)

iv. Energy (additional reservoirs and hydropower stations, low head run of river hydropower, more efficient hydropower turbines)

v. Market/price-driven transfers to other activities

vi. Using water price to shift water use between sectors

4.3.12.6 Land Use Management

Land use is the major factor that affects the runoff in a stream. Therefore, there is a need for the implementation of good land use practices in the country in order to conserve the water resource. This will require the change of attitudes of the people in animal herding and land husbandry principles and strategies. This is very important for the conservation of the water resource for the present and future generations.

4.3.12.2.7 Promoting Regional Partnership

Almost all rivers in Swaziland are international rivers. Therefore, there is the need to establish partnership in the utilisation of international waters through:

The implementation of the protocol on Shared Watercourse Systems in the SADC Region and other bilateral agreements for the benefit of the country through the implementation of joint water resource project between Swaziland South Africa and Mozambique.

Encouraging and stimulating partnership within the context of SADC in conformity with the international Law of the Non-Navigational uses of International Watercourses.

4.3.13 Conclusions

The impact of climate change on water resources in the Usutu river basin has been evaluated using WatBall model. Model parameters were determined during the calibration stage using two sets of 10 years of daily time series data (rainfall, stream flow and potential evapotranspiration).

The results of three GCM models were used in simulating the stream flow of the Usutu catchment in year 2075 for the wet, dry and average year for the natural conditions. All the GCM models are simulating high and low stream flows during summer and winter months respectively. Simulation results in this study are in agreement with the results of other studies that have been conducted in the Southern African region (Schulze and Perks, 2000).

Results of the study suggest that the country could experience high and low flows during summer and winter months respectively under climate change conditions. The overall water deficit under climate change conditions has been estimated to be 134million m^3 per year. Water saving through efficient irrigation water application systems has been estimated to be 47million m^3 per year. A water storage facility is therefore, needed to provide 87million m^3, the cost estimate of which has been estimated.

Harvested grapefruit at Swazican, Malkerns used for fruit juice processing

4.4 AGRICULTURE

4.4.1 Introduction

The agriculture sector plays a very important role in national development in Swaziland, and is one of the leading sectors contributiing to the GDP. The important crops grown in Swazi Nation Land (SNL) are maize and cotton, while in Title Deed Land (TDL) they are sugarcane, cotton and citrus. Crops grown in TDL are mainly for export, while those in SNL are mainly for subsistence purposes, with the exception of cotton, which is a primary source of income.

The agriculture sector is very prone to weather effects and climatic fluctuations. It was hit hard by the drought of 1992. Climatic modelling has shown that on the whole there will be chances in the weather and climatic pattern. Most models show that there will be progressing changes in both precipitation and temperatures in Swaziland in the next 75 years The months of March/April/May (autumn) are projected to have highest increases in precipitation. On average all the months will become warmer. Climatic change will have an implication on crop performance and hence on the yield.

Diseases also become prevalent under high temperatures and moisture content. Atmospheric carbon dioxide content is also expected to double by the year 2075 unless there are interventions to reduce its emission. This chapter attempts to assess the performance of maize, beans, sorghum and other crops under climate change conditions in Swaziland.

4.4.2 Baseline Information

4.4.2.1 Crop production in Swaziland

In 1990/90, the agricultural sector accounted for E135 million or 13.5% of GDP. Of this total, 22% was accounted for by maize and cotton production on Swazi Nation Land, 60% by sugar, citrus and pineapple production on Title Deed Land, and the rest by livestock (Swaziland Government, 1994a).

Agriculture and forestry establishments remain the largest employers offering about 35% of the formal private employment. The figure is even higher when considering the informal sector employment that includes family workers, small-scale traders and private homesteads.

About 11% of the land in both SNL and TDL are used for cropping and this area is gradually increasing. As an example in 1981, 142,426 ha was under cultivation while in 1991 the area under cultivation had increased to 195,000 ha (Swaziland Government, 1992). The practice of fallowing in croplands has been decreasing due to the increase in population leading to higher demands for cropped land.

Subsistence farmers generally carry out agricultural activities on SNL. They tend to diversify their production of crops by growing a mixture of maize and other crops such as jugo beans, groundnuts, and Irish potatoes in the same field. These farmers often sell their produce only when financial needs dictate and most yields are consumed by residents of the adjacent homesteads. A large part of the SNL is under maize production, which is the staple food of Swaziland.

Sugarcane is the leading crop in TDL and it is the main source of foreign exchange for the country. The value of export of sugar was 25% of the total national export in 1992 (Swaziland Government 1994b). Maize remains the most important crop on Swazi Nation Land (Table 4.13).

The country has however never been self-sufficient in maize production, and consumption needs have always been satisfied by imports. The total national cereal national cereal requirements for 1991/92 were estimated at 223,000 tones of which 127,000 tones were maize. The self-sufficiency rose from 42% in 1991/92 to 59% in 1992/93 (Swaziland Government, 1994a).

A higher maize output of 153,000 tonnes was achieved in 1991 while the lowest, at 30,000 tonnes was achieved in 1983. The 1992 harvest of 46,000 tonnes was the second lowest of all years.

Table 4.13: *Area under major crops in the 1994 - 95 cropping season*

CROP	WHOLE COUNTRY (ha)	SNL (ha)	TDL (ha)	TOTAL PRODUCTION (m tons)
Sugarcane	37,000	-	37,000	3797749
Citrus	3,660	-	3,660	59000
Cotton	26,652	10,652	13,000	6200
Maize	58,787	54,757-	3,630	71390
Irish potatoes	107	-	107	5804
Pineapple	1,480	-	1,480	19656
Rice	249	-	249	-
Beans	4,771	4,166	605	2064
Tobacco	289	194	95	20
Groundnuts	3,041	3,041	-	297
Sorghum	147	147	-	62
Sweet potatoes	2,386	2,386	-	2064
Jugo beans	2,453	2,453	-	120

source: Swaziland Government

4.4.2.2 Sensitivity to climate

Agricultural production in Swaziland is very sensitive to climate and climate variation. The fluctuations in yearly crop and livestock production are mostly due to inter-annual variations in weather (Table 4.14).

The different crops are sensitive to climatic-related elements. As for example when temperatures fall below 21 °C sugarcane growth fails. If the temperatures are too low the sucrose content for the sugarcane is also low. Crops like cotton will not tolerate heavy rainfall. The rainfall in Swaziland is sporadic and there are often prolonged periods of drought. This leads to the dying of cattle in the lowveld, which is most prone to drought.

4.4.2.3 Maize

Maize forms the stable diet, and it is the most common crop grown in Swaziland. The present area under maize production stands at 58,787 ha with 93% of the area (54,757 ha) under Swazi Nation Land (SNL). However maize production in the country does not meet the demand and this leads to importation of large proportion of the required maize and maize products.

Maize grows well on a wide range of soil types throughout Swaziland provided the pH of the soil is around 5.0, but prefers deep, well-drained soils. Rainfall in excess of 760 mm during the growing season is necessary for full development. The maize crop is very sensitive to water shortages, particularly at tasselling and silking and does not yield well if distribution is irregular.

Table 4.14: *Climatic thresholds of Swaziland crops*

Crop Type	Temperature limits	Moisture limits	Growing season
Sugarcane	Optimum temperature for sprouting is 32-38 °C Below 21 °C growth is slow, or fails.	At least 1500 mm of rain needed per annum.	16-16 months duratior
Citrus	Will withstand light frost for short periods only Growth activity is reduced below 13 °C Can withstand temperature of over 38°C	Average annual rainfall of 875 mm required High atmospheric humidity increases incident of pests and diseases	Perennial crop
Maize	21-30 °C at tasselling 18-21 °C for germination	450-600 mm	October to April Growing season is normally 4 months
Pineapple	Cannot tolerate frost Optimum temperature of 20-36 °C.	Can tolerate drought Wide range of rainfall (635-2,500 mm)	Perennial
Cotton	34 °C for germination 24-29 °C for growth 32 °C for later continuous growth	1,000-1,500 mm rainfall Will not tolerate heavy rains	October to April
Tobacco	21-27 °C	Minimum of 250 mm rainfall needed Continual rain during growing season leads to diseases	October to April
Banana	Mean monthly temperature of 27 oC is optimal Temperature below 21 oC result in reduced growth	2,000-2,500 mm rainfall, well distributed	8-16 months
Groundnuts	Killed by frost	At least 500 mm rainfall	October to March

Tusseling maize crop - the staple diet.

The Lowveld areas are considered marginal for maize production, unless irrigation is available. Maize is also sensitive to extreme temperatures. Too cold (highveld winters) inhibit growth while too hot (Lowveld summers) shorten the life of the plant and interfere with pollination.

The optimum period for maize plantation is after the first spring rains in October through mid November. Early planted (August-September) maize is liable to maize streak. Late planted (December-January) is also susceptible to streak, drought and witchweed. Out of the harvest of about 3000 kg /ha a farmer can lose 50 kg/ha/day by planting after the end of October. Maize planted at the end of December rarely yields more than 250 kg/ha. Hybrids will always outyield open pollinated varieties by as much as 750 kg to 1500 kg/ha, but new seed, which is expensive, must be brought each year.

A farmer who rarely exceeds 500 to 1000 kg /ha will gain no advantage from planting expensive hybrid seeds because other husbandry input require improvement as a priority. Open pollinated (local selections) may mature in 130 to 200 days, while some hybrids may mature in as little as 100 to 110 days.

4.4.2.4 Sugarcane

There has been an increase in sugarcane production in the country with farmers in SNL growing it. All the cane cultivated in the country is under irrigation, and the sugar industry is therefore able to better cope with drought situations. The sugarcane is planted mainly in the lowveld and lower middleveld where temperatures are optimal. Export represents about 82% of the total sugar. For the current base period the country produces an average of about 3807000 tones of sugarcane per annum.

4.4.2.5 Citrus

The citrus industry produces grapefruits, oranges, soft citrus and lime. Seven estates whose activities fall under the auspices of the Swaziland Citrus Board produce the fruit. About 60% of the fruit are exported.

4.4.2.6 Cotton

Cotton is grown on about 27,000 ha in the whole of Swaziland, with 11,000 ha being in the SNL. High yields for cotton can only be obtained where seasonal temperatures are high and with plenty of sunshine. Growth is poor above 800 m altitude. Cotton tolerates drought but is particularly susceptible to waterlogging. Only hybrid cottonseeds are grown in the country (Albacala 72 and Deltapine). Cotton can only be planted after the legal planting date (October), which has been set to control diseases and pests.

4.4.2.7 Beans

Beans are adapted to a wide range of climate conditions but do not yield well under extremes of temperature. Hot, dry wind during flowering can cause severe blossom drop and may shrivel mature pods. Beans are often killed by frost. Similarly cool, wet-seasons are highly unfavourable because beans are easily injured by excessive moisture, and are subject to attack by diseases which thrive under such conditions.

The optimum amount of rainfall is 400 to 500 mm of rain, well distributed over the growing season. Beans are very susceptible to drought, particularly during flowering and pod set which normally takes place 6 to 9 weeks after planting. Irrigation is required where plantings are recommended outside the seasonal rain (October to March). The following are recommended planting seasons:

Highveld: October - February

Middleveld: August - September: January - March

Lubombo: September - October: February - March

Dry Middleveld: January - March

Lowveld: February - August

There are several bean varieties with varying length of maturity. Contender has a short growing season of 110 days, while Speckled Sugar, which is the most popular type matures unevenly in 120 - 140 days. Brown Haricot is a long season variety that matures in about 150 days. About 2000 tones of beans are produced annually in the current base period.

4.4.2.8 Pineapples

Pineapples are grown in the middleveld by the company Swazican on its own land and on leased land, and to a lesser extent, by farmers on Swazi settlement scheme. In addition, Swazican imports some pineapples from the Republic of South Africa.

Sorghum stalks

4.4.2.9 Sorghum

Sorghum grows best with rainfall of 650-900 mm. It is more drought resistant than maize. Sorghum is very sensitivity to soil acidity and no crop will be obtained if the pH is less than about 4.0. There are hybrid sorghum varieties (e.g. NK 300 and D036) as well as open pollinated varies (Red Swazi and Ntuli Red).

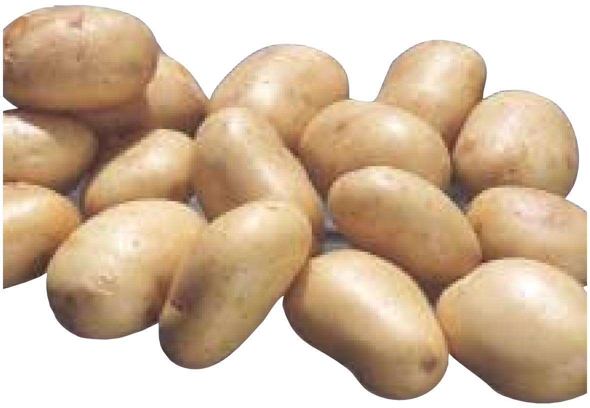
Hybrid varies tend to require better fertility and more rain than open pollinated varieties which will do moderately well in marginal rainfall areas. Most varieties are expected to flower within 60 to 75 days of planting with maturing in a further 50 to 60 days thereafter.

Harvested pine apples

4.4.2.10 Potatoes

Potatoes produce heaviest yields in areas with cool days and adequate moisture. Frost can kill potatoes. Summer production in the Lowveld is unsatisfactory because of too high temperatures. Summer production in the Middleveld is difficult because of pest and disease problems associated with temperature and moisture. Potatoes can be grown in the highveld during summer; again disease problems reduce yields.

Potatoes



4.4.3 Methods of estimating effects of climatic changes on crop yield

4.4.3.1 Simulation of crop yields

The Decision Support System for Agrotechnical Transfer (DSSAT3) comprehensive software system was used to simulate the yield of three crops under present climatic conditions and under projected climatic and atmospheric conditions. The three crops for which simulations were run are maize, sorghum and dry beans. The simulations were done for three sites; Big Bend, Malkerns and Mbabane, representing the lowveld, middleveld and highveld respectively.

The simulations were done with all other conditions such as fertilisation, weeding and pest and disease control being optimised. Simulations were done to project yields for the year 2025 since reliable historical climatic data available for the weather stations dated back to 30 years.

The output of the modelling includes not only the harvest yield, but also parameters such as biomass yield, stalk yield and nitrogen content of the crop. For this project only the harvest yield was considered. Simulations were done using climatic patterns based on three climate simulation models; CCEQ, GFDL and UKTR under three conditions for each; low change (low), medium change (medium), and high change (high) in environmental conditions.

For maize the simulations were further done to determine sensitivity of yield to changes in planting dates and changes in atmospheric carbon dioxide.

4.4.3.2 Effect of climatic change on other crops

Expert judgement was used to suggest likely effects of climatic changes to other crops that could not be supported by the DSSAT3 software. These judgements were based on the known climatic requirements and threshold conditions for the crops. For example, cotton will not tolerate heavy rains and will need temperatures of between 24-29°C for growth.

4.4.3.3 Comparison of model output with actual yields

Reliable experimental data on yields for the crops in Swaziland was lacking for all the stations. In an attempt to compare the outputs of the projections with actual yields average yields under SNL, which were obtained during a census (1992-1993) were used (Central Statistical Office, 1993). The actual yield will depend to a large extent on the management standard. The management standard under SNL conditions tends to be lower on average, even though there are always those individual farmers who have high standards. Table 4.15 shows average yield from Swazi Nation Land for selected crops.

Table 4.15 *Average yield (kg/ha) under present situation for different crops.*

CROP	BIG BEND	MALKERNS	SITEKI
Maize	1640	2320	920
Sorghum	799	2320	1860
Beans	1000	1202	-

Source: *Central Statistics Office, 1993*

4.4.4 Results

4.4.4.1 Maize

The projected yields for maize for Big Bend and Malkerns are shown in Table 4.16. A decrease in the projected yields was observed for most of the models for both Big Bend and Malkerns when the maize was planted during the recommended period, which is the second week of October. (Tables 4.16 and 4.17)

The change in projected yield for Big Bend ranged from -59% (CCEQ low) to -30% (UKTR medium). This was an indication that a decrease in maize yield is expected in Swaziland under the expected climatic change conditions. This could have a negative impact on the country's status of food security.

The projected doubling of the population in 25 years will further increase the demand for food. The area under maize production is currently decreasing due to a number of farmers in both Swazi Nation Land and Title Deed Land shifting from growing traditional crops such as maize to sugarcane which is considered more profitable.

In the event of doubling atmospheric carbon dioxide concentrations, the change in projected yield would not be significant. The predicted change in maize yield for Big Bend (CCEQ low) would be from -59% to -57%, and for CCEQ high, it would change from -33% to -17%.

The projected yields showed great improvement when changing the planting season from the traditional second week of October to the second week of August. There was an increase in the projected yield of up to 9% under Big Bend conditions when using the CCEQ medium prediction model (Table 4.16). The projected yield increase was even greater under Malkerns conditions, recording an increase of as much as 28% (CCEQ low) prediction model.With planting done earlier than August the projected yield was reduced at all sites and for all the models. The recorded reduction in yield was as much as 85% at Big Bend with CCEQ low.

4.4.4.2 Sorghum

The simulations indicate a decrease in the yield of sorghum for all the other weather stations except at Mbabane. For Big Bend the decrease in yield is pro-

Table 4.16 *Projected maize yield (kg/ha) under different crop and model conditions.*

Period / treatment	Model	Big Bend			Malkerns		
Present situation (Baseline)		6427			5466		
		Low	Medium	High	Low	Medium	High
2025 Planted October 14	CCEQ	2655	4398	4329	3358	3333	3481
	GFDL	4275	4304	4194	3137	3421	3350
	UKTR	4268	4513	4426	3306	3305	3359
2025 Planted August 14	CCEQ	3804	7011	6231	6988	5238	7390
	GFDL	6673	4298	6847	6217	5242	5332
	UKTR	6732	6651	6565	5547	5247	5957
2025 Planted June 30	CCEQ	940	3148	5336	1681	2647	1466
	GFDL	3134	3168	3149	2524	2441	2300
	UKTR	3031	3027	3114	2732	2553	2415
2025 Planted Octobert 14 and double CO_2	CCEQ	2714	4399	5336	3318	3333	3477
	GFDL	4267	4298	4230	3350	3421	3137
	UKTR	4260	4292	4405	3306	3305	3359

Table 4.17 *Projected change in maize yield (%) under different crop and model conditions.*

Period / treatment	Model	Big Bend			Malkerns		
		Low	Medium	High	Low	Medium	High
2025 Planted October 14	CCEQ	-59	-32	-33	-39	-39	-36
	GFDL	-34	-33	-35	-43	-37	-39
	UKTR	-34	-30	-31	-40	-40	-39
2025 Planted August 14	CCEQ	-40	+9	+3	+28	-4	+35
	GFDL	+4	-33	+7	+14	-4	-2
	UKTR	+5	+4	+2	+2	-4	+9
2025 Planted June 30	CCEQ	-85	-51	-16	-69	-52	-73
	GFDL	-5	-51	-51	-54	-55	-58
	UKTR	-53	-53	-52	-50	-53	-66
2025 Planted Octobert 14 and double CO_2	CCEQ	-57	-32	-17	-39	-39	-36
	GFDL	-33	-33	-34	-39	-37	-43
	UKTR	-33	-33	-31	-40	-40	-39

jected to range from 78% (UKTR: low) to 59% (GFDL: medium).

The yield for Malkerns is projected to fall by between 25% and 8%. The yield for Mbabane is expected to increase by a margin of between 60% and 8%. This can be attributed to the fact that the temperature for Mbabane is expected to increase, as well as the rainfall.

4.4.4.3 Beans

The projected yield for beams is expected to decrease for all the places by the year 2025 except under Big Bend conditions when planted during the usual period of February. The reduction in Mbabane is expected to range from 11% to 23%, while that for Malkerns is expected to range from 30% to 46%. An increase in yield at Big Bend is expected. The expected increase in yield ranges from 38% to 191%.

4.4.5 Expected effect of environmental change to other crops

The effect of environmental change to other major corps in the country could not be simulated due to lack of simulation model to support them. However some possible effects were deduced on the basis of projected weather data and climatic requirements for the crops. For example for cotton the projected increase in rainfall may bring about waterlogging of the crop.

The high rainfall and high temperatures may result in high incidence of pests and diseases especially in the middleveld. This may result in decline in yield. Potatoes, being temperate crops may not do well since temperatures will be high. The may be high incidences of diseases due to high moisture and temperatures. The yields are generally expected to decline. Some areas such as the middleveld, which are currently suitable for growing potatoes, are expected not to be suitable in the future.

Table 4.18 *Projected sorghum yield (kg/ha) under different crop and model conditions (year 2025).*

Station	Situation	Model		
		CCEQ	GFDL	UKTR
Big Bend	Low	2311 (-66%)	2397 (-62%)	2227 (-78%)
	Medium	2669 (-65%)	2857 (-59%)	2288 (-75%)
	High	1553 (-68%)	1708 (-67%)	1708 (-75%)
	Present	6931		
Malkerns	Low	4561 (-14%)	4406 (-11%)	4360 (-25%)
	Medium	4710 (-18%)	4935 (-8%)	4846 (-23%)
	High	3969 (-18%)	4112 (-8%)	4104 (-23%)
	Present	5284		
Mbabane	Low	8486 (+60%)	5824 (+14%)	8195 (+18%)
	Medium	6006 (+10%)	6250 (+18%)	7957 (+10%)
	High	6250 (+55%)	5820 (+46%)	5718 (+8%)
	Present	5284		

The temperature is expected to be suitable for sugarcane production in most regions in the country. The increase in rainfall and temperature is expected to have a positive impact on pineapple performance

Yield for citrus is expected to decrease due to high incidences of pests and diseases. The overall expected effect on crop production is a decline in yield for temperate crops and an increase in tropical and subtropical crops.

4.4.6 Adaptation

One of the main adaptation strategies that may be followed is a change of growing the season in the country. The normal planting season for maize middle of October. When maize was planted in the second week of August there was a projected increase in the yield in most areas

Late planting (mid December) is projected to lead to decline in yield. Another adaptation strategy would be to grow varieties that are tolerant to high temperatures and high rainfall. This would require breeding of crops to suit the conditions. There may be changes in the types of crops grown in the different regions in the future. For example sugar cane may be grown predominantly in the highveld as opposed to the current situation where it is grown predominantly in the lowveld and the middleveld.

The type of crops grown in the country may have to change. For example potatoes may not be grown in the country in the future, and crops such as cassava may be the main root crop.

4.4.7 Conclusion

The effects of climatic change in Swaziland will vary with different crops. The effect will however be negative for maize, which is the staple crop in the country. The maize yield is expected to decline by as much as about 60% in other areas of the country unless some measures are taken.

The highveld may not be suitable at all for growing maize in the next 25 years. The impact may be positive for some crops such as sugarcane. The climatic change will bring about changes in cropping pattern and dates. One of the adaptation measures that may be followed is to change the planting season of the crops. When planted during the first week of August, maize could produce increased yields.

The outlook for the agriculture sector on the whole is not favourable. The predicted degrease in maize yield of as much as 60% would offset the goal of the goverment for self-sufficiency in Maize. The high population growth and demand of land for cash crops such as sugarcane and pineapples may further compound the reduction in yield. More of the maize may have to be imported, draining the limited foreign reserves of the country.

A large percentage of the population could end up on food aid. The government mayl have to set up strategies to assist the population. The agriculture sector does not only directly provide employment, but also provides raw material for other manufacturing industries. With reduction if yield of major crops such as maize, people may lose their jobs due to lack of raw material.

The combination of food shortage and lack of employment could lead to high crime rates. The government may not be able to fulfil its goals of increasing rural income and improving the nutritional status of the population. As the predictions indicate that maize yield may be increased by early and timely planting, means should be found to have enough tractors in the "Tractor Hire Scheme" of the goverment. Finance should be made available to purchase inputs such as fertilizers and hybrid seeds. The use of land should be controlled to minimise the conversion of land used to grow food crops to growing cash crops such as sugarcane.

4.4.7.1 Limitations of project

i. The lack of experimental data made it not possible to calibrate and statistically test the effectiveness of the modelling under Swaziland conditions. Average yields for the different crops were used to demonstrate the relationship between projected yield and actual yield. There is need to carry out experiments in the four agro-ecological zones and to further calibrate the model.

ii The DSSAT3 Model used was fully developed for a limited number of crops. Modules for important crops such as sugarcane, potatoes and cotton are still lacking. There is need to fully develop the missing modules for it to be more comprehensive in its usage.

Table 4.19 *Projected dry beans yield (kg/ha) under different crop and model conditions (year 2025).*

Station	Situation	Model		
		CCEQ	GFDL	UKTR
Big Bend	Low	2136 (+38)	4391 (+183)	3977 (+157)
	Medium	4409 (+184)	4478 (+189)	4415 (+184)
	High	4498 (+190)	4505 (+191)	4520 (+191)
	Present	1552		
Malkerns	Low	3975 (+32)	4068 (-30)	4066 (-30)
	Medium	4018 (-46)	3992 (-30)	4097 (-30)
	High	3822 (-35)	3914 (-33)	4150 (-29)
	Present	5869		
Mbabane	Low	2299 (-21)	2439 (-16)	2239 (-23)
	Medium	2526 (-13)	2500 (-14)	2473 (-15)
	High	2531 (-13)	2580 (-11)	2239 (-23)
	Present	2915		

Chapter 5

Mitigation Options Analysis

5.1 INTRODUCTION

In accordance with article 4.7 under the UNFCCC, member states in the developing world are expected to ensure that greenhouse gas emissions are linked to sustainable development through encompassing environmental considerations and socio equity in their drive for economic growth.

As indicated in the inventories, CO_2 per capita of 0.871 Gg is on the low side compared both to the African region and lower still compared to the developed world's average. In view of this, it is Swaziland's position that GHG emission reduction is linked to sustainable development goals of economic growth, environmental protection and socio equity. In the same vein, Swaziland recognises its extreme vulnerability to climate change owing to the nature of its national circumstances. For this reason the country commits itself outlined resources permitting to undertake programmes aimed at avoiding emissions, and hence the protection of the climate.

Although Swaziland has not yet put in place a Climate Change Policy per-se, its commitment to climate change is manifested through a number of initiations both in the national and international fronts amongst which are the following:

i. Ratification of international protocols/conventions related to the environment.

ii. Formulation of several national development and environmental policies, each of which in one way another contributes to avoidance of emissions and/or mitigation of climate change.

iii. Including environmental concerns in the Swaziland National Energy Policy (SNEP) being developed with assistance from the Danish Cooperation for Environment and Development (DANCED).

In addition, Swaziland, with assistance from UNDP/GEF has undertaken as part of the enabling activities for the preparation of the national communication, studies in mitigation analysis. The mitigation analysis will assist in the formulation of appropriate policies and measures which will go a long way towards avoidance of GHG emissions.

5.1.1 Enabling Activities For The Preparation Of The National Communication

As part of this activity, an in-depth study on mitigation analysis and strategies involving an examination and development of the baseline scenario, and analysis of various mitigation options including changes in policy, was undertaken by a multidisciplinary team.

The main focus of the study was to develop baseline scenarios in energy and forest sectors. The rationale for selecting the energy and forest sectors was largely driven by the level of emissions emanating from the former and the degree of land degradation caused by the latter together with its apparent huge GHG sink capacity. The baseline which was developed for both sectors, adopted a business as usual approach and was mainly influenced by the economic development path that Swaziland would follow without implementing any mitigation option to reduce GHG emissions and implementing strategies elaborated under the NDS, due to constraints of availability of financial resources.

In most developing countries such as Swaziland, fuel-wood is the main source of energy for rural communities. As such, there is strong interdependence between the energy and the forest sectors.

This interdependence is underlain by the fact that increasing demand for energy is associated with increasing deforestation hence the need to undertake mitigation analysis in these two sectors. Apart from supplying energy, forests and woodlands also supply timber and non-timber (e.g. fruits, honey, edible insects and medicine) products in Swaziland.

5.2 ENERGY

5.2.1 Baseline Development

Under both baseline and mitigation analysis, the following issues were considered:

i. Assessment of present energy demand and GHG emissions related to physical sources and economic sectors, and projections of these according to a baseline linked to long term development plans and goals, as stipulated under national circumstances.

ii. Identification of options for the abatement of GHG emissions, concentrating on major emitting sectors, as elaborated under inventories.

iii. Cost of reduction alternatives

iv. Implementation issues and institutional arrangements

The time frame for reporting was set between 1994 and 2030, with reporting years 2000, 2010, and 2030.

5.2.2 Methodology and Assumptions

The energy demand and GHG emissions forecast was determined with the help of the Long Range Energy Alternative Planning (LEAP). LEAP is a bottom up model developed by the Stockholm Environmental Institute based in Boston (SEI-B). The LEAP forecasts energy consumption and GHG emissions by sector and national energy demand by summing up sectoral energy consumption and GHG emissions.

In order to assess the current and future energy demand and GHG emissions in the energy sector, the following assumptions were used both in the baseline and mitigation scenarios:

5.2.3 Population and household size

Population and household size growth have influence on the demand for services and energy and thus will impact on future energy demands. Based on data obtained under macro-economic analysis, Swaziland's population is projected to reach 1.5 million by 2010 at an average growth rate of 2.7% per annum. Between 2010 and 2030, average population growth of 2.3% was assumed. By 1994, the number of households were estimated at 172,416 by 2000, 2010, 2020 and 2030, they are projected to increase to 197,620, 248,078, 311,418 and 390,931, respectively.

5.2.4 Household energy mix and GDP

Under macro-economic analysis, the number of household energy mix has been determined.The GDP projections are shown in Table 5.1, for each sector.

5.2.5 Energy intensity and demand projections

Energy intensity over technologies and devices is crucial in determining the energy demand and CO_2

Table 5.1 *Projections for average growth rates of GDP by sector (1994-2030)*

GDP per Sector	1994-2000	2001-2010	2011-2020	2021-2030
Agriculture	11%	15.2%	14.9%	13.7%
Forestry	1.3%	1.4%	1.3%	1.3%
Mining	1.7%	2.3%	2.29%	2.12%
Industry/Manufacturing	37.57%	29.28%	29.6%	32.15%
Construction	3.7%	3.6%	3.8%	3.7%
Transport & Communication	6.5%	6.3%	6.4%	6.4%
Government Services	17.7%	17.5%	17.5%	17.6%
Overall GDP as well	3.2%	4.66%	5.29%	5.00%

projections. Specific energy intensity values have been used under both baseline and mitigation analysis. To take into account the expected technological improvements of the various appliances and technologies, recognition was taken of the Autonomous Energy Efficiency Improvements (AEEI) factor. This factor allows intensity of energy use to decline as a result of the overall global effort to improve energy efficiency in production practices and technology.

5.2.6 CO_2 Emission Projections

A projection of CO_2 emissions for Swaziland by sector in million kilograms, between 1994 and 2030.is shown on Table 5.3.

The total CO_2 emissions in Swaziland are expected to grow from 875.67 in 1994 to 1075.62, 1518.15, 2147.21 and 3042.68 Gigagrams in 2000, 2010, 2020, and 2030, respectively.

Table 5.2 *Swaziland's energy demand projections by fuel type (Million GigaJoules)*

Fuel Type	1994	2000	2010	2020	2030
Electricity*	0.50	0.58	0.72	0.91	1.14
Gasoline	2.47	3.07	4.42	6.35	9.13
Kerosene	0.35	0.41	0.53	0.69	0.89
Diesel	2.54	3.15	4.53	6.52	9.38
Heavy Fuel Oil	1.69	2.10	3.02	4.35	6.25
LPG	0.17	0.20	0.25	0.32	0.40
Bituminous Coal	3.89	4.73	6.55	9.11	12.71
Firewood	8.36	9.63	12.20	15.48	19.66
Bagasse	12.13	15.08	21.69	31.19	44.85
Cow dung & Crop Residues	0.41	0.47	0.60	0.75	0.94
Totals	32.52	39.42	54.51	75.65	105.35

The expected trends in AEEIs from the various sectors over the years will largely be influenced by sector and area of application. The AEEIs in this work ranges from 0 to -1 percent.

A projection for energy demand for Swaziland is shown on Table 5.2.

The total energy demand is expected to grow from 32.52 in 1994 to 39.42, 54.51, 75.65, and105.35 million gigajoules in 2000, 2010, 2020, and 2030, respectively, to support the expected economic and population growths.

5.2.7 Mitigation in the energy sector

Mitigation in the energy sector considered three economic sectors, namely, industry, road transportation, and household, and one supply side, electricity generation.

i Supply Side

Application of advanced, more efficient steam and electric power generation through the use of high pressure Condensing Extraction Steam Turbines (CEST), using bagasse as input fuel.

Table 5.3 *Projections of CO_2 by sector in million kilograms*

Sector	1994	2000	2010	2020	2030
Industry	380.78	473.53	680.98	979.31	1488.34
Road Transport	357.90	445.08	640.07	920.48	1323.73
Households	136.99	157.01	197.10	247.43	310.60
Totals	875.67	1075.62	1518.15	2147.21	3042.68

ii End Use

In industry, energy efficient boilers, electric motors and matching electric supply to demand are options considered.

In road transportation options are improved maintenance through annual state inspection and gasoline/ethanol blending.

Under households, issues are the use of efficient lights, solar geysers, improved wood stoves, switching from wood and kerosene to LPG and electric stoves, etc. Detailed characteristics and assumptions for the identified mitigation options on both the country's energy demand and its related CO_2 emissions were not explored in the scope of this study due to certain limitations that have to do with availability of activity data and others. Undertaking such an exercise could reveal in quantitative terms the anticipated impacts due to implementation of these options on the country's energy demand and on the concentrations of the CO_2 emissions. This exercise is recommended in future development of the work in this section.

5.3 FORESTRY

5.3.1 Baseline and mitigation analysis

Mitigation analysis and strategies involved an examination of the baseline scenario and analysis of various mitigation options including changes in policy . The national baseline was developed with the assistance of COMAP (Comprehensive Mitigation Analysis Process). The COMAP was used to analyse the impact of changes in forestry cover, product supply and demand and cost and benefits of mitigation options.

5.3.2 Methodology

COMAP was used both for the baseline and mitigation analysis. The data used in the model was based on information acquired during the greenhouse gas emission survey. Additional data was obtained from relevant stakeholders and secondary sources such as articles from relevant ministries.

To establish the areal extent of various land uses under the baseline scenario in the country, the land-use map of Swaziland (Remmelzwaal &

Table 5.4 *Possible annual rates of change and causes for the change in different land-use categories.*

LAND USE CATERGORY	ANNUAL RATE OF CHANGE (%)	CAUSES
Dense forest	- 0.05	Increasing number of settlements Expansion of sugar cane cultivation Infrastructural development
Woodlands	- 0.2	Same as above
10% crown cover	- 0.2	Same as above
Rangelands	- 0.01	Increasing number of settlements Infra-structural developments Afforestation programmes
Grasslands	- 0.5	Increasing number of settlements Expansion of cropland
Protected areas	Constant; may decrease by 0.5 by 2004 and likely to increase from 2005 at 0.05	Proposed mining projects Expansion of sugar cane cultivation Declaration of protection worthy areas
Perennial cropland	+ 0.05	Expansion of sugar cane cultivation
Annual cropland	- 0.008	Increasing number of settlements Infrastructure development Expansion of sugar cane cultivation
Current Fallow	- 0.002	Increase in number of settlements Expansion of cropland
Settlements	+ 0.009	Increasing population growth
Urban	+ 0.007	
Dams & roads	+ 0.001	
Mines	+0.0001	

Table 5.5 *Projected land use patterns under baseline scenario.*

LAND USE TYPE	1994	2010	2020	2030
Dense forest	140	129.2	122.9	116.9
Woodlands	131	126.9	124.4	121.9
<10% crown cover	9	8.7	8.5	8.4
Rangelands	332	306.4	291.4	277
Grasslands	792	730.9	695.2	661
Wastelands	30	46.7	46.7	46.7
National parks	58	62.8	66	69.4
Perennial cropping	69	142.2	189.2	226.2
Annual cropping	148	145.6	144.2	142.8
Fallow	6	5.8	5.7	5.6
Tree cropping	5	5	5	5
Urban	8	17.5	28.4	46.3
Dams and roads	4	4	4.1	4.1
Mines	3	3	3	3
Not classified	3	3	3.1	3.3

Dlamini, 1994) was used. The annual rate of change in each land use category was based on the findings of the greenhouse gas emission inventory. Table 5.4 shows the anticipated rates and causes for the changes in each land- use category under the baseline scenario.

Under the baseline scenario, COMAP provided the following output:

i Land patterns under baseline and mitigation analysis

ii Estimates of the biomass (carbon) stock during the target period (1994-2030) under baseline and mitigation scenarios

iii Product and supply demand during the target period

iv Costs and benefits of mitigation options

Under mitigation, three options were considered. These options were;

i Natural regeneration

ii Forest protection

iii Reforestation

In recommending the measures to be taken under each mitigation option, secondary data (especially publications) from the Ministries of Agriculture and Co-operatives, Tourism, Environment and Communication and Natural Resources and Energy were used. Recognising the importance of policy review in mitigation analysis, existing policies and proposed policy changes were also reviewed.

Considering the seriousness of erosion in the country and its role on desertification and climate change, natural regeneration and reforestation programmes were recommended for the rehabilitating of eroded land (wasteland) sites. The recommended reduction of wasteland is 200 ha per year starting in 2001. This suggests a decrease of about 10% per annum of eroded land.

To date, protected land in the country covers about 5 800 ha. (about 4% of the total land area). The present area of protected land in the country is 6%, compared to 10% that is recommended by IUCN yet part of the protected land is being converted into agriculture and possible mining.

Land conversions in protected areas is likely to decrease by 0.5% from the year 2000/2001 if not controlled. It is for this reason that forest protection had been considered in the mitigation analysis. To mitigate against this change, the recommended increase in protected land is about 1% (100ha) per year, starting in 2001.

5.3.3 Results

5.3.3.1 Baseline scenario.

With the application of COMAP, changes in land-use patterns under baseline scenario were estimated as given in Table 5.5. From the results shown on Table 5.6 it appears that the area under forest, grasslands and rangelands is likely to decrease under the baseline scenario. This decrease is attributed to the land conversions to other land use activities, especially cropping and an increasing number of settlements.

The projected decreases are 17% for forest cover, grazingland and grassland by the year 2030. Wastelands are projected to increase by 56% by the year 2030 under the baseline scenario. It is projected there will be an increase in protected land (National parks) with increasing awareness by rural communities of the importance of environmental protection under the baseline scenario

5.3.3.2 Mitigation scenario

The intention of mitigation is to increase the area under forest and to reduce the degraded area (wasteland). Some of the mitigation measures are already in the plans of the Forestry Section in the Ministry of Agriculture and Co-operatives and the Environment Authority through the Swaziland Environmental Action Programme.

These departments overall mandate is to ensure that forestry resources are managed and conserved optimally in order to prevent degradation from exploitation (Swaziland Government, 1994). This entails maintaining a forest resource inventory and monitoring the rate of deforestation. To achieve this mandate the government intends to undertake the following activities:

i Draft a forest policy and land use plan for forestry development.

ii Identify project areas based on forest inventory.

iii Planting of buffer zones using fast growing tree species.

iv Introduction of agro-forestry activities.

v Implement sustainable management plans for indigenous forests for production of timber, medicine and other forest products.

vi Establishment of additional woodlots.

The private sector is also engaged in encouraging the communities in SNL in the production of forest for income generation. The interventions of the public sector and the private sector will contribute to an increase in the area under forest cover. The recommended annual increases under the mitigation scenario are 5% for dense forest, 2% for woodlands and forest with less than 10% crown cover. With the increase in forest cover, it is projected that area under rangelands and grasslands will be reduced by 1% and 2% respectively.

Table 5.6 *Area under different land uses (000 ha) under mitigation scenario.*

LAND USE TYPE	1994	2010	2020	2030
Dense forest	140	177.2	197.8	218
Woodlands	131	131	132	133
<10% crown cover	9	9	9	9
Rangelands	332	318	315	312
Grasslands	792	753	738	723
Wastelands	30	15.2	5.3	1.8
National parks	58	62.8	66	69.4
Perennial cropping	69	92.5	92.4	92.5
Annual cropping	148	147	147	147
Fallow	6	5.9	5.9	5.9
Tree cropping	5	5	5	5
Urban	8	10.3	10.7	11
Dams and roads	4	10.7	10.7	10.7
Mines	3	3	3	3
Not classified	3	2.4	5	1

Table 5.7 *Biomass density for different land uses (tb/ha) under baseline and mitigation senarios.*

LAND USE TYPE	Baseline scenario	Mitigation scenario
Dense forest	90	95
Woodlands	70	77
<10% crown cover	30	33
Rangelands	10	10
Grasslands	10	10
Wastelands	5	5
National parks	100	150
Perennial cropping	25	25
Annual cropping	5	5
Fallow	2	2
Tree cropping	100	100
Urban	0	0
Dams and roads	0	0
Mines	0	0
Not classified	0	0

Considering that the overall aim of mitigation is to reduce the area of wasteland and increase the area of protected land, an annual reduction of 10% is recommended for wastelands from the year 2000. Protected land on the other hand should be increased by 5% annually. The projected changes in the area under the various land uses under the mitigation scenario are shown on Table 5.6.

Using the projected changes in the area under the different land-use activities, the biomass density (Table 5.7) and pool (Table 5.8) was generated for the baseline and mitigation scenarios. The results indicate that under the baseline scenario, the biomass pool will be reduced by 6% by the year 2030 (Figure 5.1). However, adoption of the suggested interventions (natural regeneration, forest protection and reforestation) under the mitigation scenario would increase the biomass pool by 19% by the year 2030.

5.3.3.3 Product extraction rates, supply and

Figure 5.1: *Biomass pool under baseline scenario and mitigation scenario.*

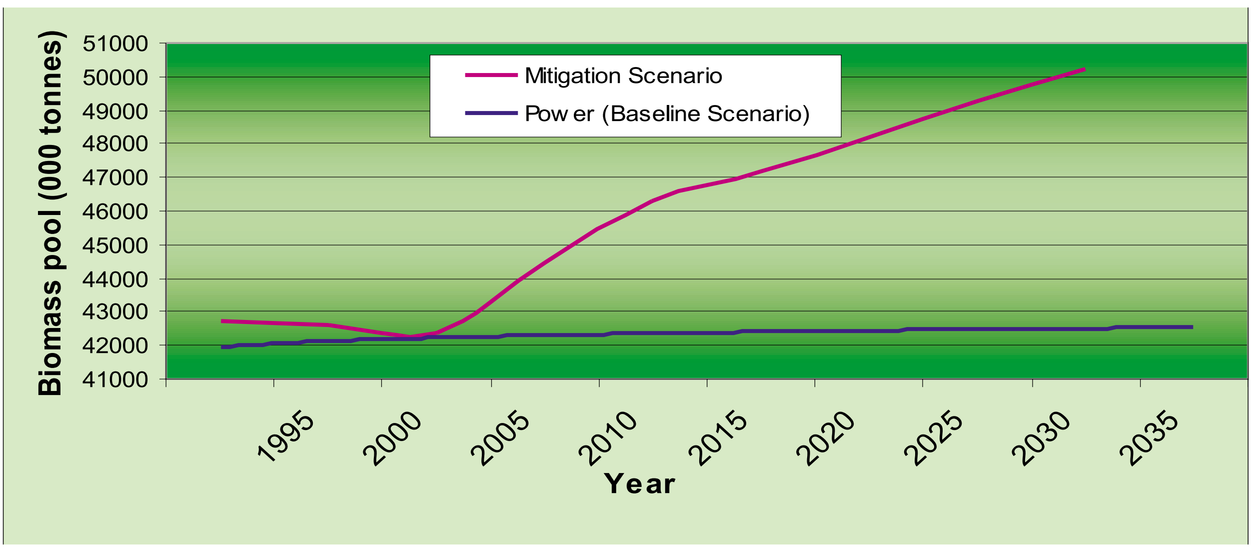


Table 5. 8 *Biomass pool (000 tonnes)*

SCENARIO	Present	2010	2020	2030
Baseline	40330	39127	38427	37749
Mitigation	42263	45812	47966	50198

demand

Under the present situation, most products are extracted at a rate that exceeds the sustainable rates. This is particularly true with respect to the extraction of fuel-wood from woodlands. On the other hand, the extraction of electricity from forest resources, perennial crops and dams is below the sustainable rates. Since the extraction rates are directly proportional to the human population, an increase in population will result in increased extraction rates. With the increasing demand, the supply of the products may be inadequate to meet the national needs unless appropriate mitigation measures are taken.

5.3.3.4 Costs of mitigation options.

There are underlying costs under the baseline scenario. These underlying costs include the cost of rehabilitating degraded land, cost of supplying alternative water sources with a reduction in return flows, maintaining personnel and equipment in forest protection. These costs will increase over the years and associated with the increasing costs will be a reduction in the benefits derived from the forest resources. Costs will also be incurred during and after the implementation of each of the selected mitigation options. The costs will include costs of labour, materials and monitoring the mitigation projects.

Table 5.9 *Baseline and Mitigation costs and benefits of natural regenaration.*

	1994	2010	2020	2030
Baseline Costs	2	65.84	75.71	306.30
Mitigation costs				
Initial Costs ($/ha/yr)	1300	1300	1300	1300
Recurrent Costs ($/ha/yr)	1	618.77	711.59	2878.77
Monitoring Costs ($/ha/yr)	5	309.39	355.79	1439.39
Total mitigation costs	1306	2228.16	2367.38	5618.16
Baseline Benefits	20	12.48	11.86	7.10
Mitigation benefits				
Timber Product	0	930.48	1070.05	4328.95
Non-timber benefits (fuel wood)	15	2326.20	2675.13	10822.37
Non-timber benefits (resin/honey/fruits)	7.5	35.38	40.69	164.59
Other benefits	0	708.63	814.93	3296.83
Total mitigation benefits	22.5	4000.68	4600.79	18612.75

Table 5.10 *Baseline and Mitigation costs and benefits of forest protection.*

	1994	2010	2020	2030
Baseline Scenario costs	45	421.09	1703.56	6891.83
Mitigation costs				
Initial Costs	1300	1300	1300	1300
Recurrent Costs	0	76.48	309.39	1251.64
Total Mitigation costs	1300	1376.48	1609.386	2551.64
Baseline Scenario benefits from land conversion	45	3.34	0.66	0.13
Mitigation benefits from forest protection	0	80.30	324.86	1314.22
Baseline benefits from forest protection	45	21.49	14.07	9.63
Mitigation benefits from forest protection	0	351.79	1423.18	5757.55

Table 5.10: *Baseline and Mitigation costs and benefits of reforestation.*

	1994	2010	2020	2030
Baseline costs	45	421.09	1703.56	6891.83
Mitigation costs				
Initial Costs ($/ha/yr)	2500	2500	2500	2500
Recurrent (Maintenance etc.) Costs ($/ha/yr)	0	529.51	6187.73	25032.81
Monitoring Costs ($/ha/yr)	0	305.90	1237.55	5006.56
Total Mitigation costs	2500	3335.41	9925.272	32539.37
Baseline Benefits	45	19.81	11.86	7.10
Mitigation benefits				
Timber Product ($/ha/yr)	0	0.00	8395.23	33963.39
Non-timber benefits (fuel wood) ($/ha/yr)	0	500.34	4068.53	16459.48
Non-timber benefits (resin/honey/fruits) ($/ha/yr)	0	5.03	20.34	82.30
Other benefits ($/ha/yr)	0	90.51	366.17	1481.35
Total Mitigation benefits	0	595.88	12850.27	51986.51

5.3.3.5 Natural regeneration

Under Natural regeneration, the mitigation costs will include the costs of fencing the project areas, personnel to monitor activities and maintainanace of the project sites. With inflation, it is projected that the mitigation costs will increase to about $5 618 per ha per year by 2030 (Table 5.9). However, the gross benefits that would be derived from the mitigation measure would amount to about $18 613.00 per ha per year by the year 2030. This means that natural regeneration would yield a net benefit of about $5 204.00 per ha per year by the year 2030.

The projected benefits under natural regeneration include better market prices for livestock as a result of increased availability and nutritional value of grasses (fodder), increased availability of plant resources for extraction and improved in crop production through irrigation as a result of increased return flows in river systems.

5.3.4 Forest protection

In Swaziland, forest protection is generally confined to nature reserves. Only a few areas (for example, the indigenous forest near Mangwaneni in Mbabane) outside nature reserves are protected. As such, the estimated baseline costs of forest protection in this study are based on the activities within nature reserves, especially the remuneration of rangers and maintenance of the reserve.

Under the baseline scenario, nature reserves are under pressure from the need for land. Commercial crop production is encroaching into nature reserves (for example, Mhlosinga in Big Bend and part of Hlane Game park), mining is also threatening a part of Malolotja nature reserve which contains an afromontane forest. It is projected that under the baseline scenario, the costs of forest protection will increase with a reduction in the benefits (Table 5.10 and 5.11). Contributing to the reduction in benefits will be the reduction in tourist attractions hence low numbers of tourists visiting the country. The projected decline in benefits is about $7.00 per ha per year. As such, there is need to identify and manage protection worthy areas on communal lands.

The costs of protecting the forests would include the cost of fencing the land, recruiting rangers to monitor activities and manage the protected areas. The gross benefits to be derived from forest protection are projected at about $5 756.00 per ha per year. The benefits would arise from increased tourism and availability of forest resources.

Chapter 6

Policies and Measures

6.1 OBJECTIVE

The determination of Swaziland to join in implementing the Convention is demonstrated by actions already taken or envisaged by the country in terms of policy frameworks, programmes and other environment-related measures which either directly or indirectly have a bearing on GHG emissions.

6.2 NATIONAL DEVELOPMENT STRATEGY

Government formulated the National Development Strategy (NDS) as the key policy framework that spells out the long-term (25 year) vision for the country. It presents the priority objectives the country has identified in its overall developmental need. In like manner it recognizes the international obligations the country has committed itself and the associated calls for action in compliance with the same.

Of the eight key macro strategic areas identified in this policy document is one on environmental management, which directly relates to issues of implementation of the Convention. It specifically places a requirement to both the public and private sectors to take environmental considerations into account in all their policy, strategy and programme's development. The country believes that such an achievement of purpose will result in a sustainable interaction with our environment and its resources for the benefit of today's and future generations.

6.3 THE ENVIRONMENT

The country has also shown its commitment to implementing Agenda 21 and its concept on sustainable development. To this end the Swaziland Environment Authority (SEA) was established in 1992 as the official authority tasked with the coordination and management of issues of the environment. Further regulations on environment impact assessment were promulgated making environment assessments mandatory on all development projects.

The Swaziland Environment Action Plan (SEAP) enumerating strategies for tackling the country's environmental problems in general and those specifically related to climate change, agriculture and land use, forestry and rural energy was prepared and adopted.

6.4 ENERGY

6.4.1 Fuel and Energy

The significance of the energy sector in issues of implementation of the Convention cannot be overemphasised. The GHG inventories exercise revealed that virtually all the country's CO_2 emissions for year 1994 emanated from this sector in processes of fuel combustion.

As part of the NDS, the fuel and energy sector aims to ensure the sustainable supply and use of energy for all. In fulfillment of this requirement, the project "Swaziland National Energy Policy" is being implemented by the Energy Section within the Ministry of Natural Resources and Energy with the assistance of the government of Denmark through the Danish Cooperation for Environment and Development (DANCED).

Prior to this project a number of projects which have a bearing on GHG emissions have been implemented in Swaziland namely:

i. Energy Planning Projects-Swaziland (with support from GTZ to the Ministry of Natural Resources and Energy)
ii. Briquetting of forestry waste (pre feasibility study initiated by Usuthu Pulp Company in conjunction with the Sabil Foundation, the Swaziland Government and GTZ)
iii. Household Energy Strategies (funded by the government of the Netherlands, IVAM Environmental Research Centre of the University of Amsterdam)
iv. Rural Electrification in Swaziland (funded by GTZ)
v. Utilization of Renewable Energy in Swaziland (Export and Industrial Development Division of the Commonwealth Secretariat assisted the Ministry of Natural Resources and Energy

to develop a cost effective strategy for the use of renewable resources)

vi. SADC Industry Energy Management Project (CIDA supported project)

vii. Maguga hydro power plant (feasibility study funded by the African Development Bank)

viii. Development of the Swaziland Electricity Supply Industry (funded by the British Development Division Southern Africa (BDDSA) and SAD-ELEC)

ix. Renewable Energy Information Network (EU funded)

x. ESMAP Swaziland Household Energy Strategy Study (UNDP and World Bank.

Through these initiatives Swaziland managed to established energy data, technology information needs and energy strategies. These provided the preliminary base for building a comprehensive energy policy and strategies for implementation of the energy policy.

The development objective of the DANCED project therefore is that the energy needs in Swaziland are increasingly covered in a sustainable and efficient manner, taking into account indigenous resources, social, economic and environmental factors.

The immediate objective is that at the conclusion of the project, the government of Swaziland will have an approved and implementable national energy policy, founded on sustainable and economically sound principles in support of the developmental objectives of the country. Implementation of such a plan will inevitably make a positive contribution to efforts of reducing the levels of GHG emissions in the country through implementation, amongst others, of energy efficiency and renewable energy technologies.

6.4.2 Supply

Swaziland's major source of commercial energy in the form of electricity, petroleum products and coal, are imported from the Republic of South Africa. The country is however a producer of high quality anthracite coal obtained from Maloma coal mine and exported to markets in South Africa. Swaziland's coal-based energy needs on the other hand are met by imports of low quality bituminous coal from South Africa.

Most of the country's electricity needs (70%) are met from the South African Electricity Company (ESKOM). The electricity supply is unstable because the grid is relatively weak and operating in excess of its rated capacity Frequent interruptions and voltage fluctuations are therefore common features. Efforts to resolve these problems and improve the reliability of the supply have culminated in the current installation of a 400 KV line linking the three countries: Swaziland, South Africa and Mozambique.

Since the demand for electricity supply is likely to increase with respect to demand of the vast majority of households which are currently not connected to the national grid, more efforts will be required for the promotion and development of alternative renewable energy resources.

It is worth noting that Swaziland produces significantly large amounts of biomass resources in the form of bagasse in the sugar industry, and wood waste in the pulp and timber industries. Opportunities exist therefore for the country to pursue the application of more efficient steam and power generation through use of high pressure condensing extraction steam turbines (CEST) using bagasse. Such systems could produce electricity sufficient for internal use by the factories and even some excess for export to the national grid by taking advantage of the available state of the art technologies in this field.

6.4.3 Rural Energy

Lack of adequate energy supply in rural households has resulted in dependency on wood as a source of fuel, thus putting pressure on the indigenous forest resources, thereby contributing to land degradation, another priority area for policy intervention. Options that are open to exploration here include, amongst others:

a) Promoting the use of fuel-efficient stoves and supporting their production locally.

b) Assessing the use of various sources of energy such as coal, wood, butane, paraffin, etc with respect to cost, efficiency, pollution, health and safety.

c) Attempting to remove the barrier of prohibitive initial capital cost of electricity supply connection through a Rural Electrification Fund.

d) To actively pursue development of alternative sources of energy such as solar, micro, hydro and biogas.

e) To promote integrated and balanced energy systems (solar for lighting and entertainment, gas for cooking, coal for heating, etc)

6.5 TRANSPORT

The transport sector is the dominant consumer of fossil-based fuels, accounting for 50% of energy's CO_2 emissions in 1994. A transport policy is under development which will seek to address energy-related issues and concerns with significant complementary input derived from the provisions enshrined in the overall energy policy.

6.5.1 Roads and Road Transport

One of the key factors to national development is the availability of adequate and reliable roads and road transport. Although by African standards, the road network of main and feeder roads are well developed, under the NDS Swaziland has designed roads and road transport strategies whose aims are to realize and expand road networks accompanied by a well coordinated maintenance programme to support the increase in internal and external flows of goods.

Whilst recognizing the importance of implementing roads and road transport strategies, the government is cognizant of the financial constraints in implementing the strategies. For this reason, the government has included in its strategies the involvement of the private sector in the construction, operation and maintenance of road networks. The following strategies have been recommended under the NDS to enable the implementation of the policies:

a) Improve the standards and supervision of design, construction and maintenance of roads.
b) Establish permanent fund- raising methods for road maintenance.
c) Investigate the possibility of using BOT , BOO and BOOT schemes to provide more and better roads.
d) Provide adequate and well maintain feeder roads.
e) Improve organizational structures to control overloading.
f) Conduct and strengthen road transport data collection, analysis and compilation.

Expanded paved roads and improved maintenance will improve on fuel consumption of motor vehicles through realization of optimum speeds, and hence emission reduction in the transport sector.

6.6 FOREST RESOURCES

Swaziland has a huge forest resource which is an important feature of the country's heritage and economy. Inspite of her small size, the country commands one of the largest man-made forests in the world, covering some 35% of the country's total land area. This is evident in the large GHG sink capacity that is revealed in the inventories section which supercedes the emissions totals, making the country a net GHG sink.

Such a position indicates that for several decades now, the country's forest resource has been actively removing CO_2 from the atmosphere even before the dictates of the Convention came into effect. Sustainability of the country's forest resource is therefore desirable in both national as well as international contexts.

There are several policies in Swaziland that are relevant to the management of ecosystems and managed forests. Existing policies include the Swaziland National Trust Commission Act (1972), Swaziland Environment Authority Act (1992).
The National Action Programme for Combating Desertification also addresses some of the concerns and threats on forestry and ecosystems. The proposed Forest Policy emphasises the need to engage in afforestation and reforestation programmes. Public awareness and the propagation of trees are also encouraged in the policy. There is need to incorporate indigenous trees in these programmes to ensure their future existence, especially those that are least vulnerable to changes in climate. As such, there is need to expedite the drafting and implementation of the policies on Land use and Forestry in the country. Apart form the existing policies, there are several other complimentary ones being drafted for submission to parliament. Such policies include the Environmental management Bill, Water Policy, Land Policy, Biodiversity policy and Forest Policy.

TConsidering the paucity of information on the key parameters of indigenous trees in the country, there is need for research on these parameters in the country. This will enhance understanding of the impacts of climate change on the ecosystems in the country. Changes in plant distribution also need to be monitored on a periodic basis, especially in the protected areas where anthropogenic impacts are controlled.

6.6.1 Forest resource management

Some identified management actions that could contribute to sustain the forest resource are as listed:

a) To prepare management plans for all forest operations for specific forest sites and or ecosystems.
b) To classify and map vegetation forest types, including the status of degradation, using an appropriate and cover classification system.
c) Evaluate and demarcate suitable land for various systems of forest practice such as production, protection and conservation forests.
d) Assessing and monitoring deforestation and land degradation, including effects of veld and forest fires and recommending and implementing remedial measures.
e) To apply appropriate silvicultural techniques and forest practices in the management of forest reserves and community forests.

6.6.2 Afforestation/Reforestation)

Issues under this programme are:

a) To establish individual and community woodlots of exotic and preferably indigenous species.
b) To promote the efficient use of fuel wood to release pressure from indigenous reserves.
c) To develop, with local communities methods to combat veld and forest fires and reduce fire hazards and emission of unnecessary CO_2.

6.7 AGRICULTURE

Government major goals in agriculture as the mainstay of the country's economy are in crop production for achieving national self-sufficiency in maize; expanding fruit and vegetable production as a means of increasing rural income and improving nutrition; and encouraging cash crop production amongst small-scale farmers.
Achieving these goals will involve the introduction of new crops to farmers as well as the intensification of production of existing crops. Some of the initiatives of the Ministry are as follows (Swaziland Government, 1994a):

a) The introduction of high yielding, drought tolerant and disease tolerant seed varieties for maize.
b) Training of farmers and extension personnel to be enhanced to meet the goal of maize self-sufficiency in Swaziland.
c) Embarking on legume improvement and production campaign by both the research division and extension services of the MOAC. The legumes are being promoted to enhance food nutrition and to widen the base for income generation for small-scale rural farmers.
d) Embarking on a programme to promote sorghum production in drier areas of the country.
e) Introducing, evaluating and crossing cotton varieties in order to identify those that are pest and disease tolerant, and superior in yield and quality.
f) Encouragement of domestic production of high quality maize and bean seeds.
g) Strengthening linkages between research, extension, NGO's, parastatals and other stakeholders.
h) Identify and develop cost effective production technologies.
i) Encourage the farmers to increase agricultural productivity by hectar

6.8 INTERNATIONAL LEVEL

At the international level, Swaziland has ratified a number of environment related protocols and conventions which either have influenced or will influence directly or indirectly emissions of GHGs:

a) Framework Convention on Climate Change
b) Biodiversity Convention
c) Montreal Protocol
d) Vienna Convention on Desertification and Drought
e) Convention on International Trade in Endangered Species (CITES)
f) Prohibition of Chemical Weapons and Land Mines

Other Conventions and protocols (notably the Kyoto Protocol) are proposed for signature and ratification by the authorities. Together with these goodwill commitments that the country accedes to, it is recognised that local resources may be insufficient or inadequate to meet the inherent requirements. It is anticipated therefore that opportunities of partnerships in areas of technology transfer as well as provision of necessary resources by external means will be explored such as the Kyoto's Clean Development Mechanisms (CDM) to effectively undertake identified implementation measures in these issues.

6.9 EDUCATION, TRAINING AND PUBLIC AWARENESS

There currently is no formal education on climate change at the local university or colleges other than general topics touched upon in other courses such as geography and the physical sciences. However with the undertaking of the project of compiling enabling activities under the UNFCCC, the involvement of educators from these institutions set the required base for introducing these concepts into curricula.

The theory and practical issues of GHG inventories, mitigation and adaptation studies can be used as a foundation in introducing climate related topics either in existing courses or in new ones.
As regards public awareness on climare change, this has been well founded through active participation of various stakeholders from government, university, private sector and NGO's in the deliberations of the climate change committee. More effort will be required to expand public awareness campaigns to the grassroot level.

Generation of activity data through surveys, inventories, experimental studies and related research to generate emission and conversion factors, continues to be a highly required exercise to improve the quality of the results of the assessments. Research and development (R&D) on climate issues as they relate to Swaziland are highly desirable for supporting the country's efforts of meaningfull intervention in such international processes.

As more interventions are embarked upon in the quest to limit emissions of GHG's through various programmes, local capacity will need to be developed in specified areas.

The advances in the science of climate change will require a continuous development of capacity in the study team to effectively and efficiently conduct the required impact assessment in a local context and to best advise on issues of adaptation, mitigation and others.

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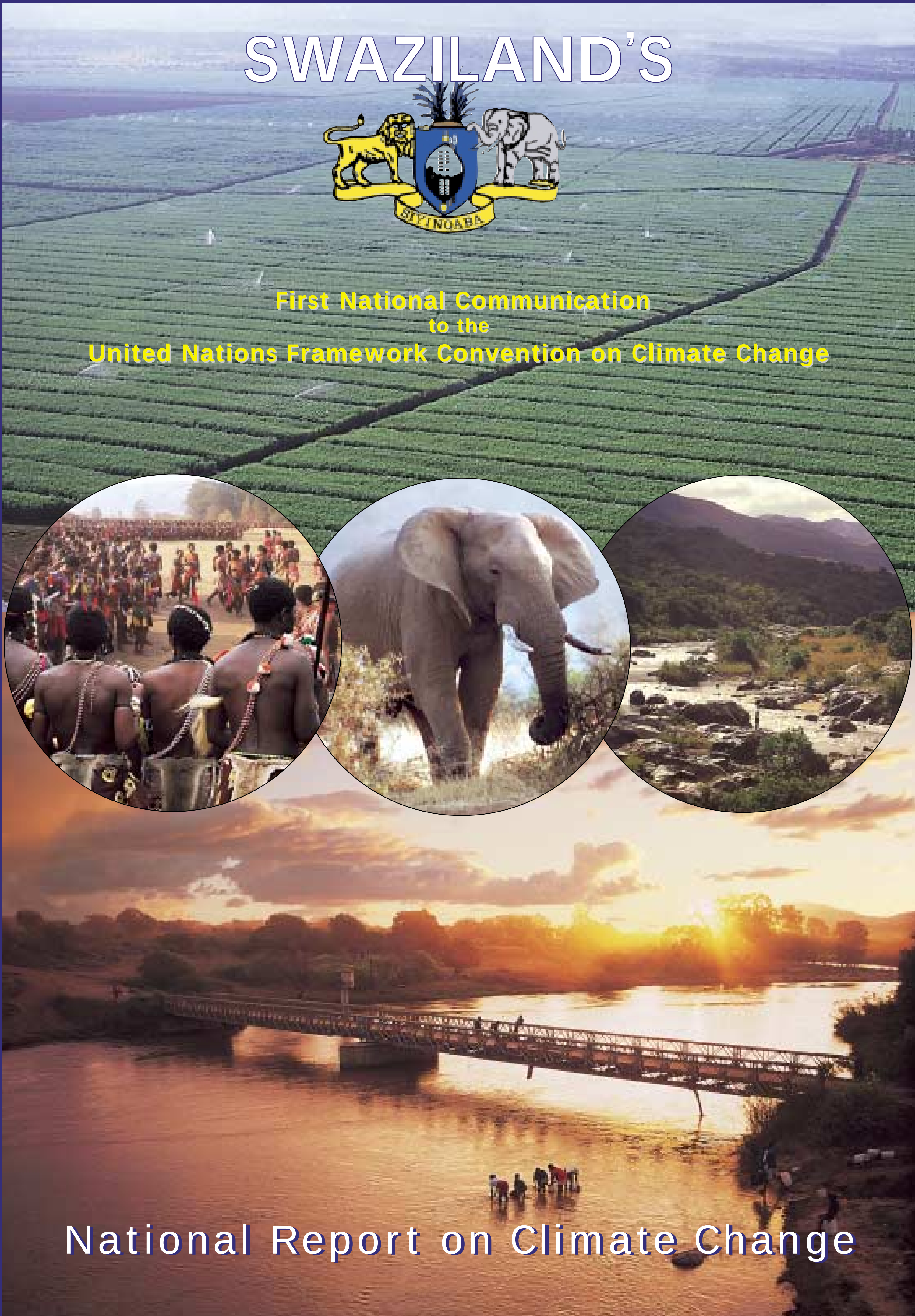

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