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LAND AND WATER DISCUSSION PAPER

4

Drought impact mitigation and prevention in the Limpopo River Basin

A situation analysis

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LAND AND WATER DISCUSSION PAPER

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Prepared by the
FAO Subregional Office for Southern and East Africa
Harare

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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Foreword

Southern Africa is a region that is particularly susceptible to climate variability and drought. It is being threatened increasingly by desertification processes, the degradation of land and water resources and the loss of biological diversity. In this environment, rainfed farming is a high-risk enterprise but also a way of life. People are committed to making the best of the scarce resources at their disposal.

Agricultural productivity is low and the production environments are normally characterized by soil moisture stress and poor soil fertility. There are large yield gaps between the average farmer and the best farmer, and returns to land, labour and capital are low. Droughts tend to reduce production below the already marginal levels, so that subsistence farming itself is threatened. These conditions occur where the local economy is least diversified and where virtually everyone depends either directly or indirectly on agriculture.

In southern Africa, more frequent exposure to drought events causes agricultural production to be out of equilibrium with the seasonal conditions, representing an inability on the part of most smallholders to adjust land use to climate variability. Thus, managing for drought is about managing for the risks associated with agriculture, and managing for climate variability must become the norm rather than the exception. Farmers must either increase agricultural productivity or develop alternative sources of income if their livelihoods are to be sustained.

Acceptance of this principle implies the need to better understand the underlying environmental, economic and social causes of drought impacts, and to identify mitigating actions that will address these underlying causes of vulnerability to future droughts.

The situation analysis presented in this report aims to provide readers with an understanding of the people and their environment in the Limpopo River Basin in southern Africa, covering parts of the four countries of Botswana, Mozambique, South Africa and Zimbabwe. It examines the biophysical, socio-economic and institutional characteristics of the basin and captures details of past programmes and practices. It concludes with a section on lessons learned and proposes options and strategies for sustainable development, with a focus on drought impact mitigation.

Acknowledgements

The idea of incorporating drought mitigation into the regular work of FAO was first put forward in 1997 by a small group of FAO technical officers at the Subregional Office for Southern and East Africa (SAFR), in Zimbabwe. The group was later expanded to include all technical officers belonging to the multidisciplinary team, led by Owen Hughes.

This team hypothesized and believed that longer-term interventions were needed in order to overcome the underlying environmental, economic and social causes of drought impacts on peoples' livelihoods and that this principle should guide the work of FAO in this area.

Many thanks are due to colleagues at SAFR for their invaluable insights and feedback during the many hours of debate on the subject. The support, guidance and encouragement given throughout by Victoria Sekitoleko, FAO Subregional Representative, are gratefully acknowledged.

In particular, the following are thanked for their contribution to the analytical work that is contained in this report: Owen Hughes, who took the original idea and developed a concept paper on learning to live with drought; Arie Remmelzwaal, a consultant who researched and compiled most of the initial draft, in particular the biophysical assessments; Karen Frenken, for her continuous involvement and substantial contributions to the sections on water resources in Chapter 2; and Mark McGuire, who was responsible for compiling a large part of Chapter 3, in particular the important social and economic characteristics of population, HIV/AIDS, human development, poverty and livelihood security. Finally, the work of Jan Schoeman and colleagues at the Institute for Soil, Climate and Water of the Agricultural Research Council in South Africa is gratefully acknowledged for gap filling, updating and completing the situation analysis.

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List of acronyms

ACFD	African Centre for Fertilizer Development (Harare)
AEZ	Agro-ecological zoning
AGRITEX	Agriculture, Technical and Extension Service (Botswana)
AIDS	Acquired Immune Deficiency Syndrome
ALDEP	Arable Lands Development Programme (Botswana)
ALES	Automated land evaluation system
APIS	Regional Agricultural Potential Information System (SADC)
ARA	Administraçaoes regional de agues (Mozambique)
ARC	Agricultural Research Council (South Africa)
ARDA	Agricultural and Rural Development Authority (Zimbabwe)
BCPD	Biodiversity Conservation and Participatory Development (GEF)
BDC	Botswana Development Corporation
BNWMP	Botswana National Water Master Plan
BRIMP	Botswana Range Inventory and Monitoring Project
BSAP	Biodiversity Strategy and Action Plan
BTC	Biodiversity and tourism corridor
CAMPFIRE	Communal Area Management Programme for Indigenous Resources (Zimbabwe)
CBD	Convention on Biological Diversity
CEC	Cation exchange capacity
CENACARTA	National Remote Sensing Centre (Mozambique)
CGIAR	Consultative Group on International Agricultural Research
CSIR	Council for Scientific and Industrial Research (South Africa)
CV	coefficient of variation
DEAT	Department of Environmental Affairs and Tourism (South Africa)
DFID	Department for International Development (United Kingdom)
DINAGECA	National Directorate for Geography and Cadastre (Mozambique)
DMC	Drought Monitoring Centre (SADC)
DNA	National Water Directorate (Mozambique)
DPCCN	Departamento de Prevencao e Combate as Calamidades Naturais (Mozambique)
DWAF	Department of Water Affairs and Forestry (South Africa)
EC	Electrical conductivity
ENSO	El Niño – Southern Oscillation
ET_o	Reference evapotranspiration
FANR	Food, Agriculture and Natural Resources Sector (SADC)
FEWS	Famine Early Warning System (SADC)
FMD	Foot and mouth disease
FSNS	Food security and nutrition survey
FSS	Food Security Strategy (SADC)
FSTAU	Food Security, Technical and Administrative Unit (SADC)
GDP	Gross domestic product
GEF	Global Environment Facility
GIS	Geographical information system
GKG	Gaza–Kruger–Gonarezhou (Transfrontier Park)
GLASOD	Global Assessment of Soil Degradation
GOB	Government of Botswana

GOM	Government of Mozambique
GOSA	Government of South Africa
GOZ	Government of Zimbabwe
GTZ	Gesellschaft für Technische Zusammenarbeit (Germany)
HDI	Human Development Index
HIES	Household income and expenditure survey
HIV	Human immunodeficiency virus
HPI	Human Poverty Index
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDNDR	International Decade for Natural Disaster Reduction
IDWG	Interdepartmental Working Group (UNCCD)
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute (Washington)
ILCA	International Livestock Centre for Africa (Addis Ababa)
IMDC	Inter Ministerial Drought Committee (Botswana)
IMF	International Monetary Fund
INGC	National Disaster Management Institute (Mozambique)
INIA	National Institute for Agronomic Research (Mozambique)
IPCC	Intergovernmental Panel on Climate Change
ISCRAL	International Scheme for the Conservation and Rehabilitation of African Lands
ISRIC	International Soil Reference and Information Centre
JLOC	Joint Logistics Coordination Centre
JULBS	Joint Upper Limpopo Basin Study (Botswana, South Africa)
LBPTC	Limpopo Basin Permanent Technical Committee
LGP	length of growing period
LHS	livelihoods system
LIMCOM	Limpopo Basin Commission
LIPWP	Labour Intensive Public Works Project
MAE	mean annual evaporation
MAP	mean annual precipitation
MAR	mean annual runoff
MARD	Ministry of Agriculture and Rural Development (Mozambique)
MOA	Ministry of Agriculture (Botswana)
MSF	Medicins Sans Frontiere
NAMPAADD	National Master Plan for Arable Agriculture and Dairy Development (Botswana)
NAP	National Action Programme of the UNCCD
NCFD	National Consultative Forum on Drought (South Africa)
NDVI	Normalized Difference Vegetation Index
NGO	Non-governmental Organization
NLC	National Land Cover Database Project (South Africa)
NPDM	National Policy on Drought Management (Zimbabwe)
O&M	Operation and maintenance
OCHA	Office for the Coordination of Humanitarian Affairs (UN)
ODI	Overseas Development Institute (London)
OFDA	Office of Foreign Disaster Assistance (USAID)
PARPA	Action Plan for the Reduction of Absolute Poverty (Mozambique)
PCN	Project Concept Note
PRSP	Poverty Reduction Strategy Paper (Mozambique)
RDP	Reconstruction and Development Programme (South Africa)
RSAP	Regional Strategic Action Plan (SADC)
SAC	Satellite Applications Centre (CSIR)

SADC	Southern African Development Community
SADCC	Southern African Development Co-ordination Conference
SCF	Save the Children Fund (United Kingdom)
SDARMP	Smallholder Dry Areas Resource Management Programme (Zimbabwe)
SDB	Soil Database
SEDAP	Southern-Eastern Dry Areas Project (Zimbabwe)
SEHA	Secretariat of State of Agricultural Hydraulics (Mozambique)
SOI	Southern Oscillation Index
SOTER	Soil and Terrain Digital Database
SPFS	Special Programme on Food Security (FAO)
SSA	sub-Saharan Africa
TFCA	Trans Frontier Conservation Area
TGLP	Tribal Grazing Land Policy (Botswana)
TOR	Terms of reference
UCEA	Unit of Agriculture Emergency Coordination (Mozambique)
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Commission on the Environment & Development
UNCMT	United Nations Country Management Team
UNDAF	United Nations Development Assistance Framework
UNDMT	United Nations Disaster Management Team
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFPA	United Nations Population Fund
UNICEF	United Nations Children's Fund
UNSO	United Nations Special Office
UNV	United Nations Volunteers
USAID	United States Agency for International Development
VEGRIS	Vegetation Resource Information System (Zimbabwe)
WCARRD	World Conference on Agrarian Reform and Rural Development
WFP	World Food Programme
WHO	World Health Organization
WRB	World Reference Base for Soil Resources
WSCU	Water Sector Coordinating Unit (SADC)
WWF	World Wildlife Fund
ZINWA	Zimbabwe National Water Authority

Chapter 1

Drought and climate variability in the Limpopo River Basin

INTRODUCTION

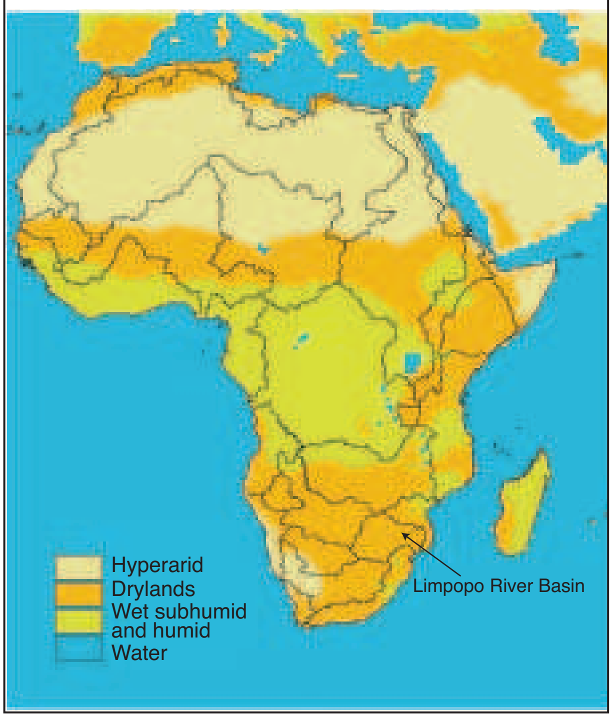
Drought is a normal recurring event that affects the livelihoods of millions of people around the world, and especially the 200 million people living in southern Africa. Climate variability, which includes erratic and unpredictable seasonal rainfall, floods and cyclones, contributes to the risk of farming across most of southern Africa, but especially in marginal rainfed agricultural areas that are characterized by low and erratic precipitation. The latter situation is reflected in relatively low and notably unpredictable levels of crop and livestock production. A serious drought or a series of consecutive droughts can be a disaster-triggering agent that exacerbates social and economic problems, and reduces the overall livelihood security of a society. These problems are most severe where economies are least diversified and virtually everyone depends either directly or indirectly on agriculture. Extended periods of drought or unusually high rainfall or flooding in these areas can have devastating effects on the already marginal levels of production, placing subsistence farming in jeopardy.

People living in areas prone to drought or flooding have developed livelihood and production systems to minimize the risks posed by extreme climatic variations. Although farmers have long maintained a suite of indigenous strategies and options to manage risk and to deal with poor overall productivity in spite of low returns to land, labour and capital, it is generally acknowledged that low-resource agriculture is no longer capable of meeting the livelihood demands of rising populations in these fragile dryland environments (Figure 1 and Box 1).

Owing to increased populations in the last century and the growing pressure on land, land use has become more intensive, and land and people have become more vulnerable to climate events. Within a more complex environment and through sophisticated production systems, people, livestock, crops and wildlife are competing for increasingly scarce resources. Over time, pressures and intensification will lead to greater susceptibility to future droughts and floods, resulting in further degradation of resources and loss of productivity – a downward spiralling effect.

Drought conditions frequently require government intervention in the form of emergency food relief, often supported by large amounts of donated food aid. Drought preparedness by governments has generally taken the form of creating food reserves (mainly maize) at national level to compensate for production shortfalls and provide for possible emergency relief. While these costly relief efforts have been perceived as a necessity, such short-term interventions have generally precluded support for longer-term development processes, particularly in those areas with dry climate conditions. As low and erratic

FIGURE 1
Dryland basins of Africa



BOX 1
Drylands

Drylands is the common name for arid, semi-arid and dry subhumid ecosystems that are characterized by low and irregular rainfall and high evapotranspiration and cyclical droughts.

In areas with summer rainfall, arid zones typically receive less than 400 mm of rainfall annually, while semi-arid and dry subhumid zones receive about 400–600 mm and more than 600 mm respectively.

Drylands as defined by the United Nations Convention to Combat Desertification (UNCCD), encompass the arid, semi-arid and dry subhumid zones where mean annual precipitation (MAP) over annual reference evapotranspiration (ET_o) is between 0.05 and 0.65.

Drylands have a "length of growing period" (LGP) of less than 180 days and mostly less than 120 days, where the LGP is defined as the period (in days) during a year when precipitation exceeds half the reference evapotranspiration (rainfall > 0.5 ET_o). Within this range, arid zones have a growing period of less than 60 days, semi-arid zones a growing period of 60–120 days and dry subhumid zones a growing period of more than 120 days.

Chapter 2 provides further information on climate.

precipitation is a key characteristic of these dryland areas, this fact of life must be reflected not only in the preparedness plans drawn up by governments, but also in the longer-term development strategies designed to prevent serious impact of future droughts on the environment and people's livelihoods.

CALLS FOR ACTION

Global

The 1986 FAO study titled *African agriculture: the next 25 years* stressed that Africa has considerable agricultural potential but that several constraints are preventing its realization. This study led to the approval of the International Scheme for the Conservation and Rehabilitation of African Lands (ISCRAL) at the 16th FAO Regional Conference for Africa in June 1990. In essence, the ISCRAL was designed to assist African countries to prevent and combat land degradation. At the Conference, several FAO member countries of the southern and east Africa region highlighted the seriousness and extent of the various kinds of resource degradation in their countries, and requested assistance from FAO in taking appropriate action.

Later, the 1992 United Nations Conference on Environment and Development (UNCED) defined desertification as "land degradation in arid, semi-arid and dry subhumid areas resulting from various factors, including climatic variations and human activities". The UNCED identified areas covering about 65 percent of the total land area of Africa under this definition. The UNCED called for the adoption of an "international convention to combat desertification in those countries experiencing serious drought and/or desertification, particularly in Africa … through effective action at all levels, supported by international cooperation and partnership arrangements, in the framework of an integrated approach which is consistent with Agenda 21" (Article 2, Part 1).

All four Limpopo River Basin countries (Botswana, Mozambique, South Africa and Zimbabwe) have signed the United Nations Convention to Combat Desertification (UNCCD). All parties to the UNCCD have an obligation to "adopt an integrated approach addressing the physical, biological, and socio-economic aspects of the process of desertification and drought" (UNCCD, 2003).

In addition, FAO activities in the follow-up to the World Food Summit (1996), whose plan of action includes multiple references to common objectives with the UNCED, are in direct support of the objectives of that initiative under Commitments 3 and 5.

Africa

In the context of the International Decade for Natural Disaster Reduction (IDNDR, 1990–2000), a Regional Meeting for Africa was held in May 1999 at the headquarters of the United Nations Environment Programme (UNEP) in Nairobi under the theme "Towards disaster reduction in the twenty-first century". Delegates at this meeting recognized in the Nairobi Declaration that the African continent is subject to a wide range of natural hazards and suffers from natural and other disasters that have serious adverse effects on societies and national economies, as well as on critical human and material resources. In this context, communities at risk across Africa find themselves even more vulnerable because of several aggravating factors, including: poverty, environmental degradation, inadequate exchange of data and information among African countries, and inadequate coordination at the continental level.

The Nairobi meeting recommended *inter alia* that cooperation among African countries in the domain of disaster prevention and risk reduction should be strengthened by adopting national and regional mechanisms to improve the exchange of information, sharing of experiences and knowledge, and technology transfer, and that African countries engaged in sound disaster prevention policies should receive due recognition and enabling support from the international community in order to achieve their set goals. Furthermore, local communities should be considered as primary actors in the design, adoption and implementation of disaster reduction policies and measures.

In 1997, the Food Security Technical and Administrative Unit (FSTAU) of the Southern African Development Community (SADC) organized a high-level drought policy seminar in Botswana in response to the threat of a serious regional drought following a strong El Niño phenomenon. The report of this seminar recognized that drought in southern Africa is a normal and recurring event, and called for long-term action in:

- investment in soil and water management, such as the improved development and management of fragile catchment areas and river basins, including small-scale irrigation;
- reviewing the appropriateness of current crop production patterns and possibilities in support of more intensified crop diversification policies;
- redirecting research towards more appropriate farming systems;
- improved rangeland and livestock management;
- reviewing institutional arrangements and physical infrastructure.

The role of FAO in drought and desertification control

For several decades, FAO has spearheaded agricultural improvement and rural development in arid, semi-arid and dry subhumid zones ravaged by drought and desertification. These activities have involved emergency and rehabilitation actions in the event of drought or other agricultural disasters, such as locust invasions. In addition, they have provided support in the formulation of policies and plans for development in the food, agriculture, forestry and fishery sectors; development of human resources – particularly for rural women – and of national institutions and legislation; and the promotion of research and dissemination of appropriate technologies in the various sectors.

These efforts have mostly taken the form of technical assistance projects in answer to specific requests by member nations. They have also sometimes been undertaken within programmes that group together projects with common priorities and themes, such as the programme to re-launch African agriculture (involving 200 projects in 30 countries); the fertilizer, seed, prevention of post harvest losses and food security programmes; the action plan of the World Conference on Agrarian Reform and Rural Development (WCARRD); and the Tropical Forestry Action Plan. Numerous desertification control and drought control activities have been implemented under these plans and projects, especially for soil conservation, pasture improvement, livestock improvement, small-scale irrigation, cereal storage, agroforestry, development of fuelwood resources, and also for nutrition improvement.

FAO also serves as one of the main partner organizations for the UNCCD. Because most of the technical objectives of the UNCCD relate directly to FAO objectives for the conservation and development of dryland resources, a number of activities implemented by FAO relate to desertification control and contribute to the implementation of the UNCCD. In 1998, more than 100 FAO field projects were directly related to the assessment and control of desertification, covering a wide range of activities, such as erosion control, improvement of water supply, forest and pasture management, local rural development through extension and participatory approach programmes, assistance in the implementation of national information systems and statistics, and formulation of investment projects. FAO support to the UNCCD is coordinated technically by an ad hoc interdepartmental working group (IDWG) established in order to deal with this matter, and composed of representatives from several FAO technical divisions. A memorandum of cooperation was signed in December 1998 between FAO and the Permanent Secretariat of the UNCCD, aimed at achieving the objectives of the UNCCD. This memorandum comprises an extensive programme, covering: (i) support to national and regional action plans and networks; (ii) compilation and dissemination of best practices; (iii) preparation and dissemination of awareness documents; (iv) establishment and implementation of information systems and databases that cover technical variables related to desertification; and (v) technical support to the UNCCD bodies and international events. The Special Programme for Food Security (SPFS), approved by the FAO Council at its 106th Session, is also playing a key role in the FAO response to the UNCED, the World Food Summit and the implementation of the Resolution on Urgent Action for Africa.

MANAGING THE IMPACTS OF DROUGHT

Definitions of drought

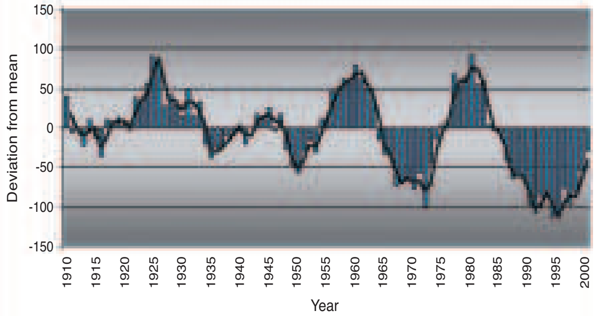
While lack of water is the underlying cause of drought, a large number of other socio-economic factors compound and intensify its effects. Wilhite (1999) states that the absence of a precise and universally accepted definition of drought adds to the confusion about occurrence and severity of drought. The various definitions of drought differ in their interpretation relative to their impacts and must be region and impact specific. Both the natural and social components of drought need to be better understood and addressed in national, regional and international policy planning (Abrams, 1997). Wilhite and Glantz (1985) describe four basic categories or types of drought:

- Meteorological drought: A reduction in rainfall supply compared with a specified average condition over some specified period; defined as a period during which less than a certain amount (e.g. 70 percent) of the normal precipitation is received over any large area for an extended period.
- Agricultural drought: A reduction in water availability below the optimal level required by a crop during each different growth stage, resulting in impaired growth and reduced yields. Agricultural drought relates to an imbalance in the water content of the soil during the growing season, which although influenced by other variables such as the crop water requirement, the water-holding capacity and degree of evaporation, is also largely dependent upon rainfall amount and distribution.
- Hydrological drought: The impact of a reduction in precipitation on natural and artificial surface and subsurface water resources. It occurs when there is substantial deficit in surface runoff below normal conditions or when there is a depletion of groundwater supplies. Hydrological drought reduces the supply of water for irrigation, hydroelectrical power generation, and other household and industrial uses.
- Socio-economic drought: The impact of drought on human activities, including both indirect and direct impacts. This relates to a meteorological anomaly or extreme event of intensity and/or duration outside the normal range of events taken into account by enterprises and public regulatory bodies in economic decision-making, thereby affecting production and the wider economy.

Occurrence of drought

According to the International Fund for Agricultural Development (IFAD), as cited by Benson, Thomson and Clay (1997), at least 60 percent of sub-Saharan Africa (SSA) is vulnerable to drought and probably 30 percent is highly vulnerable. Extreme drought in the Limpopo River Basin is a regular phenomenon and has been recorded for more than a century at intervals of 10–20 years. An example for Zimbabwe is given in Figure 2. In the period 1980–2000, the SADC region was struck by four major droughts, notably in the seasons 1982/83, 1987/88, 1991/92 and 1994/95. This corresponds to an average frequency of once every four or five years, although the periodicity of droughts is not necessarily so predictable. FAO (1994) identified three drought cycles during the years 1960 to 1993 with lengths of 3.4, 7.1 and 5.8 years, respectively. Amplitudes were 0.38, 0.35 and 0.28 standard deviations, respectively.

FIGURE 2
Zimbabwe national rainfall deviation from mean 10-year running mean (period 1900 to 2000)



Source: GOZ–ZMD (2001).

TABLE 1
Impacts of drought on different economic structures

Various aspects of the economy	Economic structure			
	Simple	Intermediate	Complex	Dual/extractive
Per capita income	Low	Low / low-middle	High-middle/high	Low/middle/high
Main sector	Agriculture	Agriculture, manufacturing	Manufacturing, service	Manufacturing, service, agriculture
Importance and nature of agriculture sector	Mainly rainfed, accounting for > 20 percent of GDP and > 70 percent of employment	Rainfed/irrigated, accounting for > 20 percent of GDP and 50 percent of employment	Mainly irrigated, accounting for < 10 percent of GDP and < 20 percent of employment	Rainfed/irrigated, accounting for 10–20 percent of GDP and 20–50 percent of employment
Intersectoral linkages	Weak	Intensive	Diffused	Weak
Engine of growth	Agriculture	Agriculture/non-agriculture	Non-agriculture	Extractive sector
Infrastructure	Limited	Extensive	Extensive	Limited/extensive
Spatial impact of drought	Largely rural, area directly affected	National, rural and urban population	Largely rural, area directly affected	Rural
Economic recovery following drought	Relatively fast	Agriculture – relatively fast Manufacturing – more slowly	Agriculture – relatively fast Manufacturing – no real impact	Agriculture Limited knock-on affects

Source: Benson and Clay (1998).

Drought conditions can be expected somewhere in the region in the majority of years, but it is rare for all countries to be drought-stricken at the same time (Bepura, 1999).

IMPACTS OF DROUGHT IN SOUTHERN AFRICA

Macroeconomic impacts

Drought is the most important natural disaster in southern Africa in economic, social and environmental terms (Buckland, Eele and Mugwara, 2000). A report by the United Nations Development Programme (UNDP) states that drought is considered by many to be the most complex and least understood of all natural hazards, affecting more people than any other hazard (UNSO, 1999).

Benson and Clay (1998) reported that little research has been done on the macroeconomic impact of drought in SSA. The main reason is that drought is typically perceived as an agricultural or food supply problem. However, for most SADC countries drought represents the most important type of economic shock they are likely to experience. It is important for governments to understand the macroeconomic impacts of drought when developing drought management policies and programmes.

Drought has primary and secondary (ripple) effects on a household or national economy. Primary or physical impacts include reduction in agricultural production, hydroelectric power generation, water intensive non-agricultural production (processing), and domestic availability of water, which has health implications. Secondary impacts are those that affect gross domestic product (GDP), e.g. reduction in industrial output may lead to inflation and lay-off of labour, which increases unemployment. These factors reduce demand, expenditure, savings and GDP.

The typology presented in Table 1 is useful in distinguishing four country economy scenarios in terms of the impact of drought. Under this approach, South Africa is classified as a dual/extractive economy that consists of a rural economy with a high level of subsistence production as well as a developed urban manufacturing and service sector. Mozambique would be classified as a country with a relatively simple economy, based primarily on agriculture. Botswana and Zimbabwe are classified as countries with an intermediate economic structure based on a combination of agriculture and manufacturing (Chapter 3 discusses the socio-economic characteristics of the four basin countries).

Primary and secondary impacts

Vogel, Laing and Monnik (1999) list the impacts associated with drought in South Africa, although these could readily be applied to other drought-prone areas in southern Africa as well (Table 2). Table 2 shows that drought impacts are much more than simply a food supply problem, depending on the duration and severity of the drought.

TABLE 2
Impact of drought in southern Africa

Primary impacts	Secondary impacts
SOCIAL	
Disrupted distribution of water resources	Migration, resettlement, conflicts between water users
Increased quest for water	Increased conflicts between water users
Marginal lands become unsustainable	Poverty, unemployment
Reduced grazing quality and crop yields	Overstocking; reduced quality of living
Employment lay-offs	Reduced or no income
Increased food insecurity	Malnutrition and famine; civil strife and conflict
Increased pollutant concentrations	Public health risks
Inequitable drought relief	Social unrest, distrust
Increased forest and range fires	Increased threat to human and animal life
Increased urbanization	Social pressure, reduced safety
ENVIRONMENTAL	
Increased damage to natural habitats	Loss of biodiversity
Reduced forest, crop, and range land productivity	Reduced income and food shortages
Reduced water levels	Lower accessibility to water
Reduced cloud cover	Plant scorching
Increased daytime temperature	Increased fire hazard
Increased evapotranspiration	Crop withering and dying
More dust and sandstorms	Increased soil erosion; increased air pollution
Decreased soil productivity	Desertification and soil degradation (topsoil erosion)
Decreased water resources	Lack of water for feeding and drinking
Reduced water quality	More waterborne diseases
ECONOMIC	
Reduced business with retailers	Increased prices for farming commodities
Food and energy shortages	Drastic price increases; expensive imports/substitutes
Loss of crops for food and income	Increased expense of buying food, loss of income
Reduction of livestock quality	Sale of livestock at reduced market price
Water scarcity	Increased transport costs
Loss of jobs, income and property	Deepening poverty; increased unemployment
Less income from tourism and recreation	Increased capital shortfall
Forced financial loans	Increased debt; increased credit risk for financial institutions

Source: Adapted from Vogel, Laing and Monnik (1999).

Not all of the impacts listed in Table 2 occur with every drought, nor do droughts typically affect the entire region or country. However, almost every year there is some subnational area affected by drought somewhere in the southern Africa region, and usually somewhere within the Limpopo River Basin (SADC, 1999). Drought is a chronic problem in southern Africa and has a major impact on rural livelihoods with the effects lingering long after the actual event. For example, Buckland, Eele and Mugwara (2000) wrote: "…the economies of the [SADC] region are particularly susceptible because of their geographical position, the high proportion of people dependent on rainfed agriculture for their livelihoods, and the strong links between agriculture and the rest of the economy … In the case of the 1991/92 drought [in southern Africa], estimates put the total number of people affected at 86 million, 20 million of whom were considered to be at serious risk of starvation. Cereal output in SADC (excluding South Africa, not then part of the community) fell from an average of 11.3 million tonnes to 6.2 million tonnes. Import needs rose to 7 million tonnes, with a further 5.5 million tonnes for South Africa. In total, 11.4 million tonnes of cereal were imported…".

Botswana experienced several periods of prolonged drought affecting the entire country from 1981 to 1986 that were caused by a succession of below average rainfall years. The cumulative effect was devastating in terms of food and water availability and caused large-scale mortality in livestock and wildlife (Bhalotra, 1987a). This drought is widely regarded as the worst to affect Botswana in living memory. A second period of drought in 1991/92 also affected the entire country and caused widespread crop failure and livestock mortalities.

In the 1991/92 agricultural season, Zimbabwe experienced the worst drought in living memory, with complete failure of crops and devastation of the livestock sector that rendered most areas semi-deserts. The economic effects were also felt outside the agriculture sector. Largely as a result of the drought, through water and electricity shortages, manufacturing output in Zimbabwe declined by 9.3 percent, with a 25-percent reduction in volume of manufacturing output and 6-percent decline in foreign currency receipts (Benson and Clay, cited in SADC–IUCN–ZRA–SARDC, 2000). In the period 1991–97, the country experienced three major droughts requiring the importation of food to alleviate the associated food shortages. Serious reductions in agricultural output resulted in reduced economic growth and loss of the much-needed foreign exchange normally derived from agricultural exports.

Mozambique regularly experiences both extremes of rainfall variability – periods of insufficient rainfall as well as severe flooding caused by excessive rainfall and cyclones (Box 2). The drought in southern Africa in 1991/92 also had enduring effects and affected more than 1.3 million people, especially the rural poor of the southern and central zones. The impacts were exacerbated by the civil war and caused widespread loss of food supplies and livestock, and environmental degradation (Manjate, 1997). The World Food Programme (WFP) alone spent nearly US$200 million in providing food aid relief. The southern province of Gaza is one of the most drought-prone as well as flood-prone provinces in the country because of its proximity to the Limpopo River and low-lying coastal areas.

In the 1992 drought in South Africa, it was estimated that 50 000 jobs were lost in the agriculture sector, with a further 20 000 in related sectors, affecting about 250 000 people (AFRA, 1993). Although the direct contribution of the agriculture sector to GDP is relatively small (about 5 percent), it still plays an important role in the economy through backward and forward linkages to other sectors (e.g. the purchase of goods such as fertilizers, chemicals and implements as well as the supply of raw materials to industry). The Reserve Bank (Pretorius and Smal, 1992) calculated the agricultural multiplier to be 1.6, and using simulation modelling calculated the loss to GDP during the 1992 drought at about 1.8 percent, representing US$500 million. This is a substantial impact from a sector playing a relatively small role in the economy.

BOX 2

Recent floods in Southern Africa

1984:

Torrential rains from the tropical cyclone Demoina (600 mm in 24 hours at St Lucia) caused extreme flood events in northeastern South Africa and adjacent Mozambique and Swaziland. Hundreds of hectares of fertile alluvial soil under sugar cane were reduced to bare rock beds. Vast areas of KwaZulu-Natal Province were isolated, rivers flooded, bridges and roads washed away. Houses collapsed under the weight of the water and many people were left stranded. Damage to roads and bridges was estimated at US$2.7 million, and the death toll rose to 60.

2000:

The tropical depression and cyclone (Eline) ravaged large parts of Mozambique, South Africa, Botswana and Zimbabwe in February. High winds, torrential rains, and severe flooding left a trail of destruction and heavy loss of life. Large areas of agricultural land were submerged, together with livestock and farming implements. Mozambique was worst affected, with up to 400 people reported dead and about a million displaced.

In April, after devastating northern Madagascar, where it left 13 people dead and 100 000 homeless, the tropical storm Hudah threatened the coast of flood-ravaged southern Mozambique before turning away to be dissipated over northern Mozambique, where 171 mm rain fell.

Drought management in the programming cycle

For many of the already impoverished, food insecure or vulnerable population groups in the Limpopo River Basin, one severe drought, or series of consecutive droughts, may result in the loss of their traditional livelihood system, and thus result in further deprivation. Moreover, consecutive droughts combined with poor natural resource management practices and inappropriate policies will result in environmental degradation and thus a serious reduction in the productive capacity of the land.

BOX 3

Combating land degradation and desertification

Recent studies have challenged the scenario of dramatically increasing land degradation. The conclusion drawn is not that irreversible changes cannot occur, but that drastic changes are inherent in the semi-arid ecosystem, and that these changes are often more dependent on rainfall than on human actions (Behnke and Scoones, 1993).

However, there are sufficient indications that degradation of soil and land resources is expanding rapidly through increasing pressure from human and livestock populations, leading to reduced productivity and diminished biodiversity. Degradation is mainly a reflection of socio-economic conditions and structures, e.g. land tenure arrangements, and lack of conservation of the land. Unsustainable use of the land is the single most important factor contributing to erosion and degradation, which is apparent through practices of overgrazing, road construction, mining, fuelwood collection, and urbanization.

Increasing pressure on the limited land resources caused by a growing population and increasing poverty calls for a new balance between ecosystems, human settlement and production systems. For planning purposes and decision-making it is essential to analyse the relationship between actual erosion and land policy, land use, land tenure, climate, population density and other relevant factors in order to restrict further damage to the land resource base.

Available overviews on erosion and land degradation in the Limpopo River Basin are ad hoc exercises and not based on systematically collected reliable field data. No sound analysis of causes has been attempted, and underlying causes such as overgrazing, intensive cropping and deforestation are only mentioned randomly. There is an insufficient database of land degradation and desertification, in particular lacking data on spatial distribution.

However, a general observation is that the most serious land degradation in the Limpopo River Basin occurs on the rangelands, in particular the communal grazing areas. Severe degradation may also be found associated with other less frequent land uses.

Climate variability and changes also have a profound effect on accelerating erosion and land degradation. Extreme rainfall aggravates the condition of already degraded land through increased runoff and flooding. Lack of rainfall and resultant drought exacerbate desertification processes. Drought acts as a strong catalyst in the initial and progressive degradation of land.

The following general rehabilitation strategies have been recommended in recent decades.

- Rehabilitation of degraded cropland; includes introduction of agroforestry and mixed cropping systems to improve the nutrient status, zero or minimum tillage systems to minimize soil erosion, and physical soil conservation measures.
- Rehabilitation of degraded rangeland; includes introduction of sustainable livestock management, group and individual title to land, zero grazing, and physical soil conservation measures.
- Rehabilitation of degraded forests and woodlands; includes improvement of sustainable communal forest management, development of communal woodlots, alternative sources of energy and agroforestry.
- Improving water management through integrated catchment management, focusing on holistic water use, with a balance between all land uses, including plantation forests, efficient irrigation systems, safe drinking-water, water for cattle, and water harvesting.
- Combating desertification by addressing the socio-economic causes as well as the physical ones. Measures include: introduction of sustainable production methods; integration of trees in crop production systems; and physical methods of wind and water erosion control. People's participation in the development of soil and water conservation strategies is essential. Programmes need to be supported by research into the causes and the most efficient methods to combat desertification.

Whereas all four countries of the Limpopo River Basin have national action programmes (NAPs) in place to implement the UNCCD, there is little to conclude yet on its impact on land degradation. NAPs are designed to make use of existing programmes and projects, and promote additional activities.

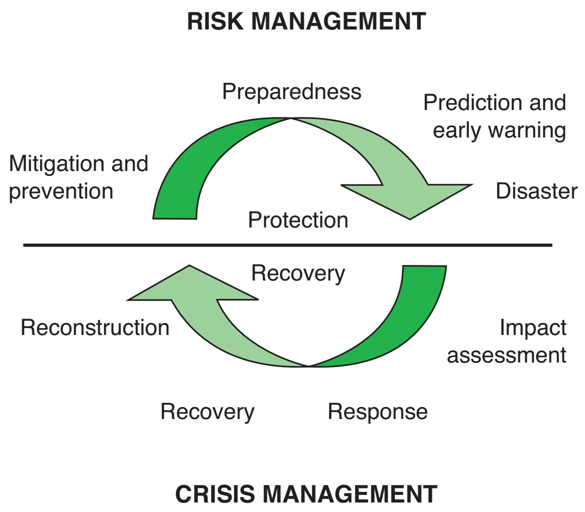
One of the major conclusions from the evaluation of past and present land rehabilitation programmes is that failures have stemmed from not involving the local communities fully in management and decision-making (Sola, 1993).

Various development partners have undertaken substantial work on drought management (preparedness, mitigation, response, rehabilitation and prevention) to help cope with these variations in climate and potentially devastating impacts (Wilhite, 1999; Vogel, Laing and Monnik, 1999; GOZ–NEPC, 1999; Knutson, Hayes and Phillips, 1998). However, more comprehensive and practical field-level interventions adopting self-reliant approaches in managing for climate variability are needed to support longer-term drought and disaster mitigation and prevention at a larger scale (Box 3).

Wilhite (1999) describes a comprehensive cycle of disaster management that can be adapted readily to a drought management scheme (Figure 3). This diagram is useful for visualizing the cyclical nature of activities associated with drought management and the need to include prediction and early warning, preparedness, and mitigation in the planning cycle. Past emphasis on crisis management has meant that society has moved from one disaster to the next without reducing the risks or the impacts. With an improvement in operational capabilities (climate and water monitoring, institutional capacity, information flow, and coordination within response structures) and mitigation and risk management, the impacts of drought could be reduced.

Vogel, Laing and Monnik (1999) also proposed a disaster management planning approach for South Africa where role-players, such as relevant government departments and non-governmental organizations (NGOs), implement and manage their specific disaster policies during periods of "non-disaster". These actions would represent risk management. When a disaster occurs (e.g. drought), each role-player would increase its capacity to respond to the event (referred to as crisis management). Once the disaster has been managed and the situation has normalized, each role-player will continue with risk management. The process of risk management is continuous in the sense that policies and programmes do not come to an end after a particular disaster.

FIGURE 3
Disaster, risk and crisis management cycle



Source: Adapted from Wilhite (1999).

Chapter 2
Biophysical characteristics

INTRODUCTION

The Limpopo River Basin is situated in the east of southern Africa between about 20 and 26 °S and 25 and 35 °E. It covers an area of 412 938 km^2. Figure 4 shows the basin in relation to major physical features of the subcontinent. The basin straddles four countries: Botswana, Mozambique, South Africa and Zimbabwe. Figure 5 shows the main overland transport routes, urban centres, rivers and nature conservation areas in the basin.

CLIMATE

Classification of the climate of the Limpopo River Basin

Climate conditions vary considerably in southern Africa, as the subcontinent lies at the transition of major climate zones. The climate in the Limpopo River Basin is influenced by air masses of different origins: the equatorial convergence zone, the subtropical eastern continental moist maritime (with regular occurrence of cyclones), and the dry continental tropical and marine west Mediterranean (winter rains) (Bhalotra, 1987b; GOB–MMRWA, 1991; Schulze, 1997; Unganai, 1998).

According to the Köppen Classification (Köppen, 1918; Rosenberg, 1999), the basin is predominantly semi-arid, dry and hot (BSh in Figure 6). The central river valley is arid, dry and hot (BWh). Here, the average rainfall is less than 400 mm with likely crop failure in 75–90 percent of years (Reddy, 1985; 1986). The South African highveldt part of the basin is temperate with summer rainfall and cool to hot summers (Cwc and Cwa). The Mozambique coastal plain is mainly warm-temperate with no dry season and hot summers.

Rainfall

The Limpopo River Basin is a region of summer rainfall, generally with low precipitation. The overall feature of the mean annual precipitation is that it decreases fairly uniformly westwards from the northern reaches of the Drakensberg Escarpment across the interior plateau. However, rainfall is highest on the Drakensberg Escarpment because of its orographic effect. There is also a north–south rainfall gradient towards the Limpopo River.

Rainfall varies from a low of 200 mm in the hot dry areas to 1 500 mm in the high rainfall areas. The majority of the catchment receives less than 500 mm of rainfall per year (Figure 7). The hot dry areas receiving about 200–400 mm of annual rainfall are located mostly within the main Limpopo River Valley itself.

Rainfall is highly seasonal with 95 percent occurring between October and April, often with a mid-season dry spell during critical periods of crop growth. It occurs on a few isolated rain days and isolated locations, seldom exceeding 50 rain days per year. Rainfall varies significantly between years, with maximum monthly rainfall being as high as 340 mm compared with mean monthly rainfalls of 50–100 mm for January, February and March.

FIGURE 4
The Limpopo River Basin in relation to country boundaries and physical features of the subcontinent

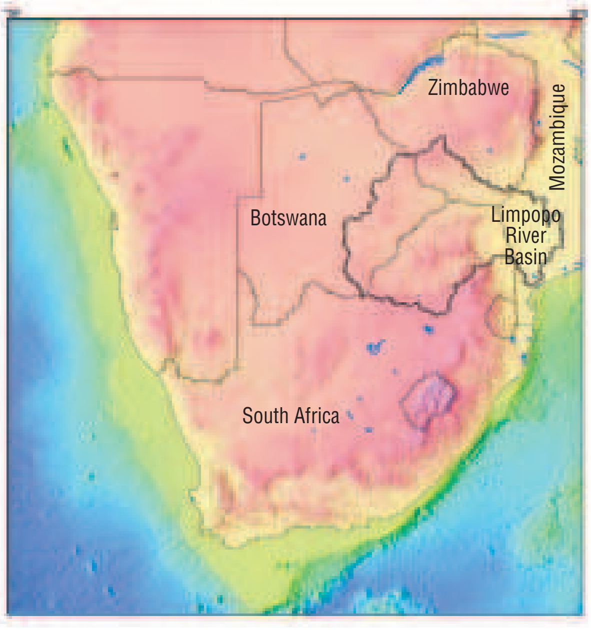
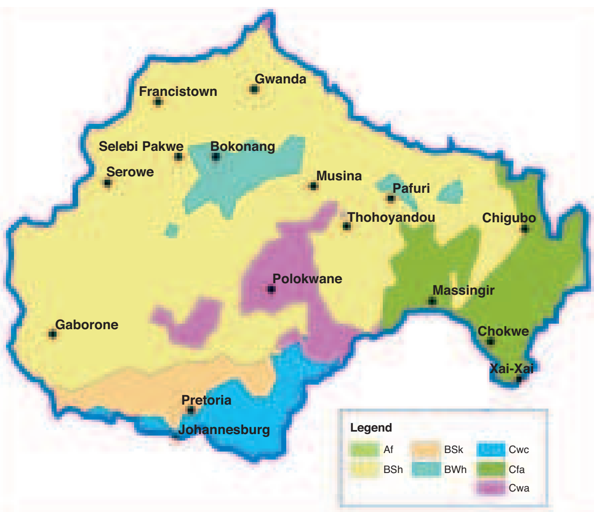


FIGURE 5
The Limpopo River Basin in relation to transport routes and urban centres

FIGURE 6
Köppen climate classes

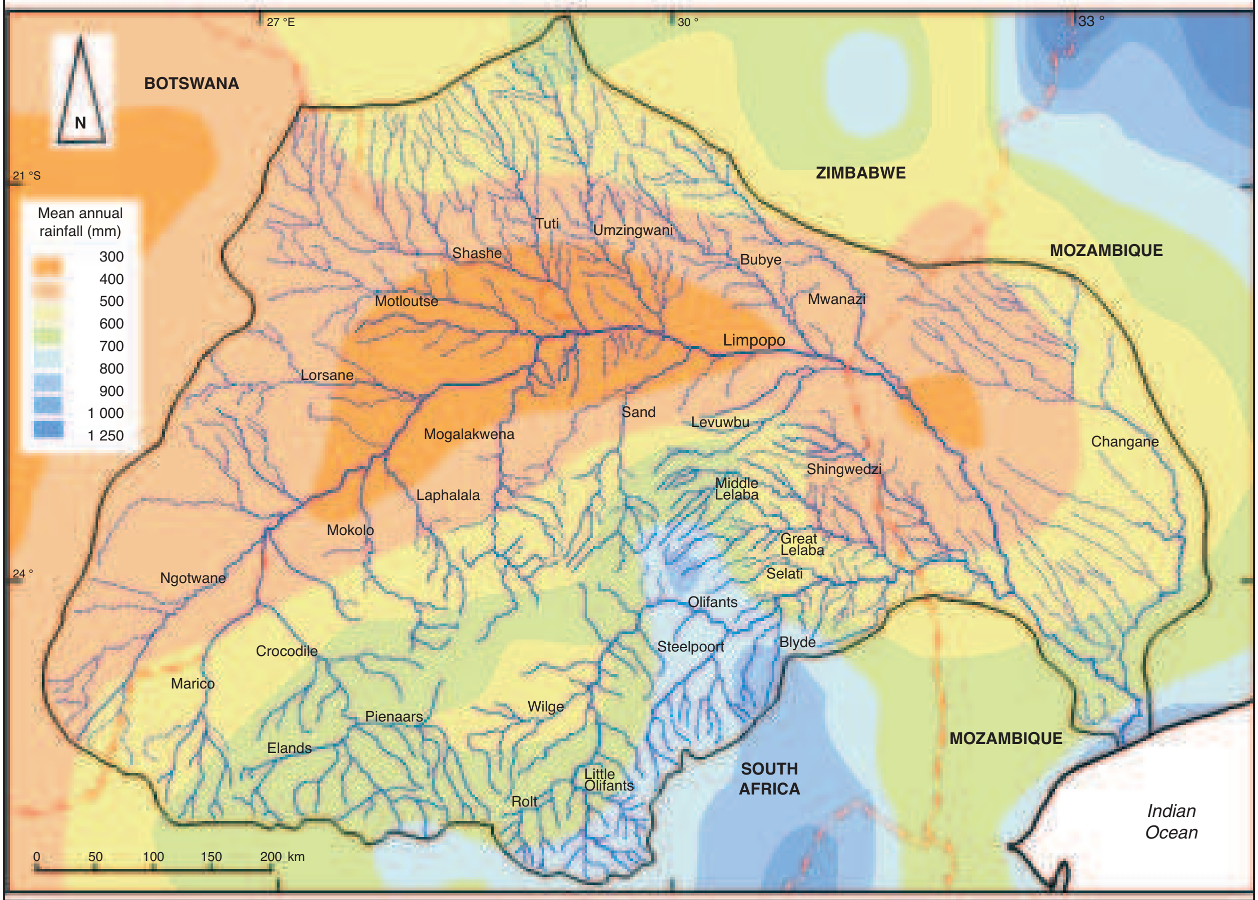


The Limpopo River Basin generally experiences short rainfall seasons, except for some of the outer limits of the basin that have higher rainfall and longer seasons. The rainfall concentration index is 60 percent and above, and this limits crop production because most of the annual rainfall is received in a short period of time.

A rainfall concentration index of 100 percent implies that a location receives all its rainfall in a single month. The rainfall season usually begins in early summer (late November to early December) for the southernmost parts of the basin and in mid-summer (mid-December to January) for the central parts of the basin around the Limpopo River itself. The rainfall season lasts an average of four months.

Rainfall in Botswana is caused mainly by convection thunderstorms, which typically occur

FIGURE 7
Average seasonal total rainfall in the Limpopo River Basin



Source: UNCTAD (2003).

as localized events with a high spatial and temporal variability. The annual rainfall in the Botswana part of the Limpopo River Basin varies from 350 mm in the northeast to about 550 mm in the southeast.

Zimbabwe experiences a single annual rainy season of five months (November–March), associated with the summer movement of the Inter-Tropical Convergence Zone over southern Africa. Within the Zimbabwe part of Limpopo River Basin, the mean annual rainfall varies from slightly more than 600 mm in the southern highveldt (Bulawayo) to less than 400 mm in the southeastern lowveldt (Tuli and Beitbridge). The annual variability is considerable, with a coefficient of variation (CV) of about 40 percent. The probability of receiving more than 500 mm of rainfall in any year is less than 60 percent in the southern highveldt and less than 30 percent in the southeastern lowveldt (with less than 10 percent in Beitbridge).

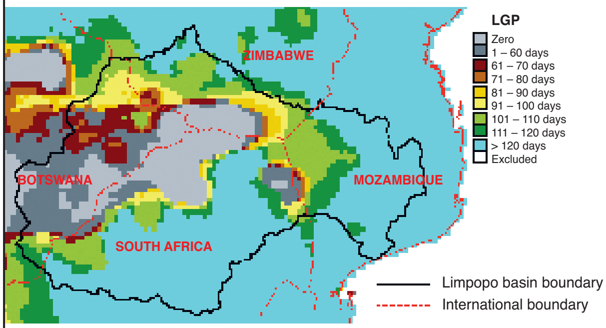
In Mozambique, the generalized rainfall pattern shows a sea-to-land gradient with a CV of about 40 percent in the Limpopo River Basin. Along the coastal strip, the mean annual rainfall is 800–1 000 mm, declining to less than 400 mm in the dry interior bordering Zimbabwe.

Rainfall generally has to exceed a minimum threshold of 20–30 mm before any runoff occurs, owing to high temperatures, low humidity and flat terrain. Many rainstorms are less than this and hence the flow regimes of rivers vary considerably. This results in high storage requirements for dams in order to deliver the yields that are required. Increased storage is costly and causes increased evaporation losses.

Evaporation

Evaporation within the Limpopo River Basin varies from 1 600 mm/year to more than 2 600 mm/year. The highest evaporation occurs in the hot Limpopo River Valley. High levels of evaporation mean that the soil dries up quickly and this reduces the

FIGURE 8
Estimated length of growing season derived from satellite imagery



amount of water available for plant uptake. This results in crops being more prone to drought.

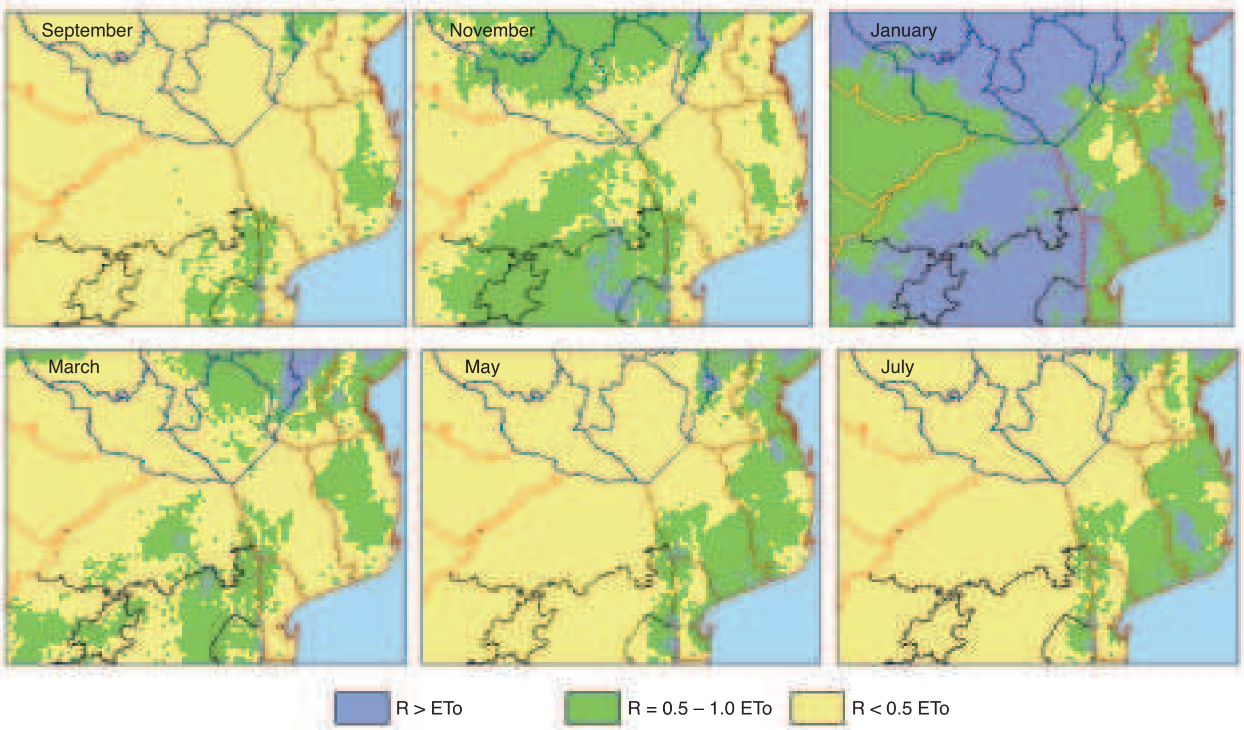
Evaporation from open water in Botswana varies from about 1 900 mm/year to 2 200 mm/year. Slightly lower annual figures of about 1 500 mm are derived from evapotranspiration calculations based on the Penman method. Daily figures range from about 2 mm to 5 mm. Evaporation is highest during the rainfall season, and it significantly reduces effective rainfall, runoff, soil infiltration and groundwater recharge. Evaporation loss from dams is significant owing to the high storage–yield relationship and flat dam basins.

Dryland subsistence farming is generally not viable given the variable rainfall, high evaporation and high evapotranspiration. Figure 8 shows the estimated length of growing period (LGP) derived from satellite imagery. Figure 9 shows the average crop water availability for selected months.

Temperature

Summers in the Limpopo River Basin are generally warm, and winters are mild. In summer, daily temperatures may exceed 40 °C, while in winter temperatures may fall to below 0 °C. The general figures for air temperature are related closely to altitude, and also to proximity to the ocean. The mean maximum daily temperature in most of the Limpopo River Basin, notably South Africa, Botswana and Zimbabwe, varies from about 30–34 °C in the summer to 22–26 °C in winter. The mean minimum daily temperature in most areas

FIGURE 9
Average crop water availability expressed as the relation between monthly rainfall, R, of selected months and the reference evapotranspiration, ET_o



Source: E. Mellaart, personal communication (2003).

lies between 18–22 °C in summer and 5–10 °C in winter.

The eastern and northern parts of the Limpopo River Basin are frost-free while the southern and western areas experience winter frosts. Frost does not occur in Mozambique and it occurs only occasionally in the southern highveldt of Zimbabwe, associated with an influx of cold dry air from the southeast. Frost-free areas also exist in the lowveldt of South Africa and along the Limpopo River in the Messina area.

Most of the higher-lying areas in South Africa and Botswana within the Limpopo River Basin experience frost, occurring most severely in the southwest of the basin. This may be very moderate in the areas of Tzaneen (Limpopo Province of South Africa) or Mahalapye (Central District of Botswana), but increases to 90–120 days of frost in Lobatse (southeast Botswana) or Mafeking (North West Province of South Africa). The average number of days with heavy frost in these areas is about 30 days. This does not imply that frost occurs over a short uninterrupted period. On the contrary, single or clusters of frost days may occur over a long period, usually between May and September. This may create a problem for late-planted crops.

Relative humidity

Relative humidity is generally higher on the eastern side of the Limpopo River Basin, and decreases inland. The relative humidity varies from less than 50 percent in September and October in the hot western parts of the basin in South Africa, to about 65 percent in January and February. Humidity in the lowveldt in South Africa varies only slightly (65–70 percent) in the same period.

Relative humidity in Botswana is comparatively low, with daytime averages of about 30 percent in winter and 40 percent in summer. However, much higher values are reached in the morning, nearing 60 percent in winter and more than 70 percent in summer. Humidity also increases before rainstorms, and is therefore highest between January and March. The dry western parts of Botswana record the lowest humidity.

Variation in rainfall and impact on growing season

There is considerable spatial and temporal variation in the rainfall regime in the Limpopo River Basin, as in most dryland areas, as much of the rainfall occurs in a limited number of rain events. A prerequisite to effective agriculture is a description of the rainfall regime in response to questions (Dennett, 1987) such as:

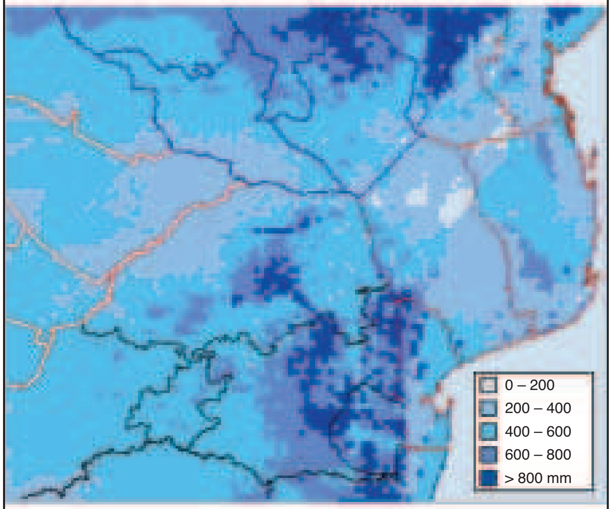
- When is rain likely to occur?
- What is the probability of a dry spell greater than a certain length?
- What is the probability of receiving a daily rainfall greater than a particular amount?

Probabilistic rainfall models to address these questions have been developed by Stern, Dennett and Dale (1982), and Stern and Coe (1982). These models have been applied to rainfall data from Gaborone and Tshane, two Botswana stations, 350 km apart. Model results calculated over a ten-year period indicate that as much as 50 percent of the total rainfall occurs in the 10 percent wettest days, and 80 percent in the 23 percent wettest days. The pattern is apparent in both dry and wet years. In addition, days with high rainfall are clustered. Understanding of such patterns is of prime interest because they determine the length of the growing season.

Reddy (1985, 1986) reported that the Limpopo River Basin in Mozambique presents a high risk of agricultural drought, depending on the type of dryland cropping systems in place. Here, there is high variation in terms of both commencement and cessation times of effective rains; that is, the risk associated with planting time. In terms of reliability, the erratic rainy season may begin any time from November to February. Therefore, average planting dates are only 50-percent reliable. Only 25 percent of the rainy seasons have 120 crop days. These begin on the average date for the rainy season, in December, whereas 25 percent of the years have 120 crop days starting later than this. Half of the remaining years have rainy seasons of more than 60 crop days.

Moreover, Reddy (1986) classified the upper Limpopo River Basin extending to the Zimbabwe border as a very high-risk area with probable crop failure in 75–90 percent of years. The dry semi-arid zone of the middle Limpopo River Basin extending to the lower Limpopo just off the coastline was assessed as a moderate to high-risk dryland agricultural zone where crop failure is expected in 45–75 percent of years. Kassam *et al.* (1982) determined the pattern of growing period zones in Mozambique. The interior of the Limpopo River Basin permits one growing period per year in 30 percent of the years, two growing periods per year in 45 percent of the years, and three growing periods per year in 25 percent of the years. The

FIGURE 10
Total rain for the summer season, October–March



mean total dominant LGP for the middle and upper Limpopo River Basin was calculated at less than 120 days, compared with a gradient from 120 to 270 days at the coast (Figure 8).

Using gridded SADC–RRSU data, Mellaart (personal communication, 2003) illustrates the distribution of rainfall over ET_o in the basin area in Figures 9–12. The class $R < 0.5\ ET_o$ denotes non-arable conditions. The class $R = 0.5–1.0\ ET_o$ indicates marginally arable to arable conditions. The availability of good soils with favourable water-holding characteristics determines the agricultural potential of these areas. The class $R > ET_o$ is restricted to mountainous areas of the eastern escarpment receiving high orographic rainfall. These generally steep areas are generally under plantation forestry.

FIGURE 11
Total evapotranspiration for the summer season, October–March

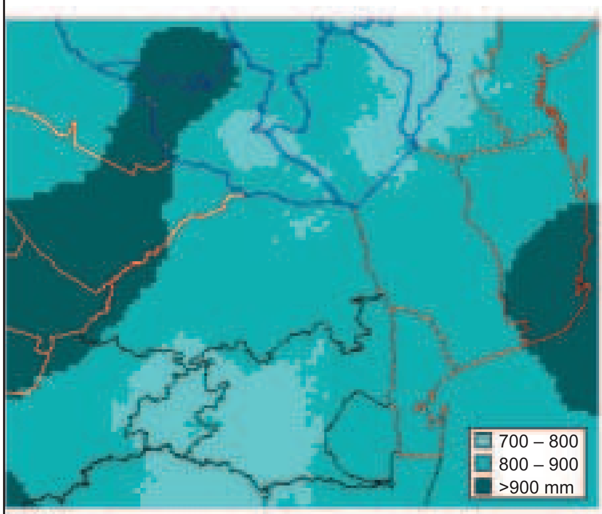
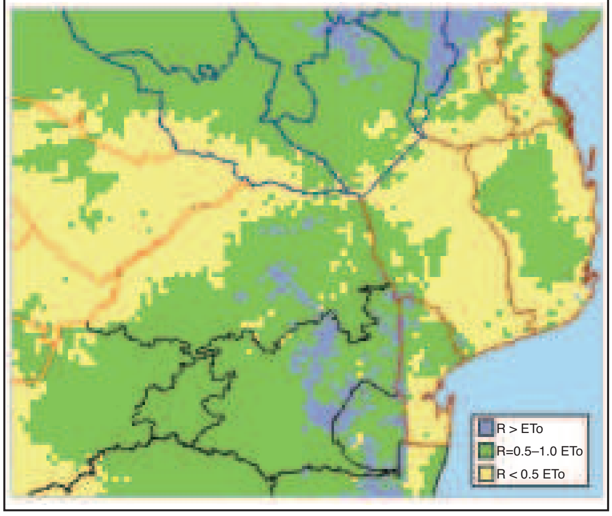


FIGURE 12
Total water balance for the summer season, October–March



Source: E. Mellaart, personal communication (2003).

Reliability of climate forecasts

Predicting drought is very complicated and has so far been unreliable, although there are strong indications for cyclic occurrence of drought, notably in southern Africa. In general, cycles of drier years are followed by successive seasons with opposite conditions. However, after two dry years in a recognized drought cycle, there is no guarantee that the third year will also be a drought year.

El Niño/La Niña phenomena and the Southern Oscillation

In a study on the impact of El Niño – Southern Oscillations (ENSOs) on the climate and crop production in Zimbabwe, Deane (1997) found that ENSO events (Box 4) do affect the subcontinent and that these provide instruments for assessing climate events at the natural region level. Deane concludes that research on the ENSO phenomena has the potential to result in improved management of the risk posed by weather through enabling potential drought years, as well as years with very good rainfall, to be better prepared for.

Recurrent droughts have put strong political pressure on meteorological services and early-warning systems to produce reliable forecasts.

BOX 4

El Niño – La Niña events and the Southern Oscillation

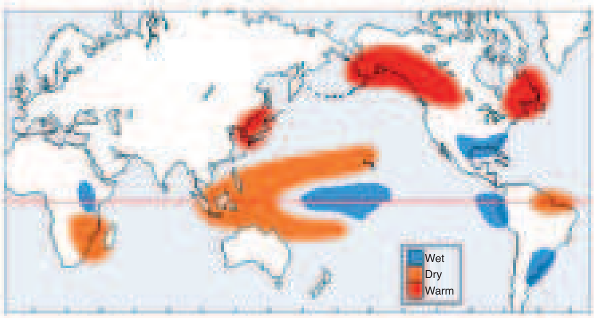
El Niño refers to the large-scale warming of the equatorial eastern and central Pacific Ocean due to a disruption of the ocean-atmosphere system (Figure 13). El Niño events occur irregularly at intervals of 2–7 years, although the average is about once every 3–4 years. They typically last 12–18 months. They have important consequences for weather and climate around the globe, including lower than normal rainfall for South Africa accompanied by higher than normal rainfall for central-east Africa. La Niña refers to unusually cold ocean temperatures in the equatorial Pacific. The impacts of La Niña tend to be opposite to those of El Niño. Various indices of sea surface temperature deviation are obtained by taking the average deviation over some specified region of the ocean. Figure 14 shows the Sea Surface Temperature Index for the NINO 3.4 area. (For assessing widespread global climate variability, NINO 3.4 is generally preferred, because the sea surface temperature variability in this region has the strongest effect on shifting rainfall). El Niño/La Niña events are accompanied by swings in the Southern Oscillation. The Southern Oscillation Index (SOI) is defined as the normalized difference in barometric pressure between Tahiti (French Polynesia) and Darwin (Australia). It is intimately related to the ocean temperature changes mentioned above and is a measure of the strength of the trade winds. SOI values (Figure 15) generally vary between +30 (La Niña) and -30 (El Niño). Together, these phenomena are referred to as ENSO (NOAA, 1994; University Corporation for Atmospheric Research, 2001; Pacific Marine Environmental Laboratory, 2003; Commonwealth Bureau of Meteorology, 2003).

Although substantial progress in the ENSO interpretation has been made, actual climate conditions in recent years have, to a large extent, not corresponded with the predicted outcomes. This raises concern about the reliability of the early-warning information used and applied, in particular in the southern African region. Until the mid-1990s, the general practice of declaring drought was based on the actual occurrence of drought. The severe drought of the 1991/92 season in southern Africa was only recognized officially as such as late as January 1992, well into the agricultural season.

The first time that drought was forecast in a very early stage – on the basis of global interpretations of the effects of El Niño – was in June 1997, when severe drought was predicted for the 1997–98 season (SADC, 1999). This led to actions by governments in the SADC region towards information dissemination and providing planting advice to farmers. Recommendations to farmers ranged from the planting of drought-tolerant and early-maturing varieties to destocking (Box 5). Even with improvements in the reliability of the climate forecasts, the occurrence of recurrent drought and related risks have to be accepted and integrated into land use systems sustainable under

FIGURE 13

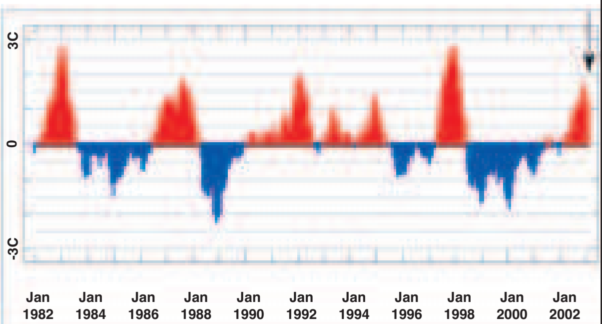
Precipitation anomalies during El Niño in the Southern Hemisphere summer



Source: NOAA (1994).

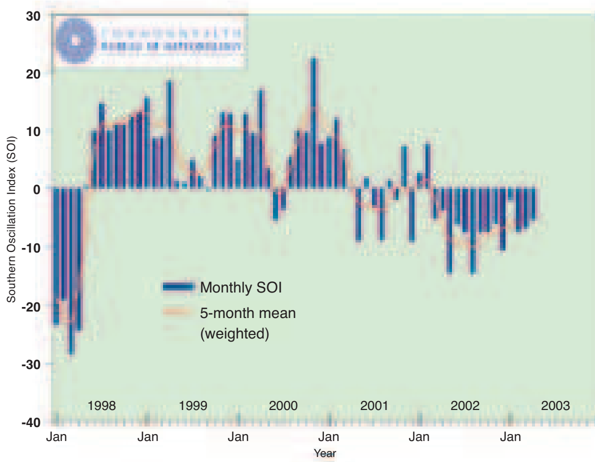
FIGURE 14

Sea Surface Temperature Index



Source: International Research Institute for Climate Prediction (2002).

FIGURE 15
Southern Oscillation Index, 1998–2003



Source: Commonwealth Bureau of Meteorology (2003).

the present climate conditions. The prospect of accelerated global warming, and associated regional changes in climate, reinforces the need for the consideration of the longer-term constraints that future climate may place on developments in the region. Recent studies conducted on climate variability and change in the region give strong indications of regional temperatures rising in coming decades (Hulme, 1996; Hulme and Sheard, 1999). Rising temperatures could change the rainfall regime in the coming decades, resulting in changes in natural vegetation, as well as agriculture and range conditions and water resources.

Long-term temperature trends

Africa is considered highly vulnerable to climate change. The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) notes a warming of about 0.7 °C over most of the African continent during the twentieth century based on historical records (UNEP, 2002). It was found with respect to Zimbabwe that the diurnal temperature range is decreasing. There

BOX 5
Farmers and climate forecasts, Zimbabwe

In Zimbabwe, only 3 percent of farmers use climate information for planning purposes. Some of the reasons given are that the information is not received in time and that farmers do not trust the meteorological information. Although farmers listen to climate forecast from radios, the poor and marginalized farmers prefer to use their traditional knowledge systems as a control. When contemporary climate forecasting deviates from traditional forecasts, the farmers' inclination is towards indigenous information for reasons that it blends well with the culture, has been tried and tested over the years, and is in a language that the farmers understand.

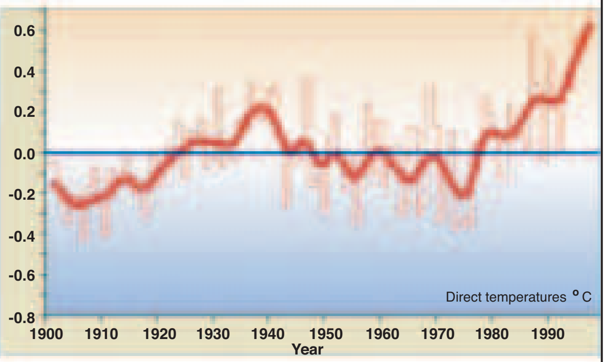
There is often a striking similarity between indigenous and contemporary climate indicators. Some indicators are the same in both systems, such as wind direction, clouds and temperature. In addition, indigenous climate predictions are also based on plant and animal behaviour.

Farmers associate heavy production of tree leaves with a good season while high fruit production is a sign of a poor season. The reasoning behind this observation is that high fruit production implies that people will be living on fruits for lack of alternative foods. The production of white flowers by a local tree called *mukuu* is also a signal for a dry season, while flower production on top branches of a tree called *mukonde* indicates a good rainy season. Other indigenous signs of an imminent drought include: heavy infestation of most tree species by caterpillars during springtime; late bearing and lack of figs in July–September of a tree called *mukute*; late maturing of acacia trees along valleys; and drying off of *chigamngacha* fruit between September and early November.

One of the most important animal indicators is the behaviour of spiders. When spiders close their nests, an early onset of rain is expected because spiders do not like any moisture in their nests. When a lot of crickets are observed on the ground, a poor rainy season is expected. The movement of elephants is associated with occurrence of rainfall because they need a lot of water. A stork flying at very high altitude is associated with a good season. Observing a bird singing while facing downwards from the top a tree is a good indicator that it is about to rain, while a lot of birds is a sign of heavy rain.

The wind blowing from west to east, and from north to south, is assumed to bring a lot of moisture and a good rainy season. The prevalence of a strong wind from east to west during the day and at night between July and early November is an indicator of drought.

FIGURE 16
Anomalies in mean surface temperatures over Africa



Source: UNEP (2002).

are more hot days and fewer cold days over time. Night-time minimum temperatures increased at twice the rate of daytime maximum temperatures. Precipitation deviations from a long-term mean are stated to have increased during the last century. While the exact nature of the changes in temperature or precipitation and extreme events are not known, there is general agreement that extreme events will become worse, and trends in most variables will change in response to warming. The expected warming is greatest over the interior semi-arid margins of the Sahara and central-southern Africa. Figure 16 illustrates anomalies during the past 100 years in mean surface temperatures in Africa. A notable upward trend/cycle is shown for the past 25 years. This rate of warming is similar to that experienced globally (UNEP, 2002).

PHYSIOGRAPHY

Physiography relates to the physical features of the earth, and it is used here to describe the landscapes of the Limpopo River Basin. The physiographic features of a region commonly affect its climate patterns and tendencies (e.g. rainfall intensity and distribution) and water drainage patterns (surface and subsurface). An important application of physiographic classification is the provision of a physical framework for land use planning in general and catchment management in particular. In addition, the physiography, together with the climate, forms the basis of agro-ecological zoning (AEZ), which is discussed in a later section.

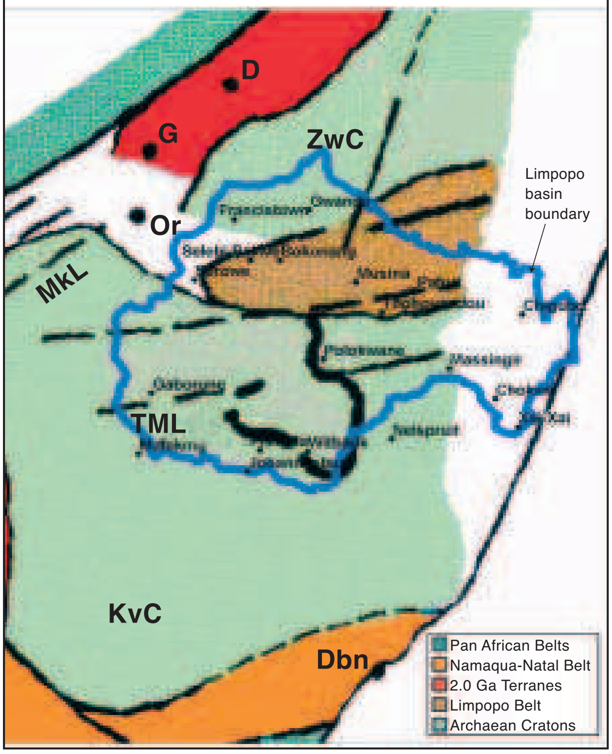
Geology

Landform and soil development are linked to geological and tectonic development at a subcontinental scale. Much of the present landscape of the Limpopo River Basin reflects recent geological events – in geological terms – following the break-up of Gondwanaland (Moon and Dardis, 1988). Tankard *et al.* (1982) and McCourt and Armstrong (2001) recognized the sequence of crustal evolutionary stages in southern Africa.

The Limpopo River Basin is located on the northeast edge of the Kaap-Vaal or Kalahari craton (KvC in Figure 17) and extends onto the southern part of the Zimbabwe craton (ZwC in Figure 17). The Limpopo mobile belt (granulite facies; shown in centre of the basin in Figure 17) and the Bushveld Igneous Complex (not shown in Figure 17) separate the two. The cratons constitute a stable shield, predominately of igneous and metamorphic rocks, at the base of the continental crust. The Kaap-Vaal craton is mostly covered sedimentary rocks. The genesis of the Basement Complex covers a period of 1 000 million years, falling within the Archaean period.

Granite and gneiss are the dominant rock types of the Basement Complex on the highveldt and escarpment of South Africa, with quartzites, granodiorites, and various slightly to moderately metamorphosed sedimentary rock occurring subordinately. The southern part of the Limpopo

FIGURE 17
Generalized tectonic framework of southern Africa



Source: McCourt and Armstrong (2001).

River Basin within the highveldt is characterized by the occurrence of Karoo sediments (Vryheid Formation), including sandstones, claystones, shales, and coal deposits. Karoo sediments and basalt also occur in a strip from northeast Botswana through southern Zimbabwe. Similar Cretaceous sediments (sandstones, grits and conglomerates) border Zimbabwe with Mozambique. The eastern strip of the lowveldt and the Lebombo Ridge are also dominated by similar Karoo formations, with subordinate occurrence of dolerite intrusions.

Cycles of geological erosion

Cycles of erosion have shaped the present landscapes of southern Africa. There is general agreement with respect to the major phases, but opinions differ regarding the more complex subdivisions (King, 1976; Partridge and Maud, 1987). Most of the Limpopo River Basin shows relatively advanced eroded conditions, and often shows younger and shallower soils as compared with less-eroded surrounding areas.

Erosion cycles during the early Tertiary period formed the African denudational surface at high or medium plateau level, such as the highveldt in South Africa. Its major occurrence is southwest of the southern divide of the Limpopo River Basin, the high-level plateau zone in Zimbabwe, the elevated areas near Polokwane (Pietersburg) in South Africa, and the flat-topped hills in eastern Botswana and Limpopo Province in South Africa.

Further erosion in the late Tertiary period formed the Post-African denudational surface. Various phases of this surface are dominant in the Limpopo River Basin. The most recent erosion was active during the Quaternary period, primarily downstream of the main rivers and tributaries in the basin area.

Most of the land within the Limpopo River Basin in Mozambique was formed by aggradational surfaces during the Quaternary and Tertiary periods, except for a band of Cretaceous rocks occurring north of the Save River to the border with Zimbabwe. Extensive, well-developed alluvial formations occur in the middle and lower reaches of the Limpopo River, and in the watercourses of the non-perennial rivers entering the Limpopo River. The oldest formations (Palaeocene and Eocene rocks) are of marine facies and correspond to the calcareous sandstones and conglomerates, which are disconformably overlain and border the effusive Karoo formations on the western border with South Africa.

The main unit of the Quaternary cover is a thick, homogenous mantle of yellowish-brown, saline, sodic, calcareous, sandy clay loam extending over the vast interior of Gaza Province west of the Limpopo River. It builds large, slightly sloping plateaus called *Mananga* developed over sedimentary, coarse and siliceous rocks. Near the incised valleys, the basal gravels have been exposed after erosion of the *Mananga* cover. Different cycles of weathering and landscape lowering reworked the resistant gravels into basal gravel floors. The highest gravels correlate to the red sandstones and conglomerates of the late Tertiary. The higher, lower and young gravels are associated with the respective *Mananga* platforms.

Physiographic description and mapping

The three major physiographic units of the interior are the South African Plateau (or Cape–Transvaal highveldt), the Zambia–Zimbabwe Plateau and the Kalahari Basin (Bridges, 1990). The Great Escarpment separates these units from the coastal ranges and coastal plains.

Figures 18 and 19, derived from digital elevation modelling, illustrate the basin structure with elevated remnants in places. The Limpopo River Valley separates the plateau areas of South Africa and Zimbabwe, and is bounded to the west by the Kalahari Basin. Towards the east, the Elephants River and several other smaller tributaries of the Limpopo River (see also Figure 7) traverse the Lebombo Ridge before joining the Limpopo River on the coastal plain in Mozambique.

At a generalized level, plains at various altitudes are the dominant landforms of the basin. These

FIGURE 18
Relief map of the Limpopo River Basin

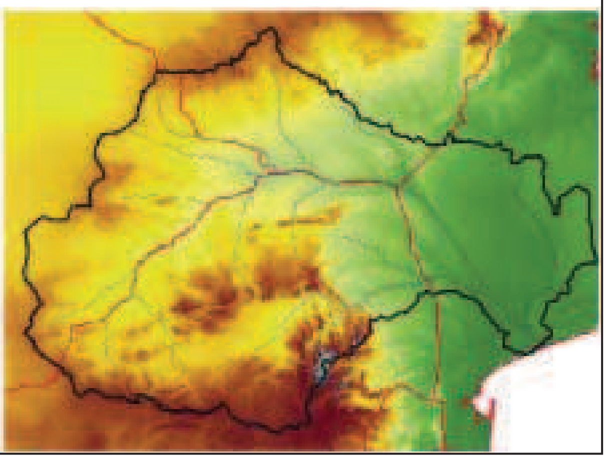
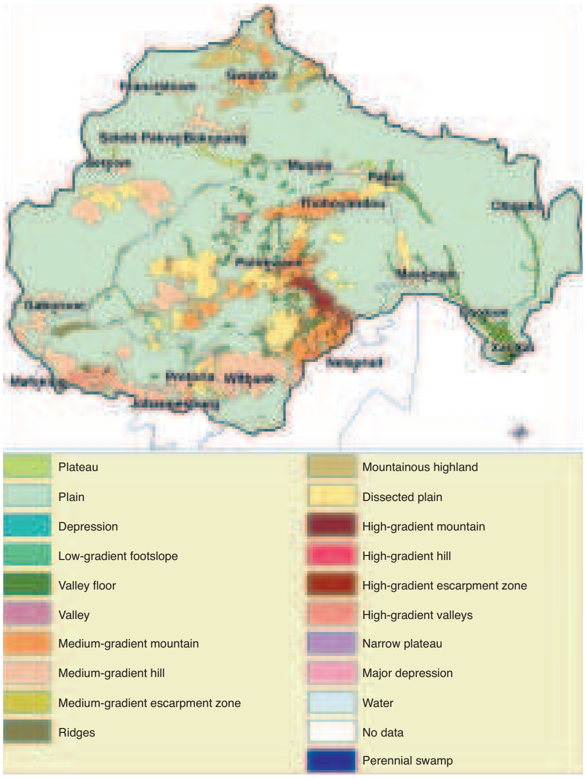


FIGURE 19
Dominant landforms in the Limpopo River Basin



Source: FAO–ISRIC (2003).

are interspersed with low-gradient hills, locally incised valleys and medium-gradient mountains (e.g. the South African Waterberg plateau and the Soutpansberg mountain range). The morphology of the basin, in particular the position of the mountain ranges, has a strong influence on the climate and rainfall pattern in the basin.

Botswana

The land systems of Botswana (De Wit and Bekker, 1990) follow the original land systems concept developed in Australia. This is a hierarchical system based on the subdivision of larger land units into smaller land units, using various criteria linked to major landforms, geomorphological forms, and geology (lithology). This approach is useful for exploratory and reconnaissance mapping, but is of limited use in regional correlation exercises given the use of local nomenclature and non-standard terminology. The Limpopo River Basin falls within the major land division of the hardveldt, a mainly flat to undulating surface with occasional hills and ridges that developed on the Basement Complex. The associated soils vary strongly, especially in depth and clay content, and hence in water-holding capacity and sensitivity to drought.

Mozambique

In Mozambique, the Limpopo River Basin is almost flat, with a gentle slope in a northwest–southeast direction. The Limpopo River crosses a fluvial plain with terraces 1–3 km wide before the confluence with the Elephants River, widening to 2–5 km after the confluence. All basins in Mozambique lie below 400 m above sea level. The Changane River Valley is unusual in that it is situated along an old beach line and flows intermittently.

The main physiographic features of the basin in Mozambique are captured on a generalized landscape map at scale 1:1 million whose units are derived from geology, geomorphology and soils. Landscape patterns are described based on landform, and topography and slope subdivisions, of which 12 classes are applicable to the Gaza Province in which the Limpopo River Basin is located (Figure 20).

South Africa

The terrain morphology map of southern Africa (Kruger, 1983) depicts six broad terrain divisions subdivided according to relief, topography, slopes, and drainage density. The map provides a useful

FIGURE 20
Landscape map of Gaza Province, Mozambique

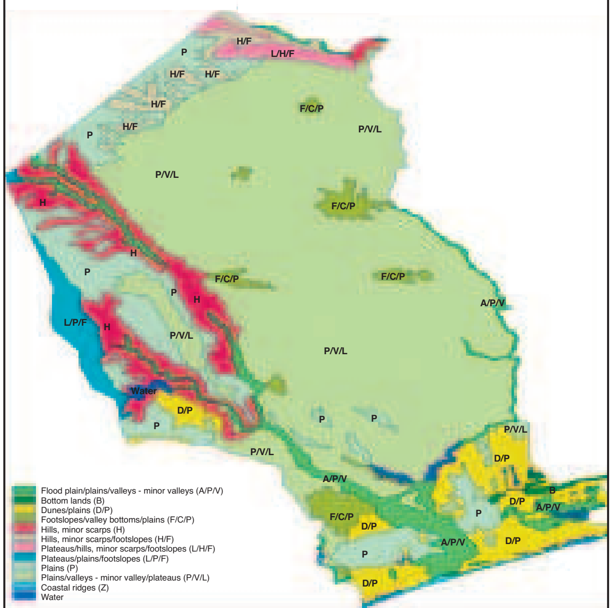
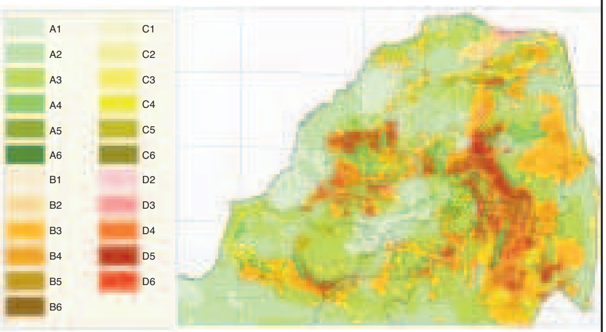


FIGURE 21
Terrain types of the northern parts of South Africa



Source: ARC-Institute for Soil Climate and Water (2004).

pattern of the landscapes of South Africa, but lacks systematic definitions of landforms and other terrain units, and is thus difficult to correlate with approaches used by other countries. At a more detailed level, the procedure for terrain description employed by the national land type survey (Turner and Rust, 1996) describes the terrain or relief of an area quantitatively by means of two parameters: percentage of level land and local relief (Table 3 and Figure 21).

Zimbabwe

Lister (1987) describes four geomorphic provinces within Zimbabwe: the Eastern Highlands, the Limpopo–Save Lowlands, the Zambezi Valley, and the Central Axis (including highveldt, middleveldt and Kalahari sandveldt). The Limpopo River Basin takes up parts of the Limpopo–Save Lowlands and parts of the highveldt and middleveldt subdivision of the Central Axis. Other than a relief map at a scale of 1:1 million (GOZ–Surveyor-General, 1984), no systematic physiographic inventory of Zimbabwe is available.

A description of the physical resources of the communal lands by Anderson *et al.* (1993) includes a generalized account of the landform of the mapped land units (1:500 000), e.g. “the landform is characteristically almost flat to gently undulating with slopes mainly less than 2 percent”. The land units described in this study cover 42 percent of the country.

TABLE 3
Terrain parameters used in the South African Land Type Survey

Percentage level land [1]		Local relief (m) [2]		Terrain type description [3]
Symbol	Class	Symbol	Class	
A	> 80	1	0–30	Level plains
		2	30–90	Level plains with some relief
		3	90–150	Plains with open low hills or ridges
		4	150–300	Plains with open high hills or ridges
		5	300–900	Plains with open low mountains
		6	> 900	Plains with open high mountains
B	50–80	1	0–30	Rolling or irregular plains with low relief
		2	30–90	Rolling or irregular plains with some relief
		3	90–150	Rolling or irregular plains with low hills or ridges
		4	150–300	Rolling or irregular plains with high hills or ridges
		5	300–900	Rolling or irregular plains with low mountains
		6	> 900	Rolling or irregular plains with high mountains
C	20–50	1	0–30	Open low hills or ridges with low relief
		2	30–90	Open low hills or ridges
		3	90–150	Open hills or ridges
		4	150–300	Open high hills or ridges
		5	300–900	Open low mountains
		6	> 900	Open high mountains
D	< 20	2	30–90	Low hills or ridges
		3	90–150	Hills or ridges
		4	150–300	High hills or ridges
		5	300–900	Low mountains
		6	> 900	High mountains

[1] Land with slope of less than 8 percent.
[2] Average difference between the highest and lowest point in the landscape as measured per 7.5 by 7.5 minute sampling area.
[3] After Kruger (1973; 1983).
Source: ARC–Institute for Soil Climate and Water (2004).

Synthesis of the physiography of the Limpopo River Basin

The following main landforms occur: plateau, hills, escarpment and plains.

Plateau

The plateau (flat to undulating, 600–1 500 m above seal level) includes the highveldt area of Botswana, Zimbabwe and South Africa. Although the Limpopo drainage system has eroded deeply into the overall plateau, it has not formed a distinct valley and thus a separate landform unit. Slopes towards the rivers are generally gradual. The plateau includes subordinate occurrence of groups of hills and ridges, which can be distinguished at more detailed scales.

In Botswana, the Limpopo River Basin starts within the transition boundary with the Kalahari sands. At Serowe, a distinct escarpment is formed in Karoo sandstone. The majority of the plateau is flat to gently undulating, in places undulating to rolling with kopjes. The main rock type is granite or granitic gneiss. Sandstones occur south of Mahalapye, and basalt dominates the eastern tip of Botswana, with some subordinate occurrences at Serowe.

Several groups of relatively small hills occur in the southern and central parts of the Botswana hardveldt, in particular near Gaborone and Palapye, often with flat tops at levels of about 1 200 m above seal level, corresponding with the African planation surface. These hills of medium relief (200–400 m above the base) consist mostly of sedimentary rock, but are also formed of dolerite (Shoshong) and other rock. The hills, e.g. the granite hills near Mahalapye, are often associated with pediments.

The plateau developed on the Basement Complex continues on the eastern side of the Limpopo River, in South Africa, also with a flat to gently undulating topography. The occurrence of Karoo sediments (sandstones and shales), including coal deposits near Middelburg and Witbank, characterizes a large area of the southern highveldt.

North of the Limpopo River, the plateau includes parts of the southern highveldt region of Zimbabwe (above 1 200 m above seal level, with Plumtree–Bulawayo as the main catchment) and the adjacent southeast middleveldt region (600–1 200 m, near Gwanda and surroundings). Tributaries of the Shashe and Limpopo Rivers, which run in a north–south direction, dissect the middleveldt. Rocks of the Basement Complex with greenstone belts dominate the geology.

Hills

In South Africa, quite large hilly areas (rolling, 400–600 m above sea level) and ridges occur in the southwest half of Limpopo Province. These hills of the Bushveldt Complex include the Waterberg Hills – which could also be described as a plateau – and also groups of hills towards the southern edge of the catchment (Pilanesberg and Magaliesberg). The lithology of these hills differs from the granite of the basement, and includes quartzite and resistant rock types.

Escarpments

The escarpment zone is a complex landscape consisting of steep hills and mountains (600–1 500 m), forming the transition from the highveldt or Transvaal Plateau to the coastal plains of the lowveldt. The escarpment at the southeast divide of the Limpopo River Basin forms the watershed with the Komati River. Some parts rise to more than 1 500 m above sea level (medium relief class).

The Drakensberg Mountains form the highest part of the escarpment, rising above 2 300 m. Low, east–west mountain ridges (e.g. Soutpansberg and Strydpoortberg) arise above the plateau and link up with the escarpment. The escarpment is characterized by a complex of steep slopes between low and high levels, dissected plateaus and plateau remnants, with associated hills, valleys and basins.

Plains

The plains (gently undulating to undulating, 0–600 m) are the lowveldt of South Africa and Zimbabwe, and the coastal plains of Mozambique. The higher western part (300–600 m) forms the piedmont zone of the escarpment, consisting of eroded foot slopes, developed in mainly granite. Dolerite intrusions occur throughout the lowveldt.

The South African and Mozambican plains are separated by the Lebombo Ridge, which is a cuesta, or a tilted plateau with a steep escarpment bordering the lowveldt and a gradual dipslope of about 5 percent descending east into the coastal plains of Mozambique. This ridge, consisting of rhyolite, is more prominently developed towards the south, outside the Limpopo River Basin.

West of the Lebombo Ridge, north–south zones can be distinguished by rock types. In the Kruger National Park, there is a distinct zone of Karoo basalts, followed by Karoo sediments of the Ecca series (shales and sandstones) lying west.

The southeast lowveldt of Zimbabwe is a broad pediplain with elevations of generally less than 600 m and an almost flat to gently undulating topography. The transition to the middleveldt is gradual. The pediplain of the southeast lowveldt is developed in paragneiss of the Limpopo and Zambezi mobile belts, Karoo volcanics, and for a small part in Karoo sedimentary rocks.

In Mozambique, landforms in most of the interior basin east of the Limpopo River comprise flat to gently undulating plains, valleys, minor valleys and plateaus, not exceeding 5–8 ° in slope and 100 m in elevation. This unit coincides with the dominant soil characteristics belonging to the *Mananga* group of soils. Coastal dune and plain formations, extending inland from the coast to border the Changane River, dominate the landscape in the lower Limpopo River Basin. Extensive areas of floodplains exist along the Limpopo and Changane Rivers, with hills and minor scarps enclosing the middle–upper reaches of the Limpopo River as well as the Elephants River, the latter above 1 200 m.

SOIL RESOURCES

Regional overview

The soil resources of an area are an important factor in managing the effects of drought and climate variability. Those soil properties that relate to water storage (texture, soil depth and internal drainage) are particularly critical in semi-arid environments experiencing drought conditions. Soils also reflect environmental changes, and monitoring such changes is important in assessing the impacts of land use.

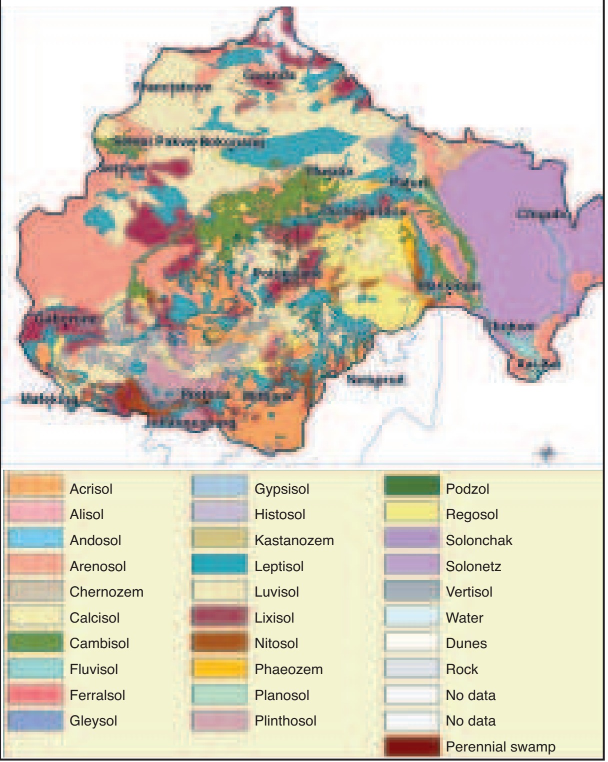
The soils in the Limpopo River Basin may be categorized broadly into two main groups: (i) old soils formed on deeply weathered parent materials, influenced by earlier erosional surfaces; and (ii) relatively young soils, formed on the more recent erosional surfaces, or on alluvial deposits. Deeply weathered ancient soils occur mainly on the plateaus (highveldt) of South Africa and Zimbabwe, and in some protected areas of the escarpment zone. These soils have formed over long periods on the weathering mantle or saprolite, and have developed under warm and humid climate conditions needed for intense chemical weathering. Younger and less weathered soils characterize the denuded hills and mountain ridges, the lowveldt, the coastal plains of Mozambique, and also large parts of the higher plains within the Limpopo River Basin where recent and subrecent erosion has removed any deeply weathered soils. Recent and subrecent climate conditions have not been conducive to strong weathering and new formation of saprolite in the eroded areas. This applies also to the highveldt; higher rainfall and higher temperatures than those occurring at present are required for progressive saprolite formation.

Extensive work on soil mapping has taken place in the last 20–30 years in the subregion, including the four countries of the Limpopo River Basin. A wealth of soil information is available, but it is not easily accessible. Different systems of mapping and classification are evident, and still in use.

FAO, in cooperation with the SADC countries and the International Soil Reference and Information Centre (ISRIC), has produced a seamless, generalized soils coverage (scale: 1: 2 million) of those countries with soil and terrain digital databases (SOTER) (Figure 22). The World Reference Base for Soil Resources (WRB) classification (FAO–ISRIC–ISSS, 1998) was used as a unifying medium of communication. However, the beta version of the CD-ROM released does not contain information on critical soil attributes such as soil depth and texture, apart from what may be inferred from a number of soil profiles for which data are given (not included here). Figure 22 shows the following:

- Arenosols (recent and preweathered sands) occur on the Mozambique coast, in a zone adjacent to the Lebombo range, and in the southern half of the Botswana part of the basin.
- Solonetz soils (sodium-affected soils) cover the bulk of the Mozambique coastal plain.
- In the Zimbabwean and northern Botswanan parts of the basin, Luvisols (soils with a clay increase, not highly leached) and Leptosols (shallow soils) dominate.
- In the South African part of the basin, Regosols (weakly developed soils) dominate the lowveldt between the eastern escarpment and the Lebombo range. Leptosols occur wherever the terrain is hilly.
- Vertisols (swelling clays) and associated Nitisols (red, fertile clays or clay loams) are found on mafic rocks.
- Acrisols, soils with a low cation exchange capacity (CEC) and low base status, dominate the highveldt of the southern basin.

FIGURE 22
Generalized soils map of the Limpopo River Basin in terms of the WRB classification



A message that might not be conveyed effectively by overview maps, presenting taxonomic information only, is that the soil cover is highly variable and mostly thin except for the areas covered by sandy blanket surface deposits in the southwest, the coastal plain in the east and the highveldt plateau in the south. This is due to the hard and variable geology, the dry climate and the process of basin incision.

Status of soil mapping in the four basin countries

Botswana

Extensive soil mapping in the 1980s covered most of the country at a reconnaissance scale of 1:250 000, including the Limpopo River Basin. Systematic soil description, classification and analytical methods were developed, as were computerized systems for storage and retrieval of soil information, in which 3 500 soil profiles were captured (Remmelzwaal, 1988). The soil database (SDB) developed in Botswana has become the FAO SDB standard (in terms of quantity and quality, it is one of the most comprehensive and reliable databases in Africa). An ongoing soil survey (1:50 000) is taking place within the agricultural areas. The general soil map of Botswana (De Wit and Nachtergaele, 1990) provides information and spatial distribution on a national basis.

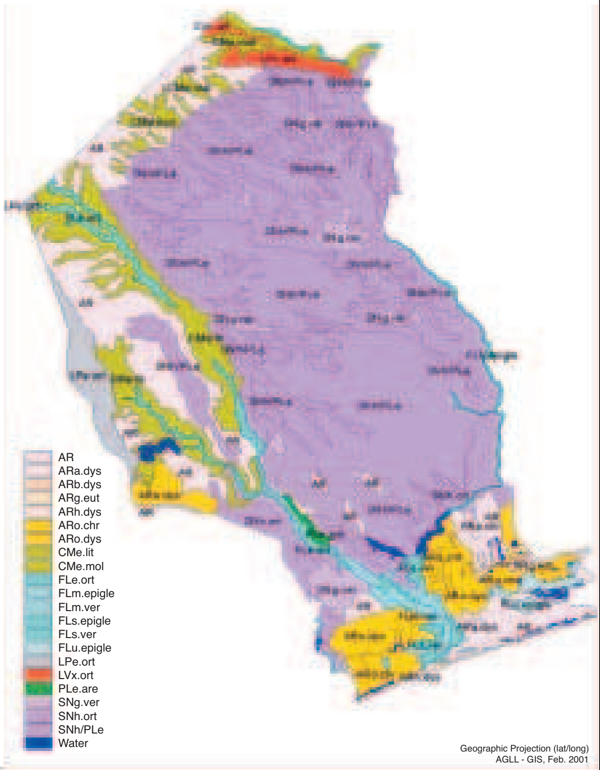
The Limpopo River Basin is covered by a series of soils and land suitability reports and maps which include the following areas: southeast central district (Remmelzwaal, 1989), northern central district (Moganane, 1990), Gaborone (Moganane, 1989), Lobatse (Mafoko, 1990), and northeast district (Radcliffe, Venema and De Wit, 1990).

Mozambique

Soil distribution in Mozambique generally follows the physiographic characteristics (Figure 23). The southern region and the coastal plains have sandy soils, except for the rich alluvial deposits along the major rivers and streams.

Soil survey activities in Mozambique started in the 1940s with the compilation of the first soil map of Mozambique (Schokalsky, 1943). In the same decade, exploratory studies covered large areas, done principally by the Centro de Investigacoes Cientifica Algodoeira, which compiled the second

Figure 23
Dominant Soil map of Gaza Province, Mozambique



soil map of the country at a scale of 1:6 million (CICA, 1948). Soil studies continued over the years, and in the early 1970s various foreign consulting firms (e.g. Loxton-Hunting, COBA and ETLAL) completed reconnaissance surveys of large areas. During this period, two published soil maps covered the whole country: (i) Carta dos Solos (scale: 1:4 million); and (ii) the Soil Map of the World (scale: 1:5 million) (FAO–UNESCO, 1974a; 1974b). In Mozambique, 34 different soil units of the FAO–UNESCO system occur, comprising 16 major soil units. However, for areas defined as belonging to the Limpopo River Basin (with the exception of a narrow coastal strip north of Maputo), the reliability of soil units is reported as poor for the upper reaches of the Limpopo River in Gaza Province to the Zimbabwe border, extending north to the Save River; and fair for the middle and lower zones of the Limpopo River to the coast. This map served as the inventory of soil resources, providing essential phase data until its revision in 1984 (Voortman and Spiers, 1984). In 1991, a revised national soil map based on descriptions of 800 soil profiles was produced at scale of 1:1 million (digitized), using the 1988 FAO–UNESCO–ISRIC legend (INIA, 1995). The National Institute for Agronomic Research (INIA) maintains computerized soil records using the FAO–ISRIC SDB. Specifically, the soils of the Limpopo River Basin were covered by a general reconnaissance survey as part of the Limpopo Master Plan studies by Selkhozpromexport (1983), covering an area of approximately 4.17 million ha.

South Africa

South Africa has a vast database on soil and terrain conditions, the national land type database, containing the data of a complete coverage of land type maps at a scale of 1:250 000. This database contains soil classification, soil attributes, terrain and climate data (Turner and Rust, 1996). A second database contains descriptive and analytical data of a vast number of representative soil profiles. These databases are archived at the Institute for Soil, Climate and Water of the Agricultural Research Council (ARC). Eleven 1:250 000-scale land type map sheets cover the Limpopo River Basin. Detailed soils maps are also available for a 2-km-wide strip along the Limpopo River and for most irrigated areas in the South African part of the basin. The Generalized Soil Patterns of South Africa is the most recent national soil map compilation (GOSA–Land Type Survey Staff, 1997). The main soil groupings of the legend are subdivided according to properties such as base status, topsoil development and texture (in brackets, the number of subdivisions):

- A red-yellow well-drained soils lacking a strong textural contrast (4);
- B soils within a plinthic catena (2);
- C soils with a strong textural contrast (2);
- E soils with high clay contents (1);
- F soils with limited pedological development (5);
- G Podzolic soils (1);
- H rocky areas (1).

The map is useful for an overview of the spatial distribution of the main soil types in the Limpopo River Basin and its relationship with the main landscape units. The dominant soil groups are A and B, with C, E and H subordinate or occurring in complex. The oldest and most-weathered soils (B with low base status) are found on remnants of the African erosion surface. This surface is of Tertiary to Cretaceous age (Partridge and Maud, 1987) and, within the Limpopo River Basin, constitutes the highveldt southeast of Pretoria. Soils from group A with high base status are dominant in the eroded areas nearer to the Limpopo River.

Zimbabwe

The most comprehensive map available is the Soil Map of Zimbabwe, at a scale of 1:1 million (GOZ–DRSS, 1979). Although there is large uncertainty with respect to the accuracy of the information for some areas, this map is widely used. The legend to the soil map reflects primarily the degree of weathering and leaching of the soils, and the influence of geology. Nyamaphene (1991) provides a relevant summary of the soils of Zimbabwe, with details on the properties and distribution of the major soil groups.

The soils of the communal lands of Zimbabwe, which cover 42 percent of the country, were mapped at a scale of 1:250 000 in a physical resource inventory (Anderson *et al*., 1993). The information is presented as land units, which represent a combination of features such as geology, erosion, soils and land use. Typical soil profiles are classified according to the Zimbabwe soil classification system, and have been correlated with the legend of the Soil Map of the World (FAO–UNESCO–ISRIC, 1990) and soil taxonomy (Soil Survey Staff, 1975).

A project under the auspices of FAO, the ISRIC and the UNEP aims to update the 1979 soils map with information from the communal lands study. Information will be digitized and contribute to the revision of the 1:1 million Soil Map of the World.

Soil classification and correlation

The sustainable use of major soil groupings and specific soil types requires differential management. Soil classification is an important element of soil science, and allows transfer of information relevant to soil resources in comparable environments. Efficient transfer requires correlation of the different classification systems.

Botswana and Mozambique use the FAO soil classification system (FAO–UNESCO–ISRIC, 1990). The South African binomial system of soil classification (MacVicar *et al.,* 1977) is applied to all major mapping programmes in South Africa. The revised South African soil classification (GOSA–Soil Classification Working Group, 1991) introduced new soil forms for the arid and semi-arid regions, which were underrepresented in the first edition. Thompson and Purves (1978) developed the classification system used in Zimbabwe, based on the inter-African pedological system of the 1960s.

Soil correlation between the first version of the legend of the Soil Map of World (FAO–UNESCO, 1974a) and the South African, Zimbabwean and Botswana soil classification systems was undertaken in the 1980s (SARCCUS Standing Committee for Soil Science, 1984). Although the results of this first effort are still relevant, there have since been two revisions of the FAO system: (i) the revised legend of the Soil Map of the World (FAO–UNESCO–ISRIC, 1990); and (ii) development of the WRB (FAO–ISSS–ISRIC, 1994, 1998; ISSS–ISRIC–FAO, 1998; ISSS Working Group RB, 1998a, 1998b).

In preparation for developing the SOTER, Remmelzwaal (1998) correlated the South African soil forms with the soil units of the WRB (FAO–ISSS–ISRIC, 1998), and between the South African soil forms and the legend units of the generalized soil map of South Africa (GOSA–Land Type Survey Staff, 1997). These classification efforts contain several useful elements for the 1:1 million South African SOTER soils definition currently under preparation, but require further analysis, and probably a development towards a larger and more precisely defined set of soil groups. Remmelzwaal (1998) also proposed the transfer of soil series information from the South African land type maps to the new SOTER system. The FAO classification and description systems are the ones most commonly used in the SADC region. The SOTER system has close links with the FAO approach, and its wider introduction would promote the standardization of soil and terrain description in southern Africa. The SOTER should be organized in such a way that it readily provides the basic information needed for land evaluation and AEZ.

The Africa volume of the Soil Map of the World (FAO–UNESCO, 1974b) shows major deficiencies as its compilation took place when insufficient soil information was available from southern Africa. The new SOTER standardized soil map covering the Limpopo River Basin (Figure 22) would facilitate land evaluation and appraisal of land suitability for various uses, once the necessary soil attributes have been provided.

Major soil units of the Limpopo River Basin

This section contains an overview of the major soil units in the Limpopo River Basin, based on available soil maps and reports and using soil classification terminology defined in the World Reference Base for Soil Resources (FAO–ISSS–ISRIC, 1998). Their occurrence is linked to the physiographic units applied to the Limpopo River Basin (above).

Soils of the high plateaus and escarpment

Highveldt

Non-incised plateau areas in the southeastern part of the basin, the highveldt east of Pretoria in particular, are mainly covered by Acrisols and Ferralsols. These deeply weathered and highly leached red-yellow soils reflect long periods and cycles of soil formation. They are characterized by an acid soil reaction, high or moderate clay contents, low CEC of the clay, and low base saturation. Ferralsols and Acrisols also occur in watersheds adjacent to the Limpopo River Basin, in South Africa and in the northern highveldt and eastern highlands of Zimbabwe. Within the Limpopo River Basin, these soils also occur as relicts in southeast Botswana, in North West Province in South Africa and at the Northern Divide in Zimbabwe. Associated soils include Leptosols, Regosols and Histosols on incised topography.

In the western highveldt areas of the basin, Arenosols and Regosols are dominant on sandstone and sandy surface deposits. These occur extensively in Botswana, and also in the western parts of South Africa, and to some extent in Zimbabwe towards the Mozambican border. Occasionally, Fluvisols and Gleysols occur on alluvial deposits.

Incised highveldt

Parts of the highveldt within the basin consist of incised topography. Examples occur in relatively close proximity to the Limpopo River in Botswana, Zimbabwe and South Africa. The soils in these areas reflect the rejuvenating effects of stream incision on the landscape (mostly in the form of shallow profiles). They also reflect the current relatively dry climate. Dominant soils on the granite/gneiss Basement Complex are Lixisols and Luvisols, with slightly acid to neutral soil reaction extending to alkaline in poorer drained conditions. These yellowish-red soils are of sandy loam to sandy clay loam texture, with medium to relatively high CEC and medium to high base saturation. Associated soils are Regosols, Arenosols and Leptosols. Calcisols, Planosols and Solonetz may occur in the lower positions of soil catenas. Most Calcisols and Solonetz occur in the driest parts of the basin.

The soil sequences found on basalt and other basic rock include Vertisols, Regosols, Luvisols and Calcisols. These predominantly dark-coloured clayey soils generally have a high base status and CEC. Basalt occurs at the border near Gaborone, and eastwards in a strip from the extreme northeastern part of Botswana across Zimbabwe towards Mozambique. Soil patterns on basalt are variable, often dominated by shallow Regosols. Vertisols occur predominantly in lower and alluvial positions, such as on the Springbok Flats north of Pretoria. Luvisols, Lixisols and Nitisols are the main soils in Zimbabwe, particularly in areas with mafic rocks (greenstone belts) around Bulawayo (highveldt) and Gwanda (middleveldt).

Hills, mountains, and higher parts of the Escarpment

Hills and mountains exhibit a larger variety of rock and weathering materials than the relatively level plateaus and plains. On the lower and middle slopes, a variety of soils occur such as Regosols, Luvisols, Cambisols and Lixisols. Leptosols dominate the higher and most-eroded hills and mountain slopes.

Soils of the lowveldt and coastal plains

Lowveldt

Soils of the escarpment foot slopes and the lowveldt itself are at best moderately weathered and show a wide range of soil characteristics, depending on parent material, position, erosion, etc. They include Vertisols, Planosols, Solonetz, Lixisols, Luvisols, Phaeozems, Cambisols, Arenosols, Regosols and Leptosols. All these soils have a neutral or alkaline soil reaction, a high base status and medium or high CEC values. However, textures and some other properties such as soil depth, colour and structure show a wide variation.

The interior plains and low plateaus of the basin in Mozambique consist almost entirely of Solonetz, associated with Solonchaks and Arenosols in secondary occurrence across large areas to the east of the Limpopo River. These soils coincide with the *Mananga* landscape and exhibit characteristics of coarse texture, very low water retention capacity, and low inherent fertility (especially nitrogen and phosphorus). Coupled with a low rainfall environment, these areas impose severe limitations on rainfed agriculture.

There are two distinct belts of soils running north–south on the western side of the Lebombo Ridge. Soils formed on basalt occur immediately west of the ridge. These consist of dark brown Luvisols in high landscape positions and dark grey and black Cambisols and Vertisols in lower landscape positions. Further to the west is a belt of soils mainly developed on shales and sandstones, with Lixisols, Luvisols and Arenosols dominant.

Nitisols are found in some specific locations, such as on the Lebombo Plateau. This soil type shows more intensive weathering and soil formation than generally found in the low plains, and is characterized by intermediate CEC, relatively high base saturation and high clay contents. This belt extends towards the south outside the basin.

Coastal plains and alluvial areas

The dominant soils of the coastal dunes and coastal plains of Mozambique are Arenosols, with Gleysols found in secondary occurrence. Alluvial deposits upstream from Messina are found mainly in narrow strips along the Limpopo River and its main tributaries. The most common soils are Cambisols, Luvisols, and Arenosols on terraces and levees, with some Fluvisols on recent deposits.

Downstream from Messina and into Mozambique, Fluvisols dominate the extensive floodplains along the Limpopo, Changane and Elephant Rivers. Cambisols are characteristic soils of the hills and minor scarps bordering the Limpopo and Elephant Rivers, extending north from their confluence.

Problem soils and environmental aspects

Some of the soils of the Limpopo River Basin may be regarded as problem soils. The constraints may be inherently present or caused by unsustainable use (Barnard *et al*., 2000; Van Der Merwe *et al*., 2000; Nzuma, Mugwira and Mushambi, 2000). Depletion of soil resources may result from a range of interrelated natural and anthropogenic factors, whose processes and causes are elaborated more fully in the section on land degradation (below).

Restricted water-holding capacity

Although the rainfall of the basin is mostly low and erratic, large rain events occur periodically. The best soils have the ability not only to absorb and make available to plants small rainfall events of 5–10 mm, but also to absorb, store and make available the water from rain events of 50–70 mm. Three common restrictions are: inadequate soil depth (restricting the plant water reservoir); high clay content (causing runoff and low water availability); and excessively low clay content (causing excessive drainage and restricting the plant water reservoir). The presence of slowly draining material beneath a permeable rooting zone may add considerably to the profile water-holding capacity (Box 6). Figure 24 shows some examples of problem soils in the South African part of the basin.

BOX 6

Beneficial drainage-retarding layers beneath the rootzone

In the South African soil classification system (MacVicar *et al.*, 1977; GOSA–Soil Classification Working Group, 1991), the presence of drainage-retarding layers beneath the rootzone (soft plinthic B horizon, gleycutanic B horizon, signs of wetness) is recognized for its beneficial effect on rainfed land use under restricted rainfall conditions. The soil forms in which drainage-retarding layers occur at the bottom of the profile (Avalon, Bainsvlei and Pinedene) have become known for their favourable water-holding properties and good crops. The reason is that more plant-available water is held than the amount suggested by the matric potential alone, corresponding to soil depth and texture. This phenomenon is difficult to quantify because of lateral water movement above the drainage-restricting layer.

Erodibility and crusting/surface sealing

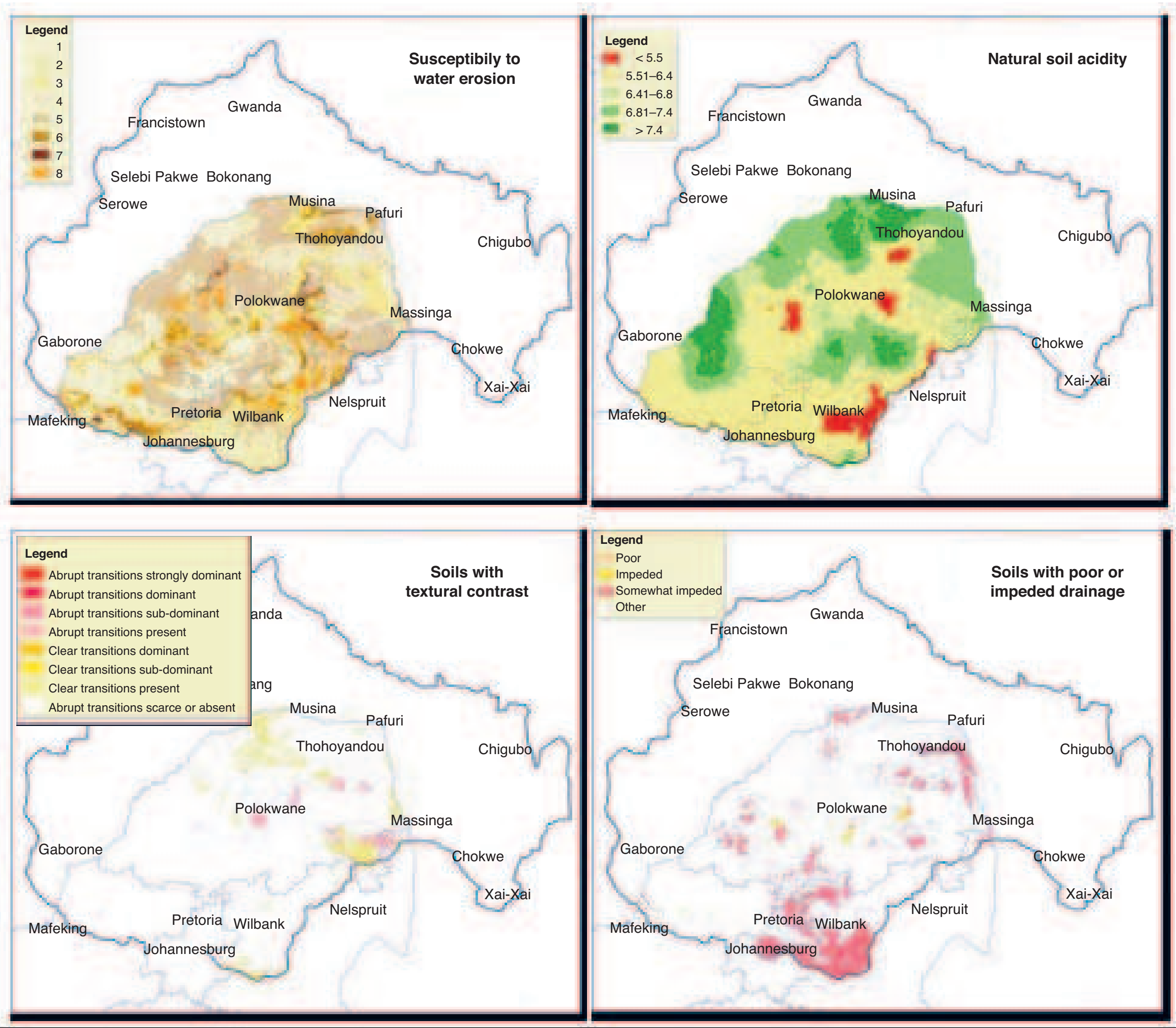
Four relatively permanent land characteristics determine the susceptibility of land to water erosion. These are slope gradient and length, rainfall erosivity and the susceptibility of the soil to water erosion. The latter is of concern here. Solonetz and Planosols generally have low structural stability, resulting in adverse macrostructure conditions in the subsoil and susceptibility to crusting of the surface horizon. These conditions stem from the presence of relatively easily dispersible clay minerals or clay-size quartz (Bühmann, Rapp and Laker, 1996; Bühmann, Van Der Merwe and Laker, 1998; and Bühmann, Beukes and Turner, 2001) and may be aggravated severely by sodicity. These soils are rendered susceptible to erosion and require adequate management. Southern African soils in general are susceptible to crusting/surface sealing owing to a low organic matter content, high rainfall energy and sparse vegetation cover in places.

In the western arable districts of the basin, wind erosion is an acknowledged problem. This is caused by the prevalence of sandy soils (Arenosols), cultivation practices and low rainfall resulting in low plant biomass production and soil organic material. Smit (1983) and Hallward (1988) have pointed out that the main danger of wind erosion is the loss of fine materials (fine silt and clay) from topsoils in the form of dust. By losing fine material, the soil loses much of its ability to provide plants with water and nutrients.

Textural contrast

The strong textural contrast displayed by Solonetz, Planosols and some Luvisols renders them problematic from a plant-extractable water viewpoint. Some members (mostly Solonetz or Planosols) display an abrupt transition between the topsoil (or sandy layer beneath the topsoil) and the subsoil with respect to texture, structure and consistence. The material above the transition is usually of light texture, permeable and can be penetrated readily by water and roots. The material below the transition is usually clayey, dense, very slowly permeable and can be exploited by roots to

FIGURE 24
Examples of soil attributes affecting resilience and sensitivity in the South Africa part of the Limpopo River Basin



a very limited extent. The subsoil is characterized by very low water stability and, thus, is highly susceptible to water erosion, particularly deep gullying, when exposed. In other members (certain Luvisols), the textural contrast is less prominent. A clear transition is found between the topsoil and the subsoil in respect of texture, structure and consistence. The topsoil is relatively sandy in relation to the subsoil, and the subsoil is clayey and dense, but commonly not to the extreme. Nevertheless, these soils are less water stable than the norm, and water infiltration is slower than the norm, rendering them prone to water erosion. Sodium is often present in the subsoils of both types, contributing to water instability and erodibility. Because of the severely limited effective depth and plant extractable water-holding capacity, textural contrast soils have become known as "droughty" agricultural soils.

Vertic properties

Vertisols and soils with vertic properties are common in South Africa and Botswana. They are reported to suffer from crusting, runoff, erosion and other forms of degradation (Van Der Merwe *et al.*, 2000). This rather negative picture is not generally applicable, but depends rather on specific occurrence, development, and management. For example, crusting is not typical of Vertisols. On the contrary, well-developed Vertisols have a surface mulch layer and cracks rather than crusts. Infiltration rates are impeded after the first rains close the cracks and, hence, are susceptible to waterlogging, especially after heavy rains. Although

Vertisols have a high water-holding capacity, they also have high water retention unavailable to plants. Nonetheless, vertic soils belong to the better and most fertile soils, but they require good management with low tillage and stubble cover.

Acidity

Acid problem soils are those most frequently reported, often without indicating their specific occurrence in the basin. Most acid soils are found in areas with relatively high rainfall, e.g. on the northern and southern fringes of the basin, in particular the South African highveldt areas occupied by Ferralsols and Acrisols. Acrisols and other inherently acid soils also occur locally in the more central parts of the basin, in southeast Botswana, in some of the central higher rainfall parts of Limpopo Province in South Africa, and in similar areas of Zimbabwe and Mozambique.

Salinization of irrigated soils

Inappropriate irrigation methods have led to saline soils, and in the worst cases result in the formation of Solonchaks, characterized by high salinity. Commercial irrigation normally applies improved management systems to control and monitor salinity levels, but under small-scale irrigation salinity is not always well managed. According to Barnard *et al.* (2000) about 10 percent of all irrigated soils in South Africa suffer from salinity or sodicity in one form or another, and this problem is likely to increase with the expected scarcity of water. Mashali (1997) discusses causes of salinization, its impact on production, and options to improve management.

Salinity is a major factor limiting the use of land developed for irrigation in this basin in Mozambique. Saline soils occupy 8 percent of the total productive area in the upper Limpopo River Valley, 30 percent in the middle Limpopo River Valley and as much as 70 percent in the lower Limpopo River Valley, where the Chokwé irrigation scheme is located.

The Chokwé irrigation scheme is the largest in Mozambique, and dates back to plans initially drawn up in the 1920s to irrigate the Limpopo River Valley. It was constructed in the early 1950s. It has supported intensive irrigated agriculture in the Limpopo River Valley, but has suffered badly from gross negligence in maintenance. By 1992, it was able to irrigate barely half of its design command area of about 33 000 ha (Tanner, Myers and Oad, 1993). In the past 40 years of irrigation, groundwater has risen to within about 30–50 cm of the soil surface, and the already significant land area out of production because of high soil salinity is increasing annually. The irrigation scheme suffered serious physical damage during the large-scale flooding in February–March 2000.

The problem of salinity is aggravated by the lack of adequate water management skills and by the poor drainage systems, resulting in soil fertility loss from waterlogging and salinization. Saltwater intrusion into deep-seated "soil" materials in the dry season exacerbates the risk of salinization, particularly during high tides. This is observed in the coastal areas of Xai-Xai District, from where the Limpopo River enters the sea, extending up to 50 km inland. The view is held that some Limpopo River Basin areas are too saline for complete reclamation to be economic.

Organic matter and nutrient depletion

Intensively cultivated soils in the basin generally undergo serious decline in organic matter. This results in structural and biological degradation and contributes to acidification. Organic matter contents are reported to have dropped to unacceptably low levels, leading to undesirable changes in soil structure and sharp yield declines. Folmer, Geurts and Francisco (1998) assessed the loss of soil fertility in Mozambique from agricultural land use, producing a map at scale 1:3 500 000. Negligible loss in soil fertility was reported for the middle and upper zones of the Limpopo River Basin, compared with moderate to high fertility loss south of Chokwé, particularly in Xai-Xai District and areas on both sides of the Limpopo River extending to the coast. Another study by Tique (2000) in the northern district of Chicualacuala links farmer observations to soil fertility declines associated with land pressure and reduced fallow periods in the district.

Soils with a serious decline in fertility as a result of cultivation are commonly reported from Zimbabwe and South Africa, but their extent is not known owing to the lack of monitoring on a wider scale (Van Der Merwe *et al.*, 2000). However, the negative impact on production is well documented from experimental plots and other observations. Their main occurrence is associated with soil types that are already of low inherent fertility (Box 7). Nabhan (1997) discusses general aspects of these soils and presents management options for addressing the problem. Low fertility soils, together with soils with a low organic matter

BOX 7

Nutrient deficiencies in the Maputaland sands linked to human health disorders

Pooley, Fey and Willis (1997) and Ceruti, Fey and Pooley (2002) have linked unusually high incidences of dwarfism and the endemic occurrence of Mseleni Joint Disease in a narrow north–south corridor of the Maputaland coastal plain to nutrient deficiencies in the recent Quaternary sands (Fernwood soil form). Soil samples were collected along transects through the high incidence area. Pooley, Fey and Willis (1997) found a suboptimal supply of calcium, phosphorus, zinc, copper and boron, and as all the deficient elements have been associated in medical literature with skeletal disorders, hypothesized that these might exert their influence synergistically. Ceruti, Fey and Pooley (2002) confirmed all soils to be deficient in Bray-1 extractable phosphorus and ammonium-EDTA extractable copper and zinc, with respect to critical levels for maize growth, having averages of 4.5, 0.5 and 0.4 mg/kg, respectively. There was a marked difference in ammonium-acetate extractable potassium and ammonium-EDTA extractable selenium between the low- and high-incidence areas, with average values of 209 and 27 mg K/kg, and 0.46 and 0.09 mg Se/kg, respectively. Other nutrients studied did not show anomalies between the two areas. In a subsequent study (Ceruti, Fey and Pooley, 2002), topsoil samples were collected at 1-km intervals along a roughly east–west transect (34 km) through the area with a high incidence of Mseleni Joint Disease. These were analysed for: phosphorus, potassium, manganese, iron, copper and zinc (Ambic-2 method); calcium and magnesium (KCl extraction); and boron (hot water extraction). In a subtractive maize growth pot trial, using a complete nutrient solution from which one element was withheld per treatment, yields for the minus phosphorus, potassium, calcium, sulphur and zinc treatments were all below 80 percent, relative to the complete treatment, indicating deficiencies of these elements. Plant tissue analysis showed deficiencies of phosphorus, potassium, calcium, magnesium, copper and zinc. Pockets within the landscape of multiple deficiencies were indicated, with copper and zinc deficiencies throughout the landscape.

content, are the main focus of a large number of soil fertility programmes, which have been implemented throughout the region. Chapter 4 discusses the results of these programmes.

Resilience and sensitivity of soils in relation to erosion and drought

Erosion-induced loss in soil productivity is a major threat to food security. There is sufficient evidence of a relationship between changes in productivity and cumulative water erosion, following a negative exponential curve. This means that initial yield decline is severe but that after prolonged erosion the yield decline lessens (Tengberg and Stocking, 1997).

Resilience and sensitivity of soils are important factors relating to changes in productivity (Table 4). Resilience describes the property of a soil to withstand an external force; it is site specific and relates to the erosion rate or the ease of restoring the land. Solonetz (sodic soils) are one of the least-resilient soil types, while Vertisols are one of the most resilient. Sensitivity describes the degree to which the soil changes when subjected to an external force, such as erosion; and relates to the relationship between soil loss and yield or how easy it is to degrade the land. Good, productive soils are more sensitive than eroded soils. The combination of the two factors is important. Tengberg and Stocking (1997) analysed a number of major soil units with respect to these factors. The sensitivity to yield decline from erosion was found to be highest in Phaeozems and lowest in Luvisols. Of the soils studied, resilience to erosion was highest in Phaeozems and lowest in Ferralsols and Acrisols. Of key importance are: soil organic carbon, erosion-induced acidity, and soil–water relationships.

Food security issues are related strongly to soil resilience and sensitivity as these factors determine critical production levels of a soil. The number of years required to reach this level varies considerably, and is dependent on management and soil type. The time taken for the major soil groups to reach their critical production level is, in increasing order: Ferralsols, Acrisols, Luvisols, Phaeozems, Cambisols and Nitosols.

It is concluded that Acrisols and Ferralsols are unsustainable under any continuous use without rest, and that Luvisols and Cambisols allow

TABLE 4
Factors affecting soil resilience and sensitivity

	Intensive rainfall	Low SOM	Steep slopes	Sodic soils	Poor management	Drought	Deforestation	Luvisol	Vertisol
Vertisol	Low S Low R	Low S Low R	N/A	Mod S Low R	Low S Mod R	High S Low R	High S Low R	N/A	
Luvisol	High S High R	High S High R	High S Low R	N/A	High S High R	High S High R	High S Mod R		
Deforestation	High S High R	High S Mod R	High S Low R	High S Low R	High S Mod R	High S Mod R			
Drought	N/A	High S Low R	High S Low R	High S Low R	High S Mod R				
Poor management	OF = S Low R	High S Mod R	High S Low R	High S Low R					
Sodic soils	High S Low R	High S Low R	N/A						
Steep slopes	High S Low R	High S Mod R							
Low SOM	High S High R								
Intensive rainfall									

S = sensitivity; R = resilience; OF = determined by combination of other factors; SOM = soil organic matter.
Source: Stocking and Murnaghan (2000).

continuous use only under good management. Management is related to soil cover. Bare or poor soil cover can result in productivity declines within 5 years, moderate cover indicates a period of 20–50 years, and a good cover 100–200 years (Tengberg and Stocking, 1997).

Although not always based on sufficiently long records of monitoring soil conditions, the importance of soils, their management and erosion risk in relation to food security is evident. This may also be extended to drought as a major factor in food security, and to drought as a factor in accelerating erosion. The results of soil resilience studies are very relevant to land use planning, in particular in drought sensitive areas.

TABLE 5
Rainfall and evaporation figures for major subcatchments (Figure 25)

Catchment	Area (km^2)	MAP (mm)	MAE (mm)
Mahalapswe	3 385	454	2 000
Lephalala	4 868	513	2 328
Lotsane	9 748	430	2 000
Mogalakwena	20 248	386	1 902
Motloutse	19 053	430	2 000
Shashe	18 991	485	2 154
Umzingwani	15 695	475	2 065
Sand River	15 630	384	1 690
Nzhelele	2 436	422	2 160
Bubi	8 140	315	2 427
Luvuvhu	4 826	715	1 635
Mwenezi	14 759	465	1 810
Elephants	70 000	500	1 700

WATER RESOURCES

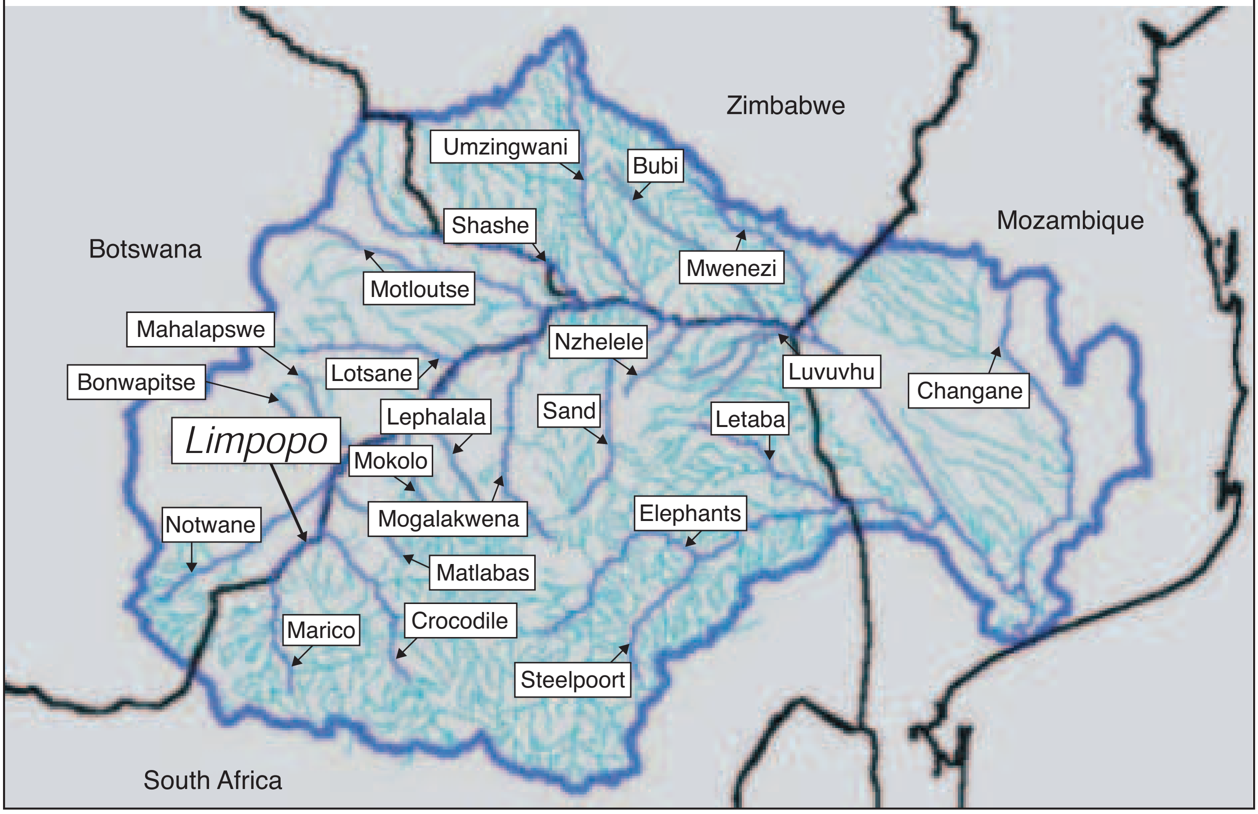
The section on rainfall (above) showed that the mean annual rainfall of the basin varies considerably (200–1 500 mm) and that the bulk of the basin receives less than 500 mm/year (Figure7). Rainfall is highly seasonal with 95 percent occurring between October and April. The rainy season is short with the annual number of rain days seldom exceeding 50.

Figure 25 shows the major rivers and streams within the Limpopo River Basin. Table 5 lists the main subcatchments constituting the basin and the area, mean annual precipitation (MAP) and mean annual evaporation (MAE) of each.

Table 5 shows that the Elephants (known as Olifants in South Africa) subcatchment (Figure 25) ranks first in terms of area, covering 17 percent of the basin. It receives the third-highest rainfall and has the third-lowest evaporation. Most of this sub-basin (84 percent) is located in South Africa, including the high-rainfall parts. To the north, in Zimbabwe, there is a short divide with the Zambezi River Basin near Bulawayo, and further east along the watershed, with the Save River.

The southeastern Limpopo River Basin borders the Incomati River (with the upstream Komati and Sabie tributaries), whose basin covers the southern half of the Kruger National Park and the adjacent Nelspruit area. To the south and southwest, the boundary is shared with the watershed of the Orange River, which flows into the Atlantic

FIGURE 25
Major rivers and streams within the Limpopo River Basin



Ocean, with the Vaal River as the nearest most-northern main tributary.

The western boundary of the Limpopo River Basin borders on the internal drainage system of the central Kalahari Desert and the Okavango Delta. After swinging eastward between Limpopo Province in South Africa and southern Zimbabwe, the Limpopo River receives the Shashe River and flows about 240 km to Mozambique, where it reaches the fall line. In this zone, the river drops about 250 m, with most of the drop concentrated in 43 km of rapids, especially those at Malala, Molukwe and Quiqueque. The Limpopo River is unnavigable until its confluence with the Elephants River, 209 km from the coast in the Indian Ocean. Though partially blocked by a sandbar at its outlet, coastal steamers can enter the river at high tide.

Other tributaries are the Changane River (left bank and downstream of Chokwé), with an area of 43 000 km^2, and the Lumane River (right bank), with an area of 1 030 km^2. Both the Changane and Lumane Rivers are entirely in Mozambique, but have very low runoff coefficients and long periods with no discharge at all.

Surface water resources

FAO (1997) has provided an overview of the hydrology of the Limpopo River Basin. The main river can be divided into the following logical reaches:

- Upper Limpopo River, down to the Shashe confluence at the South Africa–Botswana–Zimbabwe border; runoff from South Africa and Botswana.
- Middle Limpopo River, between the Shashe confluence and the Luvuvhu confluence at the South Africa–Zimbabwe–Mozambique border (at Pafuri); runoff from Botswana (Shashe), Zimbabwe and South Africa.
- Lower Limpopo River, downstream of Pafuri to the rivermouth in the Indian Ocean; runoff from Zimbabwe (Mwenezi), South Africa and Mozambique.

Several tributaries originate in Botswana, the most important being the Shashe River, which forms the border between Botswana and Zimbabwe before flowing into the Limpopo River. Other major tributaries, ranked according to decreasing mean annual runoff (MAR), are the Motloutse, Lotsane, Notwane, Bonwapitse and Mahalapswe Rivers. The main tributaries within Zimbabwe are the Shashe and Umzingwane Rivers, with the Mwenezi and Bubi Rivers as other major tributaries. The Mwenezi River originates in Zimbabwe, but joins the Limpopo River in Mozambique.

The most important tributary within South Africa is the Elephants River, which originates between Johannesburg and Witbank and flows into the Limpopo River in Mozambique. Important tributaries of the Elephants River are the Shingwedzi and Letaba Rivers. Major tributaries of the Crocodile–Limpopo part of the Limpopo River Basin, ranked according to decreasing MAR, are: Luvuvhu (which joins the Limpopo River at Pafuri), Mokolo, Mogalakwena, Marico, Lephalala, Nzhelele, Sand and Matlabas Rivers.

The part of the Limpopo River Basin in Mozambique is estimated to contribute 10 percent of the total MAR runoff of the river. The Limpopo River, which was initially a perennial river in Mozambique, can actually fall dry for up to a period of eight months per year, mainly as a consequence of abstractions in the upper catchment area (GOM–DNA, 1995). Downstream of Chokwé, the Changane River (an intermittent tributary) joins the Limpopo River. Although it drains 43 000 km^2, it has a very low runoff coefficient and periods with no discharge at all. The Lumane River, the last of the most important tributaries, originates in Lake Pave and receives water from the sandy hillsides and, therefore, flows permanently.

Hydrological studies of the Limpopo River Basin

Görgens and Boroto (1999) mention the following hydrological studies of parts of the Limpopo River Basin (year and executing countries in brackets):

- Limpopo Water Utilization Study (1989, Botswana);
- Botswana National Water Master Plan Study (1990, Botswana);
- Joint Upper Limpopo Basin Study (JULBS) (1991, Botswana and South Africa);
- various studies on a number of tributaries (Botswana and South Africa);
- Surface Water Resources of South Africa (South Africa);
- Zimbabwe National Master Plan for Rural Water Supply and Sanitation (1986, Zimbabwe);
- Monografia hidrografica da bacia do rio Limpopo (1996, Mozambique);
- Hydrological Modelling of the Limpopo Main Stem (1999, South Africa).

According to Görgens and Boroto (1999), hydrologically, the JULBS study was particularly significant, as it revealed the existence of significant transmission losses, attributable to alluvial channel and floodplain recharge and channel evaporation, as well as riparian consumptive use by the well-established riparian bush.

Table 6 shows the catchment area of each tributary of the Limpopo River as well as the naturalized MAR and the denaturalized MAR for each tributary, as derived from the above sources. Different studies have employed different hydrological estimation techniques and covered various long-term periods and denaturalization horizons. Thus, the comparison of MARs is merely indicative.

Pallett (1997) has estimated the total natural runoff of the Limpopo River at more than 5 500 million m^3. Recent figures for South Africa (GOSA–DWAF, 2003a–d) indicate a figure of about 8 000 million m^3. Entering Mozambique, the main river has an average natural MAR of 4 800 million m^3 (FAO, 1997). According to Görgens and Boroto (1999), the current MAR at its mouth is about 4 000 million m^3, almost 2 000–4000 million m^3 less than the estimated natural MAR.

From Table 6, the following observations can be made:

- The Elephants River, which joins the Limpopo in Mozambique, has the largest catchment area and is also the largest contributor of flow to the Limpopo River. The Massingir Dam in Mozambique is located on the Elephants River.
- The Luvuvhu River is the tributary with by far the highest unit runoff and also has a high ratio of denaturalized to naturalized MAR (86 percent), indicating a relatively low level of development in the catchment. The water of the Luvuvhu River also flows directly into Mozambique at Pafuri.
- The Crocodile River, which is the tributary with the second-largest catchment area, has a low ratio of denaturalized to naturalized MAR (43 percent), indicating a high level of development in its catchment.

The naturalized MARs of the Shashe, Umzingwane, Bubi and Mwenezi Rivers are not known. However, the level of development in the Umzingwane is known to be high because a

TABLE 6
Characteristics of the Limpopo River Basin from upstream to downstream

Reach	Country	Tributary	Catchment area (km^2)	Naturalized MAR (million m^3)	Denaturalized MAR (million m^3)	Unit runoff (denat. MAR) (mm)
1	South Africa	Marico	13 208	172	50	3.8
1	South Africa	Crocodile	29 572	391	205	6.9
1	Botswana	Notwane	18 053	55	24	1.4
1	South Africa	Matlabas	3 448	382	21	6.0
1	South Africa	Mokolo	7 616		117	15.4
1	Botswana	Bonwapitse	9 904	15	15	1.5
1	Botswana	Mahalapswe	3 385	13	13	3.9
1	South Africa	Lephalala	4 868	150	99	20.3
1	Botswana	Lotsane	9 748	62	62	6.4
1	South Africa	Mogalakwena	20 248	269	79	3.9
1	Botswana*	Motloutse	19 053	111	111	5.8
Total for upper reach			139 103	1 620	796	5.7
2	Botswana	Shashe	12 070	250	250	20.7
2	Botswana	Other	7 905			
2	Zimbabwe**	Shashe	18 991	462	462	24.3
2	Zimbabwe**	Umzingwane	15 695	350	350	22.3
2	South Africa	Sand	15 630	72	38	2.4
2	South Africa	Nzhelele	3 436	113	89	26.0
2	Zimbabwe**	Bubi	8 140	53	53	6.5
Total for middle reach			81 867	1 300	1 242	15.2
3	South Africa	Luvuvhu	4 826	520	492	102.0
3	Zimbabwe**	Mwenezi	14 759	256	256	17.4
	Zimbabwe**	Other	4 956	36	36	7.3
3	South Africa	Elephants	68 450	1 644	1 233	18.0
	South Africa	Other	13 996	2 352		
3	Mozambique	Changane	43 000			
3	Mozambique	Elephants	1 550			
	Mozambique	Other (e.g. Lumane)	40 431	315		
Total for lower reach			151 537	5 123	2 017	21.7
Total			412 938	± 8 043	± 4 055	±9.8

Notes:
* Denaturalized MAR will change when utilization of the Letsibogo Dam increases.
** According to Görgens and Boroto (1999), the MAR for Zimbabwe is the denaturalized MAR; according to GOZ–MRRWD–DWD (1984), the given MAR is the naturalized MAR.
Sources: Görgens and Boroto (1999); GOSA–DWAF (1991); GOSA–DWAF (2003 a–d); GOB–MMRWA (1992); GOZ–MRRWD–DWD (1984); FAO (1997).

TABLE 7
Characteristics of the Botswana sub-basins of the Limpopo River Basin

Tributary	Catchment (km^2) (GOSA)	Naturalized MAR (million m^3) (GOSA)	Naturalized MAR MAR*** (GOB)*	Denatural. MAR (million m^3)	Unit runoff (mm)	MAP (mm)	MAE (mm)
Notwane	18 053	54.7	85.0	24.3	1.35	450–500	1 950
Bonwapitse	9 904	14.8	55.0	14.8	1.49	400–450	2 000
Mahalapswe	3 385	13.2		13.2	3.90	400–450	2 000
Lotsane	9 748	62.3	195.0	62.3	6.39	300–400	2 100
Motloutse**	19 053	111.1		111.1	5.83	300–400	2 100
Shashe	12 070	250.0	270.0	250.0	20.71	400–450	2 100
Other	7 905						
Total	80 118	506.1	605.0	475.7	5.94		

Notes:
* 55 = Bonwapitse + Mahalapswe; 195 = Lotsane + Motloutse.
** Denaturalized MAR (111.1) will change when utilization of the Letsibogo Dam increases.
*** According to Görgens and Boroto (1999).
Sources: GOSA–DWAF (1991), GOB–MMRWA (1992), Görgens and Boroto (1999).

large number of small to large dams have been constructed in its catchment. Some dams have also been built in the Shashe catchment.

Botswana

The Botswana part of the basin feeds into the upper reach of the Limpopo River. It consists mainly of the following sub-basins:

- Notwane,
- Bonwapitse and Mahalapswe,
- Lotsane and Motloutse,
- Shashe (part also in Zimbabwe).

The catchments of some sub-basins are difficult to define, as the topography is very flat towards the Mkgadikgadi Pans and the Central Kalahari. The development of surface water resources is also complicated by the semi-arid environment where potential evapotranspiration is about four times higher than the rainfall and where streamflow records are relatively short and of poor quality. This explains why estimates of catchment areas and related runoff figures differ between one study and the other. Table 7 lists relevant water catchment information from various sources.

With the exception of the Shashe River, most of the available water resources are highly developed. The demand for water is increasing rapidly because of rapid urbanization and industrial development. The total water demand of Botswana was estimated at 193.4 million m^3 for 2000. Of this total, 24 percent goes to urban centres, 23 percent to livestock, 18 percent to mining and energy, 15 percent to irrigation and forestry, 11 percent to major villages, 5 percent to rural villages, 3 percent to wildlife and 1 percent to settlements (GOB–MFDP, 1997). Owing to high water demands, most of the subcatchments have a water deficit and rely on water importation and water saving techniques to meet demand. The potential storage capacity of dams in Botswana is estimated to be almost 300 million m^3, but this potential is not regularly realized.

The Notwane sub-basin

The Notwane River rises on the edge of the Kalahari sandveldt and flows northeast until it reaches the Limpopo River some 50 km downstream of the confluence of the Limpopo River with the Marico River. About one-third of Botswana's 1.6 million population reside in the Notwane Basin, which includes the urban centres of Gaborone, Molepolole, Mochudi, Kanye, Lobatse and Jwaneng.

Domestic water needs dominate water use in the Notwane sub-basin and demands are growing rapidly. The large urban centres account for more than 60 percent of the domestic water demands. Gaborone consumes 50 percent of all urban use (i.e. 30 percent of national domestic water use) and this is expected to increase significantly because of rapid urbanization (i.e. up to 40 percent of national domestic demand by 2020).

In order to address inequalities of water abstraction, the South African Department of Water Affairs and Forestry is planning the transfer of 124 million m^3 of water per year from the Crocodile West and Marico Water Management Area to Gaborone in Botswana (GOSA–DWAF, 2003c).

The Gaborone and Bakaa Dams are located on the Notwane River and are the main sources of domestic water supply to Gaborone and surroundings. The Nywane Dam serves Lobatse, which is also linked by a pipeline to the Gaborone Dam. The catchment contains about 200 small dams which result in an estimated 25-percent reduction in runoff, serving primarily livestock needs. In most years, the catchment has a water deficit, and water importation from South Africa from another part of the Limpopo catchment (i.e. from the Molatedi Dam on the Marico River) to Gaborone is one of the mitigating measures. The completion of the North–South Water Carrier, which is designed to transport water from the Shashe Dam near Francistown to Gaborone, will bring much needed relief to the stressed local surface water and groundwater resources, and secure water resources up to 2020 (Pallett, 1997).

The Bonwapitse and Mahalapswe sub-basins

The Bonwapitse River has its upper catchment in the Kalahari sandveldt and is seldom in flow. The Mahalapswe River also contributes very little to the flow of the Limpopo River and normally does not have surface runoff during the winter. However, water is stored in the sand bed and this is an important source of domestic water for small communities and their livestock along the river reaches. No large dams have been constructed and no potential exists. Small dams provide suitable water resources for stock watering, small-scale irrigation (horticulture) and in some cases also serve domestic uses of small villages.

The Lotsane and Motloutse sub-basins

Both rivers flow mainly during summer rainfall and have limited development potential owing to the relatively flat terrain and restricted options for the building of larger dams. Development potential is suited primarily for small communities, livestock and small-scale irrigation. Communities along the river reaches often access water stored in the sandy riverbed or small dams and depend on this for most of the winter months. However, investigations for the Botswana National Water Master Plan (BNWMP) have shown that the sand volume of riverbeds is generally limited in depth and, hence, does not support a major abstraction capability (GOB–MMRWA, 1992). A total of 366 small dams have been constructed in Central Region, mostly located in the Lotsane and Motloutse catchments.

The Motloutse River has an MAR of 111 million m^3/year. Construction of the Letsibogo Dam is probably the only significant development and will serve primarily the industrial town of Selebi-Pikwe and surrounding local needs, including potential irrigation (Box 8). Its potential contribution to the North–South Water Carrier is uncertain.

BOX 8

Irrigation with gypsiferous coal mine water

A simulation study in Botswana with gypsiferous coal mine water with an electrical conductivity (EC) of about 310 mS/m^3 (Jovanovic *et al.*, 2001) led to the conclusion that, under the particular climate and soil conditions of Selibe-Pikwe, large amounts of effluent mine water can be disposed successfully of through irrigation. Between 18 and 32 percent of the total amount of salts added through irrigation was predicted to leach after 11 years, the remainder being precipitated in the soil profile in the form of gypsum. A slow process of gypsum dissolution and leaching by rainfall was predicted after the cessation of irrigation with mine water. This means that large quantities of salt can be immobilized in the soil profile, removed temporarily from the water system, and released in small amounts into the groundwater over an extremely long time period.

The Shashe sub-basin

The Shashe sub-basin shows potential for development. To date, there are 146 small dams in the Francistown region, and the Ministry of Agriculture is investigating various small- to medium-sized irrigation schemes. The existing Shashe Dam serves Francistown and Selebe-Pikwe. During Phase-I of the North–South Water Carrier Project, the Shashe Dam will also transfer water via Selebe-Pikwe to Gaborone, supplementing local water resources of the main towns on-route including Palapye, Mahalapye, Palla Road and Mmamabula. Construction of the Letsibogo Dam on the Motloutse River will relieve the Shashe Dam, to serve primarily Francistown and growing urban and peri-urban areas in the region.

Further phases of this project will construct and link the Lower Shashe Dam and duplicate the pipeline from Selebe-Pikwe to Gaborone providing for all water demands until 2020, given current water use trends (IUCN, 1999). Thereafter, Botswana will have to resort to international water sources from the Limpopo, Ramokgwebana and Zambezi Rivers (GOB–MFDP, 1997). Three possible dam sites in the Limpopo River are being investigated, including the Pont Drift Dam, the Martin's Drift Dam and the Cumberland Dam. Several committees are responsible for joint planning and decision-making (see Chapter 3).

South Africa

The South African part of the Limpopo catchment feeds into all three river reaches mentioned in the beginning of this section, and can be grouped into two major components (Table 8):

- Crocodile/Limpopo River Basin up to the confluence with the Luvuvhu River (near Pafuri) at the border with Zimbabwe, South Africa and Mozambique;
- Elephants River Basin, which leaves South Africa through the Kruger National Park and joins the Limpopo River in Mozambique.

Storage capacity in the Limpopo River Basin

Effective storage and bulk distribution of water is located mainly in the upper part of the Crocodile River and the upper and middle parts of the Elephants River. Only a few additional development options exist within the Limpopo River, which are basically the Pont Drift, Martin's Drift and Cumberland dam sites. The present infrastructure is limited to run-of-river abstractions by irrigation farmers in a narrow band around the main stem of the Limpopo River, primarily along the South African side of the river.

Some 100 large dams exist of which about 40 are categorized as major dams with a capacity of more than 2 million m^3. The total capacity is almost

TABLE 8
Characteristics of major South African sub-basins of the Limpopo River Basin

Tributary	Catchment Area (km^2)	Naturalized MAR (million m^3)	Denaturalized MAR (million m^3)	Ecological reserve (million m^3)	Unit runoff (denatural. MAR) (mm)
Marico	13 208	172	50	29	3.77
Crocodile	29 572	391	205	82	6.93
Matlabas	3 448	382	21	76	6.03
Mokolo	7 616		117		15.35
Lephalala	4 868	150	99	17	20.28
Mogalakwena	20 248	269	79	41	3.92
Sand	15 630	72	38	10	2.41
Nzhelele	3 436	113	89	12	26.02
Luvuvhu	4 826	520	492	105	101.95
Elephants	68 450	1 644	1 233	366	18.02
Other	13 996	2 352		266	
Total	185 298	5 066	> 2 400	1 004	13.07

Source: Görgens and Boroto (1999); GOSA–DWAF (2003a–d).

2 500 million m^3. Of these, the following dams are key sources for domestic water (capacity in brackets):

- Roodeplaat (41.2 million m^3), Vaalkop (56.0 million m^3), Roodekoppies (103.0 million m^3) and Klipvoor (42.1 million m^3) in the Crocodile catchment;
- Molatedi (201.0 million m^3) on the Marico River (water supply to Gaborone, Botswana);
- Witbank (104.0 million m^3), Middelburg (48.1 million m^3), Loskop (362.0 million m^3) and Arabie (99.0 million m^3), and the Phalaborwa barrage on the Elephants River;
- Ebenezer (69.1 million m^3) and Tzaneen (157.0 million m^3) on the Letaba River (serving Polokwane, Tzaneen and surroundings);
- Vondo (30.5 million m^3) and Albasini (28.2 million m^3) on the Luvuvhu River.

Some other major dams, used mainly for irrigation, but with capability for domestic use include:

- Hartebeespoort (186.0 million m^3) on the Crocodile River (currently experiencing water quality problems);
- Marico (27.0 million m^3) on the Marico River;
- Mokolo (145.0 million m^3) on the Mokolo River (currently serving irrigation and the Matimba power station);
- Blyderivierpoort (55.2 million m^3) and Rooipoort (proposed) on the Elephants River;
- Glen Alpine (20.0 million m^3) and others on the Mogalakwena River;
- Nzhelele (55.3 million m^3) on the Nzhelele River.

The future construction of the Rooipoort Dam on the Elephants River and a proposed dam on the Steelpoort River will make the system highly regulated and it will probably exceed its full capacity by about 2020. However, if more emphasis is put on water demand rather than water supply management, the construction of the dams can be postponed for a number of years. Most of the water-needy population is located far from the existing dams and, thus, costly distribution networks will be required in order to include them in supply systems. The most suitably located dams and their future extended supply capacity include:

- increased height for the Arabie Dam and the future Rooipoort Dam until 2020 and possibly 2035;
- proposed new dam on the Steelpoort River until 2020 and possibly 2030;
- the Middle Letaba Dam until 2020 and possibly 2030;
- the Vondo Dam is already close to its limit and the Nzhelele Dam has only a limited capacity;
- the Glen Alpine Dam can also only serve the immediate surroundings until 2020.

Water is imported from the Vaal River catchment (Orange River Basin) to urban areas (Johannesburg and Pretoria) in Gauteng Province in order to augment local water resources (Box 9). A significant portion of the return flows from these water uses enters the Limpopo catchment and as such supplements the capacity.

However, recent surveys by the Department of Water Affairs and Forestry (DWAF) make it evident that most of the rural households in the Limpopo River Basin in South Africa cannot be

BOX 9

The Lesotho Highlands Water Transfer Scheme

The Lesotho Highlands Water Project is the largest civil engineering project in Africa and is the world's second largest water-transfer scheme.

The first phase (1A) of the proposed four-phase scheme, comprising a giant dam at Katse in the central Maluti mountains, an 82-km transfer and delivery tunnel system reaching to the Ash River across the border in South Africa, a hydropower station at Muela, and associated structures, has been completed. This phase was commissioned in 1998, and an average of 17 m^3/s of water is now being delivered to South Africa.

Phase 1B, comprising the Mohale Dam, a 145-metre-high dam on the Senqunyane River some 40 km southwest of Katse, a 32-km transfer tunnel between the Mohale and Katse reservoirs, a 19-metre-high concrete diversion weir on the Matsoku River and a 5.6-km tunnel, is in progress. The Mohale reservoir and Matsoku diversion will add 9.5 and 2.2 m^3/s to the yield of Katse. Completion of these components is scheduled for 2003/04.

Completion of all four phases could transfer 70 m^3/s to the Vaal River system for urban use in Gauteng Province (Anon., 2003). A portion will be released in the Limpopo watershed (mainly the Hartebeespoort Dam) as return flow.

served by surface water only. Present indications are that up to 52 percent will use only groundwater, and the majority of remaining communities will use a combination of groundwater and surface water (GOSA–DWAF, 1999a–c).

Water management areas

In preparation of a national water resource strategy, the country was subdivided into 19 water management areas. Of these, the following four constitute the Limpopo River Basin in South Africa (Table 9).

Crocodile (West) and Marico water management area

Particularly evident from Table 9 is the overriding importance of water transfers into this water management area. In total, nearly 45 percent of the current water available in the water management area is supplied by transfers from the Upper Vaal water management area and beyond. Almost 30 percent of the total water available for use is from effluent return flows, most of which results from water transferred to the large urban and industrial centres in the water management area. Also significant is the contribution of groundwater, representing about 40 percent of the yield available from the water resources naturally occurring in the water management area.

DWAF plans the transfer of 124 million m^3 of water per year from the Crocodile (West) and Marico water management area to Gaborone in Botswana.

Limpopo water management area

In the Sand subarea, groundwater is of overriding importance, while the contribution of groundwater to the total water available in the water management area is among the highest of all water management areas. However, well over half of the available water originates from surface resources, which require careful and efficient management. Water transfers into the water management area serve to augment supplies to the larger urban and industrial areas as well as some mining developments, and are vital to the economy of the water management area. Also noticeable is the volume of return flows estimated to be available for reuse, the quantification of which requires improvement.

Elephants water management area

Large quantities of water are also transferred into the Upper Elephants subarea. These constitute about 22 percent of the total water available in the water management area. Of note is the significant contribution of groundwater, which constitutes nearly 20 percent of the water naturally occurring in the water management area. Usable return flows also represent a substantial proportion of the water available for use in the water management area. However, there is particular uncertainty about the quantity of return flow from irrigation water use, which may have an important impact on the total water availability in the water management area.

Luvuvhu and Letaba management area

Surface water is the dominant source of supply in four of the five subareas. The only exception is the Shingwedzi subarea where more than half of the water available is abstracted from groundwater, while water is also transferred into the subarea

TABLE 9
South African water management areas and sub-basins of the Limpopo River Basin: available water in 2000

Subarea	Natural resource		Usable return flow			Total local yield	Water transfers	Grand total
	Surface water	Groundwater	Irrigation	Urban	Mining and bulk			
	(million m³/year)							
Crocodile (West) and Marico water management area								
Apies/Pienaars	38	36	4	106	2	186	182	368
Upper Crocodile	111	31	21	158	15	336	279	615
Elands	30	29	3	10	14	86	71	157
Lower Crocodile	7	29	14	1	8	59	112	171
Marico	14	12	2	3	1	32	0	32
Upper Molopo	3	9	0	5	2	19	0	19
Subtotal	203	146	44	283	42	718	519	1 237
Limpopo water management area								
Matlabas/Mokolo	35	7	3	1	0	46	0	46
Lephalala	38	4	0	0	0	42	0	42
Mogalakwena	50	15	3	4	0	72	3	75
Sand	10	71	0	10	0	91	15	106
Nzhelele/Nwanedzi	27	1	2	0	0	30	0	30
Subtotal	160	98	8	15	0	281	18	299
Elephants water management area								
Upper Elephants	194	4	2	34	4	238	171	409
Middle Elephants	100	70	34	5	1	210	91	301
Steelpoort	42	14	3	1	1	61	0	61
Lower Elephants	74	11	5	2	8	100	1	101
Subtotal	410	99	44	42	14	609	172	781
Luvuvhu and Letaba management area								
Luvuvhu/Mutale	88	20	5	2	0	115	0	115
Shingwedzi	1	2	0	0	0	3	0	3
Groot Letaba	133	12	13	1	0	159	0	159
Klein Letaba	21	9	1	1	0	32	0	32
Lower Letaba	1	0	0	0	0	1	0	1
Subtotal	244	43	19	4	0	310	0	310
Total for Limpopo basin	**1 017**	**386**	**115**	**344**	**56**	**1 918**	**709**	**2 627**

Source: GOSA–DWAF (2003a–d).

from the Luvuvhu River catchment. Also noticeable is the volume of return flows estimated to be available for reuse, the quantifications of which require improvement.

The quality of the water from the Limpopo River poses serious problems during periods of low flow, in particular upstream of the confluence with the Shashe River (P. Nell, personal communication, 1999). Water pumped from the riverbed from deeper than 1–2 m is very costly and rapidly becoming of inferior quality owing to salinity, herbicides, toxic elements and heavy metals such as boron.

Zimbabwe

Zimbabwe is divided into six hydrological zones (A–F). The Limpopo catchment corresponds to Zone B, which has 30 hydrological subzones, covering a total area of 62 541 km² (16 percent of Zimbabwe's land area). The catchment has an MAR of 1 157 million m³ or 19 mm, which is less than 6 percent of the total MAR of the country (GOZ–MRRWD–DWD, 1984). Table 10 summarizes the characteristics according to the main tributaries.

The Limpopo River Basin has a highly variable and unreliable flow, and consequently an unreliable water supply. The rivers are intermittent with peak flows in February followed by low flow from May to early November. The reliability of runoff can be indicated by the percent CV, which is the difference between the highest runoff and the lowest runoff of the catchment over time, expressed as a percentage of the MAR. The higher is the percent CV, the less reliable is the runoff. For the Limpopo catchment in Zimbabwe, the CV is 130 percent, which reflects a low reliability, hence the greater the risk of water shortage in the area, unless groundwater sources exist (GOZ–MRRWD–DWD, 1984).

The priority of water allocation in this catchment goes to domestic and industrial purposes, followed

TABLE 10
Characteristics of the Zimbabwe part of the Limpopo River Basin

Tributary	Catchment area	MAR	MAR	Storage	Flow right	Commitment	Potential remaining	MAP	MAE
	(km^2)	(mm)	(million m^3)					(mm)	(mm)
(1)	(2)	(4)	(3)*	(5)	(6)	(7) = (5) + (6)	(8)	(9)	(10)
Shashe	18 991	24.33	462.0	178.5	15.0	193.4	310.9		2 000–2 150
Umzingwane	15 695	22.30	350.0	592.1	25.1	617.1	131.0	475	2 065
Bubi	8 140	6.51	53.0	21.3	0.1	21.3	33.6	315	2 425
Mwenezi	14 759	17.35	256.0	341.7	7.8	349.5	103.3	465	1 800–1 810
Other	4 956	7.26	36.0	12.6	17.3	29.9	7.9		
Total**	62 541	18.50	1 157.0	1 146.1	65.2	1 211.3	586.7	465	1 800–2 425

* According to Görgens and Boroto (1999), the MAR given in column (3) is the denaturalized MAR, but according to GOZ–MRRWD–DWD (1984), the MAR given in (3) is the natural MAR (see also Table 7, where it is put as denaturalized MAR).
** There is a discrepancy between the area of the catchment given above (62 541 km^2) and the area according to FAO (1997) (51 467 km^2). An explanation may be that the FAO study had included part of the Limpopo River Basin in the adjacent Save or Zambezi basins, which should be corrected

Source: GOZ–MRRWD–DWD (1984).

by mining and finally agriculture. The city of Bulawayo is supplied by the Mzingwane, Inyankuni and Ncema dams; Gwanda by the Mtshabezi Dam, Kezi by the Shashani Dam, Mwenezi and Rutenga by the Manyuchi Dam. Beitbridge receives its water directly from the Limpopo River (GOZ–MRRWD, 1999). Most irrigation schemes also receive their water from dams. However, in the schemes developed along the major rivers, sand abstraction is practised. The river sand acts as the aquifer into which boreholes are sunk in order to abstract irrigation water. The water is normally found at 3–10 m below the riverbed.

Storage capacity in the Limpopo River Basin

There are 2 168 dams in the Zimbabwean part of the Limpopo River Basin. However, regardless of the potential available in dams and rivers, the water demand of the rural communities is rarely satisfied. This can be explained by a lack of the costly infrastructure needed to bring the water to these communities. In Zimbabwe, the total capacity of the dams has fallen by about 29 million m^3 in the last three years as a result of siltation (Pallett, 1997; GOZ–MRRWD–DWD, 2000).

Currently, of the total MAR, almost 99 percent of the water is already being harnessed/stored. The potential for development exists in places where the MAR is larger than the storage and/or flow rights. However, where the MAR is less than storage, it means that the subcatchment has been developed or already has more dams constructed than can be filled up with the MAR. These dams can still fill up during wet years with a higher runoff than that reflected by the MAR. This is significant when the total commitment is larger than the MAR. Total commitment includes both storage and flow rights. Where a subcatchment has no dams in it, the flow rights will exceed the storage rights.

Mozambique

To a large extent, Mozambique's water resources are conditioned by the fact that they form part of international river basins, where neighbouring countries upstream are increasingly exploiting available water resources. Such action is claimed to exacerbate downstream problems of water shortages and drought in Mozambique.

An extensive number of studies and reports have provided assessments of national water resources (GOM–DNA, 1986, 1998) and other hydrological assessments (MacDonald and Partners, 1990), including irrigation development in the Limpopo River Basin (Sogreah, 1993).

Using data cited in Sogreah (1987), the basin at the Chokwé station (Figure 5) covers 342 000 km^2 and the MAR is 5 280 million m^3, calculated over a period of 34 years (from October 1951 to September 1985). Figures given above reveal that about 4 800 million m^3 enters Mozambique, which means that less than 10 percent is generated within Mozambique. The area of the Limpopo River Basin within Mozambique is 84 981 km^2, which is about 11 percent of the total area of the country and 21 percent of the total area of the basin (Table 6).

The main tributary, the Elephants River, has a basin of 70 000 km^2, most of which is in South Africa (68 450 km^2). The Elephants River is regulated by the Massingir Dam, with a capacity of about 2 200 million m^3. At the Massingir Dam site, the MAR is 1 800 million m^3, calculated over the same period of 34 years. The Massingir Dam controls 34 percent of the total flows at Chokwé. Mihajlovich and Gomes (1986) estimated that the annual volume of water entering the station of Mapai on the Limpopo River (upstream of the confluence of the Limpopo and Elephants Rivers) is 3 510 million m^3, calculated over a period of 32 years, representing 65 percent of the total flows at Chokwé. However, the discharge is very irregular and may be practically zero in winter.

Downstream of Chokwé, the Changane River (an intermittent tributary without regulation structures), drains a basin covering 43 000 km^2, but it has a very low runoff coefficient and long periods with no discharge at all. The Lumane River, the last of the most important tributaries, originates in Lake Pave and receives regular inflows from the sandy hillsides. It has a discharge of about 10 m^3/s. Table 11 shows the flow regime of the Elephants and Limpopo Rivers in Mozambique.

Sogreah (1993) noted that more than 75 percent of the annual volume occurs during only three months (January–March), which is quite extreme even in comparison with other rivers in the south of Mozambique, and that the whole dry semester (May–October) represents less than 10 percent of the annual flow.

The annual inflow CV is 1.07 for the Limpopo River at Mapai and 0.61 for the Elephants River at Massingir (comparable with those of the Sabie, Incomati and Umbeluzi). In addition to the irregularity of natural inflows, which calls for the construction of dams in order to guarantee a regulated annual volume, another problem lies in the form of offtake in the neighbouring countries. Many dams have been built in Zimbabwe and South Africa and the effect of water storage in these countries may be seen in recent years in terms of change in the discharge recession curves during the dry season.

TABLE 11
Flows measured at the Massingir and Chokwé stations

Flow	Frequency	Elephants at Massingir	Limpopo at Chokwé
		(million m^3)	
MAR		1 800	5 280
Annual runoff surpassed	1 in 2 years	1 600	2 800
Annual runoff surpassed	8 in 10 years	700	850
Annual runoff surpassed	9 in 10 years	550	400
Minimum annual runoff	(1982–83)	253	63

Offtake in countries upstream of Mozambique may have a favourable effect in reducing floods, but it is detrimental in low-water periods, when water requirements are most acute. Citing Sogreah (1993), South Africa and, to an unknown extent, Botswana and Zimbabwe are extracting considerable quantities of water from the Limpopo River Basin, estimated at 1 173 million m^3 in 1980 (GOSA–DWA, 1985). This figure was projected to increase to 1 385 million m^3 in 1990 and 1 723 million m^3 in 2000. The corresponding figures for the Elephants River Basin were 1 038, 1 188 and 1 254 million m^3, but their origin is questionable as they were presented within a negotiation framework.

The effect of the increase in abstractions is already apparent in the dry season in the Limpopo River, where it has become normal to find it completely dry for some months each year. Sogreah (1993) used recession curves of different years to demonstrate an increase in their gradient in more recent years, and developed a number of scenarios for analysis of water abstractions and their impact in Mozambique.

Between October 1981 and September 1986, the mean inflow at Massingir was 792 million m^3, which is only 44 percent of the mean over a period of 34 years. The reason for this is not offtakes in South Africa, but rather climate conditions. The mean inflow of the five earliest years (1961–66) was 834 million m^3. Conversely, the mean inflow in 1973–1978 was 2 976 million m^3, which is 165 percent of the 34-year mean. The possibility of several successive dry years occurring means that large-capacity dams will have to be built and will enable a maximum of only 60 percent of the natural inflow to be regulated (Sogreah, 1987).

Groundwater resources

Groundwater is used extensively in the region, mainly for irrigation and rural supplies. Communities are often located at significant distances from river reaches and depend solely on groundwater resources for survival.

Botswana

Most of the rural population is located far from surface water resources and depends mainly on groundwater resources. Traditionally, most major villages have also used groundwater, which is now being augmented by local or regional surface water supplies, including the North–South Water Carrier. Most smaller rural villages can derive their domestic water needs from groundwater without depleting the available resource. However, in periods when rivers and local dams are dry, these groundwater resources are overexploited to also serve livestock watering needs. Groundwater resources at Jwaneng and Orapa are being overexploited resulting in so-called groundwater mining, which is depleting available groundwater reserves.

Botswana's groundwater is characterized by very low recharge rates, low probability for high-yielding boreholes and relatively high salinity. In the Limpopo catchment of Botswana, the mean recharge to groundwater ranges from 1 to 3 mm/year in the Kalahari and northwestern parts of Central Region to 5–9 mm/year for most of the eastern areas, except for the Tuli Block. Extended drought periods affect the reliability of these sources and require active monitoring and management. The low recharge precludes any large-scale development of groundwater because it would lead to unacceptably high rates of groundwater exploitation (mining) and subsequent damage to the resource.

The median yield from successful boreholes is moderate to low ranging from 3 to 6 m^3/h for most of the Limpopo catchments in Botswana. The best production areas are between Gaborone and Mahalapye and in smaller areas around Ramotswa and Palapye. They have been defined into 10 production areas, including well fields at Palla Road, Ramotswa, Lobatse, Ramonnedi, Molepolole, Mochudi, Palapye, Serowe, Paje and Shashe. The Palla Road and Ramotswa well fields have the highest capacity and will probably be linked as sources to the North–South Water Carrier Project. Dolomite aquifers in the Kanye, Sekoma, Molopo and Mashaneng areas have significant storage capacity and high yields.

Sandstone formations, which are linked to the central Kalahari, have the largest recharge areas and total storage, but often have high salinity and require large numbers of boreholes. Occasionally, sand rivers provide good recharge and storage capacity for local extraction, but generally they have inadequate capacity for regional uses. The main aquifers and their related storage and yield capacities are listed in the national water master plan (GOB–MMRWA, 1992). Subsequent national development plans (GOB–MFDP, 1997) provide upgraded information based on groundwater investigations and compliance monitoring.

Groundwater quality is often deficient with high salinity and excess concentrations of fluorides, nitrates, and other harmful elements in some regions. The total dissolved solids range from 1 000 to 1 500 mg/litre for most of the Limpopo catchments in Botswana, and increased levels of nitrates are occurring near irrigation and within settlement areas.

Conjunctive use of surface water and groundwater is essential for sustaining water quantity and quality requirements of users. Monitoring programmes are being implemented to protect and manage groundwater and surface water against pollution and overexploitation. Active management of water demand and water quality is critical to managing drought and the impact of drought in Botswana.

However, the management of groundwater is complicated by the "common pool" problem. While individual use or misuse may not result in a significant problem, the combined impact is often unacceptable. It is then difficult to determine who is responsible and how the situation is to be regulated.

South Africa

Rural communities and irrigation farming make extensive use of groundwater, extracting a total of about 850 million m^3/year. It is estimated that more than 55 percent of rural communities are supplied from groundwater as their only source. Most of the remaining communities use a combination of groundwater and surface water (GOSA–DWAF, 1999a–c).

Dolomite aquifers occur in the Crocodile River Basin and the Blyde River area, but are generally distant from the needy rural communities. Most rural communities are located on minor aquifer types with an average borehole yield of about two litres per second. Communities north of Soutpansberg are located on poor aquifer types yielding less than 1 litre/s. The water they provide often fails to meet domestic water quality standards because of high salinity. Only the southeastern parts of the former Bolobedu area of Lebowa have reasonable groundwater potential and quality.

On average, 5–10 boreholes need to be drilled for each community and they can generally serve only communities of fewer than 2 000 people. There are indications that up to 27 percent of boreholes have a water quality that is marginal or poor for

> BOX 10
> **Overexploitation of groundwater in Limpopo Province, South Africa**
>
> The Dendron area is one of the prime examples in South Africa where uncontrolled extraction of groundwater on private farms for irrigation purposes greatly exceeded recharge, leading to unsustainable development. In the 1970s and 1980s, on a cluster of farms on which boreholes supplied copious volumes of groundwater, a flourishing potato production industry developed in this semi-arid area. The area receives 440 mm mean annual summer rainfall, and the seasonal recharge varies between 3 and 35 mm (1–8 percent of the MAP). After a number of years and great expenditure, the granite aquifer became depleted and potato production ground to a permanent halt.
>
> There were two issues in this case. The first was a lack of recognition of the fossil nature of the groundwater body, and the second was the way safe delivery was estimated. Borehole yield information was based on the initial drilling-rig blow test of the borehole. This test was later shown to be overgenerous. In recent years, DWAF has been recommending 30–50 percent of the blow yield for long-term use (Bang and Stimie, 1999).

domestic use and causing it to have a number of limitations for crop irrigation. Key problem areas are: the Springbok Flats and surroundings, where high fluoride concentrations are common; the area north of Soutpansberg, where high solute concentrations are found; and areas around Dendron (Box 10) and along the main stem of the Limpopo River, where high evaporation influences the salinity level of the water.

Zimbabwe

The Limpopo River Basin area in Zimbabwe is not well endowed with groundwater. Most of the wells in the communal areas that are used for household purposes, caring for livestock, and watering of gardens, run dry long before the rainy season starts. However, in addition to a few groundwater aquifers, the basin also has subsurface water stored close to the surface in a few *dambo* (wetland) areas. True *dambos* no longer exist in most parts of Matabeleland South Province, primarily because of land degradation over the years from prolonged droughts and overstocking. However, vegetable production on seasonal wetlands does occur on communal lands near Matopo, Esigodini, Godlwayo and some other areas (DANIDA, 1990).

Data on the exact extent and quantity of groundwater are not available. Areas with reasonable groundwater reserves, both in terms of quantity and quality, are found in two areas (Figure 5). The first is around Esigodini, south of Bulawayo in the Umzingwane River Basin, where the water is used for the production of vegetables and fruit under irrigation. The second is in the Malipati area at Manjinji, near the southern reaches of the Mwenezi River, where there is potential to irrigate up to 1 000 ha, out of which only a very small portion is already irrigated.

The water at both Esigodini and Malipati occurs at shallow depth (20–30 m) and is of good agricultural quality. Groundwater also occurs along the Limpopo River and below the riverbed sand aquifer (3–10 m deep). The quality of water east of Beitbridge around Grootvlei is low owing to salinity, although the quantities are good (GOZ–AGRITEX, 1990). An irrigation scheme established before independence has been abandoned because of poor water quality.

Mozambique

Existing data on groundwater resources relate to information from wells (at time of construction) and to geological information. According to Sogreah (1993), the groundwater potential in the Limpopo River Basin area is limited, particularly because of the high mineralization of many of the aquifers. According to another synthesis report on water resources in Mozambique (GOM–DNA, 1999), groundwater in the vast interior area of Gaza Province is unfit for consumption because of high levels of salinity.

Six different zones are considered in characterizing the groundwater potential in the Limpopo River Basin in Mozambique:

- Dune area: a 40–60-km wide strip along the coast. Productivity is considered low to medium. Quality is good because of to the high recharge rate of 50–200 mm/year. Recent studies estimate the exploitable amount of groundwater to be about 5–10 m^3/h per km^2.
- Alluvial valleys: formed by the incised main valleys of the Limpopo and Elephants Rivers. Productivity is high, but water quality is a major problem because the rivers drain the

adjacent plains that have highly mineralized groundwater. Fresh groundwater occurs where the surface waters of the rivers replenish the aquifers directly, but care is needed to prevent overexploitation and avoid the risk of salinization of the aquifers.
- Old alluvial plains: bordering the dune area. This region does not provide any potential for groundwater exploitation as it is highly mineralized.
- Erosion plains and erosion valleys: a shallow eluvial cover of sandy clays over the entire inland area. Productivity is low in general but calcareous sandstones have higher specific yields. Water quality is usually poor, with exceptions found along water lines and local depressions that are recharged from the temporary rivulets.
- Deeper aquifer: found in the medium and lower Limpopo River Valley at depths ranging from 80 m at Mabalane to 200 m at Xai-Xai. The total exploitable groundwater in this aquifer, which seems to be enclosed by a saline cover and a brackish base, has been estimated at 300–600 m^3/h.
- Lebombo Range: the rhyolites of the Lebombo Range have very low productivity. Very few wells have been drilled in this region and the failure rate is high.

The aquifers related to the sedimentary post-Karoo formation deliver sufficient water of suitable quality for irrigation. This formation generally runs parallel to the course of the main rivers south of the Save River. The more recent deposits of the coastal dunes also provide water of good quality, but the yield is small.

Many reports conclude that large-scale groundwater abstractions in the Limpopo River Basin are very limited as a consequence of low productivity and poor water quality. There exists a deep aquifer between 250–350 m, which may be continuing to the south, but exploitation of this source is not economically feasible. Water quality becomes progressively worse downstream of Chokwé and the confluence with the Changane River. Only the dune unit can be used for small- and medium-scale abstractions without restrictions posed by water quality. For irrigation purposes, groundwater safe yields are too small and can be ignored.

Another source of water is that from the sandy hillsides in the lower Limpopo area, which is being partially used for the irrigation of the *Machongos*. *Machongo* is the local name for a type of hydromorphic soil (a kind of peat soil wetland) with very high organic matter content, part of which is in a very coarse form. While not directly under the irrigation subsector, subsurface irrigation on *machongos* is practised in Xai-Xai District. *Machongos* are found mostly along the sea coast, in the valleys of the main rivers (at the junction of the valley with the higher surrounding ground), or associated with smaller streams where the flow of water is seasonally impeded.

Interbasin and intrabasin water transfers

A number of water transfer schemes have been developed or proposed in order to address the relatively severe water shortage in the Limpopo River Basin while maintaining the current emphasis on water supply management rather than water demand management. Transfers of water may be made from one sub-basin of the Limpopo River Basin to another, within one country or between countries. This is termed intrabasin water transfer. Water can also be transferred between the Limpopo River Basin and other basins, within one country or between countries. This is termed interbasin water transfer. The Limpopo has four interbasin transfer schemes and two intrabasin schemes (Table 12).

In South Africa, water is imported from the Usutu, Vaal and Komati Rivers to serve the high water quantity and quality demands of the power stations in the Upper Elephants River Basin. In addition, continued importing of water from the Orange and Vaal River system (Box 9) and greater reuse of return flows in the Crocodile River could create surplus water in the Crocodile River, which could then be exported to supplement the Mogalakwena, Mokolo and Elephants basins. However, these return flows affect the quality of the water, and it becomes increasingly important to manage the resulting water quantity and quality in an integrated way in order to prevent environmental impacts and to ensure compliance with other water user requirements.

These transfer schemes are the subject of intense debate because of their high cost and potentially negative impacts on the environment and ecological balance. Transfer schemes affect river basin planning, water quantity, water quality, land, aquatic systems, terrestrial systems and socio-economic issues in the countries sharing the receiving or supplying basins. This requires all countries affected directly and indirectly to be involved from the outset in the planning and

TABLE 12
Interbasin and intrabasin water transfers related to the Limpopo River Basin

Name of water transfer scheme	Basins involved	Countries involved directly in scheme[1]	Countries involved/affected indirectly[2]
Interbasin water transfer schemes			
Komati Scheme	From Incomati to Limpopo	South Africa	Swaziland, Botswana, Mozambique, Zimbabwe
Usutu Scheme	From Usutu to Limpopo	South Africa	Swaziland, Botswana, Mozambique, Zimbabwe
Grootdraai Emergency Augmentation Scheme	From Orange to Limpopo	South Africa	Botswana, Mozambique, Zimbabwe, Lesotho, Namibia
Vaal-Crocodile	From Orange to Limpopo	South Africa	Botswana, Mozambique, Zimbabwe, Lesotho, Namibia
Intrabasin water transfer schemes			
North–South Water Carrier (within Limpopo basin)	From Shashe to Notwane	Botswana	Mozambique, Zimbabwe, South Africa
Molatedi Dam to Gaborone	From Marico to Notwane	Botswana, South Africa	Mozambique, Zimbabwe

[1] Countries initiating and implementing the transfer scheme.
[2] Countries sharing involved basin and which consequently are affected by the scheme.

decision-making. However, the existing treaties on the Limpopo River Basin are either bilateral or trilateral agreements and, as yet, no agreement has been established and signed by all four countries sharing the basin.

Issues such as interbasin water transfers are meant to be regulated by the protocol on shared watercourse systems in the SADC region, which came into force in 1998 after ratification by the required two-thirds majority of the SADC member states (SADC, 1998). The introduction of proper water management demand systems could postpone future transfer schemes and overabstraction from international rivers. However, the protocol fails to incorporate water demand management as an explicit strategy. Notwithstanding this, the agreement supports the requirement that national resources be used as efficiently as possible prior to international abstractions (IUCN, 1999).

Even though the Limpopo River Basin lacks a single comprehensive treaty, there is the firm commitment to cooperate through the Limpopo Basin Permanent Technical Committee, established in Harare in 1986, which includes all four countries. Negotiations are currently underway for this committee to become the Limpopo Basin Commission (LIMCOM). The draft agreement is under preparation at present and is discussed in more detail in Chapter 3.

LAND AND VEGETATION CLASSIFICATION AND ASSESSMENT

Agro-ecological zoning and land evaluation

FAO's AEZ has been developed to assist with land resources assessment for better planning management and monitoring of these resources (FAO, 1996). The AEZ system includes:

- inventory of land resources and land utilization systems;
- evaluation of land suitability and productivity;
- mapping of AEZ, land suitability, problem soils, etc.;
- land degradation and population-supporting capacity assessment.

The AEZ methodology was developed in the 1970s and is applied as a system to evaluate land for rainfed and irrigated agriculture, forestry and extensive grazing. The AEZ concept involves the combination of layers of spatial information, such as topography, physiography, soils, climate, catchments, land cover, production systems and population, combined and analysed using a geographical information system (GIS). AEZ is applied widely across the globe, including in countries in southern Africa. However, a regional AEZ map of southern Africa does not exist.

AEZ is an established reference system in Botswana, and is also used in multiple applications, including the production of land suitability maps. The general soil map of Botswana (De Wit and Nachtergaele, 1990), in combination with climate data, crop requirements and other information, has provided the basis for the national land suitability map for rainfed crop production (Radcliffe, Tersteeg and De Wit, 1992). In several areas of the northern part of the Limpopo River Basin, detailed land evaluation studies have determined land suitability for rainfed and irrigated crop production (De Wit and Cavaliere-Parzanese, 1990; De Wit and Moganane, 1990).

AEZ has been used in Mozambique since the 1970s, and a national AEZ map at a scale of 1: 2 000 000 is available (not digital). Following independence in 1975, a handful of foreign consulting firms, contracted by national directorates and secretariats, acted as the principal providers of ad hoc land resources information and their assessment for agricultural potential, applying their own methodologies and procedures. In the last 20 years, a series of multilateral and bilateral programmes (FAO, the Netherlands and the Soviet Union) have upgraded the capacity in soil surveying and land evaluation in the National Directorate for Geography and Cadastre (DINAGECA) and the INIA.

Voortman and Spiers (1981) produced a qualitative national assessment of land resources and their suitability for rainfed production in a series of five maps (mean annual rainfall; vegetation and potential utilization; agroclimate zones; terrain limitations for rainfed agriculture; and agricultural land suitability) at a scale of 1:4 million. Further systematic land resource inventories and associated studies were conducted by FAO in 1982, which compiled information nationally on land suitability for eight rainfed crops in a six volume report by Kassam *et al*. (1982). Based on the AEZ methodology of FAO (1978), this study determined the agroclimatic suitability of the major rainfed crops for each growing period zone, to arrive at the land suitability classification. It produced the National Land Resources Map at a scale of 1:2 million and determined climate suitability for maize, sorghum, millet, wheat, soybean, groundnut, cassava and cotton, each mapped at a scale of 1:5 million. The inventory was updated by Snijders (1986).

Another FAO project conducted land resource assessments at regional scale involving systematic soil surveys and land evaluation. This included an assessment of Gaza Province, in which soils, geomorphology and terrain were mapped at a scale of 1:250 000. The project also introduced the automated land evaluation system (ALES) to handle the 125 soil mapping units in Mozambique, resulting in individual land evaluations that are crop, area and land-user specific.

AEZ according to FAO standards has not yet been determined in South Africa. The closest related system currently in use is that of land type maps showing climate zones. The Institute for Soil, Climate and Water of the ARC uses statistics from weather stations to determine the climate zones and to develop ten-daily vegetation greenness maps using a normalized difference vegetation index (NDVI), which form part of the drought management system. The introduction of AEZ in South Africa is recommended, as it would also provide essential linkages with other global land resource approaches (Van Der Merwe *et al.*, 2000).

Venema (1999) used the AEZ concept to subdivide the five natural regions of Zimbabwe into 18 provisional agro-ecological zones. The zones reflect rainfall probability, LGP, and predominant soil type. The system is based on the long-established system of the five natural regions of Zimbabwe defined by the Agricultural, Technical and Extension Service (AGRITEX), based on mean annual rainfall, rainfall distribution and altitude (GOZ–Surveyor-General, 1998).

Bernardi and Madzudzo (1990) distinguished six agroclimatic zones, based on the ratio of mean annual rainfall at the 80 percent probability level and the calculated or extrapolated average annual ET_o. In the moist areas of Zimbabwe, the AGRITEX natural regions are similar to these agroclimatic zones. However, in the dry southeast lowveldt, Natural Region V has been split into two parts in order to create Agroclimatic Zone VI in the extreme south, representing the most arid climate of Zimbabwe.

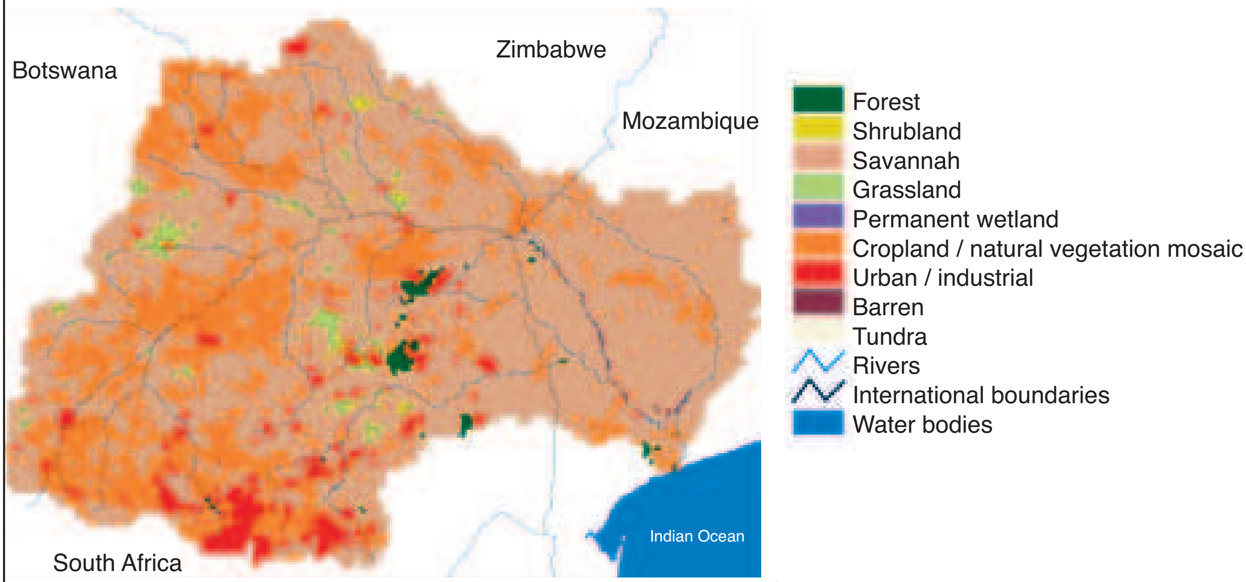
Land cover and vegetation classification

Currently, individual land cover exercises are difficult to compare as countries use different categories and legends, based on a variety of definitions. Descriptions of land cover are usually dominated by forest types, such as woodland, bushland, savannah, and wooded and open grassland. There are also differences between the database structures and descriptions, and as these have been defined without coordination, the exchange and comparison of data from different countries is difficult.

At a generalized scale, the World Resources Institute, has published generalized land cover data (GLCCD, 1998; Loveland *et al.*, 2000) and other information derived from the *Water Resources eAtlas* (World Resources Institute, 2003) for a number of Basins, including the Limpopo River Basin (Box 11). This information shows the Limpopo River Basin to be occupied mainly by savannah, cropland/natural vegetation mosaic, some grassland and urban/industrial areas (Figure 26).

Apart from the coverage of the Eastern Africa Region by UNESCO's International Classification

FIGURE 26
Generalized land cover classes of the Limpopo River Basin



Source: World Resources Institute (2003).

and Mapping of Vegetation in 1973, no regional vegetation coverage using a standardized classification and a larger scale is presently available. Using Landsat images and aerial photos, the Southern Africa Regional Office of the World Wildlife Fund (WWF) has done some mapping of land cover and land use change in southern Africa. The USGS–EROS Global Land Cover Project is also developing more standardized datasets on land cover using satellite imagery.

BOX 11
Land cover and use variables in several basins in southern Africa

- Percent forest cover: 0.7
- Percent grassland, savannah and shrubland: 67.7
- Percent wetlands: 2.8
- Percent cropland: 26.3
- Percent irrigated cropland: 0.9
- Percent dryland area: 82.5
- Percent urban and industrial area: 4.5
- Percent loss of original forest cover: 99.0

Source: World Resources Institute (2003).

Botswana

Information on forest cover in Botswana is often conflicting, depending on the definition applied to forest, woodland, etc. The land systems map of Botswana gives detailed information on the occurrence of woodlands, savannahs and grassland, including subdivision into density classes (GOB–MOA, 1990). The provisional vegetation map of Botswana by Weare and Yalala (1971) is the first detailed national vegetation map of Botswana. The most important units distinguished from northeast to southwest along the Limpopo River are:

- arid sweet bushveldt;
- mopane bushveldt;
- tree savannah (*Acacia nigrescens/Combretum apiculatum*);
- arid sweet bushveldt;
- semi-sweet mixed bushveldt.

Timberlake (1980) described and mapped the vegetation of southeast Botswana, distinguishing five main types:

- sandveldt tree and shrub savannah;
- hardveldt woodland and tree savannah;
- woodland on hills;
- shrub savannah on clay and calcrete;
- riverine woodland.

Timberlake's mapping approach was used during the soil mapping of the hardveldt (e.g. Remmelzwaal, 1989; Moganane, 1990), providing a better relationship with soil patterns as compared with the Weare and Yalala mapping. All soils reports of the standard 1:250 000 Botswana map series contain detailed descriptions of the vegetation. The overall descriptions were then combined in a national vegetation map of Botswana at a scale of 1:2 million, showing a strong relationship with underlying soil patterns (Bekker and De Wit, 1991). The four dominant vegetation associations along the Limpopo catchment from north to south are:

- *Colophospermum mopane* with *Acacia nigrescens*;
- *Combretum apiculatum* with *Acacia nigrescens*;
- *Terminalia sericea* with *Acacia tortilis* and *A. erubescence* (in sandy areas);
- *Pelthophorum africanum* with *Acacia tortilis*.

Currently, the Botswana Range Inventory and Monitoring Project (BRIMP) is re-mapping and sampling the vegetation of Botswana. About 20 percent of the task is complete. Ground data on species composition and cover is captured in GIS format.

Mozambique

Baseline information on the country's natural forest and woodland resources was first provided by a 1980 reconnaissance forest inventory, carried out in 1979–80 under an FAO–UNDP forestry sector project. At this time, the forest area of Gaza Province was inventoried at 1.3 million ha (Macucule and Mangue, 1980).

The 1980 inventory was updated in the early 1990s using visual interpretation of 1990–91 colour composite images (1:250 000) and Landsat TM (1:1 million), together with field truthing in all provinces. It produced a national land cover and land use map at a scale of 1:1 million, with quantitative data on the extent of the forest resource base by major forest type and land use classes (using the AFRICOVER legend), the extent of agricultural encroachment within the natural woody vegetation, as well as an estimate of deforestation rates. Table 13 provides data on land cover in Gaza Province according to the updated national forest inventory.

Overall, Gaza Province showed a low rate of deforestation (0.92 percent over 18 years), even though clearings of natural vegetation occurred widely along the Limpopo Corridor where many villages were created after 1972, and around the districts of Chicualacuala and Massangena. In contrast to other provinces, woody vegetation had recovered over wide areas in Chigubo, Dindiza, Nalazi and Changane districts and along the western border with Inhambane Province. Deforestation is most severe in Xai-Xai District, caused essentially by inappropriate agricultural practices, the collection of woodfuels and building materials from woodlands, and the high frequency of extensive forest fires. The forest inventory determined the allowable cut at 13 141 m^3 from an area of productive forest of 1 437 162 ha.

TABLE 13
Forest type and land use class in Gaza Province, Mozambique

Forest types and land use classes	Total (ha)
High forest (high–low density)	25 338
Low forest (high–low density)	635 923
Thicket (low–high density)	4 014 494
Grassland (open & wooded)	1 868 244
Mangrove communities	387
Dune vegetation	20 833
Agriculture	1 067 568
Irrigated agriculture	27 590
Total productive forest	1 437 162

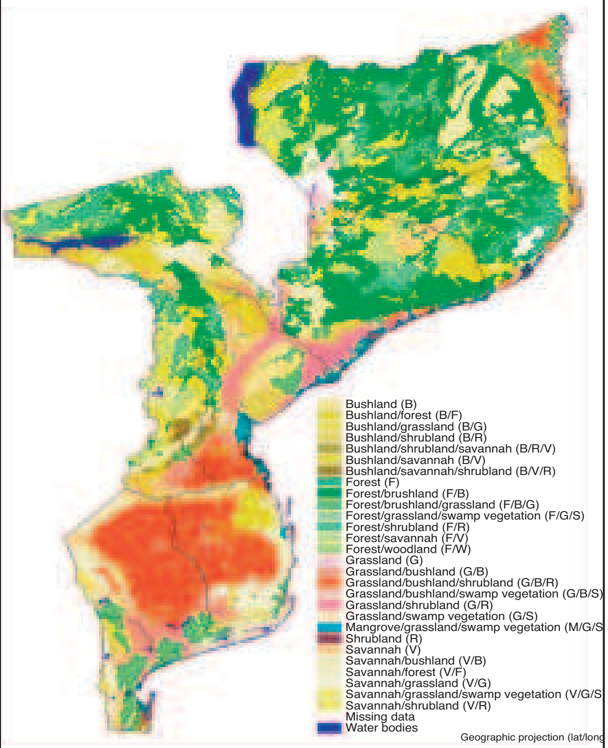
Source: Saket (1994).

Current initiatives involve the mapping of land use and land cover for the whole of Mozambique at a scale of 1:250 000 and eight selected districts at a scale of 1:50 000 scale (Desanker and Santos, 2000), using the FAO AFRICOVER legend.

The National Remote Sensing Centre (CENACARTA), created in 1989 under a French aid programme, is the supplier of satellite images in Mozambique (SPOT, Landsat, Radarsat, ERS and SPIN). Mozambique does not have a receiving station, but the CENACARTA has agreements with image suppliers in South Africa, such as the Satellite Applications Centre (SAC) of the Council for Scientific and Industrial Research (CSIR) in South Africa. The CENACARTA has technical capacities to process images and supply them in analogue and digital format.

The main biome in Gaza Province is the dry/eutrophic savannah (Figure 27), which lies between the 400-and 600-mm rainfall isohyets. It is characterized by the dominance of *Acacia* spp. and *Colophospermum mopane* on heavier-textured, base-saturated soils, and *Caesalpinoideae* and *Combretaceae* on leached, sandy and lighter-textured soils. The Miombo savannah woodlands, which typify the moist/dystrophic savannah, reach their southern limit as a whole system north of the Limpopo River estuary. Three main ecoclimate

FIGURE 27
Vegetation map of Mozambique



zones can be distinguished from upstream to downstream:

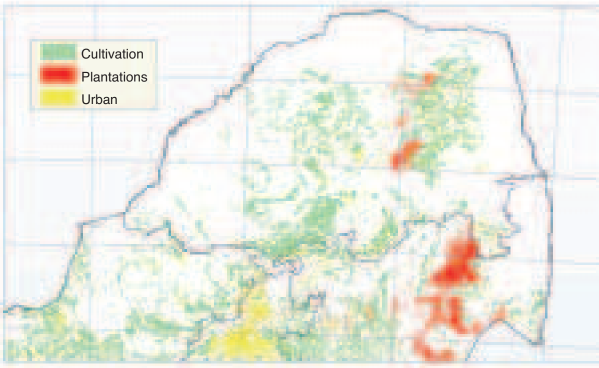
- From the border to 100 km downstream of the confluence with the Elephants River, the sand plateau is dominated by a vegetation of very dense arid sand thicket communities or by woodlands dominated by multistemmed short trees. On the slopes of the plateaus, *Colophospermum mopane* and *Acacia exuvialis* dominate an open woodland community, with woodlands of *Acacia, Commiphora* and *Terminalia* at lower elevations. Floodplains support woodland and open woodlands of *Acacia* (*xanthophloea, tortilis* and *nilotica*) with shrub-thickets of *Salvadora persica*. *Acacia xanthophloea*, a flat-topped tree with yellow bark, grows where its roots can find water easily. It is, as is *Salvadora persica*, an indicator of saline-alkaline soils on flat seasonally waterlogged soils close to the riverbanks. *Acacia tortilis* is a salt-tolerant tree found on the more permeable soils.
- In the more subhumid zone downstream to about 100 km inland from the sea, there are very open woodlands with short dense thorn thickets in the bottomlands; a result of the continued removal of woody elements for fuelwood in this region. The floodplain supports woodlands of *Acacia*. It is within this region that the transition from a xeric to moist sand thicket and woodland takes place. On the levee deposits along the Limpopo River, there are dense thickets of *Ficus, Diospyros* and *Zanthocercis*. The near floodplain supports *Acacia* or open woodlands. Around the Chokwé scheme, there are considerable reductions in the woody biomass, except in the western part where very dense thickets and woodlands of *Acacia* remain. A survey by Timberlake, Jordáo and Serno (1986) showed a close association of vegetation with soil type and drainage, determined primarily by soil texture, and by period of water inundation. Poorly drained soils support open grassland vegetation with few shrubs or trees, while the grass species present on the plains appear to depend on length of inundation by water. Sandy loam soils support an *Acacia* woodland, often associated with reasonably high soil-calcium levels. Deep sandy soils (Arenosols) support woodlands of broad-leaved deciduous tree species.
- In the coastal area characterized by a humid tropical climate, the present composition and the physiognomy of the vegetation patterns reflect anthroprogenic changes to the original mixed forest-woodland-grassland physiognomy of many species and facies.

Tique (2000) characterized the vegetation in Chicualacuala District as being dry deciduous tree savannah dominated by *Androstachys johnsonii* and deciduous tree savannah at medium and low altitudes, which is a secondary formation of *Colophospermum mopane* and other low-altitude tree savannah, occasionally mixed with smaller trees such as *Sclerocarya caffra, Kirkia acuminata* and *Combretum* spp. There is also a strong relationship between soil types and vegetation patterns on the sandy plains. *Terminalia sericea* and *Rhigozum* sp. are the dominant species on the very deep yellowish-brown sands (Ferralic Arenosols), along with *Androstachys johnsonii* and some *Commiphora, Grewia* and *Combretum*. In soils with a high clay content, *Colophospermum mopane* is dominant.

South Africa

The South African National Land Cover Database Project (NLC) was completed in 1999 (Thompson, 1999; Fairbanks *et al.*, 2000), producing a

FIGURE 28
Transformed land cover types in the South African part of the Limpopo River Basin



standardized land cover database for all of South Africa, Swaziland and Lesotho (see Figure 28 for transformed land cover types in the South African part of the Limpopo River Basin). The project utilized Landsat TM satellite imagery captured in 1994–95. The product is designed for 1:250 000-scale mapping applications, intended to provide national baseline information on land cover. Georeferenced land use types at a national scale are inferred from the land cover map, to be read in conjunction with information from Statistics South Africa and the Department of Agriculture. Data sources are available, at best, at magisterial district level.

The classification scheme is based on clear and unambiguous terminology and class definitions, designed to ensure data standardization and to conform to internationally accepted standards and conventions, such as in use for the Vegetation Resource Information System (VEGRIS) of Zimbabwe, and the FAO AFRICOVER project.

One advantage of the NLC classification is that it shows simultaneously the major land cover, based primarily on broad structural vegetation, but also incorporating land use components. There are three levels of classification and the second level includes useful subclasses based on degradation and different crops.

On the South African side, the Limpopo River Basin falls largely within the savannah biome (commonly known as bushveldt), which is the largest biome in southern Africa, occupying 46 percent of the southern African area. The vegetation is well summarized in Low and Rebelo (1996), from which extracts have been included below.

A grassy ground layer and a distinct upper layer of woody plants characterize the vegetation. A major factor delimiting the biome is the lack of sufficient rainfall, which prevents the upper layer from dominating, coupled with fires and grazing, which keep the grass layer dominant. Several variations in vegetation occur within the basin.

The mopane bushveldt dominates the undulating landscapes from Kruger National Park to Soutpansberg in Limpopo Province. The vegetation is characterized by a fairly dense growth of mopane (*Colophospermum mopane*) and a mixture of other tree species. The shrub and grass layers are moderately well developed.

The Soutpansberg arid mountain bushveldt is restricted to the dry, hot, rocky, northern slopes and summits of the Soutpansberg Mountains (Low and Rebelo, 1996). There is a distinct tree layer, which is characterized by *Kirkia acuminata*, *Englerophytum magalismontanum* and other tree species. The shrub layer is moderately developed and the grass layer is poorly to moderately developed. The Waterberg moist mountain bushveldt, although related to the Soutpansberg arid mountain bushveldt, occurs on the sandstone and quartzite soils on the rugged and rocky Waterberg Mountains. The tree layer is well developed with a moderately developed shrub layer and a moderately- to well-developed grass layer.

The clay thorn bushveldt is distributed widely on the flat plains that have black or red vertic soils southeast of Potgietersrus and Nylstroom in Limpopo Province and similar habitats in North West Province. Vegetation is dominated by *Acacia* species and turf grasses (*Ischaemum afrum*).

Sweet bushveldt occurs on deep greyish sand overlying granite, quartzite or sandstone in the dry and hot Limpopo River Valley and the associated valleys of tributary rivers in northwest Limpopo Province. The vegetation structure is mostly short and shrubby. Trees such as *Terminalia sericea, Rhigozum obovatum* and *Acacia tortilis* dominate sandy areas. Grasses dominate the herbaceous layer. The mixed bushveldt vegetation type found on undulating to flat plains varies from a dense, short bushveldt to a rather open tree savannah covering most of Limpopo Province and northern North West Province. On shallow soils, *Combretum apiculatum* dominates the vegetation. Grazing is generally sweet and the herbaceous layer is dominated by grasses such as *Digitaria eriantha* on shallow soils and *Terminalia sericea* on deeper soils.

The mixed lowveldt bushveldt is found on the sandy soils of the undulating landscapes of Limpopo Province and Mpumalanga Province on the eastern boundary of the country. Vegetation is usually dense bush on the uplands, open tree savannah in the bottomlands, and dense riverine woodland on riverbanks. This bushveldt is confined to frost-free areas. In general, vegetation has been damaged severely in vast areas and has in some cases been destroyed almost completely by overgrazing and injudicious utilization.

Zimbabwe

In Zimbabwe, the VEGRIS supports a land use database for the whole country, derived from SPOT imagery of 1992 and ground truthing. This database also contains topographic information, but no detailed species data are captured. Recently, the Zimbabwe land reform programme has stimulated the digitization of commercial farm boundaries at a scale of 1:250 000 in order to produce a national land inventory.

Land cover information is available from the woody cover map of Zimbabwe (GOZ–FC, 1998), which distinguishes the following main categories of vegetation structure:

- cultivation (27.5 percent);
- woodland (53.2 percent);
- bushland (12.7 percent);
- wooded grassland/grassland (4.8 percent);
- plantation forestry (0.4 percent).

The remaining 1.4 percent consists of water bodies, settlements, rock outcrops and natural moist forests.

Two woodland types predominate in the Limpopo River Basin: mopane woodlands and *Acacia–Combretum–Terminalia* woodlands. Mopane woodlands are quite widespread in Zimbabwe and are associated with low-altitude, hot areas with sodic or alluvial soils. *Colophospermum mopane* is the dominant species and constitutes 18.5 percent of the 101 500 ha under mopane woodland. It is used for craftwork, fuelwood, poles, railway sleepers and parquet floors.

Acacia–Combretum–Terminalia woodland type is found in the vleis in the drier parts of the country. Acacias tend to form the dominant component of these woodlands. In terms of population pressures, these woodlands are second to the miombo woodlands. Acacias provide nutritious fodder, improve soil fertility and rehabilitate degraded sites and fix sand dunes. On the other hand, *Terminalia* tends to dominate burnt sites and is important for fuelwood, poles, tools and wagon draught shafts.

The southeast middleveldt is an area of transition with low mopane woodland in the drier areas (less than 500 mm mean annual rainfall) and *Terminalia sericea* open woodland in the slightly wetter areas. *Julbernardia globiflora* is found locally on high ground, and *Brachystegia glaucescens* on outcrops of granite and gneiss. An association of *Colophospermum–Combretum–Acacia* is common in lower slope positions. *Acacia* spp. are dominant on the few areas of red clay soils derived from schist.

Colophospermum mopane is the dominant species in the southeast lowveldt, where it forms an open tree savannah. *Commiphora* tree savannah is the typical vegetation type on shallow soils over basalt, which includes *Combretum apiculatum, Boscia albitrunca, Adansonia digitata* and *Colophospermum mopane.* Mopane shrub savannah dominates moderately deep vertic soils on basalt. The Karoo sandstone areas near the border with Mozambique are characterized by *Guibourtia conjugata* tree savannah and *Guibourtia conjugata/Baphia massaiensis* woodland thicket, with *Androstachys johnsonii* thicket occurring locally.

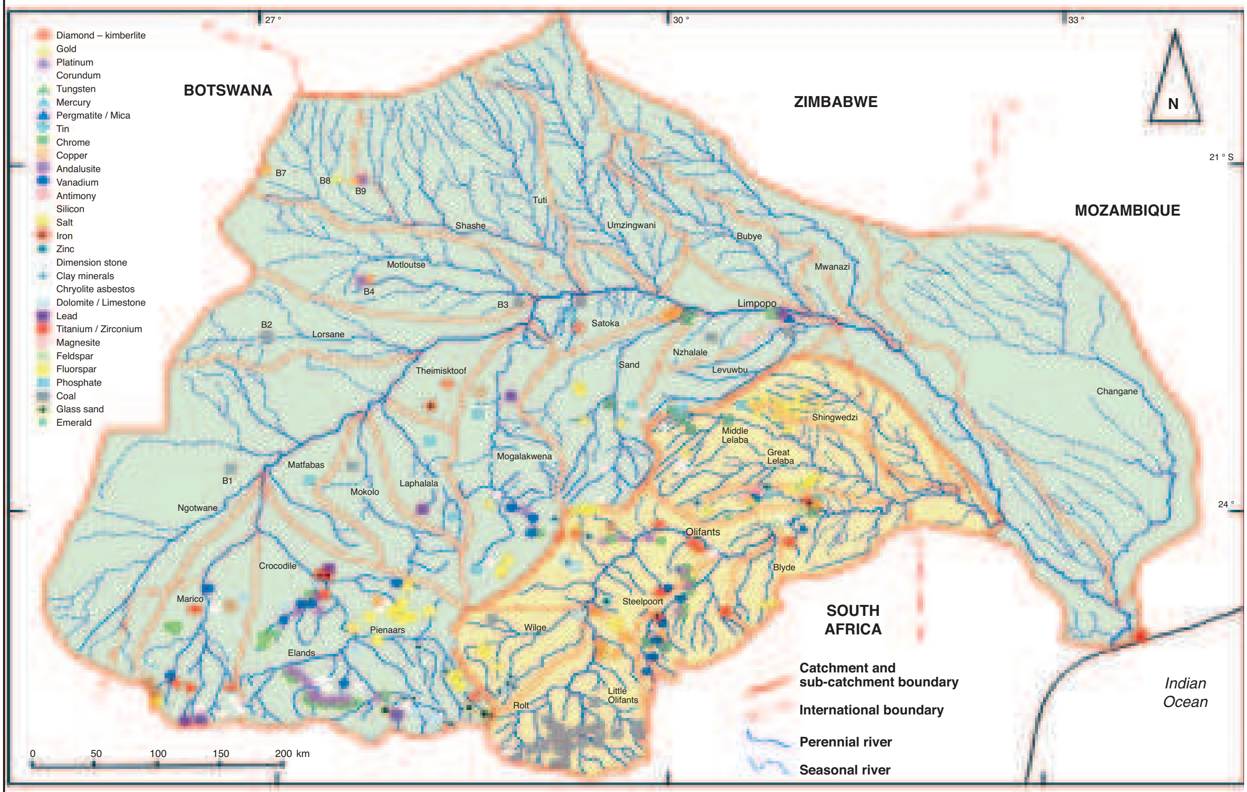
OTHER RESOURCES

Economic geology and minerals

Southern Africa is very rich in mineral and mining products, including (in order of importance): gold, diamonds, coal, platinum, iron, copper, limestone, nickel and chromium (Figure 29). In addition, quarried stone is processed for road and other construction, and sand and gravel are extracted from riverbeds and other sources. The richest concentration of minerals, in particular extensive gold fields, in South Africa is found along the Witwatersrand around Johannesburg in Gauteng Province, which is at the southern divide of the Limpopo River Basin. Botswana is especially rich in diamonds, and also has coal, copper and nickel. The main mineral reserves of Zimbabwe in the Limpopo River Basin include gold (southeast of Bulawayo), coal, asbestos, limestone, iron and emeralds. These resources are of great economic importance to local and national economies, especially in Botswana and South Africa.

The mining of minerals has significant ecological consequences. Until recently, there was a general lack of rehabilitation and ecological protective measures at mining sites. Although substantial environmental improvements have been made

FIGURE 29
Location and type of all mining operations located in the Limpopo and Elephants River Basins



Source: MMSD Southern Africa Working Group (2001).

in the last few years, many land and water areas remain heavily polluted. Some of the most common environmental effects of mining are:

- destruction of landscapes and ecosystems by open-cast mining;
- waste accumulation and groundwater contamination by leachates;
- lowering of the groundwater level;
- toxic concentrations of elements such as copper, nickel, zinc, chromium and boron;
- environmental health threats through unsafe mining operations, or specific minerals (e.g. asbestos).

Fish resources

The Limpopo River has few fish species compared with other rivers in Africa. This is primarily because of the harsh environment with its wide variations in temperature, prolonged dry periods, and highly variable river levels. There are greater fish populations in the more permanent tributaries and in the many dams built within the catchment, especially in South Africa.

The lower zone of the Limpopo River system is important to Mozambique as its flows contribute to the productivity of the coastal brackish water area, where fish and shrimp production is significant. The fisheries of the Limpopo River make very little contribution to the economy and nutrition of the people of Botswana and Zimbabwe at present. Some *Tilapia* species have been introduced in Zimbabwe from the Zambezi River system.

There are at least 30 fish species inhabiting the Limpopo River (Box 12). Fish species, such as cyprinids (*Schilbe* spp.), catfish (*Clarias* spp.), substrate-brooding tilapias (*Tilapia* spp.), mouth-brooding tilapias (*Oreochromis* spp.), the introduced trout (*Salmo trutta*) and several brackish-water species in the lower reaches of the river in Mozambique, can be a source of food and income for the people living near the rivers and dams. These same species are suitable for aquaculture wherever soil conditions permit and where water is available for a substantial part of the year. The same indigenous and introduced species can be stocked in dams and reservoirs in order to enhance fish production. However, the abundance

BOX 12

Fish species of the Limpopo River

- *Ambassis* spp., possibly three species in lower reaches;
- *Amphlius natalensis*, in coastal areas;
- *Amphlius uranoscopus,* in the lower reaches of the river;
- *Aplocheilichthys johnstoni; A. katangae;* a variety of exotic poeciliids;
- *Austroglanis sclateri,* translocated through the Orange–Vaal water transfer schemes;
- *Chetia flaviventris*;
- *Chiloglanis pretoriae, C. paratus, C. swierstrai*;
- *Clarias gariepinus*, *C. ngamensis*, *C. theodorae*;
- *Gambusia,* an exotic species;
- *Glossogobius callidus, G. giurus* in the lower reaches;
- *Lepomis macrochirus,* an exotic species;
- *Micropterus* spp., an introduced bass;
- *Mugilidae* spp. (mullet), numerous species in coastal areas;
- *Nothobranchius orthonotus*, *N. rachovii, N. furzeri* in coastal areas;
- *Oncorhynchus mykiss*, introduced exotic;
- *Oreochromis macrochir*, translocated into parts of Zimbabwe from the Zambezi River system;
- *Oreochromis mossambicus*;
- *Oreochromis niloticus,* an exotic species with a barred tail;
- *Oreochromis placidus,* probably in lower river area;
- *Perca fluviatilis,* an exotic species;
- *Psedocrenilabrus philander,* a small cichlid;
- *Salmo trutta*, brown trout;
- *Schilbe intermedius*;
- *Serranochromis meridianus,* possible in lower reaches of the river;
- *Serranochromis thumbergi,* introduced in parts of Zimbabwe from the Zambezi River system;
- *Synodontis zambezensis*; an introduced exotic species;
- *Tilapia sparrmanii, T. rendalli,* substrate-spawning tilapias.

Source: Bell-Cross and Minshull (1988); Lévêque, Bruton and Ssentongo (1988).

and catch magnitudes have yet to be determined although some estimates have been made of fish populations in some dams. Possibilities exist for fish farming in all four countries, and increasing fish production and supply should be studied and ascertained. The major problem of managing fish in available dams will always be one of re-stocking when water is plentiful after a long period of drought.

LAND DEGRADATION AND DESERTIFICATION

Land degradation and desertification are related terms or processes. The accepted UNCED definition is that desertification is land degradation in arid, semi-arid and dry subhumid areas resulting from climatic variation and human activities.

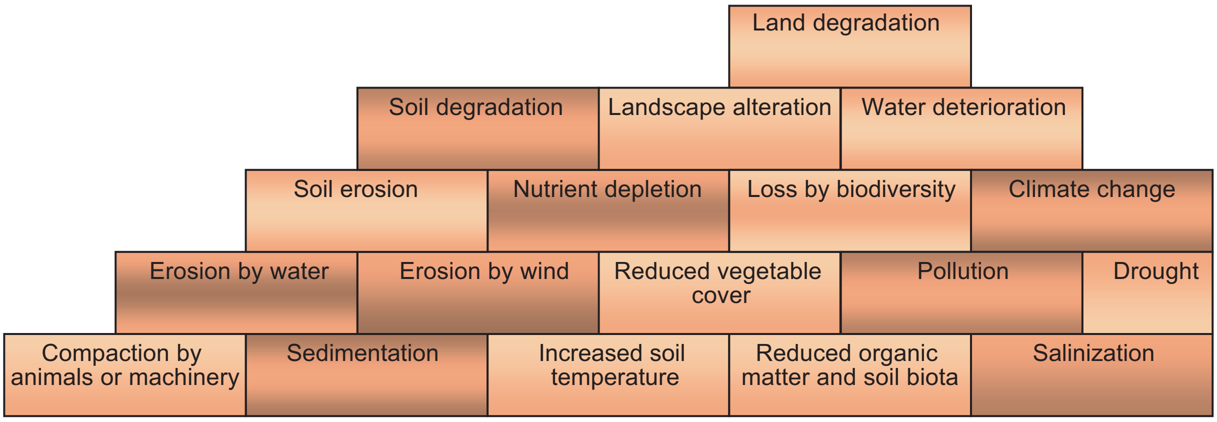
Land degradation threatens economic and physical survival (UNEP, 1999), and could lead to household and national food insecurity in many countries, including the southern African region. Crop yields could be reduced by 50 percent within 40 years if degradation continued at present rates. In South Africa, it is estimated that about 400 million m^3 of soil is lost annually. Key issues to be addressed throughout the region include declining soil fertility, escalating soil erosion, agrochemical pollution and desertification.

Main types of erosion and land degradation

Land degradation is a composite term, loosely defined as a sustained loss in the quality and the productive capacity of the land. As land degradation progresses, efforts by land users to secure a living become increasingly precarious and uneconomic. The most common indication of land degradation is soil erosion. Subtler but equally important factors include reduction in vegetation cover and changes in vegetation species composition. Stocking and Murnaghan (2000) provide sound practical guidelines on land degradation and its assessment in the field, viewing degradation from the perspective of the land user. Figure 30 illustrates how components of land degradation interlink with many other components that influence the quality and productivity of land, including how it is used or misused.

Identification of the direct and indirect causes of land degradation is essential, as any remedial measures designed to rehabilitate land must tackle the root causes of the problem in order for the reversal of land degradation processes to be successful.

FIGURE 30
The land degradation wall



Source: Stocking and Murnaghan (2000).

A clear distinction between causes, mechanisms and impacts of land degradation is often lacking in degradation studies (Mainguet, 1991), and it is difficult to distinguish between human and natural influences as both may occur simultaneously. Drought is often quoted as a direct cause of degradation, but it is also seen as the catalyst for other processes that lead to degradation.

Physical factors

Physical factors always play a role in degradation processes, but their role is less crucial than assumed in erosion hazard mapping. Nevertheless, the topography (slope in particular), the properties of the soil and underlying rock, the vegetation, and climate characteristics (rainfall in particular) are important factors in the acceleration of human-induced erosion.

Increased runoff and accelerated erosion relate strongly to poor surface conditions, including surface crusts, lack of vegetation, and compaction (decreased infiltration). In addition, the properties of soil horizons and other underlying materials play a major role, especially with respect to gully erosion. Porous materials such as weathered rock (saprolite) and soils with high hydrologic conductivity are conducive to gully erosion as relatively large and rapid subsurface flows may occur, causing collapse of the gully head or sides. Soils with weak structure and friable consistency are vulnerable to erosion, e.g. soils high in illitic or mixed-layer clays. The same applies to soils with high sodicity, inducing a high clay dispersion rate (Solonetz and Planosols).

Climate variability has a profound accelerating effect on erosion and land degradation. Extreme rainfall events aggravate the condition of already degraded land through increased runoff and flooding. Lack of rainfall and resulting drought accelerate desertification processes. Drought acts as a strong catalyst in the initial and progressive degradation of land.

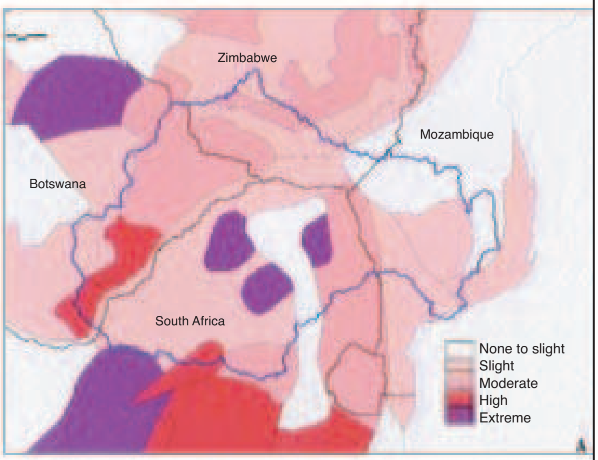
The cause of accelerated erosion is mostly a complex of several factors, as the two main spheres of influence – physical and human – are interrelated and interactive. There is always an element of human influence involved, related to the management of the resources, which may be aggravated by the conditions and characteristics of the environment (climate, soils, geology and landscape). Stable landscapes resistant to erosion normally show less erosion compared with vulnerable environments. Similarly, areas with reliable rainfall in general show less degradation than areas with frequent drought.

Most surveys and studies of land degradation conclude that the primary causes are related to land use, management and socio-economic attitudes. Increase in population is cited as the single most important cause of degradation. However, with land becoming scarce, communities may become more aware of the necessity to improve land management and conservation.

Assessment of erosion and land degradation in the Limpopo River Basin

The Global Assessment of Soil Degradation (GLASOD) by the UNEP is considered the first global assessment of the geographical distribution

FIGURE 31
Erosion severity in the Limpopo River Basin



of human-induced soil degradation (Oldeman, Hakkeling and Sombroek, 1990). Soil degradation is described in terms of: type of erosion and deterioration; cause; degree; rate; and relative extent. The overall status or severity of soil degradation is indicated by a combination of its degree and extent, represented on maps by five classes of severity: none, slight, moderate, high and extreme.

The main result of the GLASOD project is a map of the world (scale: 1:5 million) showing the occurrence of human-induced actual soil and land degradation. The occurrence of the several general areas of degradation in the Limpopo River Basin can be distinguished on the map as follows (Figure 31):

- No degradation, or stable terrain, along the lower northeast part of the Limpopo River Basin in Zimbabwe and Mozambique and in a north–south zone roughly following the Escarpment and associated mountains.
- Slight degradation along the upper Limpopo River Valley, in most of the adjacent southwest catchment in South Africa, and in southeast Zimbabwe. Most of these areas coincide with private farms. Most of the remainder of Mozambique also falls into this class.
- Moderate degradation in northeast Botswana and adjacent Zimbabwe, a north–south zone covering northeast South Africa (including Kruger National Park) and the southern tip of the catchment.
- High degradation in the southwest upper catchment in Botswana and in an area southwest from Pretoria.
- Extreme degradation in three areas in Limpopo Province in South Africa, corresponding with densely populated communal areas (former homelands of Venda and Lebowa).

Apart from the generalized pattern showing several unnaturally shaped units, the validity of the information may be questioned in a number of areas. The strong contrast between the southern part of the Limpopo River Basin and the adjacent Vaal River Basin does not seem realistic. The differences within Botswana do not appear to reflect original information or present status adequately. A substantial part of the South African lowveldt strip has no apparent erosion, notably the area covering Kruger National Park. This same unit should not include Swaziland, where some of the most degraded areas in southern Africa occur.

Hakkeling (1989) described the GLASOD results in more detail for the southern and eastern African regions covering Botswana, Mozambique and Zimbabwe, but not South Africa. This regional map shows a pattern of erosion and degradation in places quite different from that on the integrated global map. In general, the regional map provides a more accurate overview and the country descriptions below draw heavily on this information.

Botswana

The information from the GLASOD regional map (Hakkeling, 1989) indicates that almost all units fall into the overall class of high degradation, except for one area with slight degradation, because of dominant sandy soils. The units most affected by water erosion – both sheet and gully erosion – are found in the northern and southern parts of the Limpopo River Basin, caused mainly by overexploitation of vegetation and intensive cropping. Wind erosion is the dominant type of degradation in the middle units, caused primarily by overgrazing. Up to 50 percent of all units are considered to have recovered by natural stabilization from earlier degradation.

Reports from the first half of the twentieth century already expressed concern about the state of the land resources. Studies from the second half of the twentieth century indicated that the problem was severe, and that numerous examples of extreme overgrazing could be found. However, it is also claimed that such conclusions are based on flawed data, that the perception of range condition and management is biased in favour of western models, and that most of the examples of degradation are temporary conditions that are natural to a variable savannah ecosystem.

Evidence is based mainly on examples of: bush encroachment; decrease in general grass density and in numbers of the more nutritious and palatable species; and of an increase in patches of bare soil. The consensus is that rangeland degradation is occurring, but there is disagreement as to its extent, severity and reversibility. Abel and Blaikie (1989) argue that degradation should not be measured by using indicators such as short-term vegetation changes. Instead, changes in the environment should be judged according to their degree of irreversibility over longer periods. The assessment of detrimental changes must also take into account estimates of secondary production interest of the users, for which reason the productivity of communal grazing land may be higher than that of commercial ranches (De Ridder and Wagenaar, 1984).

The description of erosion and land degradation within the Limpopo River Basin (hardveldt) of Botswana is confined mostly to local observations, and although overviews have been produced (Arntzen and Veenendaal, 1986; Dahlberg, 1994), a comprehensive inventory is lacking. Ringrose and Matheson (1986) reported an increase in desertification manifested as decreased vegetation, increased erosion and reduction of soil water retention as a result of loss of soil organic matter induced by overgrazing and fuelwood collection. In this regard, the BRIMP also generates various degradation maps and datasets, based on ground monitoring and the interpretation of Landsat images specifically aimed at addressing desertification questions.

Occurrence of severe sheet and gully erosion is reported from several sites in east Botswana near Serowe and Kalamare, but erosion is generally estimated to be slight or moderate. Most of the erosion is associated with sloping land, including the footslopes of hills. The flat and slightly undulating parts of the plains show less evidence. Wind erosion is reported from areas with a bare surface, especially from fallow arable land, but the severity is difficult to estimate. This effect is most pronounced after periods of drought and reduction of the protective vegetation cover.

Mozambique

The information from the GLASOD regional map indicates that the northernmost units of the Limpopo River Basin have no livestock because of tsetse fly, hence, no erosion is described. Most other units have the overall class of slight degradation, except for two units with moderate degradation. High degradation is reported in the Changane Valley owing to crusting and sealing. Most of the degradation is caused by wind erosion – with some nutrient losses – but a variety of causes have been observed: overgrazing in the Lebombo Hills, intensive cropping along the coast, and salinization in the irrigated areas near Xai-Xai in the Limpopo River floodplain. Moreover, natural stabilization seems a common process in Mozambique.

Assessment of erosion risk in Mozambique was first undertaken on a national scale by FAO (1985) when Reddy and Mussage compiled a first approximation of an erosive capacity index. The low rainfall areas of Gaza Province were classified as a low erosion-hazard zone. High erosion-risk zones included the coastal areas of Gaza Province. Population density in the coastal belt has raised concern about dune vegetation, mangroves and coral reefs. While none of these ecotypes could yet be considered critically threatened in Mozambique, local areas of degradation have been identified and the government is anxious to take remedial action before the problems become more severe.

The various studies and surveys reviewed indicate that major problems in the development of the Limpopo Valley soils are related to salinity and alkalinity. These problems arise from the geological structure, which has very saline marine sediments under the recent alluvial sediments (primary salinization). Furthermore, mismanagement of the irrigation water supplies and of the drainage systems has raised groundwater tables and led to the efflorescence of salts at the ground surface (secondary salinization).

South Africa

The GLASOD map of Africa (Oldeman, Hakkeling and Sombroek, 1990) generally indicates less soil degradation in the Limpopo River Basin as compared with the rest of South Africa. Most of Limpopo Province shows none to slight degradation, with moderate degradation in the eastern parts, all caused by water erosion, and primarily caused by overgrazing. Moderate to high degradation resulting from pollution and acidification occurs in the south of the catchment (Pretoria–Johannesburg–Witbank area). The most severe soil degradation caused by overgrazing occurs in the former homeland areas in the central Limpopo Province.

Hoffman and Todd (1999) have provided an overview of erosion and land degradation in South Africa, in a first-phase review for the development of South Africa's national action programme to combat desertification. A number of general conclusions from this report were presented, which are also relevant to the Limpopo River Basin. The focus of land degradation has historically been on the degradation of vegetation, in particular of the rangelands. The study suggests that equal attention should be paid to degradation of vegetation, soil and water resources.

Earlier inventories of soil and land degradation have concentrated on erosion hazard with relatively little attention given to the influence of land use practices. The present view is that both land use and land tenure exercises have a significant influence on land degradation.

Hoffman and Todd (1999) state that soil and vegetation degradation is perceived as being significantly greater in communal areas as compared with commercial areas, by at least a factor of two. However, specific forms of vegetation degradation are more of a problem in commercial areas, such as change in species composition, alien plant invasion, and encroachment of indigenous woody species. It is suggested that areas with steep slopes, low rainfall and higher temperatures are significantly more eroded. Climate change in the last century may have had an impact on the intensity of erosion, but this needs to be further studied, in particular in order to define the relationship between drought and erosion.

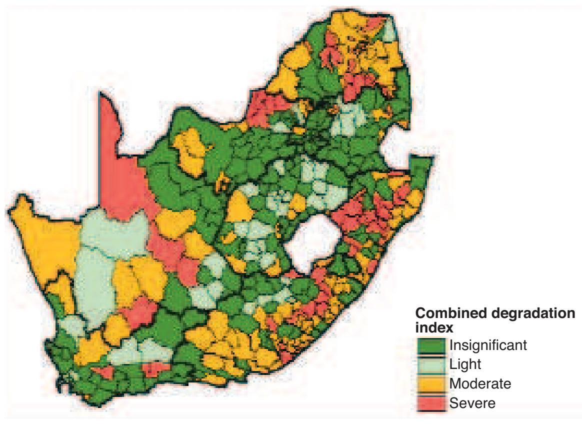
The government policy of land allocation has had a major effect on land use and land degradation. In the commercial farming areas, this has been partially conducive to sustainable land use, but not so in the communal areas, where practices of crop production, communal grazing and use of the vegetation have led to accelerated erosion and degradation. The understanding in South Africa of communal land use and production systems is poorly developed, as is its relationship with land degradation (Hoffman and Todd, 1999).

In an overview on soil degradation in South Africa, a report by FAO (1998a) states that data on degradation are incomplete and fragmented, with little information on spatial distribution and distinction between natural and human-induced erosion. Relevant land degradation information is available from a number of other sources (Newby and Wessels, 1997; Van Zyl, 1997; Scotney, 1995; Laker, 1994).

Nationally, it is estimated that water erosion affects 6.1 million ha, or more than 40 percent of the total of 14.6 million ha of cultivated soil in South Africa. Of this, 15 percent is seriously affected, 37 percent moderately affected and the remaining 48 percent slightly affected. Laker (1994) estimates that about 20 percent of all topsoil has been lost since the beginning of the twentieth century. Average annual soil loss is estimated at 2.5 tonnes/ha, equal to about 300 million tons. Wind erosion affects even more cultivated land, an estimated 10.9 million ha, or more than 70 percent. Of the affected cultivated land, 7 percent is seriously eroded, 29 percent moderately and 64 percent slightly. Compaction affects about 2 million ha, or about 15 percent of all cultivated land. Surface sealing is also a widespread and a serious problem. It is estimated that a total of 15 percent or more of the 1.2 million ha of irrigated land is moderately to severely affected by salinization and/or waterlogging. In addition, large areas are affected by pollution, acidification and fertility losses. Of the national grazing land about 3 million ha are rendered worthless for grazing as a result of encroachment by undesirable species.

Figure 32 shows the occurrence of soil and vegetation degradation combined in a single index per magisterial district. The provinces within the Limpopo River Basin are described as belonging to

FIGURE 32
Land degradation in South Africa



Source: Hoffman and Todd (1999).

BOX 13

Status of soil health in Mpumalanga Province

In a study on land quality indicators, Mpumalanga Province was stratified according to vegetation biome, maize, other crops and minesoils. Within each stratification, data were collected for the indicators set out in the table below (median topsoil values are shown):

Indicator	Grassland	Savannah	Maize	Other crops	Mine cover soil
Organic C (%)	2.51	1.28	1.16	1.19	0.53
Total N (%)	0.13	0.11	0.08	0.09	-
C/N ratio	20	13	16	15	-
pH_{water}	5.65	6.47	5.89	6.00	6.10
EC (mS/m)	33	30	40	41	36
SAR	-	-	0.20	0.39	-
P (mg/kg)	-	-	17.7	19.7	-

Median values did not reflect any serious soil ill health, the climate context being taken into account. However, lower quartile pH values tended to fall below 5.5, the threshold for acid saturation problems. Atmospheric deposition of acidifying agents from coal-fired power stations might have played a role in low topsoil pH values under grassland.

Source: Nell *et al.* (2000).

the most eroded and degraded parts of the country (which contradicts the GLASOD result). However, these estimates are based on perceptions from agricultural extension and resource conservation officers, and not on actual observations.

According to Newby and Wessels (1997), the estimated extent of degradation of vegetative cover is 25 percent for North West Province (poor to very poor condition), 87 percent for Limpopo Province (poor to critical condition) and 50 percent for Mpumalanga Province (poor to critical condition). Serious wind and water erosion is reported from North West Province, respectively 53 and 36 percent of all area affected. The mining industry – predominantly coal mining – has occupied and severely polluted 50 percent of all high potential arable land in Mpumalanga. However, this statement is contrary to the experience and results of other researchers (e.g. Box 13).

Wessels *et al.* (2001) mapped the conservation status of natural vegetation and soils in Mpumalanga Province, including the present land cover, rangeland condition, alien vegetation and bush encroachment. Table 14 summarizes some of their main findings. One-third or more of both the grassland and savannah biomes in the province is stated to be in poor to very poor condition. Visible soil erosion damage is stated to occur over less than one-third of the province.

TABLE 14

Soil and vegetation degradation in Mpumalanga

Attribute	Class	Percentage of biome in Mpumalanga
Grasslands		
Condition	Good to very good	53–75
Condition	Poor to very poor	35–42
Soil erosion	Light to considerable	14–28
Soil erosion damage	None visible	71–84
Savannah		
Condition	Poor to very poor	35–42
Bush encroachment	Severe	5
Bush encroachment	Extreme	4
Soil erosion damage	None visible	70–76

Source: Wessels *et al.* (2001).

Zimbabwe

Information from the GLASOD regional map indicates overall strong degradation in the communal areas in the northern and western part of the Limpopo River Basin adjacent to Botswana, with severe sheet and gully erosion caused by deforestation and intensive cropping. No erosion is described for the areas with commercial ranching as the dominant land use, and for national parks. The communal grazing area in the east has moderate soil degradation. As in Botswana, most units are considered to have stabilized in a natural way from earlier degradation.

The history of land degradation in Zimbabwe and the different views about it are quite similar to Botswana. Official interventions based on reports citing the occurrence of severe soil erosion have largely failed (Scoones, 1989a). The increase in crop and animal production in the 1980s is considered sufficient evidence that there is no substantial decline in the natural resource base (Scoones, 1992a). However, this may be a preliminary conclusion as the 1990s have shown a general decline.

Campbell *et al.* (1990) claim that there is sufficient evidence to indicate that cattle are linked to major environmental changes, but they also conclude that the issue of whether communal grazing practices cause degradation cannot be answered without additional data, in particular a spatial analysis.

Scoones (1989b, 1992b, 1993) finds that disregard of the heterogeneity of the environment is one of the main reasons for conflicting perceptions of environmental change. Areas will differ on the extent of degradation and the effects of the changes on secondary production. Scoones found that in most years the farmers are avoiding irreversible damage, in terms of productivity, by using strategies of herd mobility and local ecological knowledge. In drought years, migration between different savannah types is employed on a regional scale. Certain elements of the landscape or ecosystem, such as riverine strips, vleis (wet bottomlands) and drainage lines, are vital in providing fodder in critical periods.

The extent of soil erosion in Zimbabwe was mapped nationally using air photography (Whitlow, 1988). Only 5 percent of the country was badly eroded, in comparison with communal areas where badly eroded land comprised about 10 percent of the land area. Little difference was observed between cropland and grazing land. This is somewhat surprising as most arable land in Zimbabwe seems adequately protected by contour ridges. In other countries in southern Africa, erosion is always reported to be excessively higher on communal grazing land, e.g. in Swaziland (Remmelzwaal and McDermott, 1997).

Elwell (1980) calculated annual soil losses on cropland caused by sheet erosion followed by national surveys. Grohs (1994) re-interpreted Elwell's results according to administrative areas. The highest soil losses of more than 100 tonnes/ha were recorded in the north and east of the country. The lowest values of less than 5 tonnes/ha were found in the semi-arid south, within the Limpopo River Basin. On the basis of these findings, an average annual soil loss of about 55 million tonnes was calculated.

Chapter 3
Social, economic and policy environment

Improving the livelihoods of the people in the Limpopo River Basin in a sustainable manner is one of the objectives of the integrated approach to catchment basin management. Understanding the human dimension is critical to designing projects and programmes that will secure livelihoods based on stable, productive and profitable use of natural resources, particularly land use. This chapter describes the social, economic, policy and institutional dimensions that affect the capacity of the people living in the Limpopo River Basin to live with recurrent drought and climate variability.

SOCIAL AND ECONOMIC CHARACTERISTICS

Population characteristics

Chapter 2 described the biophysical diversity and challenges facing integrated management in the Limpopo River Basin. These challenges are reflected in the diversity of rural versus urban populations of the basin. In Botswana and South Africa, the capital cities are situated in, and some of the largest urban populations reside within, the basin boundaries, such as Gaborone, Francistown, Pretoria, Polokwane, Thohoyandu and Witbank. Not reflected in the basin population figures (Table 15) are other large urban centres (Johannesburg, Maputo and Bulawayo) that lie on the fringes of the basin and influence, or are influenced by, events and activities within the basin.

Aside from these urban centres, which for the most part are located at the headwaters (or near the mouth in the case of Maputo), the Limpopo River Basin is predominantly rural. On average, at the national level, the population in the Limpopo River Basin countries is just more than 50 percent rural – ranging from 31 percent in Botswana to 66 percent in Zimbabwe. However, at the subnational and district level within the basin, the population is predominantly rural – more than 60 percent. About 8 million people live in rural areas within the Limpopo River Basin (Table 16).

Botswana

According to the 1991 census, nearly 46 percent of Botswana's population was urban-based, an increase of 18 percent over the 1981 estimates (GOB, 1992b). While much of this growth is a consequence of the continued expansion of the larger urban areas such as Gaborone and Francistown, most of the increase is attributed to a reclassification of some larger villages from rural to urban.

Eighty-three percent of Botswana's people live in the eastern hardveldt region with its characteristics of better surface water and groundwater availability, good communications, proximity to South Africa, access to markets, and better-quality soils compared with the rest of the country. The Limpopo River Basin covers most of the hardveldt and falls within the rural administrative districts of North East, Central, Kgatleng and Kweneng. This catchment area accounts for 59 percent of the country's population and 28 percent of its area. The average national population density is only 2.3 persons/km^2, although the highest population density is in the districts of Kweneng (21 persons/km^2) and Kgatleng (15 persons/km^2) because of

TABLE 15
Selected statistics of the four basin countries

Country	Total area (km^2)	Area of country within basin (km^2)	As % of total basin area (%)	As % of total country area (%)	Population of country in 1998 (million)	Population in basin (million)	As % of country population (%)	Population density in basin (persons/km^2)
Botswana	581 730	80 118	19	14	1.6	1.0	59	12.5
Mozambique	801 590	84 981	21	11	16.5	1.3	7	15.3
South Africa	1 221 040	185 298	45	15	42.1	10.7	24	57.7
Zimbabwe	390 760	62 541	15	16	11.4	1.0	9	16.0
Total		412 938			71.6	14.0		33.9

TABLE 16
Estimates of rural population in the Limpopo River Basin

Country/Province	2001 rural population estimates for basin provinces	
Botswana		835 000
Central	540 000	
Kwaneng	190 000	
Kgatleng	60 000	
North East	45 000	
Mozambique		1 045 000
Gaza	1 000 000	
Inhambane	45 000	
South Africa		5 400 000
Gauteng	100 000	
Limpopo	4 300 000	
Mpumalanga	500 000	
North West	500 000	
Zimbabwe		900 000
Matabeleland South	550 000	
Masvingo	250 000	
Midlands	100 000	
Total		8 180 000

Note: Estimates based on provincial and not basin-specific figures.

the location effects of greater Gaborone (GOB, 1992b).

Although the population of Botswana is small, it has had one of the highest growth rates in Africa (3.5 percent). This high growth rate has created an age structure with a very high ratio of children (unproductive) to adults (productive). Nearly 43 percent of the country's population was below the age of 15 years in 1991. The young age structure of the population will probably persist for some time owing to high fertility levels and increasing infant and child survival rates. In the period 1992–2001, the growth rate was 2.67 percent (GOB, 2002).

Migration has played an important role in the dynamics of the country's population through either permanent urban migration or through seasonally changing settlement patterns. However, the effect of the latter is less than it was during the 1970s and 1980s as a result of more settlements being provided with piped water and other social services. In 1981, some 50 percent of the population were enumerated within 200 km of Gaborone. By 1991, 50 percent of the country's population resided within 100 km of the capital.

Mozambique

The Limpopo River Basin in Mozambique falls almost entirely within Gaza Province. It also covers portions of three districts in Inhambane Province. The catchment area of the Limpopo River Basin represents 11 percent of the total national land area and includes just more than 7 percent of the total population. The density of the population within the Limpopo River Basin ranges from 1 person/km^2 in Chigubo District to more than 100 persons/km^2 in rural Xai-Xai District. The basinwide average in Mozambique of 15 persons/km^2 compares with a national population density of 21 persons/km^2. The population density in Gaza Province follows very closely the major agro-ecological zones and biophysical characteristics (Chapter 2). Market accessibility and infrastructure have also had a strong influence on where settlements have developed.

The percentage of the population living in urban and rural areas in Gaza Province depends in part on the definition of an urban area. According to GOM–INE (1999b), nearly 93 percent of Gaza Province was considered rural, with the city of Xai-Xai on the coast the only urban centre. The 1997 census (GOM–INE, 1999a) included more of the major towns in the definition of an urban area (e.g. Chibuto, Chokwé and Macia), giving a rural percentage of 75 percent. Either way, the area is predominantly rural and the population density decreases significantly with distance from the coast and the Chokwé area.

South Africa

Nearly 45 percent of the total population of South Africa lives in the four northern provinces (Limpopo, North West, Mpumalanga and Gauteng). Limpopo Province is almost completely contained within the Limpopo River Basin, as are parts of North West, Mpumalanga and Gauteng Provinces. Limpopo Province is by far the most dominant administrative zone in the basin – representing more than half of the rural population – for a total of more than 4 million people.

The average population density of South Africa is about 33 persons/km^2 (GOSA–StatsSA, 2001b). The distribution is very skewed, with the majority of the population living in the coastal provinces and around Johannesburg and Pretoria. The population density ranges from less than 2 persons/km^2 in Northern Cape, to 40 persons/km^2 in Limpopo Province and more than 430 persons/km^2 in Gauteng.

Population density is particularly high in the former homelands. This is largely attributed to past migration policies, which prevented the African population from migrating out of the homeland areas. Migration has also played a significant role in redistributing South Africa's population, especially since the formation of the new republic in 1994. Interprovincial migration data for 1992–96 indicate that Limpopo Province and Gauteng Province lost a large number of people through outmigration. However, Gauteng Province was also the most popular migration destination in the country (GOSA–NPU, 2000).

Zimbabwe

According to the population census of 1992, about 8 percent of Zimbabwe's population resided in the Limpopo River Basin, then estimated at 850 000 people, and currently estimated at just more than 1 million. The Limpopo catchment area in Zimbabwe falls predominantly in Matabeleland South Province, as well as portions of two districts in Masvingo Province (Mwenezi and Chiredzi) and one district in Midlands Province (Mberengwa).

The average population density in the semi-arid regions of the Limpopo River Basin is generally low, ranging from 6 persons/km^2 in Beitbridge District to 23 persons/km^2 in Umzingwane, adjacent to Bulawayo, compared with 30 persons/km^2 at the national level. However, the primarily rural district of Mberengwa has a population density of 37 persons/km^2, comparable with the more densely populated rural areas around Harare.

HIV/AIDS

Sub-Saharan Africa (SSA) is home to about 70 percent of the 36 million people currently living with HIV/AIDS worldwide. In this region, an estimated 3.8 million adults and children became infected with HIV in 2000, bringing the total number of people living there with HIV/AIDS to 25.3 million. In the same period, millions of Africans infected in earlier years began experiencing ill health, and 2.4 million people at a more advanced stage of infection died of HIV-related illness.

Although SSA heads the list as the region with the largest annual number of new infections, there may be a new trend on the horizon: regional HIV incidence appears to be stabilizing. Because the long-standing African epidemics have already reached large numbers of people whose behaviour exposes them to HIV, and because effective prevention measures in some countries have enabled people to reduce their risk of exposure, the annual number of new infections has stabilized or even fallen in many countries. These decreases have now begun to balance out rising infection rates in other parts of Africa, particularly the southern part of the continent.

Among the countries of the world hardest hit by HIV/AIDS are South Africa and Botswana (Table 17). In Botswana, almost 36 percent of all adults are infected with HIV/AIDS. Life expectancy has dropped from 61 years seven years ago to 39 years today, and the figure is projected to fall below 29 years by 2010. Without HIV/AIDS, it would have been more than 66 years. The epidemic began in South Africa much later than it did in other countries in Africa. By the mid-1990s, infection rates among pregnant woman were increasing rapidly. South Africa is now facing one of the most serious epidemics in the world (U.S. Census Bureau, 2001).

The provinces that are within or largely within the basin may not always be representative of the basin country at large. In Botswana, the highly populated areas of the basin districts (parts or all of the Kweneng, Southern, South-East, Kgatleng and Central Districts) are relatively highly affected. In Mozambique, Gaza Province (covering the basin area) appears not to be among the most highly affected. In South Africa, Limpopo Province is

TABLE 17
HIV prevalence in countries in the Limpopo River Basin

	Botswana	Mozambique[1]	South Africa	Zimbabwe
Population	1 597 000	19 105 000	39 900 000	11 343 000
Population aged 15–49 years	786 000	No data	20 982 000	No data
Percent of total population with HIV	18		11	
HIV infected people	290 000		4 200 000	
Adult prevalence rate of HIV (%)	36	13	20	25.1[2]
Adult female HIV population: % of total	51	No data	55	No data
Pregnant women HIV + prevalence (%)	43		19	
AIDS orphans (living)	55 000		338 000	

[1] 2001 figures (American Friends Service Committee, 2003).
[2] CIA World Factbook gives a figure of 33.7 percent (CIA, 2003); 24 percent quoted by SADC–FANR (2003)
Main source: U.S. Census Bureau (2001)

less affected than the provinces of Mpumalanga, Gauteng and North West (parts of which are within the basin). Urban and mining centres (with the exception of the Western Cape) appear to be most affected. In Zimbabwe, Matabeleland South is slightly less affected than Manicaland and Masvingo Provinces in the east (U.S. Census Bureau, 2001).

The effects of HIV/AIDS are far reaching. It has a severe effect on affected households, children and their schooling, the level of services rendered, and on business and economic growth. HIV/AIDS creates new pockets of poverty where parents and breadwinners die and children leave school earlier in order to support the remaining children. Affected households bear the brunt of the misery caused by the epidemic. Rising sickness and death often take place against a background of deteriorating public services, poor employment prospects and endemic poverty that are not directly related to the HIV epidemic, but that may be exacerbated by it (UNAIDS–WHO, 2000).

HIV is reducing the numbers of children in school. HIV-positive women have fewer babies, in part because they may die before the end of their childbearing years, and up to one-third of their children are themselves infected and may not survive to school age. Many children who have lost their parents to AIDS, or are living in households which have taken in AIDS orphans, may be forced to drop out of school in order to start earning money, or simply because school fees have become unaffordable. Teacher shortages may be looming (UNAIDS–WHO, 2000).

Some recent survey results show just how great the future impact of HIV is likely to be on business. A 1999 study among miners in southern Africa found that more than one-third of employees in their late 20s and 30s were infected with HIV, as were one-quarter of young and older employees. Rates among workers in other sectors are similarly high, at least in South Africa. For example, in a sugar mill, 26 percent of all workers were living with HIV. There, as in the mining industry, HIV rates were higher among unskilled workers than among managerial-level workers (UNAIDS–WHO, 2000).

It remains exceptionally difficult to gauge the macroeconomic impact of the epidemic. Despite incomplete data, there is growing evidence that as HIV prevalence rates rise, both total and growth in national income (GDP) fall significantly. In South Africa, where per capita income is six times the average for SSA and the national economy accounts for 40 percent of the total economic output of the region, the overall economic growth rate in the next decade is likely to be 0.3 to 0.4 percentage points lower every year than it would have been without AIDS. Cumulating the slower economic growth over time, by 2010, real GDP may well be 17 percent lower than it would have been in the absence of AIDS. In terms of current value, that would wipe US$22 000 million off South Africa's economy – more than twice the entire national production of any other country in the region except Nigeria (UNAIDS–WHO, 2000).

AIDS is likely to cause skills shortages in most sectors of the economy, creating major bottlenecks in business and production. This will be exacerbated by its undermining effect on education, and on the potential to expand skills as quickly as they are needed. HIV infection rates are highest among individuals in the workforce without special skills; so are the unemployment rates (about 30 percent in South Africa). Thus, in theory, individuals who are not currently employed may replace unskilled workers dying of AIDS. The skills shortage can be expected to be even more acute in neighbouring Botswana, which is already importing white-collar workers (UNAIDS–WHO, 2000).

There are indications that AIDS is starting to have negative affects on resource-poor agriculture. For example, with respect to Zimbabwe, the United Nations (UN) Relief and Recovery Unit noted "productivity has been severely affected in the agriculture sector as a direct result of the HIV/AIDS pandemic in the country" (UN–IRIN, 2003).

Human development and poverty

The rural population of about 8 million people living in the Limpopo River Basin face special challenges to make a living. The biophysical description in Chapter 2 showed that this area is predominantly semi-arid, with little arable land and very low potential for agriculture. Two related concepts that are useful for measuring "how people are doing" are human development and poverty. Human development can be thought of as the process of enlarging people's choices so that they can live longer and healthier lives (SADC–UNDP, 1998). This is usually measured in terms of educational and health opportunities, as well as some measure of wealth or standard of living (Box 14). Poverty is usually defined as living below a certain income or income-poverty threshold, but it has many dimensions (IFAD, 2001).

BOX 14

Human development and poverty indices

The Human Development Index (HDI) was introduced in 1990 as an attempt to measure and rank countries according to progress in human development beyond a simple gross national product figure. Instead of using only a financial measure, the HDI is a composite of three basic components of human development:

- longevity – as measured by life expectancy;
- knowledge – as measured by a combination of adult literacy (two-thirds weight) and mean years of schooling (one-third weight);
- standard of living – as measured by purchasing power, based on real GDP per capita adjusted for the local cost of living (purchasing power parity).

The index ranges from 0 to 1. Although useful at the global scale, indices at the national level can conceal much that is happening within the country. The best solution would be to create separate HDIs for the most significant groups, e.g. by gender or by income group. Separate HDIs would reveal a more detailed profile of human deprivation in each country and disaggregated HDIs have been conducted in some SADC countries.

Similarly, human poverty is usually defined as living below a certain income level or income poverty line. From a human development perspective, poverty means the denial of choices and opportunities most basic to human development, including deprivation in health and survival, lack of knowledge, denial of opportunities for a creative and productive life, social exclusion, lack of freedom, as well as deprivation in income. Therefore, the Human Poverty Index (HPI) was proposed in 1997 as a new way of measuring poverty in developing countries. The index measures the proportion of the population affected by three key deprivations affecting their lives:

- deprivation in survival – measured by the percentage of people expected to die before age 40;
- deprivation in knowledge – measured by the percentage of illiterate adults;
- deprivation in "economic provisioning" – measured by the percentage of people without access to health services and safe water, as well as the percentage of underweight children under five.

The index ranges from 0 (low) to 100 (high). No class limits are given for low, moderate and high.

The HDI and HPI can be useful alternatives to gross national product for measuring the relative socio-economic progress of nations. They enable people and their governments to evaluate progress over time – and to determine priorities for policy interventions. They also enable instructive comparisons of the experiences in different countries.

Source: SADC–UNDP (1998); UNDP (2003).

Table 18 gives selected national-level HDI values (see Box 14) for the countries in the Limpopo River Basin. At the national level, as of 1998, three of the four countries were in the medium (values between 0.500 and 0.790) human development range: South Africa, Botswana, and Zimbabwe (SADC–UNDP, 1998). Mozambique has the lowest HDI value in the region (0.374), although in percentage terms, the situation has been improving steadily (GOM–UNDP, 1999). The impact of the HIV/AIDS pandemic on life expectancy is an important factor in slowing the growth, or reducing the HDI, especially for Botswana, South Africa and Zimbabwe.

As income is an important component of the HDI, an unequal distribution of income may skew the results, especially at the national level. Income inequality can be estimated by the Gini coefficient, which is defined as the maximum vertical deviation between the perfect diagonal and the Lorenz curve, which is a graphical representation of the proportionality of a distribution. The higher the Gini coefficient, the greater the inequality. Southern Africa has some of the highest Gini coefficients in the world and, therefore, it is appropriate to apply an adjustment for income inequality to the HDI values. The national-level HDI values for Botswana, South Africa and Zimbabwe drop dramatically, by more than 20 percent, when adjusted for income inequality. Thus, Botswana and Zimbabwe drop to an HDI of about 0.50 and South Africa moves to 0.60, which is perhaps more representative of the majority of the people living in the rural areas of these countries.

Although it is difficult to make comparisons across the four countries at the subnational level, there is also great disparity in HDI values between geographical regions and urban and rural areas.

TABLE 18
Selected human development and poverty indicators for the basin countries

Country	Global HDI (1998)	Global HPI-1 (1998)	People not expected to live to age 40 (1998) (%)	Adult illiteracy rate (%)	Population without access to safe water (1998) (%)	Underweight children under age five (1998) (%)
Botswana	0.593	28.3	37.1	24.4	10.0	17.0
Mozambique	0.341	50.7	41.9	57.4	54.0	26.0
South Africa	0.697	20.2	25.9	15.4	13.0	9.0
Zimbabwe	0.555	30.0	41.0	12.8	21.0	15.0

However, the HDI is generally lower (higher HPI) in more remote rural areas, where education, health and employment opportunities are more limited.

Botswana

Botswana has completed two national-level human development reports in recent years. A 1997 report recommended nine issues to be considered for future human development studies, the first being conducted in 2000 on the theme *Towards an AIDS-free generation* (GOB–UNDP, 2000). This report provides a detailed assessment of the impact of the HIV/AIDS epidemic on Botswana's society. With the highest reported HIV prevalence rate in the world, Botswana has recognized the importance of integrating a HIV/AIDS strategy with national development and poverty reduction.

The Botswana HPI was calculated using the percentage of children that die before the age of 5 years as a measure of a long and healthy life, not the percentage of people who will not survive 40 years of age. The HPI reveals that more than 25 percent of the population live in human poverty. The HPI values for rural areas are nearly double those in the urban areas – 39.0 compared with 16.8. These disparities are closely linked to available services such as schooling, water supply and health care (GOB–UNDP, 2000).

Mozambique

Mozambique has also produced several national-level human development reports in recent years, although the values are at the provincial level (GOM–UNDP, 1998 and 1999). Severe problems of poverty still exist in Mozambique, affecting nearly 70 percent of the population, or 10.9 million people, according to the latest poverty assessment (GOM–UNDP, 1998). The incidence is higher in rural than in urban areas, with rural headcount reaching 71.2 percent compared with 62.0 percent in urban areas. The incidence of poverty is highest in the central region, whereas the north and south are nearly equal. However, if Maputo city – which has low rates relative to the rest of the country – is excluded from the southern region, the remainder of the southern region (including Gaza Province) has poverty rates higher than the northern region, and not significantly different from the central region.

Nationally, the average household size is 4.8 persons, but among the poor the average household size is 5.6 persons compared with 3.6 persons for the non-poor. The difference is more pronounced in the rural areas (5.5 persons for the poor, 3.3 persons for the non-poor) than in urban areas (6.0 persons for the poor, 4.7 persons for non-poor). Only 32 percent of the adult rural population and 71 percent of the adult urban population are literate. The differences are greater between regions and sexes than between levels of poverty; adult poor = 54 percent literate, adult non-poor = 63 percent, whereas, males = 59 percent and females = 24 percent (change of 36 percent) and urban rural change is 39 percentage points. Given the dependence of the population on agricultural production, and the important role played by women in agricultural activity, the extremely low literacy rate of rural women has serious implications for agricultural productivity in the country (GOM–UNDP, 1998).

South Africa

The national-level HDI varies across geographical regions in South Africa. Gauteng Province has the highest HDI in South Africa (0.717) while Limpopo Province has the lowest at 0.531 (GOSA–StatsSA, 2001a). There is also a close relationship between HDI values, rural areas, and former homelands. For example, Limpopo Province has the highest percentage of rural population (89 percent) and the highest percentage of the population living in former homeland areas and the lowest HDI value at the national level.

According to a recent poverty study (Whiteford and Van Seventer, 1999), 45 percent of South Africans are poor. The figure is even higher in mainly rural areas, and Limpopo Province has the highest poverty rate in the country – nearly 80 percent – compared with 45 percent nationwide, and 32 percent in Gauteng (GOSA–StatsSA, 2001a). Another national report (GOSA–NPU, 2000) further emphasizes the relative poverty and lack of human development in Limpopo Province. Some characteristics of Limpopo Province taken from this report include:

- highest percentage of economically active females (50 percent);
- one of the lowest percentages of economically active population (21 percent);
- one of the highest unemployment rates (46 percent);
- lowest percentage of people with inside tap water and flush toilets;
- youngest population, 63 percent are under age 24 years;
- highest percentage of population aged 20 with no schooling (35 percent).

Zimbabwe

Zimbabwe has also produced two national-level human development reports, one focusing on poverty (GOZ–UNDP, 1998) and one focusing on globalization (GOZ–UNDP, 1999). The 1998 report discusses the relationship between poverty and health issues and economic development. The report states that although some progress has been made, the 1990s witnessed decreased income levels, a contraction of social expenditure, and low levels of economic growth. HIV/AIDS is also taking its toll and reducing life expectancy.

In terms of HDI and HPI characteristics, Zimbabwe also exhibits a disparity between geographical regions and between urban and rural communities. At the national level, Matabeleland South Province ranks highest (best) in terms of HDI or HPI. Four of the six districts in this province have HDI values greater than 0.60, which is near the national average of 0.62 (Table 19). Beitbridge District is the lowest in the Province, comparable with Mberengwa District (Midlands Province). The two districts in Masvingo Province, Mwenezi and Chiredzi, are ranked 74 and 65, respectively, out of the 77 districts and urban centres listed in the 1999 report.

Gwanda (urban) ranked first out of all 77 districts and urban centres in terms of lowest (best) HPI, higher than Harare or Bulawayo urban centres. This indicates good access to infrastructure (markets, schools, health clinics, water, and electricity) as compared with the more remote districts, which tend to be the poorest and least developed.

Livelihoods and food security

Understanding how rural populations live and maintain their livelihoods is crucial to understanding food security. As with many sectors presented in this situation analysis, there has been no systematic analysis of livelihoods and food-insecure populations conducted across the four countries of the Limpopo River Basin. However, using these concepts in their broadest sense (Box 15), the information that was obtained

TABLE 19
Selected poverty comparisons for Zimbabwe districts in the Limpopo River Basin

District	Non-survival to 40 years of age %	Illiteracy %	Underweight children %	Non-access to clean water %	No access to health care %	Living standard deprivation %	HPI	HDI
Mwenezi	22.0	39.1	30.3	31.7	0.7	20.9	29.8	0.44
Chiredzi	22.0	38.8	20.0	9.7	2.3	10.7	28.6	0.52
Beitbridge	16.9	37.8	10.0	14.2	3.4	9.3	27.1	0.55
Mberengwa	15.6	24.6	12.8	41.0	8.6	20.8	21.0	0.55
Bulilimamangwe	9.7	24.7	6.4	37.5	11.7	18.5	19.5	0.59
Matobo	7.7	18.5	9.0	34.1	9.3	17.7	15.9	0.60
Insiza	9.7	19.1	5.2	34.1	6.9	15.4	15.7	0.60
Gwanda rural	10.8	17.9	2.8	30.7	5.4	13.0	14.5	0.60
Umzingwane	9.7	14.7	9.3	18.7	1.0	9.6	11.9	0.62
Gwanda urban	12.0	6.6	0.0	0.8	0.0	0.3	8.7	0.67
Zimbabwe urban	16.9	19.6	10.0	1.0	8.8	3.7	16.0	0.62
Zimbabwe rural	16.9	19.6	14.7	36.5	8.8	17.1	17.9	0.62

Source: GOZ–UNDP (1999).

BOX 15

Livelihoods and vulnerability assessments

Research in recent decades has led to a wealth of methods and approaches for analysing and monitoring livelihoods and food security. The concept of using some form of livelihood system (LHS) is becoming common as the basis for development planning, understanding food security, as well as responding to various types of emergencies for many development and response agencies and organizations. Many agencies have incorporated LHS concepts into their programming cycles and development programmes (e.g. FAO and UNDP).

In general, the LHS approach is a systematic and structured way to understand how people make their living so that development and emergency response interventions can be matched more appropriately with their real needs. The basic objective is to analyse in a holistic way the various components (physical, natural, social, economic and human) that make up the livelihood structure (see DFID, 1998). These components, and the linkages and interactions between them, can than be studied to determine which factors are the most important, and which ones are least stable. In this way, more appropriate interventions can be developed. Participatory methods are encouraged so that the perspectives of the people are captured in the process.

Vulnerability assessment methods and techniques have been developed to help identify and understand food-insecure populations, generally using LHS concepts as the basis. Most methods respond to the basic definition of food security as given by the World Food Summit in 1996: "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life." Most use some combination of the generally accepted "pillars" of food security (food availability, access and utilization) in order to identify who does not meet the criterion.

As with livelihood analysis, there is no standardized approach to vulnerability assessments, although there is general agreement on basic concepts and components to consider. The outcomes may vary in terms of scale and level of detail, but the results of a vulnerability assessment should identify: (i) who and where are the most food insecure or vulnerable to becoming food insecure (to help prioritize/target populations for development/emergency interventions); and (ii) an understanding of why they are vulnerable (to help prioritize the appropriate type of intervention to meet their needs).

Sources and further information: DFID (http://www.dfid.gov.uk/); ODI (http://www.odi.org.uk/publications/susliv.html); FIVIMS (http://www.fivims.org/); SCF-UK (http://www.dinf.ne.jp/doc/japanese/twg/eng/contact/scf.html); USAID-EWS NET (http://www.fews.net/); UNDP (http://www.undp.org/); WFP (http://www.wfp.org/); IFPRI (http://www.ifpri.org); FAO (http://www.fao.org/); USAID/OFDA (http://www.usaid.gov/ofda/).

is presented to highlight the general types of livelihood systems in the Limpopo River Basin. This information is also useful for determining which populations are likely to be the most chronically food-insecure as well as at risk of drought and other climate-induced events.

The analysis of livelihoods and vulnerability are also linked closely to some of the previous sections that discussed various biophysical and socio-economic characteristics, such as the risk of a drought occurring, the type of land use and farming systems, and poverty characteristics. More detailed surveys are needed to better understand the dynamics of livelihood systems and the relationship to food security, for example, between the various sources of own production and income, especially in these drought-prone, marginal production areas.

Various organizations listed in the sources under Box 15, as well as many others at national and local levels, are involved in livelihoods and vulnerability analysis. Efforts are underway to harmonize approaches and build capacity within the SADC region in order to build baseline information and expertise in this area (SADC, 2000).

Botswana

Although the agriculture sector of Botswana contributes only 4 percent to the national GDP and formal sector employment, 65 percent of the population within the Limpopo catchment area live on agricultural holdings and derive their livelihood mainly from agricultural activities (Table 20). More than 70 percent of these agricultural holders can be found in Central District and in Kweneng District.

TABLE 20
Profile of the traditional agriculture sector in Botswana

Characteristic	Administrative districts				Limpopo River Basin	Botswana total
	North East	Central	Kgatleng	Kweneng		
Population on agricultural holdings	79 200	161 170	28 150	116 200	384 720	584 280
Households with cattle (%)	39.9	60.9	60.1	46.2	52.8	53.1
Households with land (%)	94.2	63.8	79.3	72.7	73.5	69.6
Full-time farmers (%)	83.9	77.2	73.9	82.3	79.5	80.4

Source: GOB–FAO (1995).

Increasing demographic pressures are causing farm holdings to decrease in size, resulting in reduced options for grazing livestock, and consequently small ruminants are replacing cattle. The trends have created peri-urban production systems that include larger-scale commercial and intensive enterprises characterized by specialization and intensive market orientation, e.g. poultry, pigs, milk and beef feedlot systems, generally located near centres of consumption.

There is very little formal sector employment in Botswana rural areas. One report (GOB–CSO, 1996) indicates that for all rural areas in 1994, business profits accounted for only 15 percent of average household income, compared with 43 percent from cash earnings, 19 percent from the value of own produce consumed, and 14 percent from remittances from family members in urban formal employment. Income and expenditure data contained within the report show that the average rural household in Botswana was 51 percent self-sufficient in 1993/94 in terms of food requirement by value, compared with 68 percent in 1985/86.

The interplay between agricultural and non-agricultural activities has long existed in rural areas. The World Bank (1990) and others have suggested that the core strategy to alleviate poverty must be to create employment and increase rural incomes.

The 1993/94 Household Income and Expenditure Survey (HIES) (GOB–CSO, undated) indicated:

- Low incomes in rural areas. Income is highly skewed in favour of urban households, with more than half of rural households living below the poverty line. Average rural household income was 37 percent of similar urban households, which is similar to the 1985/86 average, indicating that there has been no real relative improvement in rural income in the last two decades. Cash income for rural households is at an even lower level (28 percent of urban household cash income).
- The poorest of the poor. Of the households measured in the 1993/94 HIES survey, and in the poorest quintile, 16 percent are urban households and 64 percent rural.
- Lack of rural employment opportunities. There continue to be few rural economic opportunities outside of farming, as only 32 percent of rural household heads are employed, compared with 79 percent for urban households.
- Low improvement in social conditions. Most social indicators (malnutrition, education levels, mortality, literacy, and living conditions) are significantly worse in rural areas (GOB–UNICEF, 1993).
- Gender issues. Females head 52 percent of rural households. Such households have significantly lower incomes and access to employment than male-headed households.

Mozambique

Mozambique has been involved in livelihood and food security analysis for many years. In the early 1990s, Medicins Sans Frontiere (MSF) developed a system to classify each district in Mozambique according to several vulnerability indicators. These structural vulnerability assessments are used to determine those areas or populations that are faced with chronic food insecurity. Table 21 describes structural vulnerability for Gaza Province. Only four variables are listed here to illustrate the methodology. Severe risk of drought includes those districts with less than 600 mm/year of rainfall, where extended dry periods are typical. At moderate risk of drought are those districts that normally receive more than 600 mm/year of rainfall but can be adversely affected by regular climatic variations. At risk of flood are those areas that are low-lying and experience periodic flooding that can be detrimental to crop production. Self-sufficiency is a measure of the total food produced (cereals, tubers, etc.) from own production from the two agricultural seasons, in terms of months of consumption. Finally, structural vulnerability is determined by combining all of the different data layers listed above, i.e. climate, agricultural

TABLE 21
Structural vulnerability in Gaza Province

District	Severe risk of drought	Moderate risk of drought	Risk of flood	Self-sufficiency (months)	Structural vulnerability
Xai-Xai		X	X	10–12	None
Bilene Macia		X	X	10–12	None
Manjacaze		X	X	10–12	None
Chokwé	X		X	10–12	None
Chibuto	X		X	10–12	None
Guija	X			7–9	Slight
Massingir	X			7–9	Slight
Mabalane	X			5–6	Economic
Massangena	X			5–6	Economic
Chicualacuala	X			5–6	Food insecure
Chigubo	X			3–4	Food insecure

Source: MSF-CIS (1998).

production, livestock, sources of income, access to markets, and coping strategies. The result is a relative scale ranging from none to food crisis.

Gaza Province has the most districts of all provinces in Mozambique that suffer from structural vulnerability. This is especially the case in the four northernmost districts of the province – Massangena, Chicualacuala, Mabalane and Chigubo. These areas are particularly arid, with an increased risk of drought, very poor soils and low agricultural potential. The people living there typically produce only half of their annual food consumption needs (less than 6 months). With poor access to markets and limited alternative sources of income the people in these areas are chronically food insecure (Box 16).

For Gaza Province, changing eating habits (reduced meals) and intensifying the search for part-time work to generate income were identified as principal coping strategies. Other strategies employed (depending on the district) include: intensifying fishing and hunting; sale of charcoal and fuelwood; sale of livestock; and in the worst case, moving the family (MSF-CIS, 1998). Other livelihood surveys conducted in Gaza Province highlight the importance of remittances from South Africa to maintain household food security (Diriba, Getachew and Cooke, 1995; FEWS NET, 2001). These studies also discuss the importance of diversified farming systems, i.e. planting various types of crops in at least two fields (one in the more productive, but flood-prone lowlands, as well as one on higher ground) to spread the risk from drought or floods and enhance household income.

Another system that was developed was the Food Security and Nutrition Survey (FSNS) to monitor, collect, analyse and interpret information about the food security and nutritional status at subdistrict level (FAO, 1997). The FSNS characterizes the basic livelihood economies and the factors that influence production, sales, consumption, food needs, and health. In recognition of the variability within a district, the data collected for each district are further subdivided into three wealth classes: poor, medium, and rich. The FSNS subdivides Gaza Province into two zones: a productive coastal zone, and an arid zone.

In the productive coastal zone (Bilene-Macia, Xai-Xai, Manjacaze, Chokwé, Guijá and Chibuto), conditions are favourable for agricultural production with "relatively" fertile soils and climate. The principal staple crops are maize, manioc and rice, and cash crops include fruits, such as *mafurra* (castor beans), mango, oranges, cashew, tobacco, cotton and sugar cane. The local markets in these areas are fairly well developed and accessible. Poor families in this area manage to produce 50–60 percent of their basic needs, and the rest comes from the sale of cash crops, animals, local beer, working as a labourer in nearby fields, donations, and remittances from family members in South Africa.

The arid zone (Massangena, Chicualacuala, Chigubo, Mabalane and Massingir) has poor soils for agriculture and the rainfall is low and irregular. Most of the agriculture is along the rivers, and the main crops are maize, sorghum, millet and cassava. Livestock was an important activity in

BOX 16

Livelihood study in Massangena District, Gaza Province, Mozambique

FAO conducted livelihood studies in several provinces in Mozambique in 1998. The objective was to obtain comprehensive information about traditional farming practices in areas subject to tsetse and trypanosomiasis. Farm and non-farm activities were analysed to identify the linkages that could affect (directly or indirectly) the impact of the disease. An additional objective was to examine the scope for poverty alleviation through livestock and crop development strategies.

The survey was conducted in August and September 1998 in three districts in south-central Mozambique. The total number of households surveyed was 2 231, with 548 in Massangena District, the northernmost district in Gaza Province. This district is mostly in the Limpopo River Basin and partly in the Save River Basin, adjacent to Gonarezhou National Park in Zimbabwe. There were 2 694 households within the district at the time of the survey. At 6.6 persons per household, this converts to 17 780 people.

Some salient points derived from this survey are:

- The district is very remote and transport conditions are generally poor.
- Average annual rainfall is very low (400–600 mm) and soils have very low agricultural potential.
- Main crop is finger millet – grown by 93 percent of households – with an average yield about 400–500 kg/ha.
- Maize, although technically unsuited, is grown by 80 percent of households, with crop failure common.
- The average household grows 7 crops – more than 50 percent of households grow 7 or more crops, a risk reduction strategy to cope with erratic rainfall patterns.
- Crops ranked in terms of area planted were: finger millet, cowpeas, grain sorghum, maize, beans, groundnuts, cassava, pumpkin, and sweet potatoes.
- Only 10 percent of households sell millet regularly, and in small amounts to local farmers.
- Overall, less than 5 percent of farmers use any type of fertilizer; cattle owners (8 percent), non-cattle owners (1.7 percent).
- Overall, nearly 70 percent of households meet their household food needs regularly; only 8 percent were regularly dependent on food aid.
- Overall, 35 percent of adults generated income from non-agricultural sources such as trading, off-farm employment, small business activities, handicrafts and brewing.
- In Massangena District, the earnings from these sources in 1997 were about US$250 000.
- 39 percent earned income from handicrafts; 37 percent from brewing; 47 percent from remittances – although in small amounts and no more than twice a year.

Regarding livestock ownership:

- Cattle are owned by only 9 percent of households.
- 32 percent claimed they had previously owned cattle but lost them during the war.
- For those that own or hold cattle, the average herd size is 11 head.
- 69 percent did not own goats, and 10 percent of households owned about one-third of all goats.
- Chickens were owned by 75 percent of households, and ownership was again skewed, with 10 percent of the population owning 59 percent of the chickens.
- 66 percent of households owned only chickens and no other forms of livestock.
- Less than 1 percent owned pigs.
- More than 90 percent of the cattle sold were sold to obtain cash for a specific purpose, e.g. to pay for clothes, school fees, purchase food, buy more cattle, purchase farm assets (ploughs), or pay medical expenses.
- Cattle-owning households grow significantly more crops than do non-cattle owning households.

Source: FAO (1999b).

the area but suffered heavily during the war. The roads are not so developed and they are in poor condition, which makes transport and marketing difficult. Poor households manage to acquire food through purchases, remittances and donations. Other principal sources of household income are the sale of traditional beverage, charcoal, fuelwood and animals.

South Africa

One study of the livelihood conditions in North West Province examined the population structure according to four categories: rural dwellers, rural producers, self-sufficient "subsistence" farmers, and farmers (Data Research Africa, 1995). Similar studies have not been conducted for the entire basin area, but the categories and general relationships probably apply throughout. These subcategories are described below (with the relative percentage in each category in the North West Province study area in parenthesis).

- Rural dwellers (22 percent). Rural dwellers use these areas as rural dormitories and they do not cultivate crops or run stock. Nationally, the proportion of rural households falling into this category is about 30 percent. These households could either be marginalized (unemployed or otherwise poverty-stricken) or urbanizing households (where husband and/or wife are likely to be migrants working in urban areas).
- Rural producers (35 percent). This category is characterized the breadwinner being either a migrant or a commuter. They are engaged in a number of economic activities, including some very minor forms of agricultural production. The largest barrier to increased agricultural production is the non-availability of labour.
- Self-sufficient "subsistence" farmers (34 percent). This category includes emerging farmers with very small herds of livestock and an inclination to expand agricultural production, but insufficient farm resources prevent them from doing so. Alternatively, they are likely to be smaller or ageing households who farm small plots efficiently. "Subsistence" farming is not a very accurate description in that remittances may still be received, and small surplus production could be sold.
- Farmers (9 percent). These households are true farmers in that they have access to larger plots of land and run larger herds. The vast majority of these farmers are livestock producers or full-time farmers who make their living out of marketing farm produce. The major barrier to agricultural production is the lack of access to specialized resources.

GOSA-StatsSA also conducted a rural survey in 1997. The aim of the survey was to better understand the economies of the rural population to determine, especially: their reliance on subsistence agriculture, the impacts of high unemployment, low-income levels, and, poor infrastructure and service provision. Five of the study areas in the rural survey were in North West and Limpopo Provinces. Results from this study revealed:

- The average number of people per household was 5.5.
- Most household heads were female, 71 percent of farm decision-makers were female.
- Approximately 50 percent of respondent households occupied one dwelling constructed using brick and mortar.
- Only 32 percent had access to electricity, 25 percent to piped water.
- Most households (55 percent) had been allocated agricultural land by the tribal authority with only 20 percent having title to their land.
- The vast majority (95 percent) of grazing land was communal.
- Few farmers (less than 12 percent) had received formal training.
- About 35 percent of respondent households were engaged in farming activities.
- Almost one-quarter of respondents had experienced crop failure in 1996, with reasons being: lack of rainfall (60 percent), poor quality of soil (12 percent), crop diseases/ pests (10 percent), and floods/heavy rains (6 percent).
- Only 7 percent were engaged in farming as their sole source of income; almost 11 percent worked for a salary or commission, a further 3 percent had informal employment .
- The most important sources of income were: salaries and wages from household members (45 percent); pension, disability and maintenance grants (27 percent); and remittances from family members living elsewhere (20 percent).

LAND TENURE, LAND USE AND FARMING SYSTEMS

Land tenure

Since the 1980s, there has been renewed interest in land tenure (Box 17) in Africa as a response to the changing environment, especially as a result of

BOX 17

Land tenure

Tenure refers to control over resources or the way in which people hold, individually or collectively, exclusive rights to land and all or part of the natural resources upon it. Tenure is one of the principal factors determining the way in which resources are managed and used, and the manner in which the benefits are distributed (Rihoy, 1998). The term "land rights" may encompass rights to occupy a homestead and make permanent improvements, rights to cultivate, rights to bury the dead, and to have access for gathering natural resources such as wood. It also includes rights to transact, give, mortgage, lease, etc. areas of exclusive use, rights to exclude others, listed rights, and rights to enforcement of legal and administrative provisions in order to protect the rights holder (Adams, Sibanda and Turner, 1999).

increasing population pressure and land scarcity, commercialization of agriculture, urbanization, and globalization. In most African countries where land reform has been initiated, this has taken the form of tenure reform, i.e. conversion of customary land tenure to individualized land tenure. Land reform in Africa since 1980 has been linked closely to global macroeconomic policies and the promotion of efficient commercial agriculture and private investment in the agriculture sector. Individualization of land was considered to be a necessary step for achieving economic development in Africa.

The impact of individualization and titling on agricultural performance has been one of the central issues of land tenure in Africa, and a number of empirical studies have focused on this issue. As a critique to systematic state intervention to convert indigenous land tenure to individualized tenure, a new paradigm of evolutionary theory of land rights has been developed emphasizing adaptability and flexibility of indigenous African land tenure. However, with rapidly changing socio-economic conditions, indigenous tenure has increasingly failed to cope with emerging conflicts, and to regulate and enforce norms and rules that previously governed land.

Land reform in the Limpopo River Basin countries

Land and tenure reform is important in the four countries sharing the Limpopo River Basin. In post-war Mozambique, the return of refugees necessitated their resettlement. For post-apartheid South Africa, land reform was one of the top policy agenda items. Zimbabwe has entered a new phase of its land reform and resettlement programme and a new draft land policy has been issued. Land commissions have been set up in all four countries. Initiatives for the enactment of new land laws have also been undertaken in Mozambique and South Africa. Land tenure reform has taken different forms in the four countries, reflecting their socio-economic, political and historical conditions. In Zimbabwe and South Africa, where skewed land distribution existed along racial lines, tenure reform was combined with land redistribution and resettlement. In Mozambique, community land rights were recognized with a possibility of group registration. In Botswana, the decentralized land board system has provided an adaptable legal framework for customary land tenure reform.

Forms of land tenure and property regime

Land tenure involves the institutional as well as the social factors that govern access to and ownership of land and natural resources. It is defined in terms of a "bundle of rights" – specific rights to do certain things with land or property (Bruce, Migot-Adholla and Atherton, 1993). The form of land tenure and its relationship to agricultural performance in African countries has been one of the central issues among economists. Conventional views on the relation between land tenure and agricultural intensification assume that increasing population pressure and land scarcity will lead to evolution from a communal or collective property regime to a more privatized property regime. The underlying assumption is that more precise private ownership of land and title will encourage farmers to make investment in the land for intensive agricultural practices and technological innovations, thus contributing to the efficient use of scarce land and land conservation. However, it is important to acknowledge tenure security along with other essentials to promote agricultural development, such as informal credit, availability of technology, training and extension services, access to roads, markets and other agrarian structures (Hunter and Mabbs-Zeno, 1986; Pinkney and Kimuyu, 1994;

Roth, Cochrane and Kisamba-Mugerwa, 1994; Golan, 1994; Roth and Haase, 1998).

Most African land tenure, including the countries that cover Limpopo River Basin, is a dual system of customary and statutory land tenure. Customary tenure systems are managed by more traditional practices that are often referred to as informal, communal or collective, in contrast to private or individualized tenure. Customary tenure is regulated and managed under the rules and norms of specific community and kinship systems. The colonial governments introduced customary law to codify the norms and rules of customary land tenure. Statutory land tenure is governed by formal land law and could be contested in statutory court to protect the formal land rights of landholders. Efforts are being made to formalize customary tenure with written documentation including certificate title.

With the exception of South Africa, the major common characteristic of the basin countries is that land is held mainly under customary tenure (Figures 33 and 34). Various customary land tenure systems are generally based on similar principles, namely inheritable land rights of usufruct, land held within family lineage, with land issues being regulated and sanctioned by customary authorities. Inheritance rules vary from group to group but generally provide secure access rights for different family members. Customary land tenure is understood to be flexible, dynamic and adaptable to changing conditions such as agrarian change, population growth, and agricultural markets. However, whereas the relatively secure and flexible nature of customary land tenure is generally well recognized, there are instances where customary tenure has been disrupted or unable to adapt to the changing environment, especially when changes are sudden and large in scale such as in the event of drought and other environmental catastrophes.

Another way of classifying land tenure in Africa is by property regimes, which are categorized as private, common and state property regimes. Private property is the regime where natural resources, including land, are managed as a private property. Common property refers to the regime where natural resources are commonly managed by a group of people, who may hold a collective private ownership. In a state property regime, the state controls natural resources directly. The concept of property regime is usually applied to the case of management of pastoral grazing land in dry areas. The form of property regime is particularly relevant to farming in drought-affected areas. For example, a number of studies have shown that free movement of cattle provides a survival strategy for coping with drought and that exclusive individualized tenure regime could lead to overgrazing and have a negative effect on the flexible strategies of pastoralists for surviving severe natural conditions.

Land use and farming systems

Agriculture dominates the economies of SSA in terms of the population involved, and its contribution to GDP. For Africa as a whole, agriculture contributes 70 percent of employment, 40 percent of exports and 30–35 percent of GDP (Delgado, 1997). The contribution of agriculture to GDP in the basin countries varies from 4–5 percent in Botswana and South Africa to about 15 percent in Zimbabwe and 40 percent in Mozambique. However, the real contribution of the agriculture

FIGURE 33
Former South African homelands (northern areas)

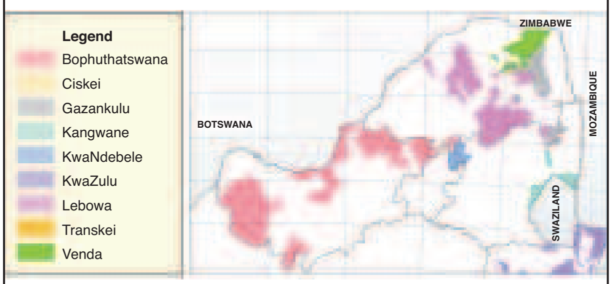
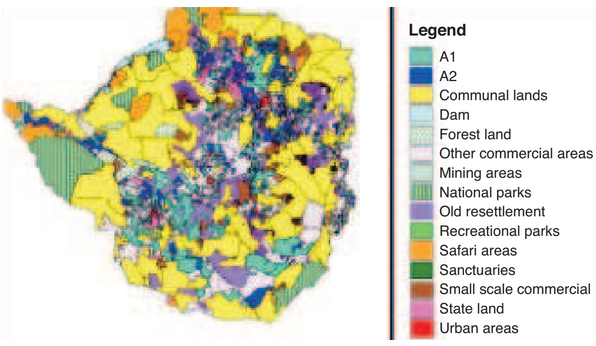


FIGURE 34
Broad land use categories in Zimbabwe



Note: A1 and A2 refer to resettlement (including former commercial farming areas).
Source: GOZ–SADC–FANR (2003).

sector in these countries is far more substantial and vital in terms of sustained food security, income generation, poverty alleviation and employment.

The prevailing land use systems in the Limpopo River Basin are a reflection of the agro-ecological potential in conjunction with cultural, socio-economic factors and policies. The traditional land use systems in the basin are primarily low-input systems based on extensive management and utilization of the natural resources. Observed changes and trends in recent years have been mainly in response to demographic pressures leading to more intensive exploitation of natural resources, resulting in irreversible land degradation. For example, as the option of grazing livestock has declined because of population pressure, small ruminants have replaced cattle. Peri-urban agriculture, consisting of intensive use of land, labour and capital, and characterized by large-scale commercial or market-oriented production in poultry, pigs, dairy, beef feedlots, and horticultural products, has also emerged near towns and urban centres in response to urbanization.

Livestock production

Livestock production in the Limpopo River Basin comprises two distinct systems: freehold commercial livestock production; and mixed crops or livestock systems under communal management. As indicated in Figure 26, the basin is covered largely by natural vegetation or a natural vegetation – cropland mosaic. Most of the natural vegetation outside nature conservation areas is used for extensive grazing.

Communal grazing

The mixed crops/livestock farming system is by far the main land use in terms of the number of people involved, the total area of land occupied, and the production output. For example, rangelands in Botswana comprise about 85 percent, of which 70 percent are communal lands. The system is characterized by ownership and management of cattle. These are kept primarily for draught power, social value and a means of saving on the hoof. They are mainly from local breeds that are generally low producers but are well adapted to the harsh climate conditions of the basin. Small stock is kept by most farmers and includes goats, sheep and chickens mainly used for own consumption and as a source of household income. It is estimated that about 70 percent of ruminant livestock species (cattle, sheep and goats) in southern Africa are kept under small-scale farming conditions, based on communal grazing systems.

Cattle herd sizes are small and are estimated at less than 10 head per household in Zimbabwe (IFAD, 1996) and 4–10 animals in Mozambique. In general, herd sizes in Botswana are relatively larger than in the other basin countries. For example, the total number of cattle in 1988 was reported at 2.4 million (FAOSTAT) while in 1998 it was estimated at 1.8 million (PriceWaterhouseCoopers, 1999). However, even in Botswana, there are indications that the number of households owning cattle has been decreasing slowly and small stock (mainly goats) increasing, in response to demographic pressure (Low and Rebelo, 1996). Distribution of livestock is skewed throughout the country, being aligned closely to human population spread.

Herd management is characterized by low-input methods of farming, where animals depend mainly on extensive grazing with little or no supplementary feeding apart from provision of water. Most communal farmers do not have adequate resources to supplement veldt grazing with purchased stock feeds. In times of drought, the area becomes overstocked owing to limited vegetation growth and greater concentration of herds on available grazing land. Ideally, the number of livestock units that can survive the more difficult seasons rather than the best or even average seasons should determine the carrying capacity of these areas. Another overriding factor is the shortage of water as this may limit animal production even where forage is available. Movement of stock as a drought avoidance strategy is hampered by land tenure structures and the fact that severe droughts generally affect large areas.

Although traditional livestock farmers generally have a sound appreciation of the interaction between livestock grazing management and the environment, the communal management and land tenure system is not conducive to controlled grazing. Hence, accountability in natural resource degradation remains elusive. Increased pressures on land use and increasing demand for livestock products have resulted in land degradation that necessitates modifications of traditional husbandry methods. For example, in 1991, the Government of Botswana developed an agriculture policy that advocated fencing of already existing and used grazing areas by farmers in order to accord them an opportunity to take responsibility for their grazing resources (GOB, 1991).

The communal grazing systems result in low milk production, primarily focused on satisfying household needs. Low supplies of poor-quality feeds, coupled with harsh climate conditions, contribute to low milk yields. Cows that calve regularly remain in relatively poor condition and rarely have the opportunity to gain weight.

The reproduction rate of cattle under communal systems reported in the literature is particularly poor compared with reproduction percentages reported in commercial systems. A calving percentage of about 50 percent is reported (De Leeuw and Thorpe, 1996), which is equivalent to a 24-month calving interval (Table 22).

The extended drought periods common to this area contribute significantly towards low reproduction. It is well documented that mortality rates increase significantly during drought periods. For example, in Zimbabwe during the 1991/92 drought, 70 percent of the cows and 98 percent of the calves died or were disposed of through emergency sales or slaughter (Moyo, 1996). Lactating cows have a higher probability than non-lactating cows of dying from extended drought.

The offtake rates of cattle under communal tenure are low: 5.4 percent according to Tapson (1982); 6.9 percent according to Bembridge (1987); and 7.5 percent according to Steyn (1988). Fenyes (1982) reported low levels of cattle sales in the former Lebowa homeland in South Africa, where 42 percent of the respondents did not want to sell cattle, as they preferred to maximize the numbers in their herds as a safeguard against losses during drought.

Socio-economic status can serve as a useful predictor of successful and progressive cattle farming, (Bembridge and Burger, 1977). Thus, successful cattle farmers have a high socio-economic status in their communities in terms of the livestock farmer's standard of livestock production and management and the general social economic development level.

TABLE 22
Botswana agricultural production indicators

Indicators	Commercial	Traditional
Livestock calving rate (%)	60	50
Livestock offtake rate (%)	17	8
Livestock mortality (%)	5	12
Average yield of crops (kg/ha)	500	200

Commercial livestock production

Commercial ranching for animal production is also an important use of the savannahs found within the Limpopo River Basin, especially in Zimbabwe and South Africa. Nearly half the area within the basin in Zimbabwe and South Africa is classified as commercial farmland predominantly used for cattle ranching. Some of these cattle farmers have switched to game farming because there are increased opportunities for better profits through tourism and hunting safaris (Low and Rebelo, 1996). Intensive grazing on improved pasture is rare in the basin and is mainly used for dairy production.

Commercial farmers tend to be responsive to the biophysical and socio-economic environment. For example, they are quick to sell stock when drought is apparent, this being a common response to drought. However, willingness to sell is dampened by tax liabilities on the sales (unless a drought is formally declared and tax relief offered). Commercial farmers generally recognize that early sales command better prices, leave more grazing for the remainder of the flocks and herds, and reduce the subsequent need for emergency sales. Fenced-in wildlife tends to be even less tolerant of drought than domestic stock owing to the curtailment of their natural need for movement in search of grazing. Where wildlife is concerned, there are fewer opportunities for sale and replacement; hence, survival feeding of valuable species is common in severe conditions.

Livestock production in Botswana

The incidence of livestock ownership in the traditional sector in Botswana is fairly low. In 1995, 53 percent of agricultural households in the Limpopo River Basin owned cattle, and 84 percent owned goats. The average herd size was 44.7 head of cattle and, on average, every cattle-owning household sold 2.3 animals and slaughtered 0.2 head for home consumption. Goat flocks averaged 30 head and average sales per goat-farming household in the basin amounted to 0.7 head and home slaughter accounted for an average 1.2 head per household.

In Botswana, the main communal grazing is located in the hardveldt regions in the east of the country, accounting for about 86 percent of the country's cattle, goat and sheep population. Although this area represents 25 percent of the potential grazing area, it supports 49 percent of the total cattle population. On average, a traditional farm (cattle post) keeps 39 cattle, 20 goats and 13 sheep whereas an average commercial farm has 1 000 cattle, 113 goats and 120 sheep. The mopane and southern hardveldt regions, although major cropping areas, also have high animal populations.

The traditional livestock production system is economically important as it accounts for a large proportion of the country's livestock industry in terms of livestock population and the number of households involved.

Commercial farming in Botswana is restricted mainly to freehold farms situated along the Limpopo River (the Tuli Block farms and other blocks of freehold farms). Some commercial livestock farming is also found in the leasehold Tribal Grazing Land Policy (TGLP) areas where the traditional system is predominant. The commercial system is relatively more advanced than traditional livestock production in terms of management practices and use of farm inputs. They also show better production performance (Table 22).

Livestock production in Mozambique

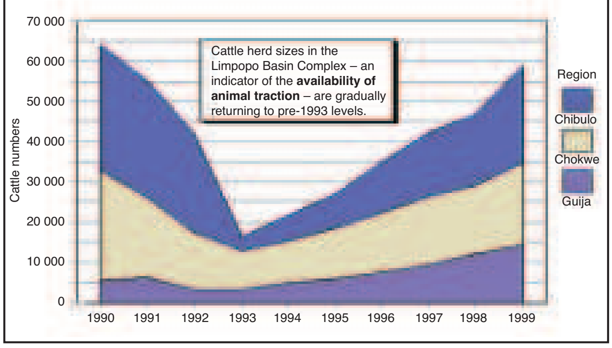
The total land area of the Mozambique part of the basin is 80 million ha, of which 36 million ha are cultivatable land and nearly 12 million ha are classified as natural pastureland. Most of the natural pastureland is in the southernmost provinces of Maputo, Gaza, Inhambane, and parts of Tete, Manica and Sofala.

The national cattle herd declined by more than 80 percent during the war from 1.4 million head in 1974 to 214 000 head by 1993. Since then the sector has been recovering with a herd population of 352 000 head recorded in 1996. Of these, 83 percent were owned by the small-scale sector (GOM–MAF, 1997). Figure 35 shows the cattle numbers in three regions of the Limpopo River Basin between 1990 and 1999.

In spite of the huge potential for livestock development, the contribution of livestock to the national economy has always been relatively small. Even in 1980/81 at the peak in livestock numbers, the livestock subsector accounted for only 5 percent of total agricultural production. At the household level, animal and animal by-products consumption is negligible with an annual consumption of meat estimated at 1.2 kg/capita per year. Per capita milk consumption is estimated at 2.4 litres. The average consumption in Africa is 13 kg/capita per year for meat, and 30 litres/capita per year for milk. At present, almost half the total protein requirement in the domestic market is imported, while imports

FIGURE 35

Cattle numbers in the Limpopo River Basin in Mozambique, 1990–99



Source: FEWS NET (2001).

accounted for 10 percent in 1981 (GOM–MAF, 1997). The use of traction animals is quite limited in Mozambique. Only 22 000 trained animals were used in 1996 (about 6 percent of the cattle population).

Although livestock production is currently relatively small in terms of national production, cattle and small stock play an important role in smallholder farming systems. Small ruminants are especially important to women and poorer households. Smallholder production systems are based mainly on mixed farming where cattle are grazed on fallow lands and on crop residues after the harvest of the main crops. The smallholder herds are concentrated mostly in the provinces of Gaza (28 percent), Tete (27 percent) and Manica (11 percent). Although these provinces contain a large percentage of the herds, production tends to be lower than the commercial and state beef production farms (Table 23). For example, Gaza ranks first in terms of relative percentage of the national herd but fifth in terms of beef production.

A large part of the infrastructure, such as dip tanks, watering points, development and quarantine stations that supported livestock development was destroyed during the war. Owing to the lack of veterinary facilities, a major outbreak of African swine fever wiped out most of the pigs in the country. However, the commercial pig industry is recovering and has grown to nearly 250 000 animals, of which 75 percent are local breeds owned by the small-scale sector (GOM–MAF, 1997).

Livestock production in South Africa

Results of the 1997 Rural Survey (GOSA–StatsSA, 1999b) revealed that 26 percent of all households

TABLE 23
Beef production in Mozambique

1996 Beef production Province	State	Private	Smallholder	Total	Percent of total	Percent by sector State	Private	Smallholder
	(tonnes carcasses)				(%)	(%)		
Cabo Delgado	0.3	33.0	1.3	34.6	4.1	0.9	95.3	3.9
Niassa	0.0	2.8	8.6	11.4	1.4	0.0	24.3	75.7
Nampula	0.0	31.1	67.1	98.2	11.6	0.0	31.7	68.3
Zambezia	11.5	201.5	3.4	216.5	25.7	5.3	93.1	1.6
Tete	1.7	0.7	73.1	75.5	8.9	2.3	0.9	96.8
Manica	5.5	25.4	69.8	100.7	11.9	5.4	25.2	69.3
Sofala	60.1	64.1	1.4	125.6	14.9	47.8	51.0	1.1
Inhambane *	5.6	0.0	32.2	37.8	4.5	14.8	0.0	85.2
Gaza *	0.0	21.9	61.2	83.1	9.8	0.0	26.4	73.6
Maputo	2.4	33.3	24.6	603	7.2	4.0	55.2	40.8
National total	87.1	413.8	342.8	843.7				
Percentage	10.3	49.0	40.6					

* Limpopo River Basin provinces.
Source: GOM–MAF (1997).

had livestock. On average, a household with livestock had 11 Zebu-type cows in milk, 14 Zebu-type dry cows, 10 sheep, 9 goats, 5 pigs, 4 horses/mules and 3 turkeys/ducks. Fifteen percent of households produced animal products, eggs (75 percent) and milk (22 percent) being the most common products. Only 5 percent of all respondents sold cattle or slaughtered livestock for home consumption, and only 2.5 percent of respondent cattle owners sold animal products. Most livestock owners had kraal facilities and used some form of tick and parasite control.

According to a recent survey (GOSA–StatsSA, 2002), 17.6 percent of farming operations in Limpopo Province keep beef cattle (numbers not given), 0.7 percent keep dairy cattle, 2.9 percent keep donkeys, 22.7 percent keep goats, 6.1 percent keep pigs, and 33.8 percent keep poultry.

Output of livestock commodities (meat, milk, eggs, skins, etc.) accounted for 25 percent of agricultural domestic product (these calculations are based on both marketed and subsistence production for the region). Animal products contribute 45 percent to total agricultural production in South Africa (Kassier and Groenewald, 1990).

A number of commercial farmers own more than one farm. Thus, in cases of drought, possibilities exist for the transfer of stock between the farms in the event of the drought being less severe in some areas. Similarly, farmers in one area are generally able to lease grazing in another unless the drought is very widespread. Hence, the movement of stock to alternative grazing is a prime strategy for dealing with localized drought.

Commercial farmers in South Africa have far greater reserves of capital to draw on in times of drought than do communal farmers. They also have better access to markets and supplies for buying feed and selling products. For most commercial farmers in South Africa, the principal concern in times of drought has been to avert loss of domestic stock and/or wildlife rather than short-term household food security. Increasingly, commercial livestock farmers have been investing in diversification opportunities to reduce drought impact through ecotourism, off-farm income and irrigation, especially for fruits and vegetables.

Livestock production in Zimbabwe

The low rainfall in the Limpopo River Basin areas of Zimbabwe makes livestock production more viable than cropping. Cattle, goats and sheep are the common livestock. Survey results from the districts of Insiza and Beitbridge, where farmers were asked to rank the importance of different livestock species, revealed that cattle are most important, followed by goats, donkeys and chickens. Cattle are valued for their high sale value, as a source of draught power as well as an important asset for household income security. Small ruminants, sheep and goats, are valued as a source of meat, and they can be converted to cash in times of need. Poultry (chickens, ducks and pigeons) are an important source of meat and are also sold for cash. Donkeys are kept almost exclusively as a source of draught power. Browse from the mopane-dominated savannah provides the bulk of livestock feed as the dry conditions limit the availability of grazing to a few months after the rains.

There are important gender differences in the ownership, access and control of livestock within the household. Men tend to own and control access to livestock species of greater importance to the household such as cattle and goats, while women own minor livestock species such as chickens and ducks.

Within rural communities, livestock ownership is often skewed. A few members of the society may own most animals while the majority of the people have very little or no livestock. Commonly, 25–30 percent of households own cattle (Sanford, 1982; Cousins, 1990). The average herd size is about 4–6 cattle per household. The top 25 percent of stockowners may control as much as 75 percent of all livestock. Livestock ownership is very much an index of wealth in rural societies, as shown by Table 24, confirming that those owning large herds of cattle are the rich who also operate large land units.

Livestock management in the Limpopo River Basin, and indeed most communal areas in Zimbabwe, can best be described as a low- or zero-input system, except for labour costs. Grazing is done on a communal basis and veldt management is poor because of open grazing systems. Therefore, overgrazed vegetation is common, especially in the fragile Region V ecosystem, which has a very low carrying capacity and can be damaged easily.

Livestock disease control is a mandate of the Department of Veterinary Services. The department provides regular dipping services in order to reduce livestock losses from to tick-borne diseases. When judged necessary, the department carries out vaccination campaigns against major disease outbreaks such as foot and mouth disease (cattle) and Newcastle disease (poultry). In the past, the department provided its services free of charge, but a livestock levy has recently been introduced as a cost-recovery mechanism. The introduction of the levy has met with much discontent from farmers because the quality of services has remained inadequate. Dip tanks are often sparsely located and dipping intervals are not maintained owing to shortages of dipping chemicals. Communal farmers often lose cattle to worm infestation, ectoparasites (e.g. mites) and bacterial and viral diseases owing to inability to diagnose and lack of money to purchase curative and preventive drugs. Disease losses are often high at the end of the dry season and during the early wet season when animals are in very poor condition. In surveys in Insiza and Beitbridge, animal diseases were listed as important constraints on animal production.

TABLE 24
Cattle ownership and crop production per household in Zimbabwe communal areas

Wealth strata	Cattle owned	Landholding (ha)	Maize sales (90-kg bags)
Poor	0.8	1.00	0.4
Lower middle	4.3	2.11	4.0
Upper middle	8.8	1.81	22.8
Lower rich	13.0	2.36	54.6
Upper rich	32.0	4.25	57.5

Source: Amin (1989).

The productivity of livestock on communal lands is very low, being characterized by low fertility, low growth rates and high mortality. Offtake of communal livestock to the formal market is very low. The national offtake figure for beef cattle is 3–5 percent in communal areas and 15–20 percent in commercial areas (Cousins, 1990). The low offtake rates in communal areas are explained partly by the multiplicity of functions of livestock and low productivity of the animals. Animals that are sold in communal areas are usually mature animals at the end of their productive life.

In recent years, the Cold Storage Company and private buyers have set up formal market centres in communal areas. Regular auctions are held, providing communal farmers with a ready market for their livestock. The markets are mainly for cattle and goats. The poor condition of animals sold at communal area markets results in farmers receiving very poor prices for their animals. Many animals are traded informally, e.g. as payment of *lobola* and other forms of barter.

During drought conditions, the markets are usually inundated with animals and prices tend to collapse. Timely disposal of animals pending a drought is very difficult to implement. The severity of the drought cannot be predicted accurately, and farmers often take the risk that animals may survive the drought. The decision to dispose of animals during an impending drought is also made difficult by the low market prices prevailing. The money earned from the sale of animals during a drought is not sufficient to purchase replacement stock after the drought because prices increase during the post-drought period owing to the shortage of animals.

Crop production

Crop production in the Limpopo River Basin is characteristically variable and unreliable primarily because of the low and erratic rainfall. Overall crop yields in the basin are much lower than those in the higher rainfall areas and there is also greater seasonal variability in crop performance. Although basin-level production data are not available, subnational agriculture statistics generally show low production from rainfed small-scale field cropping throughout the basin.

Average grain yields of maize in the traditional (communal) sector are in the order of 250 kg/ha in Botswana compared with about 800 kg/ha in Zimbabwe. The variable most critical to cropping in the traditional sector is rainfall. Thus, sorghum, millet, groundnuts, beans/pulses and oilseeds such as sunflower tend to perform better than maize. Commercial farmers realize higher yields as they are more likely to use modern technologies and apply purchased inputs such as agrichemicals and improved hybrid seeds. Traditional agriculture typically uses family labour, whereas commercial farming uses hired labour.

Another major difference between commercial and traditional agriculture is the level of market integration. Market integration can be measured to the extent to which farming inputs are purchased and farm outputs sold. The commercial farming sector is fully market integrated and it is easier for commercial farmers to obtain credit to fund drought-mitigating activities as they can provide collateral. Supplementary feeds are easier to locate and purchase for commercial farmers but the supplies tend to be expensive as they come from outside the drought area.

In the traditional sector, there is a wide spectrum of market integration. Resource-poor farmers, especially those who do not own cattle but are engaged in marginal crop production, tend to face chronic food shortages. They normally supplement their own production through part-time or full-time casual labour employment, transfers and assistance from extended family, and other off-farm activities.

Subsistence agriculture

Subsistence agriculture in the basin is typically a low-input-output system that has been adopted by local communities to minimize risks arising from climate variability and to make the most efficient use of the limited natural resources. Therefore, it is characterized by low use of purchased farm inputs such as fertilizer and certified seed as well as low management levels. There is great disparity in performance between the subsistence farm holdings and the commercial sector, primarily because of the low-level technologies used by subsistence farmers, as well as limited access to production resources.

The cropped areas, especially for annual crops, are small. Because of poor access to draught power, the majority of the farmers rely on hand-hoeing, thus limiting the area they can cultivate. Late and poor land preparations are a common feature of the basin. They stem in part from labour constraints, poor access to mechanization, and the need for draught animals to gain condition before they can be used after the first substantial rains (which are often also the "planting rains" that fall in early summer).

Crop production is very low with an average maize yield of less than 1 tonne/ha. The low yields stem partly from the fact that soils are degraded and have low nutrient levels, especially nitrogen, as a result of continuous cropping and low use of farm inputs. Inorganic fertilizers are hardly used as few farmers can afford them, given the risks of regular crop failures. The culture of using organic sources of fertilizers is mostly poorly developed, although some farmers in Zimbabwe do have a long-term tradition of collecting leaf litter from neighbouring woodlands and applying it to their cultivated plots.

The use of improved seed is limited. An estimated 90 percent of the seed is accessed from own seed or local sources (except in Zimbabwe, where there are relatively well-developed seed distribution facilities). In general, subsistence crop production in the basin is heavily dependent on low-yielding local varieties.

Marketing channels are generally poorly developed, and farmers rely on local markets especially for the food crops. Therefore, production is mainly for home consumption, although in Zimbabwe, and to a lesser degree in the other three countries, cash crop production with sunflower and cotton is found among the slightly higher income farmers.

Overall, subsistence agriculture in the Limpopo River Basin contributes a relatively small portion to national agricultural output but it is nevertheless a very important source of income and food to the majority of people living in the basin.

Commercial crop production

The Limpopo River Basin produces a wide variety of commercial crops, especially in South Africa. In South Africa, irrigated crop production is important in the provinces of Mpumalanga and Limpopo, particularly the Tzaneen and Louis-Trichardt areas. Large-scale commercial irrigation is focused on vegetable and fruit production, while smallholder irrigation is in its infant stages. Tree

BOX 18

Crop production in the Mpumalanga–Gauteng highveldt

Figure 22 shows the presence of Acrisols on the southeast edge of the Limpopo River Basin. Under the relatively favourable rainfall/evaporation conditions experienced in a rather limited area (Figures 7, 8 and 9), these high-potential soils of level or rolling plains (Figure 21) are highly valued for summer crop production (mostly maize). Maize yields are in the order of 5–7 tonnes/ha. Maize stover plays a major role in the overwintering of cattle, as the sourveldt grazing becomes unpalatable when frosted down in winter.

The potential of these leached, acidic soils with low natural fertility can only be realized under commercial agriculture as the input requirements in terms of lime, fertilizer, weed and pest control are high.

The economy of scale gives rise to relatively large farms of 600–2 000 ha, of which about half are generally cropped. This area is of immense importance to food security of the region.

crops include tea (rainfed), citrus and a variety of tropical fruits such as mango and banana (irrigated).

Rainfed large-scale commercial cultivation occupies large farm units (Box 18). In general, but particularly in the western areas, farmers also face unreliable precipitation and, hence, experience occasional crop failures similar to subsistence production.

Crop production in Botswana

An agricultural census conducted in 1993 (GOB–MOA–CSO, 1995) showed that about 99 percent of arable cultivation in Botswana was within the traditional or subsistence farming sector. The same survey also indicated that 56 percent of the subsistence farmers who planted crops in that year averaged 4 ha/household with cropped plots. However, environmental conditions have a strong influence on the performance of subsistence agriculture in Botswana, the number of farms and the total area under crops per year is quite volatile depending on the climate conditions. Thus, although almost 80 000 rural households participate in arable agriculture, of which 74 percent live in the Limpopo River Basin, not all of them have cropping activities in any given year. For example, only 63 percent of all basin farmers planted crops in 1993.

Overall, subsistence farm holdings occupy a large proportion of the country. An estimated two-thirds of traditional subsistence farmers have mixed farms comprising an individually managed cropped holding and communal grazing of livestock. In 1993, there were about 114 000 traditional farms that held more than 90 percent of all cattle and 97 percent of the area planted to crops. The Limpopo River Basin accounted for 76 percent of the total traditional sector cattle and 72 percent of the planted area.

Average yields have tended to be low reflecting the low-input/output system. In some years with relatively good rains (notably 1988, 1989 and 1995), crop production made a substantial contribution to household food requirements. Nevertheless, although subsistence agriculture might appear insignificant from a national agricultural output perspective, it is critical to the subsistence farmers themselves. They are dependent on it as a source of income and food, especially sorghum, maize, millet, beans, other pulses, and oilseeds.

The Botswana Agricultural Census of 1993 (GOB-MOA-CSO, 1995) indicated there were 253 commercial farms in the country, of which 122 (48 percent) were situated in the Limpopo River Basin. The basin accounts for 43.5 percent of commercial cattle holdings and 69 percent of the commercial holdings that practise arable agriculture. This latter figure reflects the higher incidence of irrigation availability, better soils and higher rainfall in the basin than in the rest of the country.

Horticultural production remains low in Botswana with local production tending to account for some 20 percent of local demand. There are currently 660 ha under horticultural production, 330 ha of which are either farmed by the Botswana Development Corporation or are on private farms. The balance is under small-scale projects. The country is almost self-sufficient in egg production, and poultry production expanded by 50 percent between 1991 and 1995.

Crop production in Mozambique

The war affected crop production in Mozambique considerably. However, it has started to show signs of recovery in recent years. Infrastructure, and hence support services, are still underdeveloped, and input use is very low. Most districts have minimal contact with extension services and suffer from poor management practices, lack of access to input supplies, low levels of livestock ownership, and/or subsistence-oriented farming practices. Therefore, the production potential is rarely realized even in the more fertile areas.

Yields from crops such as maize and grain sorghum are only about 0.8 tonnes/ha for maize, 0.6 tonnes/ha for grain sorghum and 0.4 tonnes/ha for groundnuts. Better management and higher levels of input use could probably double these yields. The use of manure by farmers who own cattle is not practised widely and needs to be expanded. A recent survey in Massangena District in Gaza Province revealed that less than 5 percent of farmers used any type of fertilizers and that only 8 percent of those farmers who owned cattle used manure substantively (GOM–FAO, 1998; see also Box 16). In Gaza Province, the area cultivated per family is about 1.5 to 3 ha (GOM–DAP, 2002).

Another common production strategy in Mozambique is for most families to have multiple plots, one in the more fertile lowlands (*baixas*) along the rivers as well as one in the less fertile higher ground (*serras*). In the *baixas*, they plant primarily maize, *nhemba* beans, groundnuts and manioc, while they plant sorghum, millet, pulses and other more drought-tolerant crops in the *serras*.

Crop production in South Africa

Crop production among rural communities in South Africa, including those in the basin area, can be characterized as subsistence agriculture, with maize being the main crop. Production is rainfed on very small farms with about 0.5 ha under field crops, 0.25 ha for vegetables, 0.1 ha for fruit trees and 0.3 ha of unused land. Production is based on low-input/output systems that are susceptible to drought. Although maize may not be well adapted to the relatively low rainfall conditions and the recurrence of a midsummer drought period, white maize meal is such an important part of the diet of the poorer levels of society that adoption of millet, sorghum and oilseed crops (except for groundnuts) is slow.

According to the 1997 Rural Survey (GOSA–StatsSA, 1999b), 35 percent of respondent households engaged in farming activities. The majority (90 percent) gave food provision as the purpose for farming and only 7 percent earned a living from selling produce. It is evident that most farming households place strong emphasis on subsistence income (crops and vegetables) to meet or partially meet the food requirements of the households. The most significant crop grown by subsistence farmers was maize (57 percent), with groundnuts (11 percent) and mangoes (3.4 percent) being other significant crops. Average production per hectare for these crops was 352 kg for maize, 173 kg for groundnuts and 80 kg for mangoes. Very few subsistence farmers have access to irrigation facilities. For example, only 11 percent of respondents had access to water on cropped land with the main sources being piped water (60 percent), borehole (17 percent) and irrigation canals (9 percent).

There are numerous examples of semi-commercial small-scale farming outside the traditional cropping/communal grazing and large-scale commercial operations in South Africa. Within this small-scale farming subsector, enterprises include:

- broiler and layer production;
- rearing of pigs;
- rearing of rabbits for meat and mohair;
- fish farming;
- feedlots for cattle.

Large-scale rainfed commercial crop farming within the basin is dominated by maize under monoculture (Box 18), with sunflower planted in seasons with late rains. Maize yields per hectare range from about 5–7 tonnes on the best soils on the eastern highveldt in the provinces of Mpumalanga and Gauteng to 3–5 tonnes on the western highveldt of the North West Province and 1–3 tonnes in the drier areas of Limpopo Province. Irrigated crop farming is well developed in the relatively frost-free areas and mainly produces citrus fruit, a wide variety of subtropical fruit, and vegetables. Fruit is grown for the export market and for consumption in the relatively affluent urban centres in Gauteng and beyond. Out-of-season irrigated vegetable production in the warm areas of the basin is of immense importance to the inland urban centres, considering the rather harsh winters of their hinterland.

Crop production in Zimbabwe

The following evaluation by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) describes accurately the situation in the basin province, Matabeleland South. Rainfed agriculture, the predominant production system in the SADC region, is characterized by two major problems: low productivity and instability of production. The inadequacy and uncertainty of rainfall and its uneven and irregular distribution have been further compounded by the low fertility and high fragility of soils. In addition, the subsistence and food crop sectors suffered a general neglect in terms of research, extension and provision of inputs in both the colonial and post-independence eras. The negative impact of the low emphasis on small grain cereals became progressively apparent, and the prolonged droughts precipitated a sequence of crises by dissipating self-sufficiency in food in many southern African countries. The food production gap resulted in acute hunger and malnutrition in the marginal rainfall parts of the SADC countries and, thus, it emerged as a major social issue of concern to policy-makers.

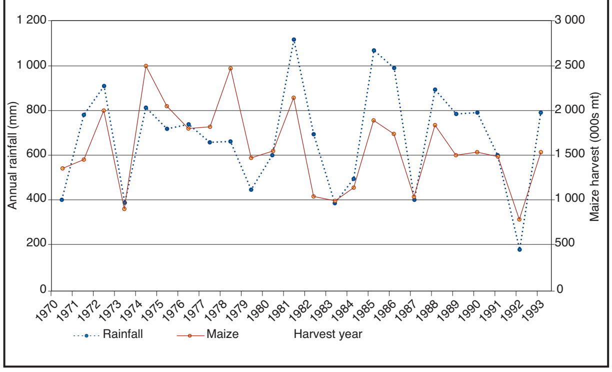
More than 60 percent of the area of Zimbabwe, accounting for 75 percent of smallholder farming areas, is located in the semi-arid region (Natural Regions IV and V) in which the basin is situated. Nearly two-thirds of the national population live in these drier parts of the country, which face a high likelihood of severe dry spells during the rainy season and frequent seasonal droughts (Hedden-Dunkhorst, 1993). The majority of the Limpopo River Basin falls within Natural Region V, the driest region of the country. This area is primarily suitable for livestock production, although rainfed production of field crops is practised throughout the region during the summer, with some irrigated crop production throughout the year.

Cropping is an important source of livelihood for communal farmers to secure adequate food supplies as well as a source of income, although production systems are extremely volatile and sensitive to rainfall patterns (Figure 36). Crops grown in the basin include maize, sorghum, cotton, groundnuts and sunflower. Average yields achieved for these major crops grown in the basin are very low, ranging from 0.40 tonnes/ha for groundnuts to just under 1 tonne/ha for maize.

Several significant trends and shifts in the production patterns have occurred in recent years:

- In all the provinces within the Limpopo River Basin (Matabeleland South, Masvingo and Midlands), production has decreased compared with the 1980s, possibly as a reflection of a deteriorating crop production potential caused by declining soil fertility and more frequent droughts.
- There has been a shift in production patterns since the late 1970s with maize gradually taking over from pearl millet, sorghum and finger millet as the major staple, even though the chances of zero grain yields are higher with the maize than the small grains. Some of the reasons for the reduced importance of small grain cereals in recent years are high labour requirements in their production and flour preparation; shifts in taste towards maize flour; limited market opportunities; and a lack of improved crop production technologies.
- Intercropping of cereals with legumes (a traditional cropping practice in the basin) has also been giving way to monocropping as a result of vigorous extension campaigns. Intercropping is now confined to isolated patches where non-cereal crops such as pumpkins and cowpeas are planted randomly at very low densities within a cereal crop plot.
- There has been more research and extension work on maize. Hence, improved maize varieties that give higher outputs with less labour compared with the smaller grain cereals are available to farmers. Consequently, there is a preference for maize production in the basin. Of the small grains, there seems to be a preference for pearl millet as a source of food, possibly because the other grains are used for beer-making and generate higher income returns than the pearl millet (Hedden-Dunkhorst, 1993). Production of sorghum has been declining although it gives more stable but lower yields than maize. Farmers have not taken advantage of this drought-tolerant attribute as they have expanded maize production at the expense of sorghum.
- There has been a clear trend towards production of cash crops such as cotton and sunflower. However, it is mainly the above-

FIGURE 36
Rainfall and maize production in Zimbabwe



Source: Rook (1994).

average farmers who have tended to benefit more from this crop diversification because they are better able to purchase the necessary inputs, prepare their fields early, hire labour, and organize marketing. On the other hand, production of groundnuts (a traditional crop in the basin) is declining, partly because of poor seed availability, low yields and high labour requirements.

Irrigation development

According to FAO (1997), the irrigation potential of the Limpopo River Basin, based on land and water resources, is estimated at 295 400 ha (Table 25). The water requirements given in Table 25 are based on selected and appropriate cropping patterns (FAO, 1997). For Botswana and Zimbabwe, other literature gives higher irrigation water requirements than the ones given by FAO (1997), which means that the already small potential of these countries might be overestimated.

Botswana

The maximum irrigation potential in Botswana is estimated at 15 200 ha, of which about 10 000 ha would need important works for water development and storage (SADCC–AIDAB, 1992). As several major towns are located in this area, including the capital Gaborone at the Notwane River, severe intersector competition for water is to be expected in future. For these reasons, FAO (1997) considers an irrigation potential of 5 000 ha as more realistic in the Limpopo catchment in Botswana. Less than 1 400 ha is at present under irrigation in the area. Of this, about 44 percent is irrigated from groundwater and 56 percent from surface water, either by pumping directly in the Limpopo River and its tributaries or from storage reservoirs (Plate 1).

Plate 1
Groundwater harvesting along the Limpopo River when surface flow has stopped.

The irrigation techniques used include: surface irrigation, i.e. furrow and basin, hoses, and hand-watering (16 percent); sprinkler irrigation (64 percent); and localized irrigation, i.e. drip and microsprinkler (20 percent). There are four categories of farming in the irrigation subsector (FAO, 1995a):

- Private irrigated farms, owned and operated by individuals, are the most numerous. Units range from 1 ha to more than 100 ha, but with smaller sizes predominating. They grow mainly high-value food crops for local markets.

TABLE 25
Limpopo River Basin: irrigation potential, water requirements and irrigated area irrigation

Country	Irrigation potential	Gross potential irrigation water requirements		Irrigated area
		Per hectare	Total	
	(ha)	(m^3/ha per year)	(million m^3/year)	(ha)
Botswana	5 000	10 500	53	1 381
Zimbabwe	10 900	11 000	120	4 000
South Africa	131 500	12 000	1 578	198 000
Mozambique	148 000	11 500	1 702	40 000
Total for basin	295 400		3 452	243 381

Source: FAO (1997a).

- Group schemes range up to 10 ha and have been developed by the government and donor agencies to provide employment and boost local incomes. Groups consist of a number of farmers, but individuals have their own plots.
- Institutional schemes are those owned and operated by government organizations, such as the Botswana Agricultural College, the Department of Agricultural Research, the Brigades Movement and the Botswana Defence Force.
- Company-owned schemes include those owned and operated by the Botswana Development Corporation (BDC) and commercial companies. BDC schemes, which total 570 ha, are located in the Tuli Block, Mogobane and Kasane.

Mozambique

Because of unfavourable climate features, the risk of harvest loss in rainfed agriculture can reach 75 percent in the interior of Gaza Province. The irrigation potential for Mozambique in the Limpopo River Basin has been estimated at 148 000 ha (UNESCO–UNDP, 1984). Given that the Limpopo River in Mozambique may stop flowing for up to eight months of the year, the above potential has to be considered as an upper limit, requiring important storage works and good cooperation between the basin countries. Historically, the irrigation subsector in Mozambique concentrated on the development of government estates. These were established during politically unstable conditions. Little attention was paid to their financial sustainability. The state companies were inefficient, resulting in irrigation management problems and deterioration of the infrastructure. Until recently, very little effort was directed towards the development of sustainable smallholder irrigation schemes.

According to the draft national irrigation policy and strategy (GOM–DNA, 2000), the following factors contribute to a decline in irrigation:

- The abandonment of irrigated lands by the original owners just after national independence and the lack of experience of the new owners, contributing to inefficient operation and maintenance (O&M) of the irrigation schemes.
- The extended civil war, lasting more than a decade, destroying several irrigation infrastructures and leading to the abandoning of others.
- The gradual reduction of public funds for irrigation.
- The lack of inputs and technical assistance in rural areas to ensure the maintenance and improvement of the irrigation schemes.

In 1968, the irrigation subsector in Gaza Province covered 27 447 ha, or 42 percent of the national area under irrigation. This included 4 000 ha of reclaimed *machongos* without any infrastructure. Essentially, this area covers the Chokwé District irrigation scheme on the Limpopo River. Established for rice growing during the colonial period (1952–1972), the scheme was managed after independence in 1975 by the state enterprise Sistema de Regadio Eduardo Mondlane. In 1987, there were 29 irrigation schemes in this part of the Limpopo River Basin. Of these, six of the smaller schemes were reportedly facing water scarcity problems. The Limpopo River mouth area suffers from serious saltwater intrusion. Salinity is a major factor in limiting the use of land developed for irrigation in these areas. Mihajlovich and Gomes (1986) projected a potential for the development of 45 000 ha by 2000, given improved operational performance, and a potential for the development in the long term of 150 000 ha suited to irrigation.

In the late 1980s, the Chokwé scheme was the main water consumer in the basin (523 million m^3/year). The Chokwé scheme extends about 50 km along both banks of the Limpopo River. Total water demand during an irrigation season is never satisfied. Sogreah (1987) and others have reported on inadequate O&M of the Chokwé scheme, the scheme being characterized by low irrigation efficiencies. Only about 20 percent of the water requirements are met because of structural and organizational issues. There is also considerable misuse of the water resources. This has negative consequences for downstream users of water in Xai-Xai District, where the shortage of water from the Limpopo River is critical.

Serious salinity and sodicity problems exist in the majority of the alluvial soils, especially in the lower Limpopo River areas. This is caused by the presence of saline and sodic lacustrian and estuarine deposits under the alluvium. It is aggravated by inadequate management of the irrigation and drainage systems (especially at Chokwé). A number of drainage programmes were operational in the past, especially in Xai-Xai District.

In 1983, the government initiated a policy recognizing the importance of family enterprises and redistributed scheme land. In 1989, 30 000 ha of scheme land were occupied as follows: 40 percent by family enterprises, 24 percent by the State, 28 percent by private individuals, and 8 percent by cooperatives. With UNDP funds, FAO was involved in rehabilitating and improving the irrigation and drainage infrastructure of about 2 000 ha of family enterprise plots in 1988–89. The government intends to have existing schemes totally rehabilitated and recovered by 2007.

The irrigation methods vary according to the nature of the crop, topography and soil. Sprinkler irrigation is used widely in sugar cane, citrus, fruit and vegetable production. Surface irrigation is commonly applied in basins for rice and in furrows for maize and vegetables. Another method, widely used by smallholders in *dambos* and floodplains, is subirrigation through the control of the groundwater table. The irrigation efficiency is low.

Despite severe water shortages in some regions, the water used for irrigation is either not charged for or provided at only a token price.

South Africa

At present, 198 000 ha are irrigated in the Limpopo River Basin in South Africa, using about 10 000 m³ of water per hectare per year. The irrigation potential shown in Table 25, based on land and water resources and a cropping pattern requiring 12 000 m³per hectare per year, is estimated at 131 500 ha (FAO, 1997). Thus, there are clear trends of less water being used on more hectares than would be suggested. The scope for irrigation development along the main stem of the Limpopo River is estimated at perhaps 4 000 ha in South Africa.

For water management purposes the Limpopo River Basin in South Africa is divided into four water management areas: Crocodile (West) and Marico, Limpopo, Elephants, and Luvuvhu and Letaba.

Crocodile (West) and Marico water management area

More than 60 percent of the total water requirement in this water management area is for urban, industrial and mining use, about 35 percent for irrigation, and the remainder for rural water supplies and power generation. Almost 75 percent of the total requirements for water in the water management area are within the Upper Crocodile and Apies/Pienaars subareas. This again reflects the dominance of the urban and industrial development in this part of the water management area. However, it also includes irrigation using urban return flows as well as the large irrigation developments in the vicinity of the Hartbeespoort Dam. Water requirements in the Elands subarea show a large component for mining, while the water transferred from this subarea is also destined mainly for mining use in the Lower Crocodile subarea. However, most of the water use in the Lower Crocodile subarea is for irrigation (GOSA–DWAF, 2003c).

Limpopo water management area

Water use is dominated by the irrigation sector, which accounts for nearly 75 percent of the total water requirement in the water management area. About 16 percent of the requirement is for urban, industrial and mining use, 9 percent for rural domestic supplies and stock watering, and a small quantity for power generation. The quantity of water intercepted by afforestation is relatively small and has little impact on the yield. Irrigation occurs throughout the water management area and development is distributed relatively evenly among the subareas. Some of the irrigation in the water management area is dependent on surface water from small dams or from run-of-river, which is at a very low assurance of supply. Therefore, the actual area irrigated varies from year to year, with the full area developed for irrigation only to be planted when sufficient water is available (GOSA–DWAF, 2003a).

Elephants water management area

The bulk of the water used in the Elephants water management area is by the irrigation sector, which represents 57 percent of the total requirements for water in the water management area. Power generation represents 19 percent of the water requirements, and urban, industrial and mining combined use a further 19 percent. Most of the water used in the Upper Elephants subarea is as cooling water for thermal power stations, which is a highly consumptive use of water and requires a relatively high quality of water. A substantial quantity is also used in urban areas, more than half of which again becomes available as return flows for downstream use. As a result of the large irrigation developments downstream of the Loskop Dam, requirements for water in the Middle Elephants subarea are dominated by irrigation. Although the most populous subarea, water use for urban and rural purposes is relatively low because of

TABLE 26
Year 2000 water requirements in South Africa

Subarea	Irrigation	Urban (1)	Rural (1)	Mining and bulk industrial (2)	Power generation (3)	Afforestation (4)	Total local requirements	Transfers out	Grand total
	(million m³/year)								
Crocodile (West) and Marico water management area									
Apies/Pienaars	41	211	7	6	15	0	280	87	367
Upper Crocodile	208	292	5	38	13	0	558	17	573
Elands	32	23	10	48	0	0	113	24	137
Lower Crocodile	137	3	3	28	0	0	171	0	171
Marico	24	5	9	2	0	0	40	7	47
Upper Molopo	3	13	3	5	0	0	24	0	24
Total	445	547	37	127	28	0	1 184	10	1 194
Limpopo water management area									
Matlabas/Mokolo	48	2	2	4	7	0	63	0	63
Lephalala	39	0	3	0	0	0	42	0	42
Mogalakwena	55	8	9	6	0	0	79	0	79
Sand	69	24	9	4	0	0	106	0	106
Nzhelele/Nwanedzi	25	0	5	0	0	1	32	0	32
Total	238	34	28	14	7	1	322	0	322
Elephants water management area									
Upper Elephants	44	62	6	20	181	1	314	96	410
Middle Elephants	336	15	28	13	0	0	392	3	395
Steelpoort	69	3	5	17	0	1	95	0	95
Lower Elephants	108	7	5	43	0	1	164	0	164
Total	557	87	44	93	181	3	965	8	973
Luvuvhu and Letaba water management area									
Luvuvhu/Mutale	97	4	10	1	0	7	119	2	121
Shingwedzi	0	0	3	0	0	0	3	0	3
Groot Letaba	126	3	10	0	0	35	174	11	185
Klein Letaba	25	3	8	0	0	1	37	0	37
Lower Letaba	0	0	0	0	0	0	0	0	0
Total	248	10	31	1	0	43	333	13	346
Total for basin	1 488	678	140	235	216	47	2 804	31	2 835

Notes:
(1) Includes component of reserve for basic human needs at 25 litres/person per day.
(2) Mining and bulk industrial water uses that are not part of urban systems.
(3) Includes water for thermal power generation only. (Water for hydroelectric power, which represents a small portion of power generation in South Africa, is generally available for other uses as well.)
(4) Quantities given refer to impact on yield only.

the primary nature of water use by these sectors. Irrigation and mining are the largest water use sectors in the Steelpoort and Lower Elephants subareas, which reflects the nature of economic activity in these areas (GOSA–DWAF, 2003b).

Luvuvhu and Letaba water management area

Water use in the Luvuvhu and Letaba water management area is dominated by the irrigation sector, which represents almost 75 percent of the total requirements for water within the water management area. The impact of afforestation on the yield from water resources in the water management area represents 13 percent of the total requirements, about 9 percent is for rural domestic supplies and for stock/game watering, and the remainder for urban, industrial and mining use. More than half of the total requirements for water within the water management area are in the catchment of the Groot Letaba River, mainly for the irrigation and forestry sectors, which shows the intensity and concentration of irrigation and afforestation in this subarea. The Luvuvhu/Mutale subarea represents a further substantial proportion of the water requirements in the water management area, followed by the Klein Letaba subarea. Irrigation is the dominant water use sector in both subareas (GOSA–DWAF, 2003d).

Table 26 provides a summary of the sectoral water requirements in each of the water management and subareas. Figures for the non-agriculture sectors are included to provide a sense of the situation in various subareas. All the requirements are given at a standard 98-percent assurance of supply.

Zimbabwe

The irrigation potential of the Limpopo River Basin in Zimbabwe, considering both land and water resources, is estimated at 10 900 ha. Of this area, 3 950 ha are under irrigation: 1 550 ha of smallholder irrigation; 1 900 ha under large-scale commercial farmers; and 1 500 ha under the Agricultural Rural Development Authority (ARDA). It is reported that the communities in this area reap a successful crop only once in five years in the absence of irrigation. Table 27 gives information on the major smallholder irrigation schemes. For the schemes irrigating from the rivers, water is pumped from well points sunk in the riverbed sand, where water is found at a depth of about 3–10 m. These are called sand abstraction systems. The other schemes receive their water from dams. In both cases, water is diverted into conveyance canals/pipes and then into the secondary and tertiary canals. The in-field irrigation technology in use is predominantly surface irrigation, where water is applied using furrows or border-strips. The farmers use syphons to apply water from the field canals into the field furrows or border-strips.

Some schemes on the Zimbabwe highveldt, such as the Mziki Irrigation Scheme, use draghose sprinkler irrigation systems. Here, the sprinkler head, riser and tripod are mounted to a hose that the farmer can drag freely as the sprinkler positions are changed during irrigation. Most of the newer schemes in the Mashonaland provinces use this technology (GOZ–AGRITEX, 1999a).

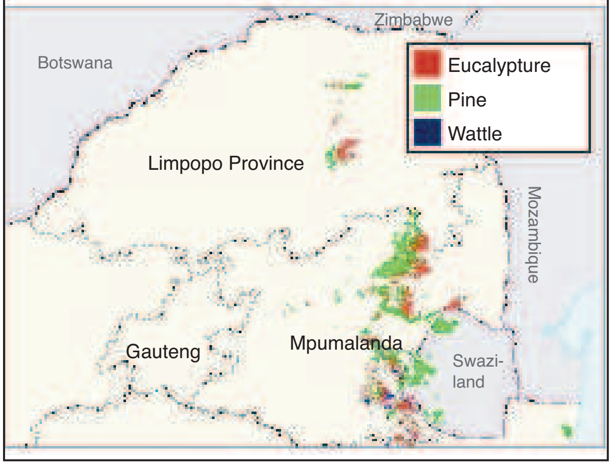
The plot sizes vary from scheme to scheme, ranging generally from 0.1 ha/household in the older schemes to 0.5 ha/household in the schemes developed after independence. Elsewhere in the country, where more water is available, the newer schemes can have plot sizes of 0.5–1.0 ha. The irrigation management committees, comprising a

TABLE 27
Major smallholder irrigation schemes in the Limpopo River Basin in Zimbabwe

Scheme	Size (ha)	Number of farmers	Technology used
Silalabuhwa	360	880	Dam and surface irrigation
Duncal	5	35	Dam and surface irrigation
Mzinyathini	12	80	Dam and surface irrigation
Tuli Makwe	102	505	Dam and surface irrigation
Masholomoshe	90	480	Dam and surface irrigation
Rustler's Gorge	30	77	Sand abstraction and surface irrigation
Mambali	22	80	Sand abstraction and surface irrigation
Bili	21	42	Sand abstraction and surface irrigation
Mankonkoni	50	100	Sand abstraction and surface irrigation
Muziki	23	60	Borehole and sprinkler irrigation
Siwaze	22	50	Dam and surface irrigation
Malikango	60	300	Sand abstraction and surface irrigation
Manjinji	52	150	Boreholes and surface irrigation
Chikwarakwara	60	166	Surface irrigation and sand abstraction
Jalukanga	42	98	Sand abstraction and canals
Kwalu	50	225	Dams and surface irrigation
Shashe	80	182	Sand abstraction and surface irrigation
Sebasa	40	80	Dam and surface irrigation
Guyu Chelesa	20	160	Dam and surface irrigation
Sukwi	24	53	Dam and surface irrigation
River Range	10	20	Dam and surface irrigation
Valley	200	400	Dam and surface irrigation
Lilombe	10	50	Dam and surface irrigation
Somunene	20	50	Dam and surface irrigation
Tshangwa	17	85	Dam and surface irrigation
Moza	23	138	Dam and surface irrigation
Total	1 445	4 546	

Source: GOZ–AGRITEX (1999b).

FIGURE 37
Plantation forestry in the northern provinces of South Africa



Source: GOSA–FSA (2003).

chairperson, a secretary, a treasurer and some other committee members, run the smallholder schemes. These are elected every two years and they are guided by the scheme by-laws in their operations.

Forestry

Forestry in the Limpopo River Basin comprises natural forests and woodlands as well as commercial or plantation forestry. The latter is practised on a relatively small scale, mainly in South Africa (Figure 37). Natural woodlands are quite extensive in terms of total area covered and are the main source of wood products, especially building materials and fuelwood for local communities. They also provide non-wood products such as indigenous fruits, mushrooms, thatch grass and material for medicinal use.

Large-scale commercial plantation forestry is the most important form of forestry economically but it requires high management levels. Plantation forestry in southern Africa is predominantly based on exotic species of pine, eucalyptus and Australian wattles. These require relatively high rainfall and, therefore, they are found in the wetter parts of the basin.

In South Africa, plantation forestry is confined to the higher rainfall belt (above about 700 mm/year) along the eastern escarpment of the Drakensberg Mountains and the adjacent highveldt of northern Mpumalanga and Limpopo Provinces (Box 19). This is the northernmost part of the South African timber belt, which originates in the Western Cape and Eastern Cape Provinces and runs along the east coast towards the Limpopo River Basin (Schulze, 1997). The area under forest in the provinces of Mpumalanga and Limpopo in South Africa has expanded steadily over the past half-century. The rest of the Limpopo River Basin in South Africa, Botswana, Zimbabwe and Mozambique is climatically unsuitable for commercial production of exotic forest species (Herbert, 1993).

The commercial forestry and related processing industry forms an important part of the economy in particular in Mpumalanga Province, where it covers 8 percent of the area and contributes significantly to GDP and employment (Scholes *et al.*, 1995).

Plantation forestry is a minor activity in Botswana, Mozambique and Zimbabwe. The total plantation area in Botswana is estimated at about 1 200 ha, with 85 percent belonging to the government and 15 percent as private woodlots.

BOX 19
Plantation forestry and water use

In the 1930s, the Government of South Africa started to establish exotic tree species plantations in order to make South Africa self-sufficient in its timber requirements and to provide more job opportunities in a diversified economy. Plantation yields vary from an average of 15 m^3/ha per year for softwood to 20 m^3/ha per year for eucalyptus and 9 m^3/ha per year for wattle (timber and bark together).

Plantation forests occur on about 1.5 million ha of land in South Africa. These forests support industries that are important to the economy of South Africa. Although the area of these forests is relatively small (little more than 1 percent of total land area), the forests place high demands on the environment (e.g. in terms of water use) compared with both the area occupied, and compared with the natural vegetation that they replace.

In the period from the 1930s to the 1950s, South Africa established a series of whole-catchment experiments to assess the impacts of commercial forestry with alien species on water resources in high-rainfall areas. The outcome of this is that the reduction of usable run-off by commercial afforestation is estimated to be about 7 percent.

Source: GOSA–DWAF (2003e).

It may be assumed that most plantations are situated in the basin. Production from eucalyptus woodlots is similar to that of unattended savannah woodland.

The occurrence of natural forests is limited in the Limpopo River Basin, and dense woodlands and forests are mainly found outside the basin, e.g. Chobe forest reserves of Botswana and Zimbabwe. These Miombo and Baikiaea woodlands comprise Mukusi (*aikiaea plurijuga)* and Mukwa (*Pterocarpus angolensis*) as the most typical species.

Community forestry

Extraction and collection from natural woodlands and grasslands (natural vegetation) is an extremely important land use in the basin. It includes utilization of prevailing natural vegetation as well as hunting and fishing. The economic/social importance of indigenous forest and wood products to local communities as a source of income and for subsistence is often underestimated. While the importance of timber/wood products has been well recognized, non-timber products are undervalued. Multiple uses of the natural vegetation in the basin include grazing and browsing of the open woodland, bushland or savannah types, hunting and collection of timber, fuelwood and non-timber products. The category of non-timber products includes:

- bark, leaves and stems for making ropes, baskets, mats and other household products such as utensils;
- fruit and other extracted substances to provide dietary supplements and ingredients for brewing;
- edible animal and plant products such as honey, insects and mushrooms;
- plant products (roots, bulbs, leaves and fruits) for medicinal and cultural purposes;
- grass and reed for thatching, weaving, basketry and other applications.

As the population has increased, also the demand for various woodland products has been increasing. This has led to local shortages of forest resources, culminating in deforestation and land degradation, especially around major settlements. Community forestry management approaches are based on the improvement of natural woodlands and planted communal woodlots that are under the communal land tenure system. These are lands that have been exposed increasingly to land degradation from overgrazing, opening of new lands to expand cropping, and overharvesting of natural fauna and flora to meet low-resource household needs. Thus, by handing over management responsibilities to the local communities, more sustainable utilization is practised. In recent years, large-scale commercial plantations have attempted to develop linkages with communities through outgrower schemes as well as by offering a variety of services and products.

In the past, there were traditional methods of managing natural resources in a sustainable manner. For example, traditional chiefs regulated harvesting of forest products and protected species threatened by extinction. Local beliefs also prevented overexploitation of certain species. Many of the traditional methods of managing resources collapsed after the control over land changed, owing to instability, civil war, resettlement and different legislation after independence.

Communities have realized the impacts of excessive harvesting of forest resources in their communal areas. Some communities have banned any form of tree cutting without consulting the local authorities. Others have introduced bans that prevent people coming from outside the community to collect any wood from their forests. Others collect levies on fuelwood traders. These restrictions on forestry resources may reduce depletion of these resources and at the same time promote the use of substitutes.

Community forestry management is a relatively recent concept that was introduced to promote sustainable community-based natural resource management by allowing communities access to wood and non-wood products while also practising conservation measures. Therefore, it is a natural resource management tool that allows sustainable utilization of natural and planted woodlands. Community forestry is generally characterized by complex management systems in terms of land tenure, ownership and user rights, management responsibility, access to the forestry products, and management of conflict between traditional and modern values (FAO, 1999a).

Community or social forestry relates to activities that involve community and individual participation in the planning, execution and management of a variety of social and economic forestry elements. It refers to activities such as farm/homestead tree planting, agroforestry practices, woodlots and the establishment of trees for conservation and preservation of indigenous species, and catchment management. In a wider sense, it also includes commercial outgrower schemes on communal land, and management and use of the natural forests and woodlands within the community boundaries.

Community forestry management approaches differ within the Limpopo River Basin as there is wide biodiversity of the vegetation. The land tenure, population pressure and the conditions and utilization of the forest resources differ among the four countries. In Botswana and Mozambique, community forestry is relatively underdeveloped and is based largely on gathering food, plants, forage, handicrafts materials, medicinal plants, fruits, fibres and wildlife species. Almost all rural dwellers, and a large proportion of the urban population, rely on fuelwood for energy.

Agroforestry

Agroforestry refers to a mixed land use where trees, crops and livestock are integrated in space and/or time. It has the advantage of providing better microclimate conditions for crop growth and supplements the soil with additional nutrients from leaves and roots. Trees with palatable foliage provide livestock fodder. Agroforestry systems also provide households with wood products, especially fuelwood and building materials, as well as non-wood products including fruit (Box 20).

Planted agroforestry is not practised much in the basin as the climate is not very favourable, especially in the tree establishment phase. Therefore, agroforestry appears to have limited potential in the semi-arid areas, although it performs slightly better in the more humid areas along the escarpment parts of Zimbabwe and in Mozambique. Natural agroforestry practices, based on improved natural woodlands management, have high potential in the basin.

Agroforestry systems comprise different combinations of trees, crops and livestock. Systems include woodlots, trees in cropland, boundary plantings and homestead plantings. Communal forestry is considered a component of agroforestry. Of prime importance is the selection of suitable tree species to interface with crops in a way that ensures complementary advantages, such as improved soil nutrients without creating undue moisture competition. Therefore, of crucial concern in the promotion of agroforestry in the basin is the

BOX 20

Agroforestry in Zimbabwe

Integration of trees into crop and livestock production systems has always played an important role in the smallholder farming sector in Zimbabwe. Traditionally, farmers deliberately left trees growing in their crop fields, albeit at low rates, for the provision of products and services including: shade, leaf litter, windbreaks, fruits, and livestock feed. Furthermore, rural communities have relied on trees as a means of survival in very dry years because they are resilient. However, agroforestry was discouraged in favour of monocropping during the colonial period.

A survey of tree planting practices in the smallholder-farming sector of Zimbabwe carried out by the Forestry Commission established the following:

- Tree cultivation is more prevalent in the higher rainfall areas and is dominated by exotics and fruit trees. Species planted in the drier areas include: paw paw, mulberry, lemon, peach, guava, marula, syringa berry, snot apple, rubber hedge, and cockwood. Their major uses were reportedly provision of fruit, poles, fuelwood and live fencing. The potential contribution of trees to crop production through soil fertility was not mentioned explicitly by farmers during the study.
- Areas around the homestead, the garden and field boundaries were very popular for tree cultivation in the study districts. The homestead and the garden were the most popular sites for planting fruit trees and live fencing (rubber hedge and cockwood). Trees for poles and fuelwood (syringa berry) were established on contours and on field boundaries. The fact that individual households control the areas planted to trees confirms the view that tree cultivation is more successful in situations where benefits can be internalized at the household level, as this provides incentives for better tree management and protection.
- Major constraints on tree cultivation include lack of protection against livestock, termite damage and persistent droughts.

Source: Shumba, Mushaka and Muchichwa (1998).

selection of tree species that are suitable for dry conditions and are compatible with typical farming systems. Most of the exotic species growing in the humid areas are not suitable. The selection of tree species should also reflect community needs (FAO, 1995b).

Urban and peri-urban forestry are related to community or social forestry as the responsibility for the planning and management of single trees, forests and parks is shared with the urban authorities. Urban forestry has scope for development in the basin

Other land use systems and activities

In addition to livestock production, crops and forestry, other activities and land uses in the Limpopo River Basin comprise:

- wildlife utilization (mostly hunting, with some tourism (Box 21);
- gathering of veldt products (for fuel, construction, food and medicines);
- craft such as woodcarving, beadwork, pottery and basketwork for sale to tourists and local markets;
- agri-/rural tourism initiatives whereby tourists come and experience the rural way of life;

BOX 21

Making the most of wildlife resources – the CAMPFIRE programme in Zimbabwe

Vast tracts of land that dominate the Limpopo River Basin provide habitats for a wide range of wild animals. Wildlife has become an important land use option in the area, and activities such as safari hunting and ecotourism are a source of revenue for the local communities. Game farming (hunting) and ecotourism (paying tourists) are well suited to the basin. South Africa and Zimbabwe have thousands of hectares under these two production systems. Zimbabwe's largest national park, the Gonarezhou, and the Kruger National Park and other game reserves (e.g. Pilanesburg and Madikwe) maintain large herds of elephants, lions, buffaloes, and other wildlife.

The Communal Area Management Programme for Indigenous Resources (CAMPFIRE) was introduced in Zimbabwe in order to assist local communities in profiting from and conserving these valuable resources. CAMPFIRE was established by a parliamentary act of 1987, allowing communities to benefit from wildlife resources within their boundaries. Communities benefit directly from income derived from animals hunted for trophy or income earned from tourism-related activities. Wildlife utilization quotas set by the Department of National Parks are marketed by district councils, and the revenue generated is passed on to the communities.

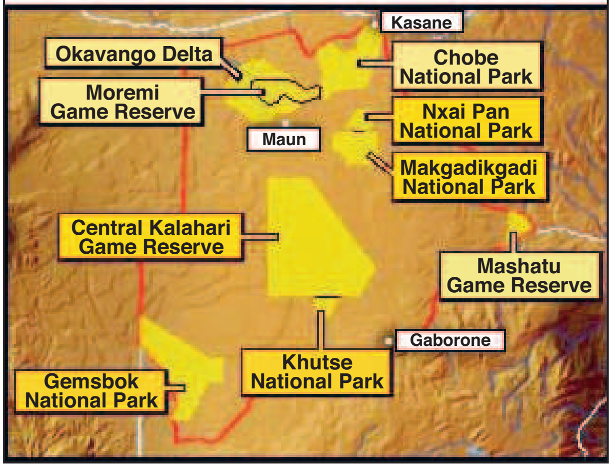
Communities living on the fringes of national parks have the greatest endowment of wildlife and, therefore, greater potential revenue earnings from CAMPFIRE. The establishment of private wildlife estates on former commercial ranches, e.g. the Save Valley Conservancy and Malilangwe Trust, has also contributed to an increase in wildlife population in the area. The harsh climate conditions in the Limpopo River Basin have kept the human population density low, thus favouring wildlife. In the basin, successful CAMPFIRE projects have been established in the districts of Chipinge, Beitbridge and Chiredzi.

The majority of CAMPFIRE funds are generated through trophy hunting. The use of CAMPFIRE funds are determined by communities in accordance with their needs, such as the construction of clinics, schools, roads and boreholes, and to develop community income generating projects, such as grinding mills and garden projects. In some districts, revenue is used to compensate for crop and livestock losses caused by wildlife. In times of drought, people may opt for cash and seed packs to offset drought impacts.

It has been argued that revenue from CAMPFIRE may be an incentive to reduce livestock population in the dry and fragile environments. However, this has not happened, even in the most successful projects, as the revenue from CAMPFIRE is usually too small to substitute benefits from livestock ownership. Nonetheless, CAMPFIRE has been very successful and improved community ownership of natural resources and interest in conservation, as well as providing alternative sources of income. A similar approach to CAMPFIRE could be adopted in other communal lands surrounding existing game reserves within the Limpopo River Basin and other similar environments.

Source: Murombedzi (1992); Makombe (1993).

FIGURE 38
Nature conservation areas of Botswana



Source: GOB (2001).

- broiler and layer production;
- rearing of rabbits for meat and mohair;
- fish farming;
- feedlotting of cattle;
- maize milling by entrepreneurs;
- mechanical contractors for land preparation, harvesting and transport services.

Conservation areas

Figure 38 show the conservation areas of Botswana. Only the Mashatu game reserve and a small southwestern portion of the Central Kalahari Game reserve are situated in the basin (see also Figure 5). In the South African part, a number of small nature reserves are located, including Madikwe, Pilanesberg, Magaliesberg. Most of the Kruger National Park is situated in the basin.

Other nature conservation areas that occupy part of the basin include the planned Gaza-Kruger-Gonarezhou Transfrontier Park (GKG Transfrontier Park). Establishment of this park (Figure 39) is aimed at supporting the broad political goals of socio-economic improvement in southern Africa, where rural areas are subject to chronic high unemployment and low income. It is also intended to enhance ecosystem management in the region.

This vision of cross-border collaboration would also give effect to the stated objectives of the SADC, which aims at synergistic regional initiatives for economic, social and conservation benefits for the subcontinent.

The area known as Coutada 16 in Mozambique will be integrated with the Kruger National Park in South Africa, with further integration across the Sengwe Communal Lands to join up with Gonarezhou National Park in Zimbabwe.

FIGURE 39
Planned Gaza–Kruger–Gonarezhou Transfrontier Park

Source: GOSA–DEAT (2001).

With its 35 000 km², this GKG Transfrontier Park will form the core of a broader GKG Transfrontier Conservation Area (GKG TFCA). This larger area around the GKG Transfrontier Park will represent land that has different forms of conservation status (including national parks, private game reserves, hunting concession areas, and community managed natural resource areas), but which cannot be integrated meaningfully into the core Transfrontier Park because of extensive intervening human settlements or other barriers. The area made up by this greater GKG TFCA, including the GKG Transfrontier Park, comes to 99 800 km² (GOSA–DEAT, 2001).

RELEVANT DROUGHT AND WATER POLICIES AND STRATEGIES

Drought policies and strategies

Policies and strategies provide the framework and guidance to support the implementation of best management practices and suitable interventions. For several years, the countries of the Limpopo River Basin (and all of the SADC) have been striving to find appropriate policies and strategies to address drought-related issues. This section provides an overview of some of the drought-related strategies, legislation and policies relevant in the four countries of the Limpopo River Basin, as well as the more general policy and strategy developments within the SADC. Although the focus is on drought and water policies, it is recognized that many national and regional policies have drought-related components, such as agriculture, livestock, land, natural resources, rural development, and poverty alleviation.

A complete review of the many drought-related policies and strategies cannot be realized within the limits of this situation analysis. Furthermore, it is recognized that there are many ministries and projects ongoing that address various aspects of drought that are not presented in this report. It is important to establish the linkages with these other policies and strategies in order to facilitate risk reduction and reduce the impacts of drought and climate variability. These other policies interface with national disaster and/or drought policies and plans, and vice versa. For example, the SADC regional policy for livestock recognizes the linkages between the livestock sector and the other priority development sectors, such as human resources development, agricultural research, wildlife–livestock disease interactions, crop–livestock interactions, and industry and trade.

General SADC drought strategies

Since the foundation in 1980 of the Southern African Development Co-ordination Conference (SADCC), the member states have been concerned with food security and the effects of drought. On becoming members of the SADC, each country signed a legally binding treaty through which all member countries agreed to coordinate, harmonize and rationalize their policies and strategies for sustainable development in all areas. The SADC now consists of 14 countries, including the four countries that form part of the Limpopo River Basin.

In November 1997, the SADC FSTAU organized a high-level drought policy seminar in Botswana, in response to the threat of a serious regional drought following a strong El Niño phenomenon. The report on this seminar recognized that drought in southern Africa is a normal and recurring event, and it called for long-term action in:

- investment in soil and water management, such as the improved development and management of fragile catchment areas and river basins, including small-scale irrigation;
- reviewing the appropriateness of current crop production patterns and possibilities in support of more intensified crop diversification policies;
- redirecting research towards more appropriate farming systems;
- improved rangeland and livestock management;
- reviewing institutional arrangements and physical infrastructure.

For a long time, the emphasis of drought strategies in the region has been on short-term mitigation measures rather than on long-term prevention programmes. In recent years, new policies have been emerging in which preparedness, rehabilitation, prevention and planning are the key elements. Current drought management strategies are attempting to treat drought as a potentially serious disaster, and to integrate it into programme management cycles aimed at mitigation and prevention.

Along with the acceptance that drought is a normal and recurrent phenomenon, new policies tend to transfer the responsibility for dealing with the impacts of drought more onto the farmer or the user of the land. New strategies are designed to ensure that drought relief assistance and programmes to support farmers are consistent with existing livelihood strategies and market development policies. This may require redefining drought relief programmes, for example, designing market-based approaches using vouchers or cash to replace food and farm input handouts as a means of ensuring food security without distorting the market (SADC, 1999). Compatibility between short-term and long-term development is an important element in the new policies, in which alternative ways of supporting farmers are recommended that will reduce their vulnerability to drought in the longer term. Long-term development programmes should be better integrated into drought relief measures, e.g. infrastructure projects, such as the building of roads, dams and other utilities. These may be accelerated during drought in the form of food or cash for work programmes.

Most SADC countries are developing explicit legal frameworks for drought management, treating drought as a recurrent phenomenon that should be included in the normal planning process of development. The countries have also recognized the need to coordinate actions on regional issues that are common to them, such as water. However, many of these policies and legal frameworks are fragmented, and implementation plans and decision-making levels are often not well defined. Most countries have high-level institutions to provide a framework for coordination and implementation. New policies tend to promote the creation of new independent drought institutions and funds, which are yet to be established. There seems to be some contradiction between the efforts of further institutionalization of drought and the newly accepted principle of increased farmer responsibility to cope with drought.

Relevant strategic progress achieved by the SADC countries includes the following areas:

- recognition that drought impact risk-reduction can be managed within the scope of long-term development planning;
- emphasis on drought policy formulation;
- highly placed functional implementation and coordination structures;
- active early-warning systems;
- special programmes launched to support specific interventions at regional level;
- implications for agricultural and general land use planning policies;
- changes in general policies as a direct result of new drought policy.

The SADC (1999) has stated that reducing long-term vulnerability to drought will require a fundamental shift in government approaches, especially towards a multidisciplinary approach in:

- promotion of drought-mitigating technologies and practices;
- poverty alleviation;
- creation of an enabling policy environment;
- adequate planning.

Progress in technology development has been limited. Practices relating to water use, food and nutrition, seed production, energy production, etc., need drastic improvement in order to enhance efficiency and reduce vulnerability to drought. Although considerable progress has been achieved in poverty alleviation and policy development, there is still a lack of government capacity to achieve these goals. For example, policies that need refinement to create an enabling environment include those that support sustainable management of natural resources including land and water (SADC, 1999).

Some of the most relevant objectives related to institutional arrangements discussed in the SADC strategy are:

- build human capacity for designing and implementing drought policies and programmes, with regional support to national governments;
- promote contingency planning for drought;
- develop data banks on early-warning food security and market information;
- promote technology development and transfer;
- strengthen management of resources.

Earlier strategy formulations have already recognized most of these objectives. The new SADC policy does not offer many practical suggestions on how other overall objectives related to drought prevention could be achieved. There is an objective related to management of water resources, but none to land resources. However, conditions during drought may have a serious impact on land through erosion and land degradation.

Enhanced management of existing water resources includes activities such as dam building, borehole construction, promotion of more efficient irrigation systems, pollution control, revision of water rights, and promotion of water harvesting. These recommended activities are all valuable, but the most fundamental issue in drought areas is the assessment of the potential for water development, which is not addressed.

Drought management strategies in Botswana

Manamela (1997) provides an overview of drought management in Botswana, which has evolved over time on the basis of much experience. However, no single policy document has been produced to consolidate this experience apart from the 1980 strategy document and to a lesser extent a 1991 white paper. The main thrust of current government policy is to include drought management in the normal planning and development process. This implies that the non-emergency aspects of drought form an important part of regular development programmes and that in emergency areas government can use existing projects, programmes and budgets to respond to the situation, albeit in an expanded and accelerated way. As such, no special structures need be created in the event of a drought.

Drought strategies in Botswana can be divided into two distinct categories: short-term drought relief programmes, and long-term drought mitigation strategies. Drought relief programmes in Botswana have been essentially short-term operations and programmes, with action taken immediately after a drought. Drought mitigation programmes are intended to help build up an overall national resilience to drought through broader national development strategies, with special attention to the rural areas.

Major objectives of the drought relief programmes have been to:

- prevent human mortality through:
  - averting deterioration in nutritional status of particularly vulnerable groups,
  - setting up emergency water supplies for human survival,
  - using labour-based work programmes to compensate households for income lost;
- protect endangered rural household productive assets required to generate household and self-sustenance (e.g. cattle breeding stock and cattle for draught power);
- facilitate rural recovery and post-drought rehabilitation.

Three practical main components related to these overall objectives are:

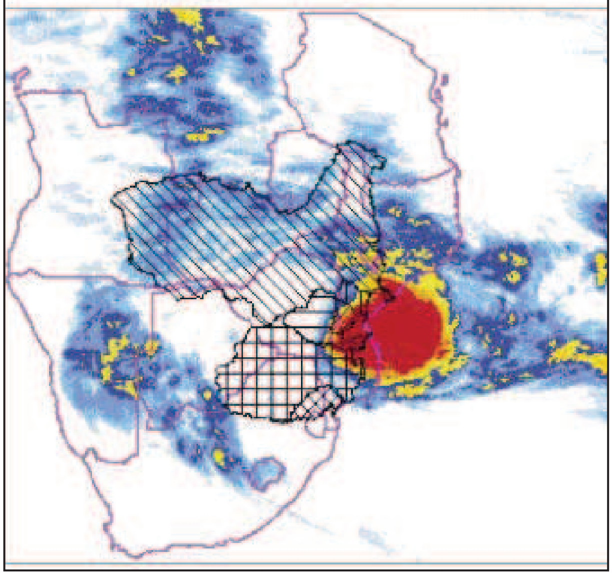
- human relief, which means that in addition to existing and ongoing institutional programmes, human feeding strategies are geared up to include specific targeted populations;
- livestock relief, which includes the provision of free vaccinations in certain drought-related conditions, an expanded livestock water development programme, the facilitation of supplies of livestock feeds and requisites, and, where feasible, incentives for an increased livestock offtake;
- arable assistance packages, which include the provision of free seeds, ploughing services, and row-planting grants.

The Botswana National Development Plan stresses the role of natural resources for present and future generations (GOB–MFDP, 1997). It envisages sustainability as a strategic concept that links populations, economy and natural resources together in the context of long-term socio-economic development. Economic diversification is seen to be a major strategy element in drought mitigation. The National Development Plan states: "The diversification of the rural economy, the expansion of non-farm employment opportunities in rural areas, and improvements in agricultural efficiency, especially for smallholders, will reduce the vulnerability of the rural areas to drought."

Disaster management strategies in Mozambique

Mozambique has had ample experience dealing with the detrimental effects of various natural disasters such as floods and droughts (Figure 40). The government created the Department for the Prevention and Response to Natural Disasters (DPCCN) in 1980 to take responsibility for providing humanitarian assistance and overall coordination in disaster response (Manjate, 1997). The DPCCN worked closely with provincial and local government structures, as well as donors and NGOs.

FIGURE 40
Cyclone Eline (February 2000) – an example of the information available to national disaster management committees



The overall approach to disaster management in Mozambique has recently been reviewed (although the demands of responding to the devastating floods of 2000 and 2001 distracted from major institutional changes). The DPCCN was restructured and renamed the National Disaster Management Institute (INGC) in 1999. The INGC was also scaled down to emphasize its role in planning and coordinating emergency prevention and response, rather than the actual operational logistics of distributing aid (FAO, 1998b). There is also a National Council for Disaster Management, comprised of higher-level ministerial staff from pertinent ministries. Although the government has acknowledged that the impacts of and response to disasters such as drought are related to the overall development of the country, there is no formal drought policy as yet. However, the formal policy guiding institutional arrangements for disaster management, including drought and the relationship with other national policies, is under review.

Drought management strategies in South Africa

In the 1990s, South Africa implemented major changes in policy related to agriculture, land use and drought. During the 1992 drought, a large number of NGOs and government departments launched the National Consultative Forum on Drought (NCFD) to coordinate a response to the drought crisis in the country. This initiative represented the broadest grouping of forces in the history of drought response in the country (AFRA, 1993). The objective of the NCFD was to ensure that relief reached the worst affected sectors and to promote the cause of the rural poor.

A new approach to disaster management was adopted in a white paper on disaster management (GOSA–MPACD, 1999) and the ensuing Disaster Management Act (Act 57 of 2002). Unlike previous policies that focused mainly on relief and recovery efforts, this act highlights the importance of preventing human, economic and property losses, and avoiding environmental degradation. This new approach aims to:

- create an environment for effective disaster management;
- promote proactive disaster management through risk reduction programmes;
- improve the ability to manage disasters and their consequences;
- promote integrated and coordinated disaster management through partnerships with stakeholders and cooperative relations between government departments;
- ensure adequate financial arrangements;
- promote disaster management training and community awareness.

The act is administered by the Department of Provincial and Local Government. It prescribes the establishment of disaster management structures at national, provincial and municipal levels. At the national level, these include: an intergovernmental committee on disaster management, a national disaster management advisory forum, a national disaster management framework, and a national disaster management centre. The duties of the latter include: communication with role players, establishing a disaster management information system, and the development of disaster management plans and strategies. At the provincial level, disaster management structures include the following (per province): a provincial disaster management advisory forum; a disaster management centre; a provincial disaster management framework; and provincial disaster management plans. Equivalent structures are to be established in each metropolitan and district municipality.

The responsibility for developing a national drought management strategy to slot into the national disaster management plan was assigned to the Department of Agriculture. A draft agriculture disaster management plan (GOSA–DOA, 2003a) and a drought management strategy (GOSA–DOA, 2003b) followed. The following priority areas and programmes were proposed for addressing drought and drought management:

- increased awareness and preparedness by way of a national drought plan;
- reduction of risk to droughts through appropriate research plans;
- establishment of mitigation plans;
- recovery and development programmes – post-drought;
- implementation of education, training and information plans;
- risk management, with a strong emphasis on an insurance-based solution, which can be applicable to the agriculture sector as a whole.

In order to fulfil its role and responsibilities, the Department of Agriculture established the Directorate of Agricultural Risk and Disaster Management consisting of three subdirectorates: one for information, policy and implementation; one for early warning; and one for post-disaster recovery and rehabilitation.

The following measures are in place or are in the process of establishment:

- an agricultural insurance bill, aimed at providing a system of agricultural insurance in order to: improve the economic stability of agriculture, enhance the income of those farmers and producers most vulnerable to losses of agricultural crops and livestock from natural disasters, provide financial assistance, and control certain activities of agricultural insurers and intermediaries.
- approaches for an integrated risk management system for identifying, reducing and managing risk, whether natural or human-induced.

Drought management strategies in Zimbabwe

Throughout the recent drought periods in Zimbabwe, the response by the Government of Zimbabwe (GOZ), local communities and authorities, as well as donors, has focused on short-term emergency response. Most local government authorities lacked the capacity to react to these disasters, let alone prepare for them in an effort to mitigate the possible impact of drought. The GOZ realized the need to develop appropriate action plans to counter both the short-term and long-term effects of drought, to develop institutional capacity, and to invest more resources in order to meet the needs of the most vulnerable population groups.

To address these issues, the GOZ developed the National Policy on Drought Management (NPDM), which was formulated in 1998 and approved in 1999 (GOZ–NEPC, 1999). The policy document discusses general drought management issues and reviews government capacities and structures to deal with drought preparedness, mitigation and response issues. Special emphasis was placed on developing sustainable livelihoods for those populations most at risk to drought-induced shocks. The policy states that these activities should be integrated with other developmental programmes and projects and that they should form an integral part of all district-, provincial- and national-level development policy and planning processes.

The NPDM emphasizes long-term drought mitigation measures, such as the harvesting and efficient utilization of water, increased agricultural productivity in both commercial and communal areas, land use planning and proper management of national resources and the environment. This paradigm emphasizes forward planning, preparedness, prevention, mitigation response, recovery and rehabilitation. The policy is designed to facilitate the sharing of risk between government and farmers, while building the capacity of individuals and communities at household level to plan and undertake activities that utilize household resources efficiently and effectively. Livelihood sustainability is premised on a balance between economically efficient and ecologically sound options for households to make a living and cope with the short- and long-term impacts of drought.

In order to achieve these objectives, the NPDM will be operationalized through a number of strategies including:

- facilitating sustainable management of natural resources;
- encouraging: crop production only in those areas that are climatically and topographically suitable for particular crops, proper mechanical and biological precautions versus soil loss, good land use practices through educational awareness campaign, and research into promotion of drought-tolerant food crops;
- ensuring correct stocking rates of domestic livestock and establishment of grazing schemes;
- supporting current policies and programmes on reforestation;
- ensuring and enforcing correct protection and management of water catchment areas, construction of more dams, and sustainable exploitation of underground water;
- accelerating rural industrialization;
- promotion of small-scale enterprises;
- reducing land pressure through resettlement and proper land use practices;
- introducing appropriate water resources management and irrigation development schemes.

Zimbabwe's agriculture policy also recognizes that the country is susceptible to recurrent droughts. The Ministries of Lands and Agriculture, Public Service Labour and Social Welfare and Local Government coordinate the development of policies and strategies to minimize the effects of drought. The thrust of the government's agriculture policy is to reduce the current emphasis on the provision of food aid in favour of a broad approach involving the development of sound strategies and schemes that help families to cope with the effects of drought. The strategy involves an improvement in water availability through the expansion of irrigation schemes, water harnessing by construction of dams, and the equitable distribution of water for irrigation. The policy also highlights the need for intensive research on improving the tolerance of staple food crops to drought and diseases.

Water policies and strategies in the SADC region

General SADC water policies

In the past decade, SADC has been in the process of developing a regional water policy and strategy as well as harmonizing national policies and legislation related to water management. In the SADC region, water is an important transboundary issue and will require well-coordinated efforts between the various countries to manage the water resources properly. SADC has realized the need for integrated water resources development and management in the region in order to combat issues such as drought, floods, and food security.

In view of the above, SADC established the

SADC Water Sector Coordinating Unit (SADC–WSCU) in 1996. The overall responsibility and day-to-day coordination of activities was entrusted to the Government of the Kingdom of Lesotho, within the Ministry of Natural Resources. The vision of the SADC–WSCU was: "to attain the sustainable, integrated planning, the development, utilization and management of water resources that contribute to the attainment of SADC's overall objectives of an integrated regional economy on the basis of balance, equity and mutual benefit for all member States."

In pursuit of the above vision, the SADC member countries have developed a legal framework in the form of the SADC Protocol on Shared Watercourses that should be applied to all water related developments and management (SADC–WSCU, 1995). Eleven member states signed this protocol in August 1995 and it came into force in 1998 after ratification by the required two-thirds majority of the SADC member states. Recently, the SADC–WSCU has amended this protocol, now called Shared Watercourse Systems Ptrotocols, in order to incorporate the current developments in international law and to align them with other accepted international legal instruments (SADC–WSCU, 2001). One example is the United Nations Convention on the Law of the Non-navigational Uses of International Watercourses, adopted by the UN General Assembly in April 1997.

In 1997, with the assistance of the UNDP, the SADC–WSCU embarked on the development of a regional strategic action plan (RSAP) on integrated water resources development and management (SADC–WSCU, 1998). This action plan represents a five-year (1999–2004) programme framework and contains 31 prioritized project concepts. These projects were presented to the Cooperating Partners at the Geneva Round Table Conference in December 1998. The plan and various donors selected individual projects for support. The final 31 project concept notes (PCNs) addressed eight major issues: legal and regulatory framework; institutional strengthening; sustainable development policies; information acquisition, management and dissemination; education and training; awareness building; public participation; and infrastructure. In relation to these major issues, the RSAP aims to harmonize policy, legislation and management of water sources in general and transboundary water sources in particular in the region.

The establishment of the SADC–WSCU and development of the Shared Watercourse Systems Protocol represent important strides towards realizing the importance of water in the region in achieving the strategic and development objective of the SADC of poverty alleviation, food security and industrial development. SADC member countries hope to achieve these goals through the implementation of the above initiatives. Many of these initiatives will have a direct impact on the management of the Limpopo River Basin or they mention explicitly the Limpopo River Basin as the project or pilot area (Box 22).

The cooperation between the countries regarding water resources has developed to reflect specific countries' demands. For example, in 1983, Botswana and South Africa had already established a joint permanent technical committee to deal with water matters of interest to these two countries. A joint permanent technical commission replaced this in 1989, followed by a water commission in November 1995 (Pallett, 1997). It was noted that a commission has more legal power than a committee, which explains the effort to establish commissions. Other examples of multinational water agreements are:

- Establishment of a tripartite permanent technical committee to manage the Incomati, Limpopo and Maputo River Basins, agreed upon by Mozambique, South Africa and Swaziland in 1983.
- Limpopo Basin Permanent Technical Committee (LBPTC) established in Harare in 1986 by Botswana, Mozambique, South Africa and Zimbabwe.
- Agreement between Mozambique and South Africa concluded in 1996, and known as the South Africa/Mozambique Joint Water Commission Agreement.
- Limpopo Hydrometric Study (1996) approved by the LBPTC on 14 August 1995.
- Establishment of a Limpopo Basin Commission (LIMCOM) is under consideration to elevate the status of the LBPTC of 1986 to that of a permanent commission.

Botswana

The Director of Water Affairs is the registrar of the Water Apportionment Board, provides the secretariat and acts as technical advisor to the board. The Water Act and the Borehole Act, administered by the board, require individuals or groups to apply for a right to use irrigation water. Responsibility for planning and implementation of

BOX 22

Selected project concept notes from the SADC–WSCU Shared Watercourse Systems Protocol

PCN 8: SUPPORT FOR THE IMPLEMENTATION PROGRAMME FOR THE SADC PROTOCOL ON SHARED WATERCOURSE SYSTEMS

Generic replicable methodologies will be tested on pilot river basins, of which one is the Limpopo River Basin. Among others, the Limpopo Technical Committee is to be involved. USAID and the Gesellschaft für Technische Zusammenarbeit (GTZ) are the donors giving the support to piloting in the Limpopo River Basin. Currently, the Terms of Reference for the implementation of the Protocol and the River Basin Management Approach on the Limpopo are being prepared.

PCN 10: SUPPORT DEVELOPMENT OF NATIONAL WATER SECTOR POLICIES/ STRATEGIES IN SELECTED MEMBER COUNTRIES

In this project USAID will collaborate with FAO and UNEP to support policy review processes in selected countries i.e. the Limpopo River Basin riparian States.

PCN 6: GROUNDWATER MANAGEMENT PROGRAMME FOR THE SADC REGION

The Limpopo River Basin has been selected as one pilot area. One of the outputs will be an assessment report of the Limpopo/Save Basin aquifer. Initial elaboration of this PCN was done in 1998 with support from UNEP. The French Cooperation is spearheading the implementation of the whole programme through the Technical Assistance (TA) at WSCU.

Additionally, the two regional projects below will have long-term implications on the Limpopo River Basin:

PCN 1: GUIDELINES FOR REVIEW AND FORMULATION OF NATIONAL WATER LEGISLATION

The project rationale is that much of the negotiation over shared water resources will depend on the development of compatible policy and legislative frameworks at national level together with the requisite institutional capacity. These frameworks and capacities are essential if each country is to negotiate shared water resources from equal positions.

The purpose of the GEF grant will be to support the development of domestic water resources legislation of SADC member countries and on its administration. Thus, facilitating meaningful negotiations on and implementation of treaty obligations concerning, the management, development and conservation of the water resources of rivers, lakes and underground aquifers the SADC member countries share with one another or with each other across their international boundary lines. FAO is the leading Cooperating partner with support from GEF.

PCN 11: FORMULATION OF REGIONAL WATER SECTOR POLICY AND STRATEGY

The long-term objective with this initiative is to formulate a Regional Integrated Water Resources Development and Management Policy and Strategy for the SADC Region. The expected project outputs are as follows:

- Regional Water Sector Policy and Strategy formulated and approved by the SADC Water Sector Committee of Ministers and the SADC Council of Ministers.
- The Regional Water Sector Policy and Strategy is being implemented and respected by SADC member States as a framework to guide cooperation in water resources and management in the SADC region.
- A consultative process for soliciting stakeholders' views on the long-term Water Sector Policy and Strategy is functioning effectively.

irrigation development rests with the Ministry of Agriculture.

Botswana accepts that food self-sufficiency is neither achievable nor sustainable. Therefore, its objectives are to improve food security at both household and national levels by giving top priority to production systems and programmes that are sustainable, efficient in resources and environmentally compatible. Any proposed irrigation project must be economically viable and sustainable. Botswana faces a substantial shortfall in water supplies (Box 23) as competing uses and

BOX 23

Botswana's vulnerability to water problems

The 1997 UN Comprehensive Freshwater Assessment showed that southern Africa is one of the most vulnerable regions for water-related problems. The water resources problem is seen as a potential limit to development and a stress on population and economic growth. The assessment classified the water resources of Botswana and Namibia as stressed and moving towards being very vulnerable by 2025.

While national-level data show Botswana withdrawing only 4 percent of its available water, the 1992 National Water Master Plan of Botswana predicted that the capital, Gaborone, will run out of water within the next 10 years based on current supplies and population forecasts. Gaborone, expected to be one of the main centres of growth of the SADC region into the twenty-first century, receives its water supply primarily from surface water sources. In fact, groundwater is considered a non-renewable resource because of the very low recharge rates, and will only be used in cases of emergency to augment existing surface water supplies in Gaborone.

Source: IIASA (1998).

consequent high opportunity cost of water makes irrigation uneconomic. Therefore, any further large-scale irrigation is doubtful (GOB, 1992a).

Mozambique

The Water Law of 1991 defines the institutional and legal framework for the licensing and allocation of water concessions (Box 24). Under this law, the National Water Council provides intersector coordination and strategic decision-making (GOM, 1991).

The government programme for 1994–99 had as its main objective the reconstruction of the national social and economic structure. In this context, a national water policy was published in 1995 (GOM–DNA 1995) and included the following salient aspects:

- The satisfaction of basic needs is a high priority and will require increased water supply and sanitation, in particular to rural, low-income groups.
- Water is regarded as having an economic as well as a social value. For services to be financially viable, the price of water should reflect its economic value, eventually covering the cost of supply.
- The operational water resources management will be decentralized to autonomous catchment authorities. The provision of water supply and

BOX 24

Institutions involved in water and irrigation development in Mozambique

The National Water Council was created in 1991. It coordinated the four ministries involved in water development: the Ministry of Agriculture, the Ministry of Energy, the Ministry of Industry, and the Ministry of Construction and Water (which chaired the council). The council's main function was to develop a national water management policy, and to monitor its execution.

The National Water Directorate (DNA) is one of the four directorates of the Ministry of Construction and Water. Its objectives are to ensure the proper utilization of groundwater and surface water resources.

The recently created Regional Water Administrations or Administraçaoes regional de agues (ARAs), which are basin authorities responsible for water development and management, have administrative and financial autonomy but report to the DNA. The ARAs are also in charge of collecting hydrological information. The only ARA created by the end of 1994 was ARA-sul, in charge of the southern part of the country up to the Save River, where most problems of water management exist.

The Secretariat of State of Agricultural Hydraulics (SEHA), under the Ministry of Agriculture, is the coordinating authority for activities relating to irrigation and drainage. Inside the SEHA, a programme has been created specifically for small-scale irrigation (Programa nacional de irrigacao de pequena escala).

Source: GOM (1991).

sanitation services should be decentralized to autonomous local agencies. These should become financially self-sufficient.
- The allocation of bulk raw water through integrated river basin management should optimize benefits to the community, balancing the interests of both present and future users. It should take into account environmental impacts, and conserve water resources for the future.
- The investment policy will balance economic development with poverty alleviation. Principal investments should be aimed at conserving the existing infrastructures and reducing water losses.
- The government will promote private sector participation. Conditions should be created for the attraction of private investment.
- Prime objectives will be the provision of basic water supply needs to low-income groups in peri-urban areas and the provision of basic water supply needs to low income groups in rural areas. Special attention will also be given to the rehabilitation of small water supply systems of urbanized centres in the rural areas as part of the process of reactivating social and economic infrastructures and activities such as hospitals, schools and commerce.

BOX 25

South Africa's water sector reform documents

- Water Supply and Sanitation Policy White Paper, November 1994.
- Fundamental Principles and Objectives for a New Water Law in South Africa.
- White Paper on the National Sanitation Policy, July 1996.
- White Paper on Water Policy, April 1997.
- Water Services Bill, published in the Government Gazette, May 1997.
- National Water Bill, September 1997.
- Water Services Act (Act 108 of 1997).
- Drought policy – water issues, June 1997.
- National Water Act (Act 36 of 1998), August 1998.
- Drought and Agricultural Disaster Policy Development.
- National Water Resource Strategy, August 2002.

South Africa

The water sector in South Africa was completely reformed following the elections in 1994. The reform process led to a series of documents and principles to guide the water management and development of South Africa. These principles guided the intensive programme of work involving the minister and other political leaders, officials from the Department of Water Affairs and Forestry (DWAF) and other government departments, organized user groups and South Africans in a process of consultation, research and synthesis. One of the results has been a new national water act, which was approved in 1998, as well as progress to integrating these concepts with other policies, such as drought, disaster and agriculture (Box 25).

White Paper on Water Policy of 1997

The White Paper on Water Policy was the product of two years of hard work and wide consultation and it represented the policy of the Government of South Africa, as approved by Cabinet on 30 April 1997. The White Paper forms an important part of the review and reform of the Water Law in South Africa, and many of these proposals are relevant to water sector reform beyond South Africa. Some of the key proposals are:

- The national government will act as the custodian of the nation's water resources and its powers in this regard will be exercised as a public trust.
- All water in the water cycle whether on land, underground or in surface channels, falling on, flowing through or infiltrating between such systems, will be treated as part of the common resource.
- Only that water that is required to meet basic human needs and maintain environmental sustainability will be guaranteed as a right. This will be known as the Reserve.
- In shared river basins, government will be empowered to give priority over other uses to ensure that the legitimate requirements of neighbouring countries can be met.
- All other water uses will be recognized only if they are beneficial in the public interest. These other water uses will be subject to a system of allocation that promotes use that is optimal for the achievement of equitable and sustainable economic and social development.

- The system of allocation will use water pricing, limited-term allocations and other administrative mechanisms in order to bring supply and demand into balance in a manner that is beneficial in the public interest.
- All water use, wherever in the water cycle it occurs, will be subject to a catchment management charge.
- All water use, wherever in the water cycle it occurs, will be subject to a resource conservation charge where there are competing beneficial uses or where such use significantly affects other users.
- The use of rivers and other water resources to dispose of wastes will also be made subject to a catchment management charge.
- The riparian system of allocation, in which the right to use water is tied to the ownership of land along rivers, will effectively be abolished.
- Water use allocations will no longer be permanent, but will be given for a reasonable period.
- In order to promote the efficient use of water, the policy will be to charge users for the full financial costs of providing access to water, including infrastructure development and catchment management activities.
- In order to promote equitable access to water for disadvantaged groups for productive purposes such as agriculture, some or all of these charges may be waived for a determined period where this is necessary for them to be able to begin to use the resource.
- In order to promote equitable access to water for basic human needs, provision will also be made for some or all of these charges to be waived.
- All major water user sectors must develop a water use, conservation and protection policy, and regulations will be introduced to ensure compliance with the policy in key areas.
- In the long term, as water does not recognize political boundaries whether national or international, its management will be carried out in regional or catchment water management areas.
- Provision will be made for the phased establishment of catchment management agencies, subject to national authority, to undertake water resource management in these water management areas.

Some of these proposals will probably pose a challenge to large water users. However, the White Paper states that the objective of the policy is not solely to promote equity in access to and benefit from the nation's water resources for all South Africans, but to make sure that the needs and challenges of South Africa in the twenty-first century can be addressed. Similarly, both the farming and the mining industry will probably have to re-evaluate their use of and impact on the water resources, and will have to pay a price for water that reflects the real economic cost, including the indirect costs to society and the environment for their water use. Other sectors, particularly the rest of industry, will also come under pressure to clean up their activities. Local governments (and the domestic users they serve) will have to examine the way they use and often waste water. Promoters of the needs of the environment will also have to justify the degree of environmental protection they seek.

National Water Act of 1998

The introductory text of South Africa's National Water Act (Act 36 of 1998) states that its purpose is to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways that take into account, *inter alia*:

- meeting the basic human needs of present and future generations;
- promoting equitable access to water;
- redressing the results of past racial and gender discrimination;
- promoting the efficient, sustainable and beneficial use of water in the public interest;
- facilitating social and economic development;
- providing for growing demand for water use;
- protecting aquatic and associated ecosystems and their biological diversity;
- reducing and preventing pollution and degradation of water resources;
- meeting international obligations;
- promoting dam safety;
- managing floods and droughts.

For achieving this purpose, the act will establish suitable institutions and ensure that they have appropriate community, racial and gender representation.

Zimbabwe

In 1995, the Government of Zimbabwe embarked on a comprehensive programme to reform the water sector. The review included the development of the Water Resources Management Strategy (ongoing), the creation of the Zimbabwe National Water Authority (ZINWA) (GOZ, 1997), the repeal of the Water Act of 1976, and, the development of the new Water Act of 1998 (GOZ, 1998). Zimbabwe chose not to establish a water resources management policy document as such. Instead, the three components were developed simultaneously in order to ensure coherence between the water legislation and the water management strategy. The following documents were produced within the scope of the review:

- Guidelines on equitable and sustainable allocation of water between and among users and uses.
- Guidelines on water demand management and increased water use efficiency in all user sectors.
- Comprehensive water pricing policies and guidelines.
- Guidelines on catchment planning for the optimum development of catchments.
- Guidelines on environmental management for sustainable environmental protection and species preservation to include development of water quality guidelines for pollution control and monitoring.
- Guidelines on how best to involve stakeholders in water resources management.
- Mainstreaming of gender in water resources both spatially and temporary to enable a rapid assessment of availability in the event of a drought or some major development that would require water.
- Quantified interrelationships between people, land and water to provide for an integrated approach to planning for the development and use of water on a sustainable basis.
- Guidelines on economic and financial analysis for determining investment priorities in the water sector and to provide for the participation of the private sector in water resources development.
- New or re-defined legal and institutional frameworks to provide for the management of the resource and the settlement of disputes in the event of conflict at both the local and international level. The legal framework should be congruent with and conform to the international conventions on water as well as the SADC Protocol on Shared Watercourses.

The development of the above documents was completed in a three-year period guided by fundamental principles adopted from several international conventions and declarations (e.g. Dublin Principles and Agenda 21). These principles include:

- Ownership of all surface water and groundwater is vested in the State. Except for primary purposes, any exploitation of water resources requires specific authority from the State. That authority should be given for a given specific economic period.
- Stakeholders should be involved in all important decision-making and management of water resources.
- Water resources should be managed on a catchment basis as rivers defy provincial and district boundaries.
- Development of water resources should be implemented on an environmentally sustainable basis.
- The skewed allocation and distribution of water must be redressed and the access to water by all Zimbabweans improved.
- Water prices should be based on the "user pays and polluter pays" principle and be socially acceptable to the different interest groups in the water sector.
- Water has an economic value in all its competing uses and should be recognized as an economic good. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources. An important corollary is that water authorities should be treated as commercial enterprises.

Zimbabwe National Water Act of 1998

After independence, and with the frequency of droughts experienced in Zimbabwe, many experts and ordinary people alike called for a complete revision of the old Water Act of 1976, most notably, because this act failed to serve the interests of all Zimbabweans and to meet the needs of contemporary society.

One of the major areas of concern was access to water. The allocation of water rights under the Water Act of 1976 was based on the principle of "first come, first served". The water rights were issued in perpetuity as long as they were being used beneficially. This provided an unfair advantage to those rights holders that were in a position to establish the first claim. In areas with water shortages, the act prevented newcomers from obtaining a share of the resource. The skewed distribution of land carried with it the skewed distribution of water as most communal people are settled in the drier parts of the country, such as the Limpopo River Basin. The demand for water rights for agricultural use increased especially after independence. However, the situation became particularly acute during periods of drought.

The Water Act of 1998 introduced a number of new features in the management and use of water resources. Its essential features include:

- The vesting of all water in the President, thus removing the concept of private ownership of water.
- Removing the concept of water rights as being issued in perpetuity, being attached to the land in respect of which they are granted. In place of this, a permit system was introduced, permitting the use of water for a specified period of time, subject to review as circumstances may demand.
- The removal of much of the differentiation in approach between the management of surface water and groundwater.
- The removal of the preferential rights to water held by riparian owners.
- The conferring on catchment councils, set up to manage the use of water in the catchment areas under their jurisdiction, of the power to issue the permits required for certain uses of water. Thus, this function is decentralized and removed from the administrative court, to which appeals may now be made under certain circumstances.
- Ensuring that catchment councils set up to manage river systems are representative of all water users in the area concerned, the intention being to involve people in communal and resettlement areas in water management.
- Introducing the ZINWA, established under the Zimbabwe National Water Authority Act of 1997.

The Water Act also introduces fees for applications for permits to use water and for the commercial use of water. There are also charges for the permission to discharge any effluent into streams or water bodies. Moreover, economic penalties have been introduced in respect of contravention of the act.

Zimbabwe National Water Authority (ZINWA)

The Government of Zimbabwe formed the ZINWA in May 1994 to coordinate the functions of regional water authorities and those of the Department of Water Resources, and to operate on commercial lines. It was considered that, in spite of the provisions of the Water Act, too much attention was given to the provision of water supplies with little effort being directed to planning and policy-making (GOZ, 1997). ZINWA would primarily be a water management and bulk raw-water-supplying parastatal. It would work closely with the catchment and subcatchment councils, involving a very high degree of stakeholder participation, whose functions would include assisting in catchment planning, environmental protection and water allocation. There would also be a commercialized engineering services section in ZINWA.

INSTITUTIONS AND SERVICES

Institutional, policy and service environments change constantly, particularly in young democracies. This section should to be viewed in that context.

SADC drought-related structures and services

Readily available information is critical for the effective management of drought and for targeted mitigation measures to reduce vulnerability of households. Historically, early-warning systems were geared towards the biophysical aspects of agricultural production, especially climate events and abnormalities in rainfall amounts and patterns that may affect regional and national food security.

The SADC Food, Agriculture and Natural Resources Sector

Since 1980, the 14-nation SADC has implemented a programme of action covering cooperation in various sectors including food security, and hence developed a food security strategy (FSS). The main objective of the FSS (SADC, 2003) is to ensure adequate food availability to meet the needs of individual households and the population of the region as a whole, and that the individual households have access to food. Over time, increasing emphasis has been placed on the demand side of the food security issue, focusing on household economies and vulnerable groups. The coordination of the Food Security Programme is the responsibility of the Food, Agriculture and Natural Resources (FANR) Directorate. The following principles underpin the Food Security Programme:

- The public sector should only finance or supply services that would otherwise be undersupplied by the private or not-for-profit sectors.
- Subsidiarity should apply (only do those things at the regional level that cannot be done at the national level).
- The important role of women should be reflected in planning and implementing the programme.
- Recognition of the multiplicity of stakeholders in the private and not-for-profit sectors as well as in the public sector.
- The economic and ecological diversity of the region requires that different food security strategies be implemented in different areas.

The scope of the Food Security Programme has widened over time and now encompasses issues of general economic development, trade, investment and poverty. This requires a clear understanding of intersectoral links and the promotion of policies to facilitate economic development rather than direct intervention in production and marketing. The following are strategic objectives of the FANR:

- Improved availability of food in the SADC region, including improvement in smallholders' competitiveness, increased efficiency of use of natural resources and increased agricultural and intraregional trade.
- Improved access to food in the SADC region, including the generation of employment and a focus on small-scale agriculture with a comparative advantage, the improvement of income stability while maintaining economic efficiency, and the development of safety nets for vulnerable groups.
- Improved nutrition in the SADC region, including improved levels of food quality and nutrition for all members of the SADC society.

A major component of the Food Security Programme is the SADC Food Security and Rural Development Hub. This is a regional resource facility meant to act as a catalyst for rural development in member countries through capacity building and resource mobilization at local and regional level. The main activities of the hub include:

- assist national governments in rural development and agricultural strategy formulation, policy analysis and research, and programme preparation, implementation, monitoring and evaluation;
- support regional policy analysis networking in food, agriculture and natural resources and promoting regional integration in trade, investment phytosanitary regulations and programmes;
- support national and regional capacity building through training and fellowship programmes;
- support regional programmes for communication in development;
- support the agricultural potential information system (APIS).

Other FANR programmes and projects are mentioned below.

Regional FANR Coordination and Cooperation Programme

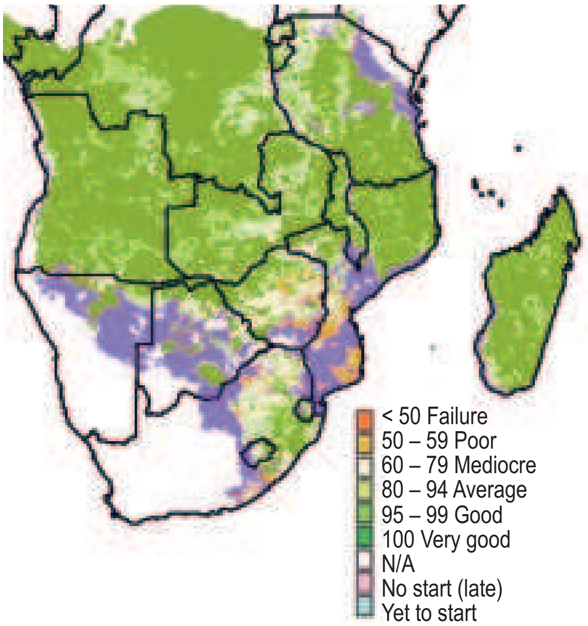
This programme provides the core financial and technical support for the processes of cooperation within the SADC on all food security, agricultural development and natural resources development issues. FANR is responsible for implementing the food security programme as well as coordinating and providing direction to the cluster of sectors within the overall FANR sector. The main functions are developing sectoral policy and strategies and coordinating the activities of the overall cluster of FANR sectors.

Regional Information System for Food Security

The generation and exchange of information relating to all aspects of food security, ranging from information about policies through socio-economic data of economies to data concerning the nutrition of households is an essential prerequisite for decision-making across all the facets of the FANR sector. The main components of the programme are:

- Regional Early Warning System;
- Regional Remote Sensing Component of the Regional Early Warning System;
- Regional Agricultural Potential Information System;
- Regional Food Security and Nutrition Information System;
- Regional Environmental Information System;
- Regional Food Security Database Project, including a market information component;
- Famine Early Warning System (FEWS) implemented in collaboration with the United States Agency for International Development (USAID) (see Figure 41 and Box 26);

FIGURE 41
Example of FEWS NET products: Southern Africa water requirement satisfaction index for maize for Dekad 28 (10/1–10, 2003)



Source: SADC–FANR (2003).

- Risk Mapping for Vulnerable Groups, implemented in collaboration with the Save the Children Fund, the United Kingdom.

These projects are interlinked and each contributes (or will contribute) to the body of information that is collected, analysed, disseminated by or stored within the system. Together, these subprogrammes will provide data relating to: climate, crop production (mainly cereals) and requirements, national and household-level economic indicators, prices and the welfare of vulnerable groups. The data will be stored centrally and made available in printed and electronic form.

SADC Drought Monitoring Centre

The Drought Monitoring Centre (DMC) is charged with the responsibility of monitoring climate extremes, especially drought, in a timely manner with respect to their intensity, geographical extent, duration and impact upon various socio-economic sectors, and of giving early warning for the formulation of appropriate strategies to combat the adverse effects of climate extremes. This contributes towards minimizing the negative impacts of climate extremes to the socio-economic environment.

The centre was established in 1991 and is colocated at the premises of the Zimbabwe Meteorological Service. It provides output products and services to its member states (SADC) and regional institutions, such as the Regional Early Warning System, and collaborates with other major climate centres. The primary roles of the DMC include:

- establishing a network of data collection contact persons within SADC national meteorological services who would send national and regional climate and synoptic data to the DMC;
- collecting, creating and updating regional climatological and semi-processed global ocean-atmosphere data bank;
- providing basic climate data, forecast products, conducting joint research on drought and agriculture, as well as providing expertise to other sectors to further work in food security analysis;
- training SADC national meteorological services staff on attachment at the DMC through conducting research in climate monitoring and prediction techniques (also through supporting their attachments at advanced international sister centres);
- providing training to SADC national meteorological services staff through workshops and the Southern Africa Region Climate Outlook Forum and strengthening links with users from sectors such as health, universities, food security (early-warning systems), water resources management, and the tourism industry, in order to ensure the correct use of climate information in strategic and tactical decision-making;
- processing remotely sensed data for application in drought monitoring within the subregion;
- preparing and disseminating advisories on impending drought and other adverse regional weather patterns to SADC country meteorological services and international and regional institutions. These include ten-day bulletins and seasonal forecasts.

The CGIAR Challenge Programme on Water and Food

The Limpopo River Basin was identified as one of three benchmark basins in Africa to provide a geographical focus for research under the Challenge Programme of the Consultative Group on International Agricultural Research (CGIAR).

BOX 26

FEWS NET: goal and services offered

GOAL

To strengthen the abilities of African countries and regional organizations to manage risk of food insecurity through the provision of timely and analytical early-warning and vulnerability information.

FUNCTIONALITIES

Alerts (drought-, flood-, cyclone-related and more)

- Emergencies: When all indicators are fluctuating outside expected seasonal ranges, local production systems and economy are on the brink of collapse, and most households show signs of extreme food insecurity.
- Warnings: Rainfall (or environmental) and usual livelihood indicators fluctuate outside expected seasonal ranges, weakening the local economy, and most households show signs of high food insecurity.
- Watches: Rainfall (or environmental) indicators show unusual fluctuations outside expected seasonal ranges and most households show signs of moderate food insecurity.

ANALYSIS OF CURRENT REMOTE-SENSING SATELLITE IMAGERY

- Normalized Difference Vegetation Index (NDVI) From the red and near infrared reflectances observed by the Advanced Very High Resolution Radiometer sensor on meteorological satellites of the National Oceanic and Atmospheric Administration.
- Rainfall estimates: Automated (computer-generated) product which uses Meteosat infrared data, rain gauge reports from the global telecommunications system, and microwave satellite observations; water requirements satisfaction index for selected crops.
- Stream flow model flood risk maps: Greater Horn and Southern Region streams and basins from the Southern Africa Flood Network and FEWS NET's United States Geological Survey (USGS) EROS Data Center.

FULL-FEATURED GEOGRAPHICAL CENTRES

- Pinpoint all relevant reports, remote-sensing imagery, weather and more based on geographical area..
- Choose from one of 17 individual countries or Greater Horn (East), Sahel (West) or Southern Region.
- Browse monthly report archive listings.

LIVELIHOODS FRAMEWORK

At the centre of FEWS NET's vision and future direction is the concept of livelihood analysis. Livelihood-based analysis refers to an approach that highlights the specific set of options that people employ in order to obtain food, cash, shelter, and other basic services.

FULLY CUSTOMIZABLE E-MAIL NEWS AND UPDATES

Several times per month, the FEWS NET team broadcasts e-mail to information subscribers. Although this is not a new feature altogether, users may now fully customize their preferences for receiving e-mail based on region, country and interest.

Source: SADC–FANR (2003).

The objectives of the Challenge Programme (starting in 2004 and running for five years) are: to increase the productivity of water for food and livelihoods in a manner that is environmentally sustainable and socially acceptable; to maintain global diversions of water to agriculture at the level in 2000, while increasing food production to achieve internationally adopted targets for decreasing malnourishment and rural poverty by 2015; food security for all at household level; poverty alleviation through increased sustainable livelihoods in rural and peri-urban areas; and improved health through better nutrition, lower agriculture-related pollution and reduced water-related diseases, and environmental security through improved water quality as well as the maintenance of water-related ecosystem services, including biodiversity.

Five interrelated research themes (Box 27) are aimed at ensuring that the same core of key research topics is addressed in all benchmark basins. These themes are intended to serve as the focal point for

BOX 27
CGIAR Challenge Programme research themes

THEME 1 – CROP WATER PRODUCTIVITY IMPROVEMENT
- Plant-level perspective: Impact and future directions of plant breeding.
- Crop and field-level perspective: New opportunities for integrated natural resource management.
- Agro-ecological system perspective: Integrating land and water management.
- Policies and institutions facilitating adoption of improvements.

THEME 2 – MULTIPLE USE OF UPPER CATCHMENTS
- Water, poverty and risk in upper catchments.
- Potential for improved water management.
- Enabling people to benefit from improved management of land and water resources.

THEME 3 – AQUATIC ECOSYSTEMS AND FISHERIES
- Policies, institutions and governance.
- Valuation of ecosystem goods and services, and the cost of degradation.
- Environmental water requirements.
- Improving water productivity.

THEME 4 – INTEGRATED BASIN WATER MANAGEMENT SYSTEMS
- Interactions and scales of analysis.
- Integrated decision-support tools.
- Good governance.

THEME 5 – THE GLOBAL AND NATIONAL FOOD AND WATER SYSTEM
- Globalization, trade, macroeconomic and sectoral policies.
- Investment and financing for agricultural water development and water supply.
- Transboundary water policy and institutions.
- Global water cycle change.

synthesizing results from the various countries and regions, and bring out generic conclusions from the overall research programme.

National institutions

Botswana

Ministry of Agriculture (MOA)

MOA operates through the following departments:

- Department of Crop Production and Forestry, with responsibility for crop production, horticulture, plant protection, land use planning, soil conservation, forestry, range ecology, beekeeping, and for providing technical extension services.
- Department of Animal Health and Production, responsible for the prevention and control of animal diseases, the operation of the National Veterinary Laboratory, and for providing extension and advisory services to farmers.
- Department of Integrated Agricultural Research. Research focuses on the areas of crop and livestock improvement, sustainable utilization of range resources, soil and water management, optimizing utilization of locally available animal feed resources, crop pests and disease management, and pasture and forage crop improvement.
- Department of Cooperatives. Cooperative societies in Botswana consist of producer cooperatives, consumer cooperatives, multipurpose cooperatives, marketing cooperatives, savings and credit cooperatives, and secondary cooperatives. The department continues to encourage the establishment and strengthening of all categories.
- Department of Ministry Management (provision of administrative support).
- Department of Agricultural Planning and Statistics.
- Division of Agricultural Information and Public Relations.

MOA launched the National Master Plan for Arable Agriculture and Dairy Development (NAMPAADD) in October 2002 (GOB–MOA, 2002). It aims at streamlining arable agriculture and dairy development programmes to address the following existing policy objectives: improvement in food security at both household and national levels; diversification of the agricultural production base; increased agricultural output and productivity; increased employment opportunities for the fast growing labour force; provision of a secure and productive environment for agricultural producers; and conservation of scarce agricultural and land resources for future generations. The plan is to be implemented over a period of ten years. The first three years of implementation will include the establishment of pilot projects in areas of high production potential designated as priority areas in the master plan. The NAMPAADD will:

- target active traditional and commercial farmers, and thus enable traditional farmers to transform to commercial farming and assist commercial farmers to upgrade their technologies and management levels;
- encourage more involvement of the private sector and civil society in both farming and the provision of supporting services – this will promote and facilitate smart partnerships between investors and landowners and among farmers themselves;
- promote the establishment of agro-industries such as cotton gins, agroprocessing plants and other enterprises such as transportation to service the agriculture industry and create additional employment opportunities in rural areas;
- depart from the present welfare-oriented approach to a business approach to farming – instead of relying on grants and subsidies, farmers and other participating entrepreneurs will be encouraged to access finance from the Citizen Entrepreneurial Development Agency and other financial institutions;
- establish with private sector involvement a contributory insurance scheme to cover agricultural production losses in years and in specific regions declared as eligible for compensation (this is expected to be a confidence-building measure that will encourage investment in agriculture and improve access to credit);
- provide an enabling environment for agricultural production, including the development of infrastructure to and in production areas with high potential.

Parastatals

The Botswana Meat Commission has a statutory monopoly over the export of beef, by-products, processed and canned meat, and live cattle. Therefore, it provides the major market for most producers. The Botswana Livestock Development Corporation acts as the public-sector buyer of cattle in the remote areas of the country where buying demand is at its weakest. It also supplies quality breeding animals. The Botswana Vaccine Institute produces and supplies vaccines (including exports) and conducts research. The Botswana Agricultural Marketing Board buys products from farmers and sells inputs. The Botswana College of Agriculture, an associate institution of the University of Botswana, offers certificate, diploma, higher diploma and degree courses in agriculture, extension and related fields.

Other institutions

Other institutions include the National Development Bank of Botswana, the Botswana Development Corporation, cooperative societies, agricultural management associations, commercial banks, private cattle traders, and a range of NGOs. Other government departments with important roles as far as agriculture is concerned include the Ministry of Works, Transport and Communications (rural infrastructure), the Departments of Geological Surveys and Water Affairs in the Ministry of Minerals, Energy and Water Affairs (water and boreholes), and the Ministry of Local Government, Lands and Housing (land allocation). In the context of drought management, the National Early Warning Unit comprises representatives of different MOA departments and the Ministries of Works and Health in association with SADC structures.

Administrative structures

The machinery of local government in Botswana reflects a long tradition of democratic consultation and devolved decision-making, and plays a crucial role in development processes, particularly in rural areas. There are four different types of local authorities:

- District and urban councils have stipulated functions by law and their responsibilities include provision of primary education, primary health care, tertiary and access roads and water supplies, as well as related issues such as sanitation, social and community development, the administration of self-help housing agencies, municipal abattoirs and markets.
- Tribal administration is composed of chiefs, subchiefs, headmen, administrative staff and the local police force. Apart from holding office in the traditional house of chiefs, the chiefs preside over customary courts that

handle 85 percent of criminal cases and 90 percent of civil cases in Botswana. There are 361 customary courts and 2 courts of appeal. Chiefs also take care of the *kgotla*, an important traditional meeting place where cases are tried, information disseminated on government policies, and where public participation is encouraged. Elections to the village development committees are held at the *kgotla* every two years, and these committees coordinate development activities within districts.

- Tribal land boards, of which there are 11, have statutory powers to allocate tribal land for residential, commercial, industrial, arable and grazing use. Some 50 percent of the land board members are elected, the remaining members being appointed by the Minister of Local Government, Lands and Housing. The land boards, which may grant customary and common law land rights in accordance with the Tribal Land Act, hold tribal land in trust. They can also cancel land use rights and impose restrictions on land use.
- District administration in Botswana is divided into 10 administrative districts and 15 subdistricts, with 9 district councils. The larger districts are divided into subdistricts for ease of administration. A district commissioner coordinates the range of development activities carried out at district level by central government, local authorities and other agencies. The district commissioner chairs the district development committee, which is an advisory body that addresses development issues that affect the district. It is made up of senior representatives of central government, the district council, the land board, the tribal administration, parastatal and other government development agencies at the tribal level.

Mozambique

The institutional environment in Mozambique underwent a process of revitalization after 1990, the year in which the new constitution was adopted. Foreign aid and advisors played a role in this process. Table 28 lists some of the prominent national institutions of relevance to basin issues.

International organizations in Mozambique

Owing to the severe economic plight of post-war Mozambique, the country has received aid from many governments in the developed world and from international institutions. The attention was drawn to Mozambique of vast numbers of university departments from all over the developed world and many cooperative research projects were undertaken. International experts assisted with the development of structures and strategies for revitalized government departments. Major permanent foreign aid structures include the UN, USAID and World Bank.

The UN System in Mozambique (UN, 2003) comprises resident programme and/or funding agencies such as UNDP, United Nations Population Fund (UNFPA), United Nations Children's Fund (UNICEF), and WFP, and specialized agencies, such as FAO, United Nations Educational, Scientific and Cultural Organization (UNESCO), and World Health Organization (WHO). In addition, non-resident UN agencies have participated in the preparation of the United Nations Development Assistance Framework (UNDAF). UNDAF is the principal country-level component of global UN reform to maximize goal-oriented development cooperation in support of Mozambique's economic and social development. UNDAF enables the UN System in Mozambique, in collaboration with its partners, to harmonize development efforts and strive for programmatic coherence and mutual reinforcement. In addition, non-resident UN agencies plan activities under the umbrella of UNDAF, and are committed to the UNDAF principles of cooperation and coordination. While each agency has its own individual country programme based on its mandate, the heads of all resident UN agencies constitute the United Nations Country Management Team (UNCMT). The Bretton Woods Institutions, i.e. the World Bank and International Monetary Fund (IMF) are invited to participate in the UNCMT as partners, and the World Bank has collaborated in the formulation of the UNDAF and its implementation through their own instruments. The UNCMT is guided by a set of common goals, objectives, and coordination modalities. Progress towards these goals is monitored by a set of common core indicators that measure the contribution and impact of the UN System on national capacity and development.

In support of Mozambique's Action Plan for the Reduction of Absolute Poverty (PARPA) to reduce poverty by one-third by 2010 and its commitments to international human rights

TABLE 28
Some of the prominent national institutions in Mozambique

Ministry	Institution	Functions
Agriculture and Rural Development	National Directorate of Forestry and Wildlife	Forestry and wildlife administration, research, economics and development
	Agricultural Market Information System	Agricultural marketing
	Early Warning Department	*Inter alia,* crop estimates
	National Directorate of Livestock	*Inter alia,* disease outbreak management (Newcastle disease, African swine fever, ticks and tick-borne diseases, and trypanosomiasis)
	National Directorate of Agriculture	Provincial directorates of agriculture
	National Directorate of Rural Extension	Agricultural extension
	Unit of Agriculture Emergency Coordination (UCEA)	Coordination of flood relief in coordination with UN agencies
	Cotton Institute	
	Agriculture Sector Public Expenditure Programme	Sustainable and equitable growth in the agriculture sector; reducing poverty and improve household food security; and protecting the physical and social environment
Public Works and Housing	National Directorate of Water	Rural and urban water policies and their implementation; strategic and integrated planning; international rivers; and provision of water supplies and sanitation services
Transportation and communication	National Institute of Meteorology	Meteorological data collection, databases and information dissemination
Environmental Action Coordination		Biological inventories and conservation
Higher Education, Science and Technology	National Institute for Agronomic Research	Agricultural and natural resources research
Fisheries		Regulation and administration of fisheries industry; semi-industrial fisheries; artisanal fisheries; small-scale fisheries; fish processing; and information and training
Health		Health strategies; integrated provincial planning; province-based support programmes; donor pooling arrangements; subsector programmes and strategies; and information systems
Tourism		Policies, strategies and action plans for promoting the tourism industry, which is to be driven essentially by private sector initiatives
Women and Social Action Coordination	Provincial directorates	People with disability; women's rights, and children

instruments, the UN System in Mozambique seeks to empower all Mozambicans – independent of gender, race, age, religion, political affiliation, and economic or social status – to participate in and gain from the development process in an equitable manner. Box 28 details UN involvement in relief work during the 2001 floods.

In 2003, the USAID programme focused on increased rural household income, effective democratic governance, increased use of essential maternal/child health and family planning services, and an enabling environment for private sector-led growth and development. USAID field activities targeted the most populous and high-potential areas of the country, i.e. the provinces of Manica, Nampula, Sofala and Zambezia, which are outside the Limpopo River Basin (USAID, 2003).

Mozambique joined the World Bank Group in 1984. Beginning with a credit from the World Bank's International Development Association for rehabilitation in 1985, the portfolio comprises 21 active projects with commitments of US$1 100 million in all major sectors in 2003.

The World Bank and other donors fully endorse Mozambique's poverty reduction agenda defined in the Poverty Reduction Strategy Paper (PRSP), in Mozambique also called the PARPA, which was presented to the World Bank and the IMF boards in 2001. The PRSP was subsequently updated in the first PRSP Progress Report of February 2003.

The PRSP/PARPA was developed through a participatory process. The key objective is the reduction of absolute poverty, and it identifies the following fundamental action areas: education, health, agriculture and rural development, infrastructure, good governance, and macroeconomic and financial management. Other areas of action as identified in the PRSP/PARPA include: employment and business development, social action, housing, fisheries, tourism,

BOX 28

UN initiatives for minimizing the impact of water disasters during the 2001 floods in Mozambique

OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS (OCHA)

- Created a web site for the Mozambique floods, set up a financial tracking page for donations and issued regular situation reports.
- With the Office of the Resident Coordinator, established the Emergency Coordination Unit, comprised of internationally and locally recruited emergency specialists and the United Nations Volunteers (UNV) who were placed with provincial teams in Beira, Quelimane, Chimoio, Tete and Maputo, and as coordinators for the data/information, communications, and public relations/media UN emergency clusters.
- In collaboration with the United Nations Disaster Management Team (UNDMT), the Office of the Resident Coordinator provided daily situation reports, mapping, emergency cluster meetings, daily updated website with weather, river and dam levels, UNDMT member reports, cyclone tracking, situation reports, reporting to donors and government, etc.

WORLD FOOD PROGRAMME (WFP)

- Acted as the lead UN agency coordinating the UN Logistics Cluster and, thus, giving direct support to the UN family, especially UNICEF and FAO by facilitating warehousing and shipment of food and non-food items including medicines, water and sanitation supplies, and seeds and tools, as well as assisting partners with office space, equipment and staff support.
- WFP and UNICEF headed the UN Assessment Cluster's formulation and piloting of emergency data gathering instruments in close consultation with OCHA, USAID, the United Kingdom's Department for International Development (DFID) and NGOs.
- Provided staff to set up a Joint Logistics Coordination Centre (JLOC) in Beira, the capital of Sofala Province and the centre of coordination for the humanitarian programme. At its peak, the JLOC was operating with 20 aircrafts. WFP managed the fleet and contributed US$2.5 million for air operations until the end of April. WFP also hired barges and boats to transport beans, rice and high-energy biscuits for Beira, Quelimane, Mutarara, Marromeu, Chinde and other locations to supplement stocks.
- Established the first requirements for field communications for the UN System and partners including installation of repeaters, e-mail, HF radio installations, and emergency hub and travel linkages on common frequencies. The OCHA Communications Coordinator then worked with WFP and UNDP to ensure proper installation, maintenance, and information to partners, including the INGC.
- Established a technical working group on food requirements to arrive at a consolidated picture of food needs. Technical working groups were formed in the Ministries of Health, Education, Public Works and Housing. Government, UN agencies, and donors led these groups, and NGOs took part together.
- WFP fed some 230 000 displaced persons in 65 temporary accommodation centres in the four affected provinces. By the end of May, about 8 000 tonnes of mixed food commodities had been distributed by ten different implementing partners.

UNITED NATIONS CHILDREN'S FUND (UNICEF)

- Coordinated the UN family's assessment and response in the area of water and sanitation and was asked by the government in late March to provide overall coordination of the sector.
- Led the UN Education Cluster and was a joint coordinator of the Assessment Cluster with WFP and OCHA. In addition, was a member of the Logistics, Shelter and Public Information Clusters.
- Assisted WHO to coordinate the UN Health Cluster.
- In collaboration with WFP, formulated and piloted needs assessment forms for emergency data gathering and analysis.
- Provided emergency staff as part of Sofala and Zambezia UN team operations.
- Provided malaria drugs sufficient to treat 1 million people, and sent teams into the field in the affected areas to conduct public awareness campaigns on health and hygiene.

(Continued)

Source: SARPN (2004).

- Provided support to the Ministry of Health for campaigns to control measles and meningitis through vaccinations and for vitamin-A supplements and helped with training government health staff in the provinces of Zambezia, Sofala and Tete in the prevention and case management of diarrhoea and cholera.
- Supported the provision of clean water in the temporary accommodation centres, by supplying water treatment equipment, bladders, tap stands and chlorine.
- Through partner NGOs, distributed jerry cans, buckets and soap, as well as 32 000 latrine slabs and plastic sheeting for shelter. About 11 000 latrines were installed, benefiting 220 000 people.
- NGO activists were trained in hygiene promotion in the accommodation centres.
- Supported nutritional surveys, and subsequent preparation of a 4-month blanket supplementary feeding programme to cover 66 000 people, including children (6 months to 5 years), pregnant women and nursing mothers. Technical and financial assistance provided to implement the programme.
- Supported a social marketing campaign to promote the use of insecticide treated bed nets, 45 000 of which were procured for distribution to the accommodation centres.
- To assist children return to school as quickly as possible, UNICEF (through the Save the Children Fund) supported the Ministry of Education to distribute school kits (60 294) and writing boards, as well as family kits to affected teachers.
- Supplied 60 tents to the Ministry of Education for use as temporary classrooms in accommodation centres and where school buildings were destroyed.
- Telecommunications and logistics support for UN and government partners.

FAO

- Funded by the OCHA, FAO assisted the Ministry of Agriculture and Rural Development's Emergency Coordination Unit (UCEA), which is set to become a permanent structure.
- With FAO technical support, the UCEA prepared weekly updates of numbers of affected families and areas lost as a result of permanent field assessments.
- FAO and the Ministry of Agriculture and Rural Development (MARD) called for a donor meeting in early March with the objective of funding agricultural kits to be provided to affected families. The meeting was successful and total coverage for the number of affected farming families was obtained.
- Up to 80 000 households benefited from the distribution of seeds and tools to plant a second season crop. FAO provided agricultural kits for 30 500 households, with funds from Italy. The kits were distributed by various NGOs based in the affected districts of the provinces of Tete, Manica, Sofala and Zambezia in coordination with local authorities.

UNITED NATIONS VOLUNTEERS (UNV)

- Recruited four volunteers each for OCHA and WFP, as well as seconding many others to tasks in the emergency relief operations.
- Provided equipment and logistics support to start the coordination centre in Beira.
- Funding volunteers to work with the Mozambique Red Cross in the temporary accommodation centres.

WORLD HEALTH ORGANIZATION (WHO)

- Coordinated the UN Health Cluster.
- Provided technical specialists for malaria, cholera, and malnutrition assessments and action planning in collaboration with UNICEF ensuring that sufficient medicines were made available in country. Provided US$83 420 of additional assistance for medicine kits and supported operational costs of the assessments.
- Provided insecticides for shelter spraying in the accommodation centres.
- Supported action plan for emergency diseases of Ministry of Health.
- UN health focal point in the INGC health technical committee.

UNITED NATIONS DEVELOPMENT PROGRAMME (UNDP)

- Coordinated the UN Cluster for Shelter, partnering with the Mozambican Red Cross and the Ministry of Public Works.
- Seconded staff to serve as food, communications, and coordination emergency staff for WFP and OCHA.
- Supported the UNV office to ensure quick and appropriate UNV selection, secondment and placement through a grant of US$100 000.
- Ensured vehicle and equipment secondment and pooling for immediate emergency response needs.

processing industry, transport and communication, technology, environment, and reduction of vulnerability to natural disasters.

One of the key challenges in achieving sustainable improvements in poverty indicators derives from the rising numbers of HIV infections. Aside from its direct impact on poverty-related indicators, this will also have severe consequences for the productive labour force and, hence, for growth. Multicountry evidence suggests that at HIV prevalence rates of 15 percent, GDP growth per capita is reduced by about 0.8 percent. Therefore, Mozambique is vulnerable to substantive reversals of its development process. Action is needed now at all levels of society in order to control the spread of HIV.

Other key constraints on the implementation of the PRSP/PARPA reform programmes include: the increasing disparity between a booming mega-projects sector and a small and medium-sized enterprise sector that the business environment does not adequately support; corruption, particularly in the financial sector; and a weak banking sector.

South Africa

Considerable transformation has taken place in the institutional environment since the change to a representative government in 1994. In the new dispensation, a relatively large spectrum of functions is delegated to the provincial and municipal levels. For the first time, all land has come under the jurisdiction of municipalities. The Department of Land Affairs was constituted to regulate *inter alia* issues of land reform (land claims, land redistribution and making state land available to communities). Probably the most important change of all was the abolition of all racial restrictions on land ownership.

Table 29 lists prominent South African institutions with direct relevance to basin issues. It does not list a large number of institutions with indirect relevance, e.g. universities in other provinces that draw students *inter alia* from the basin area. Of the institutions listed, only those branches and functions with relevance to the basin are indicated.

Zimbabwe

Table 30 lists key Zimbabwean institutions relevant to land-related issues.

International agencies

Land-related non-SADC international agencies operating in Zimbabwe include the African Centre for Fertilizer Development (ACFD), ICRISAT, and the International Livestock Centre for Africa (ILCA).

ACFD is a non-profit, autonomous international centre of the Organization for African Unity, governed by a board of directors and recognized as an international agency by the Government of Zimbabwe. It aims at stimulating the production and use of fertilizers. It operates in terms of a technical cooperation agreement with the International Fertilizer Development Centre (the United States of America). ACFD consists of two technical divisions, one for research and development and one for technology transfer. The programmes of ACFD are: land resource management, policy analysis, resource development and utilization, marketing services, human resource development, information services and engineering advisory services.

The heads of government of the SADC countries requested ICRISAT to establish a regional sorghum and millet research programme for southern Africa. An agreement for initiating the sorghum and millet improvement programmes, funded by the USAID, the GTZ and the Canadian International Development Agency (CIDA), was signed in September 1983 and the programme centre was established at Matopos near Bulawayo in Zimbabwe. In 1999, ICRISAT expanded its work and staff in the region under a new agreement with the Government of Zimbabwe. Work continued to be headquartered in Zimbabwe and conducted on a regional basis. ICRISAT consists of: Programme Director's Office, Site Leader's Office, Administrative Unit, Crop Improvement Unit, Natural Resource Management Unit, and the Farm and Physical Plant Services.

The ILCA is one of 17 international agricultural research centres financed through the CGIAR, an informal association of countries, international organizations, and private institutions. The mandate of the ILCA is to assist the efforts of countries in tropical Africa to increase the sustained yield and output of livestock products and to improve the quality of life of the people in the region. Its research structure concentrates on the three most important ruminant species in Africa: cattle, sheep and goats.

Major donors, such as DFID and USAID, have limited or no development programmes in Zimbabwe.

TABLE 29

South African institutional environment

Institution	Branch	Functions
Department of Agriculture #	Farmer support and development	Agricultural risk management
		Farmer settlement
		Agricultural finance and cooperative development
		Food security and rural development
	Trade and business development	Domestic marketing
		International trade
		Business and entrepreneurial development
	Sustainable resources use and management	Water use and irrigation development
		Land use and soil management
		Scientific research and development
	Agricultural production	Animal and aqua production
		Plant production
	Communication, planning and information management	Education and training
		Agricultural information services
		International relations
Limpopo Provincial Government	Department of Agriculture and Environment	Land redistribution; land use planning; resource conservation; control of pests and noxious weeds; infrastructure; policy development; empowering small emerging farmers; agricultural statistics
	Department of Finance, Economic Affairs, Tourism and Environment	Trade and industry; tourism; economic planning, research and policy
	Department of Health and Welfare	District health systems; social welfare programmes; poverty alleviation
North West Provincial Government	Department of Agriculture, Conservation and Environment	Sustainable natural resource management
Gauteng Provincial Government	Department of Agriculture, Conservation, Environment and Land Affairs	Sustainable agriculture; household food security; farmer settlement and support; commercial farming; resource conservation and development
Agricultural Research Council	Horticulture: Institute for Tropical and Subtropical Crops; Roodeplaat Vegetable and Ornamental Plant Institute	Research and technology exchange on all aspects of the cultivation of tropical and subtropical crops, potatoes, vegetables, hydroponic production, indigenous vegetables and indigenous flowers
	Grain and industrial crops: Grain Crops Institute; Small Grain Institute Institute for Industrial Crops	Research and technology exchange on all aspects of the cultivation of grain and industrial crops (maize, sunflower, dry beans, sorghum, groundnut, soybeans, cowpeas, millets, lupins, bambara, cotton, tobacco, hemp, flax, sisal, kenaf and indigenous fibre crops). Included are: cultivar evaluation, plant breeding, improvement of crop quality, weed control, tillage, plant nutrition, water utilization, plant pathology, entomology and nematology.
	Livestock: Animal Improvement Institute; Animal Nutrition and Products Institute; Range and Forage Institute; Onderstepoort Veterinary Institute	Sustainable animal resource conservation and utilization; livestock production for global competitiveness; livestock-based technology transfer and dissemination; maintenance of animal improvement schemes and gene, data and DNA banks; waste and effluent management; probiotics and culture management; product technology and sensory analysis services to the food and beverage industries; food safety and hygiene; laboratory diagnosis of animal diseases; production of vaccine against foot and mouth disease (FMD); research into various aspects of FMD and African swine fever, particularly their epi-zootiologies; other highly communicable diseases; training of veterinarians and laboratory workers in the recognition of dangerous epizootic diseases and in laboratory techniques; sustainable utilization of rangeland, pasture and livestock resources; sustainable improvement of animal products (meat, dairy and fibre)
	Public support services: Institute for Soil, Climate and Water; Institute for Agricultural Engineering; Plant Protection Research Institute	Characterization of soil resources; natural resources monitoring, auditing and impact assessment (climate stations and data bank); sustainable natural resources use and management; information technology; sustainable rural livelihoods; development and application of engineering technology for sustainable utilization and development of resources; protection, and reclamation of deteriorated natural resources; development of human resources in agricultural engineering technology; biosystematic services (national collections of insects, arachnids, nematodes and fungi); agricultural biodiversity information systems; integrated pest management in crops, plantations and stored products; plant pathology research and services; weeds and alien invaders; beneficial organisms

TABLE 29
South African institutional environment (continued)

Institution	Branch	Functions
Department of Land Affairs	Restitution	Promoting equity for victims of dispossession by the State, particularly the landless and the rural poor; facilitating development initiatives by bringing together all stakeholders relevant to land claims; promoting reconciliation through the restitution process; contributing towards an equitable redistribution of land rights; farmer settlement; commonages; equity schemes; non-agricultural enterprises
	Land tenure reform and support services	State land policy and administration
Department of Water Affairs and Forestry	Policy and regulation	Water resources planning and management; policy formulation; international projects; geohydrology; hydrology; catchment management; water conservation; water quality management; water utilization; Working for Water ##
	Operation	Sanitation management; commercial and community forestry; indigenous forests; water development (construction).
Water Research Commission	Water resource management	Sustainable water resource management; balancing the competing demands of domestic needs, agriculture, industry and the environment
	Water-linked ecosystems	Sustainable utilization of the aquatic environment and biota
	Water use and waste management	Management of waste and other water-polluting products; integrated solutions
	Water utilization in agriculture	Efficient use of water for production of food, fibre, fuelwood and timber; water efficient production technologies, models and information systems
	Water-centred knowledge	Knowledge-sharing and dissemination
Department of Environmental Affairs and Tourism	Environmental management	Systems of environmental monitoring and reporting; environmental management and planning; environmental education and capacity building; environmental legislation and implementation; environmental conflict management and conciliation; preventing and/or limiting pollution and environmental degradation
	Tourism	Conditions conducive to tourism growth and development
	Biodiversity and conservation	Conservation of biodiversity; transfrontier conservation areas; protected areas
Department of Health	Health service delivery	Hospital services; disease prevention and control; non-personal health services; health and welfare
	Strategic health programmes	Health information evaluation and research; medicines regulatory affairs; pharmaceutical services; district health systems; HIV/AIDS; maternal, child and women's health
Department of Education	Higher education	Development and regulation of the higher education system
	University of the North	Agricultural and environmental sciences; health sciences; computational and mathematical sciences; molecular and life sciences; physical and mineral sciences.
	University of Pretoria	Natural and agricultural sciences; veterinary science; humanities; health
	University of South Africa (distance education institution)	Geography and environmental studies; information science; agricultural management; animal health; horticulture; nature conservation; tourism management; water care
	University of the North West	Agriculture, science and technology; human and social sciences
	Tswane University of Technology	Agricultural management; animal production; nature conservation; horticulture; tourism management; biotechnology and food technology; environmental sciences; food and hospitality management; water care
	Lowveldt Agricultural College	Specializes in agronomy and horticulture (tobacco, cotton, sugar cane, drybean production, vegetable, subtropical fruit and citrus under irrigation); supporting subjects are soil science, irrigation, plant propagation, computer practices, plant protection, botany, agricultural engineering and farm management. In addition to the diploma course, special and short courses are offered

The National Department is primarily responsible for policy and issues of national implications. The provincial departments are charged with implementation.

The Working for Water programme was launched in 1995 in an effort to tackle the problem of invading alien plants and unemployment. It is a multidepartmental initiative led by the Departments of Water Affairs and Forestry, Environmental Affairs and Tourism and Agriculture. With 300 projects throughout the country, the programme aims to enhance water security, improve ecological integrity, restore the productive potential of land, promote sustainable use of natural resources, and invest in the most marginalized sectors of South African society.

TABLE 30
Zimbabwe institutional environment

Ministry	Institution	Functions
Ministry of Lands, Agriculture and Rural Resettlement	Agriculture, Technical and Extension Service (AGRITEX)	Agricultural extension, land use planning, soil and water conservation; irrigation development.
	Land acquisition and rural resettlement	Land resettlement
	Department of Research and Specialist Services	Agricultural research
	Department of Water Resources and Development	Water resources management
	Department of Livestock and Veterinary Services	Prevention, control and eradication of animal diseases and pests affecting livestock production and development
Ministry of Environment and Tourism	National Climate Committee	National focal point for the UN Framework Convention on Climate Change
	Department of National Parks and Wildlife Management	Management of parks and wildlife lands; use of indigenous plants and animals
	Department of Natural Resources	Matters pertaining to natural resources, excluding minerals; environmentally sustainable development
	Natural Resources Board	Custodian of the natural resources in Zimbabwe
	Forestry Commission	All aspects of forestry: afforestation; protection of indigenous woodlands, advisory and extension services
	Zimbabwe Tourist Development Cooperation	Promoting Zimbabwe as a tourist destination
Ministry of Energy and Water Resources and Development	Department of Water Development	Development of water resources; construction of dams, irrigation systems, water supply schemes; drilling of boreholes and wells
	Zimbabwe National Water Authority (ZINWA)	
Office of the President	Research Council of Zimbabwe	Science and technology for development
Ministry of Health and Child Welfare	National AIDA coordination programme	Health services
Ministry of Local Government, Urban and Rural Development	Urban councils	Lead organization in smallholder irrigation development; Rural Water Supply and Sanitation Programme; supervisory role over local government
	Rural district councils	
	Ward development committees	
	Village development committees	
Ministry of Transport and Communications	Department of Meteorological Services	Monitoring and interpretation of regional climate systems
Parastatals and government stakeholder institutions	University of Zimbabwe	General academic training, including agriculture
	Zimbabwe Open University	Distance teaching, including environmental science
	Agricultural and Rural Development Authority (ARDA)	Agricultural and rural development on behalf of government
	Regional Water Authority	Managing the water resources infrastructures in the irrigated lands of southeastern lowveldt
	Pig Industry Board	Research and development; genetic improvement; advisory services; training programmes
	Southern African Regional Institute for Policy Studies	Policy issues and public concerns, particularly in the areas of regional cooperation and integration, international cooperation, gender relations, social and public policy development technology and environment and economic policy
	Tobacco Research Board	Research and investigative work in connection with both small- and large-scale production of tobacco
Private	Agricultural Research Trust	Commercial food crop and horticultural research; facilities for contract research to the government, the university and to private agribusinesses

Chapter 4

Learning to live with drought and climate variability

EXAMPLES OF EXISTING PROGRAMMES AND PRACTICES

The programmes and practices discussed below have been or are currently being implemented and supported by governments of basin countries, international agencies, local institutions, communities and farmers. Some national programmes have fairly consistent objectives across the four countries. Others are specific to one country and may or may not apply to the Limpopo River Basin as a whole. There may be many programmes and practices with a bearing on some aspects of drought mitigation that have not been identified or reviewed within the scope of this analysis.

Programmes and practices are grouped according to broad themes that correspond to the information presented in previous chapters, i.e.:

- drought response programmes,
- soil and water conservation and management,
- crop production and diversification,
- livestock,
- agroforestry,
- other.

The underlying principle of most of the examples is drought mitigation or integrated resource management. However, many projects are diverse and multisectoral and do not necessarily belong to a single broad theme. The aim is to provide examples that represent a cross-section of major programmes and practices that might be of value in the identification of constraints, gaps and opportunities to be considered during later phases of programme formulation.

Drought response programmes

Various drought response programmes have been developed throughout the region, especially as a result of the droughts of the 1980s and 1990s. Many of these programmes were developed on an ad hoc basis to enable responding, primarily with relief efforts at the time, without linkages to national development activities. However, drought is becoming an important part of national and regional development planning and is being recognized as a chronic problem rather than a series of ad hoc emergencies. This is evidenced by the evolution of drought management policies and strategies.

Drought response interventions executed by most governments, NGOs and donors have taken three general forms:

- emergency drought relief;
- drought rehabilitation;
- drought mitigation.

Box 29 shows typical examples of each type of intervention. The three forms correspond primarily to the timing and duration of the response. Relief includes the actual emergency response.

BOX 29

Typical drought response programmes

Drought relief schemes have included:

- general food aid to most affected households;
- supplementary feeding programmes for:
  - children, especially under five years old,
  - pregnant and lactating mothers,
  - the elderly and disabled;
- emergency water supplies for people and animals;
- assistance in destocking livestock.

Drought rehabilitation schemes have included:

- seed-pack and fertilizer distribution;
- livestock restocking programmes;
- nutritional garden projects;
- subsidies and loans.

Drought mitigation schemes have included:

- dam construction;
- water harvesting;
- small irrigation schemes;
- food storage programmes.

Rehabilitation is reconstructing and repairing damages in the short to medium term. Mitigation focuses more on reducing the impacts of future events. Most of the drought response programmes have focused on immediate and short-term relief efforts.

Unlike cyclones and floods, a drought is a slow-onset disaster. This usually allows more time to implement a relief plan. Although perhaps not as spectacular as other disasters (e.g. dramatic scenes of raging rivers and rising waters), the effects of a drought can be more widespread and damaging, especially in these chronically drought-prone areas. To be most successful, the drought response system should ensure that emergency relief (especially food and water) is distributed quickly in order to avoid loss of life once an emergency measure is in place. This is to be followed by coordinated and integrated rehabilitation and mitigation activities to preserve livelihoods.

Botswana

Botswana's experience with drought response provides good examples of major issues to be considered in developing a drought response programme. The Drought Relief Programme in Botswana was able to achieve zero deaths attributable to drought-related malnutrition by coping with the 1982–86 droughts (Valentine, 1993). Main reasons cited for the success in Botswana were:

- targeting – the drought relief was targeted at the rural poor and other vulnerable groups to minimize income disparities during and after the drought;
- use of established infrastructure – established local and district-level supplementary feeding facilities and lines of communication and distribution were used;
- funds were available – there were surplus national funds available generated by the diamond resources of the country;
- willingness to learn from past experience;
- political will – good governance and drought relief seen as a high priority issue.

Drought relief labour intensive works programme

Following an evaluation of drought relief programmes carried out during the 1980s, the recommendations of the Government of Botswana fostered a major policy shift toward intersectoral programmes. The government also created an Inter-Ministerial Drought Committee (IMDC) in the early 1980s to help develop and coordinate various aspects of the drought response programmes. A major intersectoral programme was the Labour Intensive Public Works Project (LIPWP), developed to relieve drought-affected people, and to provide sustainable and viable projects to create employment. From 1992 to 1996, some 50 000 people were employed annually under the programme (of whom 70 percent were women). In this period, a total of about US$64 million was also spent, of which 40 percent directly on labour. Completed projects included houses, feeder roads, classrooms, daycare centres, health posts, clinics, offices, community halls and other community-based projects. The approximate annual employment of people under this drought relief employment programme is equivalent to 21 percent of Botswana's current formal economic sector employment and, therefore, provides significant employment benefit to the country.

However, the LIPWP has not been without its problems, and the Government of Botswana has acknowledged deficiencies in the programme. The "working age" group (15–64 years) was projected to increase by 42 percent between 1991 and 2001 (compared with a far lower increase of 12.4 percent in total population over the same time period). Saddled with this increasing "working" population, it will be difficult for the authorities in Botswana to withdraw completely from this public works employment programme.

Capacity building for disaster relief

The Government of Botswana started with the establishment of a national disaster relief capacity during National Development Plan 7 (GOB, 1991). This has taken place at local-authority level and the structure is now tried and tested to respond quickly to natural and human-induced disasters such as drought, floods, and livestock disease. In turn, some local authorities have formed area committees that utilize national-level funding for relief activities. The Government of Botswana intends to carry out training and simulation exercises with these structures in order to prepare effectively for the necessary disaster relief readiness.

Short-term livestock drought-related programmes

Through the IMDC, which was set up to monitor and evaluate drought situations, the government has developed short-term programmes or subsidies for livestock owners. These short-term programmes, generally referred to as drought relief livestock projects, are assessed on an annual basis and instituted as necessary. They include:

- maintenance of breeding stock, where farmers are encouraged to sell during drought to maintain breeding and young animals;
- feed supplements for energy, protein and minerals are sold at 50 percent of the cost price during drought;
- disease prevention (e.g. botulism vaccines and vitamin A) is provided free in drought years.

South Africa

Before 1992, drought response by the Government of South African focused primarily on mitigating the impact of drought on the industrial and commercial agriculture sectors (AFRA, 1993). Little was done to reduce the impacts on the economically impoverished communities of the rural areas, and response was based primarily on relief rather than mitigation strategies. South Africa has addressed many of these shortcomings by developing new policies and institutions.

Before 1994, the commercial farming districts came under the jurisdiction of national drought relief schemes. Farmers in the communal areas of the old homeland regions were assisted by special drought relief schemes implemented by the respective governments. Such schemes usually centred on: human relief (food parcels, water drilling for distressed villagers and labour-intensive public works programmes); debt relief to farmer borrowers (mainly the write-off of short-term crop production loans); and a plethora of different livestock schemes over the years.

During the 1991/92 drought, the Water Supply Task Force provided emergency water supply by means of water tankers to 950 communities, repaired existing water infrastructure, installed some 800 emergency pipelines, drilled more than 5 000 new boreholes, protected springs, and installed packaged water treatment plants. The Nutritional Task Force coordinated transport and distribution of food, while public works programmes facilitated job creation to stabilize household income. Various state structures were involved at local and regional level in drought relief.

Serious problems emerged in the implementation of the drought relief activities. The problems included: inadequate funding, rigid geographical jurisdictions, poor coordination, lack of personnel, lack of drought relief experience, poorly publicized relief measures, lack of legitimacy, poor community relations, and rigid "top-down" approaches. Owing to the absence of a common national approach to relief, most state structures at local and regional level had to act ad hoc through the drought period. The absence of meaningful community representation on any of the drought relief structures meant lack of accountability and the communities were excluded from the process of drought relief (AFRA, 1993). Additional shortcomings of past drought relief programmes included:

- Inefficient delivery mechanisms made it easier to deliver aid to communities that had better access (e.g. communications, social and physical infrastructure) than to the really disadvantaged rural dwellers.
- Ineffective credit schemes prevented farmers from developing better farm management capacity or understanding a constructive credit culture. By writing off production credit, the main aid recipients were the government-controlled banks and development corporations, which were protected from risk, rather than the farmer borrower.
- Ineffective livestock schemes, such as feed provision, subsidizing purchased feeds, subsidizing and encouraging farmers to offload surplus stock, and even operating State feedlot schemes, failed to be equitable. Moreover, they encouraged livestock owners to expect government to bear the full risk.

Nutrition security and supplemental feeding programmes

The Department of Health implements three nutrition security programmes in all of South Africa's nine provinces (R. Ochse, personal communication, 1999). These are targeted at the rural poor and those living in poor crop production areas. The programmes focus on high-risk areas such as those prone to disasters. The first was known as the National Nutrition Development Programme (1991–92), subsequently renamed the National Nutrition and Social Development Programme (1994) and now called the Nutrition Development Projects. Between 1992 and 1996, the programme's objectives were to help people to become self-reliant by assisting them to establish nutrition-security-related projects. However, because of the drought, the programme became one of social relief, with different NGOs in the provinces being contracted to deliver food parcels to the needy. After 1996, it was realized that food parcels created a spirit of dependency among beneficiaries, and hence it was decided to encourage people to start up their own nutrition development projects. Money is channelled through NGOs and community-based organizations to communities and individuals that submit business proposals for projects such as nutrition gardens, small farms, bakeries, and fish projects. The current focus by the Department of Health promotes nutrition and food security in the region, and will enable resource-poor families to better withstand the impacts of drought.

Supplementary feeding schemes

One of the several schemes focuses on nutritional feeding of children aged between zero and six years. This age group has been found to be most at risk in the event of disasters such as drought. The programme also assists pregnant and lactating mothers with food and training on nutritional aspects. Another programme, the Schools Feeding Scheme, has the objective of providing a daily meal to primary school children, who have been identified as being most at risk of malnutrition.

Lessons learned from the 1991/92 drought

In preparation of the SADC drought strategy described in Chapter 3, the main lessons learned from dealing with the 1991/92 drought and previous drought response programmes are summarized below (SADC, 1999):

- An effective early-warning system is invaluable for timely implementation of drought mitigating and relief measures, but must be accompanied by adequate infrastructure for implementation.
- The severity of drought cannot be judged only from the reduction in total annual rainfall; the interseasonal distribution is important, especially for crops.
- A rigorous definition of drought is needed in order to distinguish between impacts caused primarily by low rainfall and those exacerbated by poor land management.
- Drought conditions can be expected somewhere in the region in most years, but it is rare for all regions to be drought-stricken at the same time.
- Farm management practices should take into account the low and erratic rainfall to be expected.
- Drought subsidies should not become regular handouts, nor should they encourage poor management practices.
- Fodder subsidies have encouraged farmers to maintain higher stocking rates than appropriate, and have contributed to the bush encroachment problem in some commercial farming areas.
- The crop compensation subsidies tended to encourage commercial farmers to cultivate agronomically inappropriate crops and/or to practise cropping in unsuitable areas.
- Better targeting is needed for all drought relief subsidies.
- Drought relief boreholes tend to remain in use after a drought and become foci for unplanned settlements, hence they are no longer available for drought relief in the next drought.
- Food-for-work programmes are difficult to launch rapidly where there is no structure already in place.
- NGOs can play an extremely useful role in the administration of drought relief measures, especially in communal areas.

At a regional level, four major shortcomings of previous drought programmes have been identified (SADC, 1999):

- Lack of an unambiguous definition of drought, which left declarations of drought to be determined on an ad hoc basis rather than using scientific criteria. This led to a situation where political considerations dominated economic or social rationale.
- Lack of equity and efficiency in the distribution of the benefits, which led to a situation where a substantial proportion of drought relief funds found its way to non-deserving farmers and individuals. In addition, farmers have been encouraged to continue with unsustainable farming practices, e.g. keeping excessive numbers of cattle, and production of maize. This has resulted in damaging the natural resource base and supporting non-viable farming enterprises.
- Misappropriation of resources and substandard infrastructure as a result of hurriedly planned projects.
- The dependency syndrome created by government drought relief and recovery programmes and the distortion caused on local markets can threaten private trade.

Water and soil conservation and management programmes

Water is a critical determinant in coping with drought. With continued population growth and socio-economic development, water demands are expected to rise throughout the Limpopo River Basin and SADC region in general. For example, water demands are estimated to increase by 5–10 percent/year in Botswana (GOB–MFDP, 1997). As water resources in the basin are very limited, there is an urgent need for suitable demand and conservation management measures to sustain social and economic development. Soil conservation measures are also important in managing and conserving the water resources, as soil erosion is causing high silt loads and turbidity in the Limpopo River and its tributaries, affecting water treatment and the storage capacity of dams.

Water demand management in South Africa

Water demand management is defined as actions to influence water demand and usage in order to improve economic efficiency, equitable distribution, water storage and infrastructure development, environmental protection, and various other elements of sustainable water supply. Most of these measures are dependent on water supply infrastructure and are specific to each water sector. They may include:

- prepaid metering and effective billing systems;
- use efficiency and reduction of water waste;
- effective O&M;
- user education, awareness and training.

For farming households and rural communities, the main water use sectors are basic water supply and irrigation. For basic water supply, the following key measures are promoted:

- Provision of services at appropriate levels and fair pricing structures to promote customer satisfaction and reduce occurrence of illegal connections and associated water waste. This remains a significant problem in many communities in the basin and results in poor cost recovery and financial failure of schemes. Service delivery has to be accompanied by training, awareness campaigns and institutional support.
- Transfer of infrastructure ownership to communities and their local authorities to promote self-sufficiency and responsibility for maintenance.
- Training of operators in maintaining and operating the infrastructure for effective water use.
- Community awareness regarding the scarcity of water, the potential pollution of water, water use efficiency, possible reuse of water, water storage, etc.

For irrigation use, the following key measures are promoted:

- Appropriate irrigation scheduling techniques. Various techniques have been proposed to farmers with varying success. In some areas, such measures were considered unimportant as water tariffs were very low and water restrictions were imposed infrequently. As water becomes scarce and is shared by more users, irrigation scheduling is gaining importance and many commercial farmers are now applying these techniques with success.
- Effective operation of irrigation infrastructure to prevent water loss. Various measures are promoted to reduce water loss in distribution pipes and canals, irrigation application methods and their use during times of the day and night when evaporation is reduced.
- Effective maintenance of irrigation equipment to reduce wear and maintain efficiency.
- Soil water conservation and crop demand management methods.

To date, demand management has been largely reactive and not proactive. Appropriate techniques have been promoted at "farmers days" and through government publications. However, there is still much to do in order to achieve the desired effect on the ground. Increased water tariffs during times of drought have reduced water usage effectively and in many cases corrected the water use pattern permanently. While such financial measures may be very effective, they can have a far-reaching impact on the overall socio-economic character of communities and water use sectors. Therefore, DWAF is developing various sector water demand and tariff strategies to help guide implementation of such demand management measures.

Within the context of drought, it is essential to provide the basic water requirements to all people prior to allocations for other water use. Generally, basic water requirements for human life represent a small portion of the overall water use and can often be provided through active demand management of high-end users.

Isolated rural settlements, subsistence farming households, small-scale farmers, and those communities with inadequate water infrastructure are most at risk of suffering extensive damages requiring emergency intervention by governments and international aid organizations. DWAF is implementing an extensive programme of providing basic water supply and sanitation services to rural communities in South Africa. It received its original impetus from the broader Reconstruction and Development Programme (RDP) which was the main vehicle for rectifying past inequalities in the first five years of full democratization.

Recent studies by the Directorate of Water Services Planning (GOSA–DWAF, 1999a–c) have assessed the water needs of all communities in South Africa and developed suitable development strategies for addressing all relevant criteria for sustainable, effective and equitable water supply services. Minimum criteria for the RDP include:

- a minimum quantity of 15–25 litres/capita per day;
- accessibility of water within 200 m from each dwelling (household);
- assurance of availability 98 percent of the time;
- minimum flow at access points of 10 litres/minute;
- potable water quality.

Table 31 shows the progress made in supplying basic water and sanitation infrastructure. Service delivery is spread relatively evenly across the country, including the basin areas of Limpopo, Gauteng, Mpumalanga and North West.

Most of the completed projects have yet to be transferred to local authorities for O&M. This phase of development is especially important to long-term sustainability, and it requires proper training, education, and awareness by users of issues such as water conservation, water quality, loss management and drought management.

Other water management issues

In addition to water demand management, some other important programmes have addressed a variety of issues.

Waste water disposal and pollution monitoring and control

This includes finding effective ways of managing and disposing of sewage sludge and hazardous wastes so that they do not contaminate water resources. Mitigation measures are required to prevent groundwater pollution from pit latrines and irrigation (i.e. fertilizer application). Reuse of water and reclamation from water waste can supplement present water use effectively. These types of measures are mainly applicable in high-density population areas where the cost of such actions can be shared.

Optimization of existing infrastructure

Optimization of infrastructure use is a further area of potential water saving. Operating rules of dams and bulk supply infrastructure need to be reviewed regularly. Monitoring systems, through effective metering, pressure management and inspections, are essential for a focused O&M programme, including groundwater pollution vulnerability maps and groundwater monitoring guidelines. In some South African schemes, water losses are 20–30 percent because of leaking, illegal connections, poor maintenance of infrastructure, and ineffective operation and billing systems.

Integrated water and soil resource management

All the basin countries are involved in various regional and national programmes related to the prevention of soil degradation, e.g. Earth Summit, and the UNCCD. These efforts call for national action plans and programmes to be developed,

TABLE 31
Access to basic water and sanitation infrastructure

Period	Water			Sanitation		
	Supply (basic level or higher)	No improvement In supply	Access to services	Supply (basic level or higher)	No improvement in supply	Access to services
	(million persons)		(%)	(million persons)		(%)
March 2003	40.2	6.4	86	29.2	17.3	63
March 2002	37.8	7.8	83	27.6	18.1	60
1994	23.9	15.9	60	17.4	20.4	49

Source: GOSA–DWAF (2003f).

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Plate 2
Water harvesting techniques for improving land productivity

which will require the responsible departments to liaise with international and regional institutions, national and provincial government departments, universities, NGOs, the private sector and land users. For example, South Africa has initiated a national action programme to combat desertification. This programme involves the DWAF, the Department of Agriculture, and the Department of Environmental Affairs and Tourism (DEAT). The National Botanical Institute assessed the current status of desertification (Hoffman and Todd, 1999) and the DEAT is drawing up a strategy document on the combating of desertification.

Resource conservation programmes and research
The LandCare programme (GOSA–DOA, 2000) is a community-based and government-supported land management programme that offers financial support and technical assistance to community groups in order to help them to deal with land degradation and productivity problems (Plate 2). Each country has research programmes dealing with improved methods of preventing the deterioration of soil as an agricultural resource. These include: soil conservation structures, techniques and systems; and the development and implementation of suitable techniques, earthen dams and subsurface drainage. Extension efforts are channelled towards testing and implementing these results in cooperation with farmers who could influence communities.

Other research initiatives
Research is also being conducted to stimulate rainfall through so-called cloud seeding. One of the pilot projects is taking place near Tzaneen, South Africa. Preliminary results indicate that an increase in rainfall of up to 60 percent can be achieved, depending on locality, seeding method and cloud type. Such measures may have some potential for drought relief and may be cost-effective in reducing the variability in rainfall (Steffens and Fletcher, 1995).

To summarize water management issues, the National Conservation Strategy of Botswana (GOB, 1990) highlights the increasing pressures on water resources in Botswana and sets overall development and conservation goals:

- better and sustainable natural resource uses;
- optimization of existing resource uses and resource sharing;
- education of and participation by the public in order to improve the environment (water awareness);
- demand management and suitable development of water resources and supply;
- conservation of all main ecosystems (including the aquatic environment);
- maintenance of renewable resources (i.e. water resources and systems);
- cost-effective restoration of degraded renewable resources;
- prevention of groundwater mining (i.e. when extraction is higher than the recharge resulting in depletion of available groundwater storage);
- reduction of evaporation losses from storage dams and soils;
- prevention and control of water pollution;
- development of integrated catchment management and conservation strategies in consultation with neighbouring countries.

Crop production and diversification programmes

In addition to drought response programmes and water and soil management, there is also general recognition that arable agriculture may not be sustainable in arid and semi-arid areas. Measures are needed to promote crop production systems that are sustainable and include risk reduction and enhance the ability to cope with periodic drought. Extensive work has been conducted in Zimbabwe along these lines and this is used here to illustrate important practices and issues.

In addition to various other programmes and related activities, Zimbabwe's Ministry of Lands, Agriculture and Rural Resettlement recently launched the Smallholder Dry Areas Resource

Management Programme (SDARMP) and the Southern-Eastern Dry Areas Project (SEDAP). The basic objective of SDARMP is to mobilize communities into organizational structures capable of identifying, planning and managing income generating projects. SDARMP intends to support communal area farmers in the most marginal and drought-prone areas of the country, which include Chiredzi and Mwenezi Districts within the Limpopo River Basin.

Technologies developed for dry areas in Zimbabwe

SDARMP and SEDAP will build on research and practices that have been developed for marginal rainfall environments, such as the Limpopo River Basin, aimed at stabilizing and increasing crop yields. These include:

- Improved planting material. Crop improvement efforts have focused largely on early maturity as a drought escape mechanism and on high yield. A number of high-yielding and early-maturing open and self-pollinated varieties of small grains, cowpeas and groundnuts are now available.
- Seedbed preparation. The ox-drawn mould-board plough is the most innovative land preparation technology ever introduced to replace the hand hoe in the smallholder-farming sector. In addition to reaching greater soil depths, it ensures considerable inversion of the soil and is faster than the hand hoe. Although readily available, this technology is linked closely to cattle ownership. Ox-drawn cultivators were introduced for secondary land preparation (weed control). However, as is the case with the mould-board plough, these are beyond the reach of many farmers, especially the non-cattle owners who rely on the hand hoe.
- Row planting and monocropping. Farmers are encouraged to row plant and monocrop instead of broadcasting their seed. This facilitates the mechanization of operations such as planting and weeding and enables farmers to better manipulate plant densities in the event of a drought.
- Soil fertility improvement. Reasonable crop yields cannot be obtained on the granitic sandy soils without regular applications of inorganic fertilizer, manure or lime. Based on extensive on-station and on-farm research, the application of NPK basal fertilizer and nitrogen top-dressing in combination with some 40 tonnes of cattle manure (once every four years) is recommended for the major cereal crops grown in the basin.
- Moisture conservation practices. A number of moisture conservation practices such as ridge, tied ridge and furrow planting have been designed, tested and promoted widely. These practices have resulted in increased crop yields owing to the harvesting and concentration of the available moisture in some years. The practices also tend to improve crop response to fertilizer although this has not been consistent on sandy soils.
- Conservation farming. This approach involves minimum disturbance of the soil surface by using an ox-drawn ripper tine to open the planting furrow. It has been recommended as a soil, water and draught-power conservation strategy (Plate 3). However, because of the open grazing regime in communal areas, little crop residue remains in the field as cattle eat it during the dry season. Furthermore, the roaming animals compact the soil thus rendering reduced tillage unattractive owing to poor water infiltration into the soil.

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Plate 3
Conservation farming

Botswana

In Botswana, the Arable Lands Development Programme (ALDEP) was adopted as a vehicle for improving the productive capacity of resource-poor farmers (GOB–IFAD, undated). The principal objective of the ALDEP was to assist small subsistence farmers to increase the production of basic foodgrains (sorghum and maize), legumes and sunflower in order to achieve self-sufficiency at household and national levels, raise rural revenues and improve income distribution. The programme comprised the following components: (i) on-farm investment; (ii) seasonal inputs; (iii) strengthening of the extension service; (iv) strengthening of the credit service; (v) strengthening of the marketing, input supply and distribution system; (vi) project management and coordination; and (vii) monitoring and evaluation.

About 40 000 farming households were assisted with ALDEP packages between 1982 and 1995, and 45 percent of these were female-headed. Under the programme, farmers were encouraged to use improved farming practices such as row planting, water harvesting and soil moisture conservation techniques. In addition, 170 demonstration farms have been established to promote the adoption of appropriate technology by farmers. In terms of crop production, ALDEP farmers have higher yields than non-aided farmers, despite constraints placed on the ALDEP by a weak extension service and disruptions during times of drought.

South Africa

Alternative crops

There is a widespread movement towards alternative crops that are better adapted than the traditional maize to harsh climate conditions and low inorganic fertilizer input. The LandCare movement is a vehicle for bringing about change. It promotes integrated farming, with crop rotation and fodder legumes, for example, to replace the much-valued maize stover for the overwintering of cattle (stover remaining on the land is needed in conservation tillage). The movement puts a high premium on participatory learning and people orientation. The focus seems to remain on rendering maize production (maize as the main crop, with or without intercropping with dry beans, soybeans or lupins) sustainable, rather than promoting crops that are relatively unknown in South Africa, such as various millets and grain amaranth (H.J. Smith, personal communication, 2000). There is much room for interaction and technology exchange with other SADC countries.

Intercropping

Intercropping is still very common on smallholder farms as a risk reduction strategy against the failure of a particular crop and because of to land pressure, as families try to maximize use of the land they have (where rain is not strongly limiting, intercropping gives more crop per land area). The most common system is to intercrop cereals (e.g. maize) with legumes (e.g. beans). Another system uses pumpkins and watermelons. The intercrop is grown on a minor scale, just to ensure enough for home consumption. The farmers aim to produce in such a way that the cereal yield is not lowered compared with when the cereal is grown alone. Research has shown that apart from the complications of managing two crops on a piece of land, intercropping has the advantage of improving ground cover and hence prevents soil erosion which would otherwise be increased by wind in drought years. Legumes also increase soil friability and fertility. Intercropping will probably continue on smallholder farms, and therefore more research is required in this field.

Extension

Extension staff and representatives from research institutions and agricultural input companies (e.g. seed companies) train smallholder farmers to use certain agronomic strategies that result in improved yields, and thereby enhance their ability to mitigate the effects of drought and help ensure improved food security.

Officers of the LandCare movement have found that up to fourfold increases in crop yield can be achieved with very modest increases in monetary inputs. The concept that they illustrate to farmers is one of doing a number of basic production tasks a little better. These are, in decreasing order of importance: improved weed control (mostly by hand); improved planting techniques (planting density, planting depth, and placement of fertilizer); improved fertilization, by supplying the most basic fertilization needs; and improved pest control, in most cases combating stalk borer by hand insertion of a few granules at knee height (C.E. Steyn, personal communication, 2000).

Rural engineering

The ARC-Institute for Agricultural Engineering is currently implementing the rural engineering programme that forms part of their effort to assist resource-poor communities to farm more efficiently and improve their yields. The emphasis is on the development of infrastructure, equipment and machinery that is appropriate for use by smallholder farmers. The institute also offers practical training in the application of technologies. The agricultural engineering programmes are integrated with other disciplines. Appropriate technologies enhance the production efficiency of farmers, thus ensuring food security and ability to cope with disasters such as drought.

Indigenous technologies

Farmers in southern Africa have developed a series of crop management strategies that enable them to cope better with their harsh production environments. The effect of the available technologies on crop yields tends to vary from year to year largely owing to rainfall fluctuations. They include:

- Crop diversification. Crop diversification is included in order to reduce risks and spread labour input requirements. Farmers plant up to five or six different crops within a given growing season and although these crops are largely monocropped some limited intercropping is still practised, especially with low densities of melon, pumpkins or cowpeas.
- Use of traditional crop varieties. Farmers still predominantly plant the late-maturing and low-yielding local varieties of small grain cereals, cowpeas and groundnuts. These varieties guarantee farmers some yield as they are adapted to the low rainfall and poor soils found in the basin.
- Staggered planting. Despite the fact that crop yields decrease with late planting, farmers stagger the planting of some key crops such as maize during the cropping season in order to reduce the risk of total crop failure in the event of a mid-season drought. Moreover, this enables farmers to stretch their other limited resources such as labour and animal draft power.
- Use of organic fertilizer sources. It is difficult to obtain reasonable crop yields from basin soils without adding organic or inorganic fertilizer. However, because of the high cost and the risks associated with its use in marginal rainfall environments, there is limited use of inorganic fertilizer in the basin, especially by the poorer farmers. Such farmers have resorted to the use of leaf litter and humus as the majority of them have no access to manure, as they do not own cattle. However, because of the widespread deforestation occurring in these areas, the amount of leaf litter available is rather limited. Consequently, crop yields and livelihoods of these farmers continue to be worse than those using inorganic fertilizer or those with access to cattle manure.
- Cultivation of bottomland areas. Farmers have traditionally produced crops such as rice and early maize in the vleis or wetland fringe areas as a food security measure. However, the increased number of people cultivating these fragile areas in an uncoordinated and haphazard manner is rendering the practice unsustainable.
- Use of natural pesticides. Farmers traditionally use plant species such as blackjack *(Bidens pilosa*), marigold (*Tagetes minuta*) and chowa (*Datura stramonium*) instead of inorganic chemicals to control termites, aphids, cutworms and other insects.

Animal production and health programmes

As indicated in Chapter 3, the best-adapted land use in most of the basin is animal husbandry, utilizing extensive grazing on the natural grasslands. Therefore, animal production is a critical issue in any long-term drought mitigation strategy for the Limpopo River Basin. In addition to relief programmes to alleviate livestock mortalities and loss of livelihoods for the farmers, animal production must be incorporated into the integrated resource management strategies in terms of mixed farming systems, impacts on soil and water conservation and management, and national and regional livestock disease control programmes. All the basin countries have livestock programmes in place, aiming at supporting and developing livestock production. These include:

- short-term drought relief programmes;
- drought subsidies and loans to farmers;
- watering point development for livestock;
- livestock production and improvement subsidies;
- disease control and prevention;
- fencing of grazing areas (communal) to aid livestock and range management;
- commercial cattle range development to facilitate livestock and range management;
- livestock marketing programmes to increase offtake for smallholder farmers;
- development of cattle feedlots to reduce grazing pressure and prevent further degradation of the resource base;
- disease control and prevention through erection of dipping tanks and cattle posts in communal areas;
- technical advice on livestock management and herd dynamics;

- irrigation water for integrated livestock-crop production systems;
- livestock water development programmes;
- development of land care programmes;
- use of crop residues as supplementary feeding;
- animal traction (e.g. the Southern African Network for Animal Traction promotes the use of animal traction to encourage better crop production and provide additional crop residues for feeding working animals and enhancing nutrient transfer).

The SADC–FANR cluster comprises a number of areas of cooperation, including livestock production and animal disease control. The FANR Livestock Production and Animal Disease Control Sector has implemented several programmes successfully in recent years. Programmes with relevance to the basin include the facilitation of the establishment of veterinary science faculties in various member states, including Zimbabwe and South Africa; the Botswana Vaccine Institute; and the Regional Tsetse and Trypanosomiasis Control Centre. The sector has also developed heart water vaccines through the regional heart water project with technical support from the University of Florida in the United States of America. SADC–FANR has identified the following challenges in current policies and strategies (SADC, 2003):

- regional cooperation on optimal sustainable rangeland utilization and animal feed flow, especially across borders;
- lack of infrastructure and information on marketing of livestock and livestock products;
- inadequate use of animal traction and organic manure to complement agricultural mechanization and expensive inorganic fertilizers;
- overstocking and overgrazing in local communities;
- unlawful use of pesticides in the region, especially non-biodegradable products;
- absence of concrete interventions to address the constraints facing women.

Forestry and agroforestry programmes

The scope for further plantation forestry development in the Limpopo River Basin is limited by the limited availability of water resources, and environmental concerns about the loss of habitats and biodiversity. Plantation forests use a relatively high amount of water compared with other land uses. Other negative effects include soil degradation, primarily soil acidification. Forest fires and related effects also pose a serious hazard (SADC, 1996b).

There is already strong competition for land and water between forestry and other users. The present strategies of commercial forest development aim to reduce these negative effects by improving sustainable management (Evans, 1999) and by increasing the multiple use of plantation forests through the more direct involvement of local communities in the production and use of plantation forest products. Other non-commercial factors will become more important in the further development of plantation forests, such as land rehabilitation and habitat protection.

Botswana

Forestry is not carried out on a large scale in Botswana, and is mainly of a social forestry type. Therefore, although some areas have been gazetted as forest areas (e.g. Chobe District), government intervention has been more in the area of facilitating initiatives such as backyard nursery programmes, woodlots, a national tree seed centre, and a few farm and village tree planting projects.

Otsyina and Walker (1990) provide an overview of agroforestry development in Botswana. Currently, there is no research done by the government or the university in forestry or agroforestry. However, research is conducted by NGOs, in particular by Veld Products Research and the Forestry Association of Botswana. The research focuses on identifying suitable species for dry conditions and indigenous fruit tree species. Potential interventions and agroforestry technologies applicable to Botswana have been proposed by the SADC (1996a), aiming to alleviate identified constraints such as soil degradation, fodder shortage and shortage of fuelwood and timber. Several activities have already been established in Botswana, such as the use of trees in dune sand stabilization. Recommendations concentrate on alleviating degraded situations around cattle posts and homesteads by planting of multipurpose trees. Other recommended applications include windbreaks, live fences, fodder banks and woodlots. A variety of tree species are recommended, with emphasis on indigenous species, in particular nitrogen-fixing *Acacia* spp., such as *A. karoo, A. erioloba, A. tortilis, A. senega/, A. nilotica, A. nigrescens* and other species such as *Sclerocarya birrea* and *Boscia albitrunca.*

Mozambique
Potential interventions and agroforestry technologies applicable to Mozambique have been proposed by the SADC (1996a), aiming to alleviate identified constraints (above). A variety of tree species is recommended, with emphasis on indigenous species, in particular nitrogen-fixing *Acacia* spp. and others such as *Albizia* spp., *Combretum* spp., *Zizyphus* spp., *Terminalia sericea,* and *Sclerocarya birrea*. Mozambique has the potential to develop agroforestry, and offers a wide range of applications (Lulandala, 1991). Agroforestry is considered a priority in research and implementation activities, with a focus on community forestry. Recommended applications include:

- planting trees on dunes along shores;
- planting trees in cropland, contour strips, and degraded areas;
- planting multipurpose trees and woodlots near villages;
- planting nitrogen-fixing trees in combination with leguminous plants in order to improve soil fertility;
- planting trees and shrubs with good fodder production.

Plate 4
Agroforestry: growing bambara nuts between young orchard trees

South Africa
Limited community forestry and agroforestry programmes have been implemented in South Africa in the higher rainfall areas in the eastern regions of the basin). Potential interventions and agroforestry technologies applicable to South Africa have been proposed by SADC (1996a), aiming to alleviate identified constraints (above). Recommended activities include planting of multipurpose trees and fruit trees in specific locations, mixed and hedgerow intercropping, live fences, and woodlots (Plate 4). For each of the situations, specific tree species are recommended, with emphasis on indigenous species, in particular nitrogen-fixing *Acacia* spp.

Zimbabwe
There has been renewed interest in agroforestry research and development work in Zimbabwe since the early 1980s. This is in recognition of the key role that this land use system can play in food security enhancement and poverty alleviation. In 1989, an inventory exercise commissioned by the National Agroforestry Steering Committee captured some of these initiatives. A total of 14 research projects were implemented by three institutions (the Department of Research and Specialist Services, the Forestry Commission, and the University of Zimbabwe) in the high and low rainfall areas of the country. Twelve of the projects were station-based while two were on farmers' fields. In terms of emphasis, 36 percent of the projects focused on soil fertility improvement, 21 percent on fodder provision for livestock, and 43 percent on both soil fertility and fodder. A total of eight extension projects were initiated by the AGRITEX, the Forestry Commission, Environmental Development Action, GTZ/ARDA, the Nyanga Development Project, French Cooperation, the Bikita Peoples Council and the Glen Forest Training Centre. The projects covered both the high and low rainfall areas. Only one of the projects concentrated on soil fertility improvement, two on fodder provision, four on both soil fertility and fodder, and one on fuelwood supply.

SADC-FANR forestry sector
The forestry sector of the SADC–FANR has developed programmes on training and education, improved resource management, improved knowledge of the resource base, focused research, resource utilization, marketing and environmental management. Most of these programmes have focused on data and information gathering, and institution building at the national level. There has been limited regional collaboration and cooperation in areas of common concern, such as

overexploitation, law enforcement and promotion of community-based programmes. Problems of sustainable forest output persist, as millions of rural households use fuelwood for energy. There is a paucity of regional interventions aimed at developing and promoting appropriate alternative energy sources.

Information regarding appropriate forest management systems for the various indigenous forest types is lacking in most SADC member states. This is partly attributed to past national policies that gave higher priority to the establishment, management and protection of exotic softwood and hardwood forest plantations than to the indigenous forests (SADC–FANR, 2003).

The SADC–FANR (2003) identifies the following challenges in its current policies and strategies:

- the need to create public awareness and for education to address agroforestry practices, afforestation, fire control and overgrazing;
- the need to improve forestry and sericulture practices in order to address deforestation, genetic erosion, forest pests, disease control, invasive alien species, management and conservation of shared forests and forest resources, and law enforcement;
- the need for a regional strategy to develop small- and medium-scale forest-based industries, as well as appropriate fuelwood and charcoal production systems, especially in rural areas;
- lack of information to facilitate trade in forest products and a strategy to develop standards, guidelines and other mechanisms for recording, preserving and equitably sharing benefits from the use of traditional forest related knowledge;
- lack of concrete interventions to address the constraints facing women.

Nature conservation and tourism

The two main forms of nature conservation are: nature and game preservation, and degradation control. Nature and game preservation is a very important land use in the Limpopo River Basin, and takes place in reserves, parks and wildlife management areas. The main differentiation is according to the management and interference with the ecosystem, which is very low in reserves, and higher in parks and wildlife management areas.

Degradation control is often linked to nature conservation areas, but may also occur independently, e.g. in communal areas. Degradation control and land rehabilitation may take place without or with low interference, e.g. with fencing only, or with high interference, e.g. through land use planning and rehabilitation schemes.

A significant part of the Limpopo River Basin is utilized for ecotourism and conservation. The northern half of the Kruger National Park falls within the basin. Nature reserves and private game farms in the South African part of the basin include: Letaba Ranch, Honnet Nature Reserve, Messina Experimental Farm and Nature Reserve, Blouberg Mountain, Lesheba Wilderness, Buzzard Mountain Retreat, Happy Rest Nature Reserve, Marekele National Park, Lapalala Wilderness, Touch Stone, Doorndraai Dam Nature Reserve, Hans Strijdom Dam Nature Reserve, Mabalingwe Nature Reserve, Potgietersrus Nature Reserve, Warmbaths Nature Reserve, Langjan Nature Reserve, and Blyde River Canyon Nature Reserve. As these are privately administered, the total area covered by them in the basin and their role in terms of job and wealth creation is difficult to ascertain.

Game ranching research

The Messina Experimental Station of the South African Department of Agriculture is running a long-term (about 15 years) research programme on game ranching (B. Bekker, personal communication, 2000). The programme is assessing two production systems: (i) game production as a single enterprise, and (ii) mixed game and cattle production. Research focuses on the economics of production, assessment of carrying capacity, stocking rates, habitat selection by species, and biological and ecological norms for the area. The programme also pays attention to training and demonstration of production techniques to game ranching farmers. If game ranching were to be promoted in the region, along the lines of Zimbabwe's CAMPFIRE programme (Box 21), the research station has accumulated a wealth of information that would be of value.

WHAT HAS BEEN LEARNED

Tables 32–34 highlight some of what has been learned from the information presented. They also indicate perceived gaps in the understanding of the situation.

TABLE 32
Pertinent issues emerging from Chapter 1

Issue	What has been learned	Knowledge gaps
Basin from global perspective	Drylands constitute the bulk of the basin	
	UNCCD obligations apply to ratifying governments	The requirements are demanding; Is substantial progress being made in terms of the various NAPs?
Meteorological drought	The most important natural disaster in southern Africa	How to isolate its effects from those caused by land use factors
	The most complex and least understood of all natural hazards	Predictability of rainfall variation patterns
Occurrence of drought	Basin highly vulnerable to drought; one or more "ordinary" drought events per year in basin; extreme drought events recorded for more than a century at 10–20 year intervals; rare for all countries to be drought-stricken at the same time; consecutive droughts may occur	Cycles and periodicity; predictability; early warning
Impact of drought	Most important natural disaster in economic, social and environmental terms: - macroeconomic: biggest type of economic shock SADC countries are likely to experience, particularly agriculturally dependent economies; - socio-economic: food and water insecurity, poverty, health; - environmental: damage to natural habitats. Effects of impacts linger long after the actual event.	Proactive mitigating measures
Magnitude of disaster drought events	Example of 1991/92 drought period: - Botswana: widespread crop failure and livestock mortalities; - Mozambique: more than 1.3 million people affected, especially the rural poor of the southern and central zones; - South Africa: estimated 50 000 jobs lost in the agriculture sector, with a further 20 000 in related sectors, affecting about 250 000 people; - Zimbabwe: worst drought in living memory; owing to water and electricity shortages, manufacturing output declined by 9.3 percent, with a 25-percent reduction in volume of manufacturing output and 6-percent decline in foreign currency receipts.	Appropriate risk management systems, taking cognizance of the need for preparedness – impact assessment – response – re-construction – prevention cycles

TABLE 33
Pertinent issues emerging from Chapter 2

Issue	What has been learned	Knowledge gaps
Climate		
Climate classification	Gradation from west to east: tropical dry savannah, grading to warm temperate rainy with dry winters and hot to cool summers, and to a tropical rainy climate (Mozambique coastal belt).	
Rainfall	MAR: 200–1500 mm; spatial distribution: low along main river course in central-western part; high along eastern escarpment; about half the basin < 500 mm.	Are there atmosphere-oceanic interactive systems besides the ENSO that affect the area?
	Rainfall season: October/November–March/April; not particularly highly concentrated; effective moisture season may either be short or longer but intermittent; midsummer drought a common phenomenon.	Land suitability of various niches (AEZ) for drought-tolerant crops and cultivars
	Variability: high between seasons and within the season.	Quantification of long-term variability
Evaporation	ET_o of summer season (October–March.): 600–1 000 mm; spatial distribution the opposite of rainfall distribution; R = 0.5–1.0 ET_o indicates marginally arable to arable conditions; about half the basin climatically suited to arable agriculture.	Is ET_o sufficiently reliably modelled (taking the limited number of temperature recording stations into account) particularly for application at local level?
Temperature	Maximum temperatures: 30–34 °C in summer and 22–26 °C in winter; minimum temperatures: 18–22 °C in summer and 5–10 °C in winter. Frost: high-lying areas (bulk of basin) receives frost; severe in southeast highveldt.	Modelled interpolation between remote stations with intervening terrain features
Climate change	Africa considered vulnerable to climate change; temperatures (night temperatures?) appear to rise slowly.	Corroboration from other climate recording and expertise centres

TABLE 33
Pertinent issues emerging from Chapter 2 (Continued)

Issue	What has been learned	Knowledge gaps
Physiography		
Geology	Hard and soft geology plays an important role in the genesis of physiographic units and soils, e.g. deep, sandy soils of gentle topography or clays associated with Quaternary surface deposits, particularly in Botswana (sandveldt) and Mozambique; Lithosols and sodic soils associated with hard basement complex granite.	Best practice land use technologies for various unique land types (climate–terrain–soil landscapes), e.g. plains with excessively drained sandy soils in arid and semi-arid areas
Geological erosion cycles	Deep, porous soils associated with rolling remnants of old land surfaces; shallow soils associated with young, incised erosion surfaces.	
Main physiographic regions	Three major physiographic regions: Cape–Transvaal highveldt, Zambia–Zimbabwe Plateau and Kalahari Basin; separated from the coastal plains by the Great Escarpment. Altitude and longitude codeterminants of rainfall zones.	
Soil resources		
Data availability	Ad hoc rather than systematic soil surveys; general scarcity of detailed or semi-detailed soil maps; soil data mostly not easily accessible; different systems of classification.	Availability of soil survey data at appropriate detailed scales; interpretations; correlation between classification systems in use
Importance	Soil properties related to water storage (texture, soil depth and internal drainage) are particularly critical in semi-arid environments experiencing drought conditions.	
Two main groups	Old soils formed on deeply weathered parent materials, influenced by early erosional surfaces: favourable physical properties when not excessively sandy; often leached and acid; include the Arenosols of sandy deposits; the presence of slowly draining material beneath a permeable rooting zone may add considerably to the profile water-holding capacity.	Locally fine-tuned fertilizer and lime requirements for appropriate levels of crop production. Soil loss prediction expertise
	Relatively young soils, formed on the more recent erosional surfaces: often shallow and steep.	
Problem soils	Restricted water-holding capacity: Three common restrictions are inadequate soil depth (restricting the plant water reservoir), high clay content (causing runoff and low water availability), and excessively low clay content (causing excessive drainage and restricting the plant water reservoir).	Best practice land use technologies to deal with adverse soil conditions. Merging of western technological insights with indigenous knowledge.
	Erodibility and crusting/surface sealing: Solonetz and Planosols generally have low structural stability, adverse macrostructure conditions in the subsoil and susceptibility to crusting of the surface horizon; aggravated by the presence of relatively easily dispersible clay minerals, clay size quartz and sodicity.	
	Textural contrast: Displayed by Solonetz, Planosols and some Luvisols; renders them problematic from a plant extractable water viewpoint. Some members (mostly Solonetz or Planosols) display an abrupt transition between the topsoil (or sandy layer beneath the topsoil) and the subsoil with respect to texture, structure and consistence. The material above the transition is usually of light texture, permeable and can be penetrated readily by water and roots. The material below the transition is usually clayey, dense, very slowly permeable and can be exploited by roots to a very limited extent. The subsoil is characterized by very low water-stability and is thus highly susceptible to water erosion, particularly deep gullying, when exposed. In other members (certain Luvisols), the textural contrast is less prominent.	
	Acid soils: Acid problem soils are the most frequently reported. Most acid soils are found in areas with relatively high rainfall, e.g. on the northern and southern fringes of the basin, in particular the South African highveldt areas occupied by Ferralsols and Acrisols. Acrisols and other inherently acid soils also occur locally in the more central parts of the basin, in southeast Botswana, in some of the central higher rainfall parts of Limpopo Province of South Africa, and in similar areas of Zimbabwe and Mozambique.	
	Organic matter and nutrient depletion: Intensively cultivated soils in the basin generally undergo serious decline in organic matter. This results in structural and biological degradation and contributes to acidification.	

TABLE 33
Pertinent issues emerging from Chapter 2 (Continued)

Issue	What has been learned	Knowledge gaps
Surface water resources		
The river system	Botswana: Four major tributaries join the Limpopo River from Botswana and feed into the upper reach of the river; total naturalized MAR (difficult to estimate): 605 million m^3/year; contributes 8 percent to total river flow; difficult to develop.	Is flow adequately monitored at appropriate catchment levels to support modelled data?
	Mozambique: Three major tributaries join the Limpopo River from Mozambique and feed into the lower reach of the river; total naturalized MAR: 795 million m^3/year; contributes 10 percent.	
	South Africa: About 20 tributaries join the Limpopo from the South African side and feed into all three reaches of the river (Upper, Middle and Lower); total naturalized MAR: 5 066 million m^3/year; contributes 67 percent.	
	Zimbabwe: Four major tributaries join the Limpopo River from Zimbabwe and feed into the middle reach of the river; total naturalized MAR: 1 157 million m^3/year; contributes 15 percent.	
Reliability	Highly variable and unreliable flow (CV of 130 percent); water supplies consequently unreliable.	
Surface water extraction	Botswana: About 21 percent of naturalized MAR being abstracted, almost all from Notwane tributary; water development made difficult by low and erratic flow, level terrain and high evaporation; some potential for development in Shashe; domestic water needs dominate water use; South Africa plans to transfer 124 million m³ water per year from the Crocodile West and Marico water management area to Gaborone.	Riparian sands and sandy alluvia as natural storage reservoirs?
	Mozambique: entering Mozambique the main river has an average natural MAR of 4 000–4 800 million m^3/year, yet irrigation water scarcities are reported, due to abstractions upstream.	What are the problematics with respect to irrigation water? Figures appear to suggest opportunities, rather than constraints.
	South Africa: Available water about 2 627 million m^3/year of which 1 017 million m^3/year is surface water; the rest comes from imports, groundwater and return flows. About 20 percent of naturalized MAR being abstracted; commonly regarded as the maximum that can be economically developed; abstraction takes place from all tributaries; in some tributaries, water for the ecological reserve is undersupplied.	
	Zimbabwe: 1 211 million m^3/year committed.	Apparent discrepancies in figures.
Groundwater resources		
Importance	Rural communities far from surface water resources depend on groundwater resources for household use and livestock (in South Africa, more than half of rural communities); uneconomic to serve all rural communities from surface water resources.	
Availability and quality	Botswana: Very low recharge rates; low probability for high-yielding boreholes; overexploitation during drought periods; sand rivers provide good recharge and storage capacity for local extraction; relatively high salinity (TDS 1 000–1 500 mg/litre for most catchments); commonly excess concentrations of fluorides, nitrates.	Detailed information on the distribution of health-related dissolved solids (e.g. nitrates, fluorine)?
	Mozambique: Coastal dune area: medium recharge rates and good quality; alluvial valleys: good recharge, high salinity; old alluvial plains: no potential due to high salinity; deep aquifer (80–200 m): low salinity and low recharge.	
	South Africa: Most rural communities located on minor aquifer types with an average borehole yield of about 2 litres/s. Communities north of Soutpansberg are located on poor aquifer types yielding less than one litre per second. Crocodile (West) and Marico: groundwater represents about 40 percent of the water resources; dolomite aquifers in places; Limpopo: in the Sand subarea, groundwater is of overriding importance; contribution of groundwater to the total water among the highest of all water management areas; Elephants: groundwater constitutes nearly 20 percent of the water; dolomite aquifers in places; Luvuvhu and Letaba: in Shingwedzi subarea, more than half of the water available is abstracted from groundwater.	
	Zimbabwe: Not well endowed with groundwater; reasonable groundwater reserves found in two areas only; Limpopo riverbed sand aquifer: low quality owing to salinity, although the quantities are good.	Data on exact extent and quantity of groundwater.

TABLE 33

Pertinent issues emerging from Chapter 2 (Continued)

Issue	What has been learned	Knowledge gaps
Interbasin and intrabasin water transfers		
Botswana	Transfer of 124 million m³ water per year from the Crocodile West and Marico water management area to Gaborone being planned.	
South Africa	Crocodile (West) and Marico: 42 percent of current water supplied by transfers from the Upper Vaal water management area and beyond. Elephants: 22 percent of current water supplied by transfers, mainly from Vaal River system.	
Land cover and land use		
	Savannah grassland, and shrubland: 67.7 percent, Cropland (rainfed): 25.4 percent, Cropland (irrigated): 0.9 percent, Forest: 0.7 percent, Urban and industrial: 4.5 percent.	Detailed breakdown of land use; local-level crop statistics.
Land degradation and desertification		
Key issues	Escalating soil erosion, declining soil fertility, agrochemical pollution and desertification.	Clear distinction between causes (human vs natural); mechanisms and impact of land degradation; role of drought; extent of rangeland degradation, deforestation and bush encroachment.
Botswana	Mostly alleged strong rangeland degradation, including bush encroachment; localized wind and water erosion.	Systematic inventory; agreement on extent of rangeland degradation.
Mozambique	Mostly light degradation (wind erosion); low erosion hazard; soils susceptible to salinity and sodicity; salinization in the irrigated areas.	Monitoring systems; benchmark sites; clear baselines; systematic data collection processes; adoption of area-specific best practice land use technologies.
South Africa	Soil and vegetation degradation significantly greater in communal areas in comparison with commercial areas (by at least a factor of two).	
Zimbabwe	Overall strong degradation in communal areas in northern and western areas adjacent to Botswana, with severe sheet and gully erosion caused by deforestation and intensive cropping.	Agreement on extent and degree of stabilization; how to achieve success in curbing degradation.

TABLE 34

Pertinent issues emerging from Chapter 3

Issue	What has been learned	Knowledge gaps
Population characteristics		
Density	Botswana, Mozambique and Zimbabwe cluster between 12.5 and 16 persons/km^2; South Africa, 57.7 persons/km^2.	
Urban centres	Botswana: two main urban centres: Gaborone and Francistown; South Africa: several main urban centres; Witwatersrand economic hub situated immediately outside southern border of basin.	Basin-specific statistics
Rural population	Basin predominantly rural; about 8 million out of 14 million people (58 percent of basin population) live outside the urban centres.	
Human development and poverty		
Human development index	Botswana, South Africa and Zimbabwe: medium; significantly lower (20 percent) when adjusted for skewed income distributions; Mozambique: low.	Basin-specific statistics; recent trends; rate of progress; relation to Millennium Development Goals (UNDP)
Human poverty index	Mozambique: 51, Zimbabwe: 30, Botswana: 28, South Africa: 20.	
People not expected to survive to age 40 years (%)	Mozambique: 41, Zimbabwe: 41, Botswana: 37, South Africa: 20.	

TABLE 34

Pertinent issues emerging from Chapter 3 (Continued)

Issue	What has been learned	Knowledge gaps
Adult illiteracy rate (%)	Mozambique: 57 Botswana: 24, South Africa: 15, Zimbabwe: 13.	Basin-specific statistics; recent trends; rate of progress; relation to Millennium Development Goals (UNDP
Underweight children under age of 5 years (%)	Mozambique: 26, Botswana: 17, Zimbabwe: 15, South Africa: 9.	
Livelihoods and land tenure		
Persons in basin deriving their livelihood mainly from agricultural activities (%)	Botswana: 65, South Africa: ±35, Mozambique: no exact figures; very high. Zimbabwe: not given.	Systematic analysis of livelihoods and food insecure populations conducted across the four countries; basin-specific statistics; recent trends
Land tenure	Dual system: customary land tenure (common property regime) and statutory land tenure (private property regime); South Africa excepted, land is dominantly held under customary tenure; 70 percent of basin area in Botswana is communal lands.	Sustainable land use systems for customary land tenure situations; appropriate mix of indigenous knowledge and science
Farming systems		
Livestock production under communal management	Dominant system; economically important; about 70 percent of ruminant livestock kept under small-scale farming and communal grazing systems; communal management systems not conducive to controlled grazing; overstocking common during periods of drought.	Veldt-condition monitoring systems and data
	Large stock: mixed crops/livestock system under communal management characterized by ownership and management of cattle; kept primarily for draught power, socio-economic status and a means of saving on the hoof; mainly local breeds that are generally low producers, but well adapted to the harsh climate conditions of the basin; herd sizes are small; indications are that the number of households owning cattle has been slowly decreasing and small stock (mainly goats) increasing in response to demographic pressure; low input farming; animals mainly depend on extensive grazing with little or no supplementary feeding apart from provision of water; poor reproduction rate; high mortality rates during drought; low offtake rates. Botswana: In 1993, there were 114 000 traditional farms, holding more than 90 percent of all cattle; the basin accounted for 76 percent of the total traditional sector cattle; however, incidence of livestock ownership in traditional sector fairly low: in 1995, only 53 percent of agricultural households in the basin owned cattle; average herd 44.7 head. Mozambique: Cattle herd drastically reduced during the war (from 1.4 million in 1974 to 214 000 in 1993); since then the sector has been recovering; largely owned by the small-scale sector; large potential for stock farming; use of traction animals quite limited; only 22 000 trained animals used in 1996 (6 percent of the cattle population). South Africa: In Limpopo Province, only 18 percent of farming operations kept cattle in 2002. Zimbabwe: Livestock farming the most viable enterprise in dry basin areas; browse from the mopane-dominated savannah provides the bulk of livestock feed, as the dry conditions limit availability of grazing to a few months after the rains.	Veldt-condition monitoring systems and data; appropriate marketing systems; value adding to animal products; agritourism; integrated farming systems (game, grazers, browsers, and value adding)
	Small stock: kept by most farmers and includes goats, sheep and chicken mainly used for own consumption and as a source of household income. Botswana: In 1995, 84 percent of agricultural households in the basin owned goats; goat flocks averaged 30 head. Mozambique: Small stock particularly important to women and poorer households. South Africa: In 2002, 33 percent of farming operations in Limpopo Province kept goats.	Relation between small stock and land degradation; browsing capacities; browser/grazer relationships; area-specific best practice technologies

TABLE 34
Pertinent issues emerging from Chapter 3 (Continued)

Issue	What has been learned	Knowledge gaps
Commercial livestock production	Half of the area within the basin in Zimbabwe and South Africa is classified as commercial farmland; predominantly used for cattle ranching; high responsiveness to biophysical and socio-economic environment; quick to sell stock when drought is apparent; the latter a common response to drought; in Botswana, restricted mainly to freehold farms situated along the Limpopo River.	
Rainfed crop production under communal farming systems	Revolves around maize, sorghum, beans, groundnuts, vegetables and millet in places; mangoes, banana and avocado important household crops in high rainfall escarpment and lowveldt areas; typically a low-input, low-output system aimed at minimizing risks arising from climate variability and making the most efficient use of the limited natural resources; characterized by low use of purchased farm inputs (fertilizer and certified seed) and low management levels; cropped areas small owing to poor access to draught power; majority of farmers rely on hand hoeing, limiting the areas cultivated; late and poor land preparations a common feature partly owing to labour constraints, poor access to mechanization and the need for draught animals to gain condition before they can be used; yields are low (0.25 tonnes maize in Botswana, 0.8 tonnes in Zimbabwe and Mozambique; 0.25–1.0 tonnes in South Africa); low yields partly due to soil degradation, nutrient depletion owing to continuous cropping, low nitrogen and other farm inputs; culture of using organic sources of fertilizers mostly poorly developed; use of improved seed is limited; in general, heavily dependent on low-yielding local varieties.	Basin-specific statistics; area-specific best practice technologies
Rainfed commercial crop production	Mainly on South African highveldt; large plantings of mainly maize and sunflower; relatively high yields owing to better natural resources, farm inputs and management; yields variable, but total crop failure infrequent; stover used for stock feed, retarding progress with conservation tillage.	Appropriate conservation tillage practices
Irrigated crop production	Botswana: Potential area under irrigation 5 000 ha; 1 300 ha currently irrigated of which 660 ha are under vegetables; basin accounts for 69 percent of the commercial holdings practising arable agriculture (largely irrigated), reflecting the higher incidence of irrigation availability, better soils and higher rainfall in the basin areas compared with the rest of the country. Mozambique: Potential area under irrigation 148 000 ha; 40 000 ha currently irrigated; originated as government schemes; little attention paid during war years to financial and technical sustainability; some schemes planned for rice production; large range of crops with maize, sugar cane, citrus and vegetables important; severe salinity and sodicity problems. South Africa: Potential for irrigation estimated at only 131 500 ha; 198 000 ha currently under irrigation; difference can be explained by "stretching" of water; mostly high-value crops produced (vegetables, citrus and subtropical fruit); mostly highly managed commercial enterprises; number of smallholder schemes, struggling to succeed. Zimbabwe: Potential area under irrigation 10 900 ha; 4 000 ha currently irrigated: 1 550 ha smallholder irrigation, 1 900 ha under large-scale commercial farming and 1 500 ha under the ARDA; crops not stated.	Monitoring systems and data on land degradation and water use
Forestry, agroforestry and conservation areas		
Commercial plantation forestry	Restricted to South African escarpment areas with more than 700 mm rain; economically important; based on exotic pine, eucalyptus and wattle species; requires high management levels; only 1.7 percent of total water resources in the basin area of South Africa used by afforestation.	
Community forestry and woodlands utilization	Natural woodlands quite extensive; main source of wood products, especially building materials and fuelwood for local communities; provide non-wood products (indigenous fruits, mushrooms, thatch grass, and material for medicinal use); economic/social importance of indigenous forest and wood products to local communities often underestimated as a source of income and for subsistence.	
Agroforestry	Natural agroforestry practices based on improved natural woodlands management have high potential in the basin; planted agroforestry not practised much in the basin owing to unfavourable climate, especially in the tree establishment phase; appears to have restricted potential in the semi-arid areas.	
Conservation areas	Several smaller and a few major conventional conservation parks (including much of the Kruger Park) are situated in the basin; plans are afoot for establishing transfrontier parks, of which the planned Gaza–Kruger–Gonarezhou Transfrontier Park would be largely within the basin.	While poverty persists in the region, how would poaching be curbed in multiple land use situations?

TABLE 34
Pertinent issues emerging from Chapter 3 (Continued)

Issue	What has been learned	Knowledge gaps
Drought strategies and policies		
General SADC policies	Acceptance that drought is a normal and recurrent phenomenon; to be integrated into programme management cycles aimed at mitigation and prevention; long-term prevention programmes needed rather than short-term mitigation measures; key elements: preparedness, rehabilitation, prevention and planning; responsibility for dealing with the impacts of drought policies to be shifted more onto the farmer or the user of the land; new strategies to ensure that drought relief assistance and programmes to support farmers are consistent with existing livelihood strategies and market development policies; compatibility between short and long-term development. Five strategic areas: - soil and water management; - rangeland and livestock management; - appropriateness of crop production patterns; - appropriate farming systems; - institutional arrangements and physical infrastructure. Objectives related to institutional arrangements: - to build human capacity for designing and implementing drought policies and programmes; regional support to national governments; - to promote contingency planning for drought; - to develop data banks on early warning, food security and market information; - to promote technology development and transfer; - to strengthen management of resources.	Acceptance and implementation
Botswana	Main thrust in policy is to include drought management in the normal planning and development process; in emergencies, government to use existing projects, programmes and budgets to respond to the situation, albeit in an expanded and accelerated way; short-term drought relief programmes and long-term drought mitigation strategies. Drought relief: essentially short-term operations and programmes, with action taken immediately after a drought. Drought mitigation programmes: building overall national resilience to drought through development strategies with special attention to the rural areas. Three main practical components: - human relief: human feeding strategies to include specific targeted populations in addition to existing and ongoing institutional programmes; - livestock relief: the provision of free vaccinations under certain drought-related conditions; an expanded livestock water development programme; the facilitation of supplies of livestock feeds and requisites; where feasible, incentives for increased livestock offtake; - arable assistance packages: free seeds; ploughing services; row-planting grants.	
Mozambique	No formal drought policy at the time of this report; formal policy guiding institutional arrangements for disaster management, including drought and the relationship with other national policies, were under review at the time.	

TABLE 34
Pertinent issues emerging from Chapter 3 (Continued)

Issue	What has been learned	Knowledge gaps
South Africa	New approach to disaster management adopted in a white paper on disaster management and ensuing Disaster Management Act of 2000; previous policies focused mainly on relief and recovery efforts; the act highlights the importance of preventing human, economic and property losses and avoiding environmental degradation; the act is administered by the Department of Provincial and Local Government; it prescribes the establishment of disaster management structures at national, provincial and municipal levels. Responsibility for developing a national drought management strategy to slot into the national disaster management plan assigned to the Department of Agriculture; a draft agricultural disaster management plan and a drought management strategy followed. Priority areas and programmes for addressing drought and drought management. Increasing awareness and preparedness by way of a national drought plan: - reducing risk to droughts through appropriate research plans; - mitigation plans; - recovery and development programmes – post drought; - implementation of education, training and information plans; - risk management with a strong emphasis on an insurance-based solution, which can be applicable to the agriculture sector as a whole.	How to progress from concepts to practice; workable drought management systems; effectiveness of drought management structures
Zimbabwe	National Policy on Drought Management (approved 1999): government capacities and structures to deal with drought preparedness, mitigation and response issues; emphasis on developing sustainable livelihoods of populations most at risk to drought-induced shocks; activities to be integrated with other developmental programmes and projects; to form an integral part of all district, provincial and national-level development policy and planning processes.	
Water policies/strategies		
General SADC policies	Water an important transboundary issue; SADC Water Sector Coordinating Unit (SADC–WSCU) established in 1996; coordination of activities: Ministry of Natural Resources, Government of Lesotho; ensuing actions involving SADC–WSCU: - Protocol on Shared Watercourse Systems (1998); - Regional Strategic Action Plan (RSAP) on integrated water resources development and management: five-year action plan (1999–2004); one of the actions is the formulation of a regional water sector policy and strategy.	
Multilateral organizational structures	Limpopo Basin Permanent Technical Committee (LBPTC) established 1986 by Botswana, Mozambique, South Africa and Zimbabwe; establishment of the Limpopo Basin Commission (LIMCOM) under consideration to elevate the status of the LBPTC to that of a permanent commission.	
Botswana	Water Apportionment Board administers the Water Act and the Borehole Act, requiring individuals or groups to apply for a right to use water for irrigation; any proposed irrigation project must be shown to be economically viable and sustainable; substantial shortfalls in water supplies, competition for water and high cost of water make it difficult for irrigation projects to be economically viable.	
Mozambique	Water Law of 1991 defines the institutional and legal framework for licensing and allocation of water concessions; National Water Council provides intersector coordination and strategic decision-making; National Water Policy (1995) highlights: - satisfaction of basic needs is a high priority; - operational water resources management to be decentralized to autonomous catchment authorities; - principal investments to be aimed at conserving the existing infrastructures and reducing water losses; - private sector participation.	How to maximize irrigation development and general water use efficiency in practice

TABLE 34
Pertinent issues emerging from Chapter 3 (Continued)

<table>
<tr><th>Issue</th><th>What has been learned</th><th>Knowledge gaps</th></tr>
<tr><td>South Africa</td><td>Water sector completely reformed following democratization in 1994, leading to National Water Act (1998) and National Water Resource Strategy (2002), with emphasis on:
- meeting basic human water needs;
- equitable access;
- redressing past racial and gender discrimination;
- aquatic ecosystems and biodiversity;
- international obligations;
- managing floods and droughts.</td><td>Effect of non-permanency of water allocations on irrigation farming investment and entrepreneurship</td></tr>
<tr><td>Zimbabwe</td><td>Water sector reforms since 1995: New Water Act (1988) and Zimbabwe National Water Authority (ZINWA), with emphasis on:
- correction of skewed distribution;
- environmental sustainability;
- economic value of water to be reflected in pricing;
- stakeholder involvement.</td><td>Study of current food shortages and their relation to land and water reform</td></tr>
<tr><td colspan="3">Institutions and services</td></tr>
<tr><td rowspan="2">SADC institutions</td><td>SADC–FANR: operational since 1998; focuses on food security strategies for the region; aiming at improvement of smallholders' competitiveness (rural development); increased efficiency of use of natural resources; increased agricultural and intraregional trade; improved access to food and nutrition; assisting national governments with strategy and policy formulation; networking; information and training. Operates through the following programmes: food security, regional coordination and cooperation, regional information system for food security; makes use of early-warning systems, remote sensing, GIS, marketing and environmental information systems.</td><td rowspan="2">How to integrate effectively with national efforts</td></tr>
<tr><td>SADC Drought Monitoring Centre: focuses on monitoring climate extremes, especially drought; collaborates with major climate centres; provides training; issues advisories.</td></tr>
<tr><td rowspan="4">National institutions</td><td>Botswana: Mostly state departments within the Ministry of Agriculture; about six parastatals, dealing with the livestock industry, marketing and training; commercial institutions include the National Development Bank, Botswana Development Corporation, cooperative societies, agricultural management associations, commercial banks, private cattle traders, and NGOs.</td><td></td></tr>
<tr><td>Mozambique: Several directorates, institutes and programmes within the Ministry of Agriculture and Rural Development and other ministries are supported by a number of international organizations, among which are a large UN system, USAID and the World Bank. Several international institutions provided assistance during recent flood events.</td><td></td></tr>
<tr><td>South Africa: Considerable transformation has taken place since 1994; a large spectrum of functions is delegated down to the provincial and municipal levels; all land came under the jurisdiction of municipalities; the Department of Land Affairs regulates inter alia issues of land reform; the most important change of all has been the abolition of all racial restrictions on land ownership. A large number of central and provincial government institutions, parastatals and training institutions serve the basin area directly or indirectly.</td><td>Regulations for and enforcement of the many new acts; how to effectively roll out services at municipal level; orchestration of service delivery, taking into account the institutional complexity</td></tr>
<tr><td>Zimbabwe: Several departments, commissions, institutes and programmes within the Ministry of Lands, Agriculture and Rural Resettlement, the Ministry of Environment and Tourism, the Ministry of Energy and Water Resources and Development (as well as others) serve the basin area. A few international organizations provide support.</td><td></td></tr>
</table>

OPTIONS AND STRATEGIES FOR SUSTAINABLE DEVELOPMENT

The following sections suggest six avenues of development as priority areas.

Livestock and range development

Animal husbandry is an essential economic activity in most African farming systems. In order to feed the growing human population, more land will need to be devoted to the cultivation of cash crops and, as land is a scarce resource, there will be a reduction in its availability for pasture and fodder. On the other hand, the increase in food and cash crops will make available more crop residues, many of which represent valuable animal feed resources. However, there is a need to increase the efficiency of resource utilization for sustained production.

A careful assessment and analysis of the production environment is required in order to formulate livestock development strategies that will lead to better use of local resources, contribute more effectively to food security, improve the living standards of poor people and ensure the sustainable development of livestock production. Sansoucy (1995) has identified the key factors of this overall strategy as being:

- political support for fair commodity prices and proposed strategies;
- better definition of the target recipients' needs;
- increased efficiency of use and management of natural resources;
- linking production and post-production components to effective services, infrastructure and marketing (Box 30);
- more appropriate policies for the use of common land and rangeland;
- improved capacity and commitment of national and international agricultural centres and NGOs to implement strategies that contribute to the development of livestock production in specific agro-ecosystems.

Sansoucy (1995) also observed that the availability and efficient use of local natural resources is the key to livestock production. A successful livestock development strategy requires the formulation of resource management plans that complement the wider economic, ecological and sociological objectives. Particular attention needs to be given to land use systems and to the natural resources required for improved livestock production. The strategy will also need to consider the social, cultural, political and institutional elements that affect the management of natural resources. On the policy side, issues relating to land use, common property, legislation, price policies, subsidies, levies, national priorities for livestock development and research capacity have to be addressed. Again, the implementation of action programmes requires both technical and institutional support and, equally important, government commitment.

One of the key challenges to livestock development is how to develop strategies that are long term, will ensure sustainable resource utilization, and at the same time ensure that the effects of drought are minimized. Before introducing technology to rehabilitate degraded land, it is imperative that institutional arrangements

BOX 30

Considerations relating to communal stock farming

Buying in fodder is seldom a realistic option in communal areas, where most stockowners are subsistence farmers and cannot afford to buy feed. In a situation of drought, fodder availability is commonly low. Subsidizing fodder appears to be an essential component of drought management.

Communal area farmers are generally reluctant to sell animals during a drought for a number of reasons, including:

- they are not commercially oriented and have different reasons for keeping livestock;
- most herds and flocks are small;
- they do not know how long the drought will last;
- by the time the drought is apparent, the animals have lost condition and their sale value has fallen;
- sale points tend to be few, with stock losing further condition before reaching the sale points.

There may also be the suspicion among communal area farmers that they are being coerced by government to de-stock. From a communal farmer perspective, livestock numbers are usually the best insurance against drought. With larger stockowners this form of insurance is often accompanied by herd splitting, either maintaining control (e.g. through herders) or distributing animals to poorer relatives to look after in return for the milk, draught and dung outputs.

be in place to monitor and ensure adherence and implementation. The following technology and policy options are relevant and need to be pursued.

- Develop water supplies. Before any development takes place, very careful consideration should be given to the possible impact on the distribution of wet and dry season grazing to settlement patterns and on the efficiency of feed utilization. King (1983) found that increasing watering frequency (e.g. from a two-day to a one-day regime) increases the metabolic rate and, hence, decreases the efficiency of the utilization of scarce feed resources.
- Breeding for increased adaptability in indigenous breeds, with selection schemes based on producers' herds. Traits of economic importance to drought resistance need to be conserved and developed.
- Introduce multispecies to encourage a better utilization of the vegetation. There is growing evidence that the combination of different species, including wildlife and livestock, has a positive effect on plant and biodiversity. Agricultural tourism needs to be studied.

Finally, it is important that government take a holistic approach to resource management by building capacity through increased analytical skills at farming level as well as school and university levels. Any sustainable livestock development strategy has to take full account of producer and consumer objectives. For many livestock producers in the SADC region, the first priority is household food security and family welfare. Less tangible future sustainability of resource use is often traded off against immediate food needs. On a national scale, social and economic objectives may be in conflict with environmental objectives or have different time scales. Therefore, it is conceptually useful to bring these different implications for environmental sustainability, social development and economic growth together in one "national wealth" indicator, i.e. holistic resource management.

Appropriate crops and production technologies for rainfed areas

In drought-prone areas, particularly where soils are shallow and poor in natural productivity, appropriate technological advances should be developed and trialled. These would aim at improving agricultural production during non-drought periods. Farmers should be encouraged to reduce the area grown to maize in highly drought-prone areas with poor soils until such time as there are acceptable cultivars with high drought tolerance. Instead, they should be encouraged to grow crops that are adapted to dry conditions through their ability to grow and mature in short growing seasons with low rainfall. The farming systems recommended to the farmers should be low-input systems to lessen the economic risk. Crop farming systems to be considered include appropriate forms of conservation tillage.

Revitalization of irrigation

Irrigation could be a strong stabilizing factor in the basin. There are two levels at which irrigated agriculture operates in the basin, each with a valuable contribution to make with respect to poverty reduction and household food security. These are: (i) highly managed, high-income fruit and vegetable crops, mainly for exporting or marketing in the urban centres; and (ii) small-scale irrigation schemes that produce vegetables and other food and fodder crops, mainly for local consumption. Both are needed and both are to be developed within the constraints of water availability.

Water use efficiency is to be the main developmental goal. This includes catchment management, water development, effective reticulation systems, and effective on-farm water management, including scheduling, weed and pest control, and seed quality.

As is the case with all of the other developmental issues, effective institutional support (including assistance from international institutes) would be the cornerstone of sustainable development.

Catchment management as a tool in drought mitigation

The catchment management approach, together with AEZ, is the most suitable method to address problems related to land degradation, unsustainable land use, effects of drought, etc. In particular, the spatial aspects of constraints and other issues in the Limpopo River Basin are best dealt with by these two approaches.

An FAO study highlights soil and water conservation issues in semi-arid areas (FAO, 1986). Another study (FAO, 1987) indicates several important aspects of integrated catchment management:

- concepts for policy and strategy development for improved catchment management;

- catchment management as a conceptual framework for diversified development planning;
- development of multiple-use options, such as agroforestry, forest production, and conservation measures. The first step is identification and assessment of current problems and constraints, such as resource problems and their effects (floods, drought, low production, erosion, etc.) and socio-economic problems (land tenure, land and labour shortage, lack of social organization, infrastructure, etc.);
- incentives for community involvement in integrated catchment planning and development. Incentives include direct incentives in cash and kind, and indirect incentives in fiscal support and provision of services, e.g. improving land tenure security, technical and social services, and community organization.

Reducing household vulnerability to drought

Potential impacts of drought, and specifically household vulnerability to drought, can be categorized into:

- type of drought impact and the type of household vulnerability;
- location of household and vulnerability types within national physical and institutional boundaries;
- relationship between national drought impacts and regional physical and institutional resources.

The type of drought impact is related closely to the type of farming practice and its extent. Different strategies are required for large commercial farmers, emerging farmers, small-scale farmers and subsistence-farm households. Household vulnerability is different for these farming types and they each require specific capacity building and suitable support programmes to reduce their drought vulnerability.

Different categories of farming and household types may share the same physical, climatological and institutional characteristics. They often share the same resources (water and land) and need to be developed and managed through integrated programmes (i.e. river catchment management), cooperative, institutional and community participation (i.e. disaster management centres) and intergovernmental monitoring and risk management programmes (i.e. the SADC).

BOX 31

Modern developments and concepts in conservation – transfrontier conservation areas

The conservation of natural resources and biodiversity has become a fundamental global concern and is recognized increasingly as a social–cultural issue. This may conflict with traditional concepts of conservation, as current conservation legislation in most countries does not recognize different levels of conservation protection, other than proclaimed nature reserves.

Following this holistic concept, conservation is also supposed to take place outside the officially protected areas. Conservation should become part of the overall sustainable management of forests and woodlands, which are primarily used for a variety of other purposes, including grazing, extraction and recreation.

There may be a wide range of applications and emphasis in conservation, depending on local conditions and uses. For example, formal recognition of conservation-worthy areas outside nature reserves may provide landowners and communities with an incentive to identify and register sites of special significance.

For the Limpopo River, catchment management is an international affair and requires intergovernmental monitoring, evaluation and early-warning systems. Information sharing and cooperative governance is essential to this drought management programme.

Exploring opportunities for wildlife development and tourism

Transfrontier conservation areas

Dongola/Limpopo Valley TFCA

This proposed transfrontier conservation area (TFCA) (see Box 31) encompasses a large tract of land around the tri-nation point of Botswana, South Africa and Zimbabwe, including public and private game reserves, private farms and communal land. This low rainfall area offers better prospects for game parks, game farming and tourism than most of the other present land uses. The area is particularly unsuited for dryland crop production. Scale enlargement is necessary to provide options for the game population, in particular elephants, to move from exhausted areas that have received little rainfall and need recovery, to areas with better grazing and browsing.

TFCAs between Mozambique, South Africa and Zimbabwe

Recent regional initiatives such as the TFCAs and the Lebombo Spatial Development Initiative provide frameworks for enlarging the scope and concept of conservation. The World Bank has developed a multimillion-dollar proposal to revitalize rundown wildlife areas in Mozambique and link some of them with parks in South Africa and Zimbabwe (see Chapter 3).

The aim of these initiatives is to develop joint objectives, strategies and programmes in order to foster sustainable economic growth and to promote the sustainable use of natural resources, while at the same time managing for the conservation of transboundary ecosystems and associated biodiversity. This is to be achieved by identifying, planning and implementing projects (with full stakeholder participation, including local communities) that aim to improve transport, agriculture and ecotourism through focusing on specific development nodes. The term conservation area in this context does not refer to the traditional park type protected area, but incorporates different levels of protection within an overall area of management that allows for controlled habitation and the utilization of resources.

The Mozambique TFCAs comprise three major components. The central one is situated in the Limpopo River Valley, connecting the Banhine and Zinave (the latter in the Save River Basin) National Parks in Mozambique with the Kruger National Park in South Africa and the Gonarezhou National Park in Zimbabwe. Although wildlife populations in Mozambique have been devastated, animals in this area have migrated traditionally towards the Limpopo River. The state of the habitat is very good and there is potential for artificial and natural game restocking. The Kruger National Park is reaching saturation point, in particular with respect to elephants, which provides excellent opportunities for Gaza Province to absorb the excess of game.

The southern component (south of the Limpopo River Basin) is the Maputaland TFCA, connecting national parks and nature reserves in the coastal area of Mozambique and South Africa with the Lebombo hills and lowveldt of Swaziland, creating a unique combination of big-game parks, nature zones, wetlands and coastal zones. The northern TFCA component (north of the Limpopo River Basin) connects unique and well-preserved mountainous areas in Mozambique with the Chimanamani National Park in Zimbabwe. It is not clear in which way connections may be established between the three TFCA components.

Proposed biodiversity conservation and participatory development (BCPD) projects under the umbrella of the Global Environment Facility (GEF), and requested by the World Bank, is another very important initiative to conserve biodiversity and develop tourism. These projects will focus on establishing a sectorally integrated and sustainable system for the management of biodiversity and important catchments through a participatory development process in biodiversity and tourism corridors (BTCs). The corridors will connect protected and protection-worthy areas of globally significant biodiversity, while maintaining and enhancing the integrity and continuity of interlinking habitats. The BCPD projects will also support agrobiodiversity by promoting indigenous knowledge systems in the use of medicinal plants in the BTCs.

Cultural tourism

In Limpopo and Mpumalanga Provinces in South Africa, there is growing interest among tourists in traditional village life and experiencing African culture at grassroots level. These provinces have a variety of interesting traditional features to offer, such as handicrafts, pottery, basketry, paintings, and traditional food. Day visits to traditional villages are slowly becoming more popular, e.g. in Venda (Louis Trichardt - Thohoyandou area).

Tour operators are investigating the willingness of villagers to entertain visitors to see how they live. Some projects have started, e.g. in Giyani, where the community hosts occasional day visitors. The revenue is used in community projects, e.g. the reliable provision of clean water. There are operational problems, such as good communication, the provision of toilets and refreshments, and reliability of bookings (villagers have to be available on agreed dates). Village visits must also be sustainable – they will collapse without commitment.

ISSUES TO CONSIDER

The following points are put forward for consideration in the context of sustainable development.

Policy-related issues

Long-term economic progress depends heavily on developing a more productive dynamic and equitable agriculture sector, within a sustainable rural environment.

National governments must demonstrate greater commitment to addressing the problem of drought management by adequately funding research and development projects.

Existing policies, strategies and structures should be consolidated and rationalized, perhaps in a single document. What is needed is a clearer vision of the individual role of various government programmes and structures in mitigation, preparedness, emergency response, and drought rehabilitation.

Improved vertical and horizontal integration of policies and action plans and monitoring of projects is essential.

Problem-solving extension approaches are needed, considering the general socio-economic and natural resource conditions prevalent in the basin.

In order to address the needs of rural people, interdisciplinary, collaborative, problem-focused and participatory approaches would have to be developed.

The role of agriculture in the regional economy and society at all levels is recognized. Therefore, it is imperative that all agriculturally related research and development role players optimize their management processes and strategic approaches so as to maximize their impact on three of the important objectives (challenges) identified regionally: poverty reduction, wealth creation and household food security.

District/municipal drought committees should be strengthened (they should take responsibility for monitoring and reporting on drought impacts).

Community involvement

It is essential for policy-makers to realize that problems can never be solved at the national level if they are not tackled from the grassroots.

People-centred/farmer-centred approaches should be adopted. In this respect, it is important that the needs and aspirations of potential beneficiaries/communities be taken into consideration during the initial planning of any intervention strategy.

Inherent capabilities, intelligence, knowledge and responsibility of rural people will have to be taken into consideration and respected.

Given appropriate incentives and support, the rural communities are perceived to be willing to cooperate in initiatives aimed at using natural resources judiciously.

Ways should be sought for the community to be more involved in drought monitoring.

Community vulnerability assessment should be incorporated into the early-warning technical committee functions (this would prewarn authorities of community vulnerability and so help in targeting relief).

As environmental issues are related largely to communal land, every community should have natural resource management programmes and committees to steer them.

Institutional issues

Focused building and maintaining of institutional capacities will be an important consideration.

BOX 32

Systems approach

Research has done far better in increasing individual commodity yields in input-intensive single-enterprise agriculture than in improving the productivity of complex systems. Furthermore, the use of modern science has tended to focus on commodity yields rather than long-term sustainability. Researchers generally favour the approach where researchers study a piece of the system according to their own interest and specialization, and the results are then combined to create a picture. At best, it is a slow and often inefficient approach to problem solving. At worst, the pieces of the jigsaw puzzle fail to produce a meaningful picture.

What is required is a systems and interdisciplinary approach to the sustainable improvement of complex systems. This problem-focused approach requires a multidisciplinary team searching for greater understanding of the interaction between human needs and motives, the needs of animals, and the constraints imposed by the institutional, economical, infrastructural and natural environment. Teams must be encouraged to find innovative, cost-effective and simple solutions to problems and to grasp opportunities.

Technology and training

Challenges facing small/resource-poor farmers will probably become more severe in future, accompanied and often caused by environmental degradation, owing to water scarcity and droughts.

Measures for reducing poverty and food insecurity need to be explored and developed at all levels. These include appropriate and locally acceptable technologies for improved crop and animal production.

There is an inadequate understanding of the dynamics and socio-economic complexities of integrated crop-livestock farming systems.

Environmental education and appropriate development projects with large local content and participation, adequately supported by appropriate public policies, are essential. Every development programme should have a separate component for disadvantaged rural groups, especially women.

Environmental education should be given prominence in formal education, especially at primary and secondary levels.

Sustainable resource management calls for action on the broad and complex front of rural development. It is not merely a matter of agricultural production but rather comprises widespread sustainable rural growth and development (Box 32).

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4
LAND AND WATER DISCUSSION PAPER

Drought impact mitigation and prevention in the Limpopo River Basin

A situation analysis

Southern Africa is particularly susceptible to climate variability and drought and is increasingly being threatened by desertification processes, degradation of land and water resources and loss of biodiversity. Although rainfed farming is a high-risk enterprise, it is also a way of life and people are committed to making the best of the scarce resources at their disposal. However, droughts tend to reduce production to below the already marginal levels, thus threatening subsistence farming. These conditions occur where the local economy is least diversified and where almost everyone depends either directly or indirectly on agriculture. Frequent exposure to drought causes agricultural production to be out of equilibrium with the seasonal conditions, representing an inability on the part of most smallholders to adjust land use to climate variability. Thus, managing for drought is about managing for the risks associated with agriculture; managing for climate variability must become the norm rather than the exception. Farmers must either increase agricultural productivity or develop alternative sources of income if their livelihoods are to be sustained. The situation analysis presented in this paper aims to provide readers with an understanding of the people and their environment in the Limpopo River Basin in southern Africa, covering parts of Botswana, Mozambique, South Africa and Zimbabwe. It examines the biophysical, socio-economic and institutional characteristics of the basin and captures details of past programmes and practices. It concludes with a section on lessons learned and proposes options and strategies for sustainable development, with a focus on drought impact mitigation.

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