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LAND AND WATER DISCUSSION PAPER

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A perspective on water control in southern Africa

Support to regional investment initiatives

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Preface

In October 2002, the Director General of FAO proposed a long-term regional programme on the improved use of water for agriculture to the governments of Angola, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe.

Following favourable responses, including that of Botswana, FAO commissioned a diagnostic study to examine the root causes of crop and livestock productivity decline in the face of recurrent droughts, resultant water shortages and the failure to harness the potential for effective water use.

The diagnostic considered current water use and the potential for improvement to increase production and reduce the vulnerability of farmers to drought in ten countries: Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe.

The diagnostic was carried out at FAO's Subregional Office for Southern and East Africa (SAFR) in Harare according to the issued terms of reference (TOR), by three consultants: a socio-economist (who was also the team leader), a specialist in soil fertility and land management, and a specialist in water resources management. The studies were conducted almost exclusively from the desk, with support from FAO staff in Harare and Rome.

The study forms part of FAO's support to the NEPAD CAADP. It elaborates a perspective for the land and water management 'Pillar 1[1]' of the CAADP at sub-regional level and provides a **framework for national initiatives in order to assist the formulation of bankable projects.** The perspective also attempts to provide a background diagnostic for the proposed SADC Irrigation Development and Water Management Project submitted under Pillar 1 of the NEPAD CAADP Flagship Programme.

[1] Pillar 1 is entitled *Extending the area under sustainable land management and reliable water control systems.*

Acronyms

AEZ	Agro-ecological zone
Al	Aluminium
Ca	Calcium
CIMMYT	International Maize and Wheat Improvement Centre
DMC	Drought Monitoring Centre
FAO	Food and Agriculture Organization
FARMESA	Farm Level Applied Research Methods in Eastern and Southern Africa
GDP	Gross domestic product
GNI	Gross national income
HDI	Human Development Index
IFAD	International Fund for Agricultural Development
IIASA	International Institute for Applied Systems Analysis
IMF	International Monetary Fund
LGP	Length of growing period
Mg	Magnesium
Mn	Manganese
N	Nitrogen
NEPAD	New Partnership for Africa's Development
NGO	Non-governmental organization
O&M	Operation and maintenance
P	Phosphorus
RMD	Resource management domain
S	Sulphur
SADC	Southern African Development Community
SAFR	FAO Subregional Office for Southern and East Africa
TOR	Terms of reference
UNDP	United Nations Development Programme
Zn	Zinc

Executive summary

Poverty and agriculture

The very widespread, and deeply entrenched poverty of the region is especially severe in rural areas, where sustenance for the majority comes derives from chronically low and volatile income based on agricultural production – whether for subsistence or for market – and where alternatives are few. The low and volatile incomes lead to food insecurity and vulnerability to internal and external shocks. The primary shock is drought within an already dry climatic regime. The outlook for those in both rural and urban areas who rely on agriculture for livelihood and/or for food is further threatened by the HIV/AIDS pandemic.

Growth of the national economies is having only modest impact on poverty. The non-farming sectors provide off-farm incomes and critical remittances from migrant workers, but are not significantly reducing dependence on agriculture for employment and income – some 7.7 million more people are now dependent on agriculture than a decade ago. Without significant prospects for movement into other sectors with higher income-earning potential, the sole option for alleviating or reducing poverty for large numbers of rural people is to increase the output of farming. There is some scope (for example, in Angola, Mozambique, Zambia and Zimbabwe) to develop land for new settlement, but where this is not practical, improvement in living standards must come mainly from increased production from the land now in use.

There has been little overall change in the production of major staples over the past three of four decades, with their supply, broadly, keeping pace with population. Yields vary greatly, between years and between countries. Recent changes in area and output of major cash crops have been more pronounced than those for food crops. Cash crop yields vary substantially between years although less than for food crops. It is apparent, however, that the incentives and opportunities for cash production are leading these crops in a quite different direction to that of the food staples.

Farmers do not always select enterprises most suited to the natural and economic environments. There appears to have been little change in how farmers use available resource. Crop and livestock yields are generally not increasing and the mix of crops changing very slowly. Very high proportions of cropped area used for staple food prevention. While these staples have apparent advantages of easy preparation and high palatability, they have a high production risk in fragile environments.

Natural resources and farming systems: limits of soil fertility and soil moisture

Of the 14 major farming systems of Sub-Saharan Africa, 11 occur in one or more of the ten selected SADC countries and six are most important: (i) **highland temperate mixed,** covering most of Lesotho and nearby South Africa and the Eastern Highlands of Zimbabwe; (ii) **cereal-root crop mixed,** predominant in the dry sub-humid zone of Angola, Zambia and Mozambique at relatively low altitudes; (iii) **maize mixed**, the most important and predominant in the dry sub-humid zone of Zimbabwe, Zambia and Malawi at relatively high altitude; (iv) ***s*****mallholder within large commercial areas***,* typical for the former homelands in South Africa and also occurring across the border in southern Namibia and Botswana; (v) **agro-pastoral millet/ sorghum**, over large areas in the dry sub-humid zones of Angola and Zambia and the semi-arid zones of Botswana, Namibia and Zimbabwe; and (vi) **pastoral**, especially in the semi-arid zones of Botswana, Namibia and Angola, is characterized by extensive cattle rearing.

Most soils in Southern Africa are inherently low in major crop nutrients (particularly N and P) and many micro nutrients (e.g. Zn, S and Mg). More than half of the region has sandy or coarse, gravely soils with low capacity to retain nutrients and hold moisture. Acid ("infertile") soils occur in areas with higher rainfall in Mozambique and Zambia. Low use of mineral fertilizer and burning or grazing of crop residues in smallholder agriculture is gradually depleting some essential plant nutrients.

While total seasonal rainfall is usually more than sufficient to grow an annual crop in all but the arid zone, only part of the precipitation is available for crop growth: (i) much of the rainfall comes in high-intensity storms and the soil is unable to absorb it all; (ii) rain falls in summer, when temperatures are the highest and some evaporates before being used by the crop; (iii) mid-season dry spells are common; and (iv) poor cultivation practices have caused a deterioration of the infiltration rate, permeability and retention capacity of the soils. These factors commonly result in moisture stress and reduced crop yields.

Runoff is generally 'flashy' responding to high intensity rainfall events. The Rift lakes and extensive areas of wetlands on the higher erosion surfaces offer significant volumes of storage and attenuate and diffuse the otherwise flashy hydrographs from upstream catchments. Baseflow recession in the region is very marked with river flows declining to fractions of wet season volumes as soon as the dry season commences and then tailing off to minimal baseflows as the dry season extends.

The recharge of shallow groundwater circulation on the saprolite soils developed over the Basement Complex is also significant. The deeper horizons on the higher elevation (older) erosion surfaces store significant volumes of groundwater but with low transmissivities. This groundwater is slowly released during the dry season, sustaining dambos and upland springs and seeps. The deeper groundwater circulation associated with carbonate rocks, for example in the Copper Belt, offer highly transmissive aquifers that are exploited for large scale commercial irrigation, as in Zambia.

Improving water control for agriculture

The key to successful water management for agricultural production in the region is water storage, the main means of which are: (i) as moisture in the crop root zone; (ii) as groundwater in shallow, annually recharged aquifers; and (iii) in natural or artificial reservoirs or tanks, especially those formed by dams, The great majority of cropping in the region is and is likely to remain, rainfed even though there is scope for more irrigation. Storing soil moisture in the crop root zone is thus probably the most important of the three means. The basic ways of improving the amount of soil moisture available to crops, which have been well known and practised for centuries, are closely linked to soil fertility management techniques. The present situation in the ten countries is mixed, with some farming systems more advanced than others. Some 70-85% of rainfall in water-scarce farming systems is "lost" from cropped fields through run-off, deep infiltration, evaporation and use by weeds and failed crops. Water harvesting technology has been proved able to reduce these losses, increase crop yields and ensure domestic water.

Irrigated areas, while constituting only a small proportion of the sub-region's cultivated area, are important for production of high value cash. Most irrigation systems are reported to be poorly managed with only a fraction of the design command under operation.. The available estimates of irrigation potential appear to indicate considerable potential for further irrigation development - of the order of ten million hectares. This is, however, misleading because the available information does not indicate the probable unit cost and general economic merit of the 'potential. Without at least reconnaissance level studies of most of the sites and preferably full feasibility level work, no valid conclusion can be reached about the quantitative potential for economically attractive, financially viable and technically sustainable irrigation development can be reached. There is some scope for expansion of use of groundwater for irrigation, especially in the limited areas where it is available at shallow depths and accessible by small dug wells.

Two important points need to be stressed. First the range of options in water control is broad, from low intensity, extensive initiatives in soil moisture conservation to high intensity, concentrated investments in conventional hydraulic control. Second, each management solution has its own attendant risk and cost. The costs of conventional irrigation in Africa are notoriously high, not only in procurement of hardware, but also in the application of management.

There is, nevertheless, scope to raise incomes and reduce vulnerability to climate through improved water control. It is therefore important to put investment in water control in a measured context. First the rain-fed systems need to be stabilised to confirm the production of staple foods. It is only then that the contribution from more expensive irrigation can be judged. Complete resolution of the problem of low and unreliable farm production will require conducive policy formulation, institutional behaviour and investment beyond the farm, in addition to investment and improved management within the farm..

The policy environment

Farmers are confronted by many interacting factors which limit their capacity and motivation to raise productivity. The natural resource and climatic conditions and the wide economic and policy frameworks all interact to create the conditions in which farmers operate. Even maintaining, productivity depends on how farmers manage their businesses, which they do in four main areas – selection of enterprises, husbandry of crops and livestock, investment to raise productive capacity and marketing.

A range of economic and policy factors which apply beyond the farm strongly affect farmers' motivation and capacity for change and how they tailor their investments and operations. The business environment is determined largely by the rate and nature of economic growth and by the policy stances of government, which are heavily inter-related. There has been much progress in policy reform in most of the ten countries in recent years – especially in reducing macro-economic imbalances, taking on commitment to and encouraging the private sector and reducing the "crowding-out" behaviour of parastatals. While such reforms have greatly improved the overall investment climate, there remain significant obstacles to improving farm productivity within the sector-specific policy frameworks

A subregional strategy

Increased productivity of water and thus of land, depends on its better use which, in turn, requires three groups of actors to play effective roles: (i) farmers must improve the use of other resources to complement better water use: (ii) those concerned with marketing, in its broad form, must facilitate the best use of products from farms; and (iii) governments must create a framework which allows and encourages the other actors to play their roles.

To address rural poverty in the region, a primary objective must be **higher productivity of land and water**. Achievement of the full potential for increased productivity depends on attention to two both those factors which apply directly to farmers on their farms and should be addressed there and those which apply (directly or indirectly) beyond the farm and must be addressed in that sphere. A strategy to address these factors consists of two thrusts.

The first thrust needs to be directed to farmers and farmer groups to pursue the objective of **productive and profitable farm operations** by (i) improving farm management; and (ii) improving the delivery of water serves . The three categories of water control cited the NEPAD CAADP 'pillar' in land management and water control provide suitable targets.

The second thrust needs to address factors which apply mostly away from the farmers and their farms and which act against the creation of effective sets of incentives, with the objective of **expanding economic opportunities for farmers**. The focus of the tactics - to upgrade the economic and business frameworks - would be on role players beyond the physical boundaries of farms, whose activities affect farmers directly but "distantly", such as government regulatory agencies and private concerns in marketing.

Chapter 1
Background

Agriculture in the economy

Population

The ten countries concerned have a combined population of 117 million, representing 14 percent of the total population of Africa. South Africa has by far the largest population of the ten countries, while those of Botswana, Lesotho, Namibia and Swaziland are small (Annex 1 for population and economic data). Average annual population growth for the ten countries (2.2 percent) is lower than that for Africa as a whole (2.8 percent) and higher than that for the world (1.5 percent). Within the group, annual population growth ranges from 3.2 percent for Angola to 1.7 percent for South Africa.

Urbanization and industrialization have had a modest impact on the rural and agricultural populations. The proportion of the population living in rural areas has fallen in all ten countries, but only in South Africa has the absolute rural population fallen. The agricultural population of the ten rose by a total of 7.7 million between 1991 and 2001, with only South Africa able to reduce dependency on agriculture to provide employment. Since 1991, Angola, Malawi, Mozambique and Zambia have each added more than 1 000 000 to the number of people depending on agriculture. The pressure on natural resources is increasing as agriculture is asked to provide livelihoods and food for rising populations.

Economic growth

The economies of the ten countries are small and have narrow production bases. Among the world's economies, South Africa (which generates 75 percent of the total national income of the ten) ranks 34 by size and the others from 85 to 152. Gross national income (GNI) per person for the ten averages US$1 330 and ranges from US$3 100 for Botswana to US$160 for Malawi. The ten countries rank between 89 and 199 among the 208 in the World Bank's estimates of income per person.

Only South Africa has a truly diversified economy, with 8 percent of its output coming from agriculture and major contributions coming from higher-value mining, manufacturing and services sectors. Botswana and Angola, where mining is important, have agriculture sectors contributing 4 and 12 percent of gross domestic product (GDP). The other economies have a much greater dependence on agriculture, the highest being for Mozambique (64 percent of GDP), Malawi (64 percent) and Zambia and Zimbabwe (20 percent each).

Annual economic growth for the ten was considerably different in the 1990s to that in the 1980s. In the 1990s, economic growth in Mozambique and Namibia was much higher and in Malawi and South Africa moderately higher than in the 1980s. Angola, Lesotho and Zambia had slightly lower growth in the 1990s. Growth in Botswana, Swaziland and Zimbabwe slowed greatly in the 1990s.

The highly variable annual economic growth rates are headed by Mozambique (6.7 percent in the 1990s), Botswana (5.2 percent) and Namibia (4.6 percent). The countries with generally the worst poverty indicators (Malawi, Mozambique, Zambia and Zimbabwe) had mixed experiences of total and agricultural growth in the 1990s. Mozambique enjoyed the highest economic growth and, relative to other countries, high agriculture growth. Malawi had the fifth fastest national growth but topped agriculture sector growth. Zambia and Zimbabwe had among the lowest national growth rates and were in the middle of agriculture sector performers.

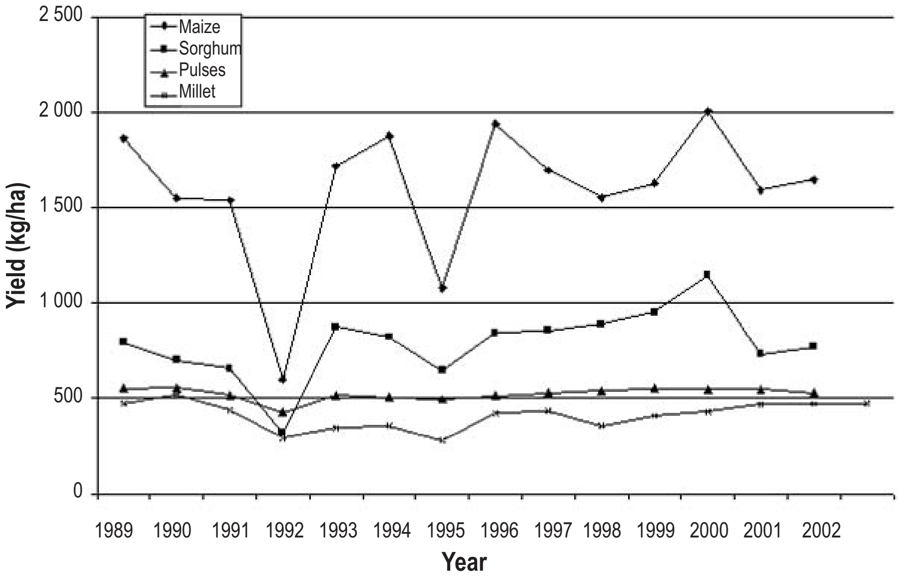
Growth in the agriculture sector was able to outpace that of the national economy only in Malawi, Zambia and Zimbabwe in the 1990s, but was generally able to grow faster than the population depending on it. Compared with population growth, sector product growth was much higher in Malawi, Mozambique and Namibia, and much lower in Angola and Botswana. The overall picture is one of modest growth in both the agriculture sectors and the national economies relative to population. Growth in the non-farm sectors has been insufficient to reduce dependence on agriculture for employment or income.

Agricultural production

Food crops. There has been little overall change in the production of the four major staples (maize, sorghum, pulses and millet) in recent decades (Annex 2 for selected food crop production data). While there have been substantial shifts within individual countries, the overall outcome for the ten is that the rate of increase in production of these crops has not matched that of population. Supply to the ten countries of these key staples is generally keeping pace with population growth. Trade in these commodities is minor; in the past three decades, there have been small increases in imports and reductions in exports.

Yields for the four crops vary considerably from year to year (Figure 1) and from country to country. The greater annual variation in the yield of maize and sorghum reflects the fact that they are less drought tolerant than millet.

Figure 1
Average yields of food crops



Maize, the dominant staple for the great majority of the region's people, is the greatest user of agricultural land, about 9.2 million ha. Total production in 2000 (three-year average 1999-2001) exceeded that for 1990 (three-year average 1990-92) by 1 percent. There was little overall change in area (-1 percent) or yield (+5 percent). Lesotho, Malawi and Mozambique increased production by expanding area and raising yields and Angola by a greatly higher yield from reduced area. South Africa, Swaziland and Zimbabwe reduced both area and yield. Maize supply to domestic markets has been increased primarily by reduced exports, especially in South Africa. Angola, Lesotho, Malawi and Mozambique have increased supply much faster than their populations, by large rises in production and reductions, or restrained increases, in imports.

Sorghum, the second most important grain crop, uses about one-tenth as much land as maize. The sorghum production of the ten countries rose by about 20 percent between 1990 and 2000, with a 29-percent increase in yield more than offsetting a 15-percent reduction in area. Lesotho, Malawi and Mozambique accounted for almost all of this increase, all three expanding area and raising yield. Zambia and Zimbabwe increased production marginally, the former by expanding area and the latter by raising yield. Botswana, Namibia, South Africa and Swaziland reduced their sorghum area substantially. Sorghum supply has increased in line with production, with only Botswana and South Africa increasing exports and all countries' imports remaining largely unchanged.

Production of pulses, which are critical to sound nutrition, increased by 20 percent between 1990 and 2000 as total area expanded by 18 percent and yield by 2 percent. Angola, Lesotho and Mozambique increased area and yield substantially to gain the greatest proportional increase in production and account for the great majority of the subregion's additional output. South Africa and Swaziland retreated from sorghum production with large reductions in area and small changes in yield. Zambia increased area significantly to offset a large fall in yield. The supply of pulses is increasing steadily in all countries except Malawi and Namibia. Imports are significant only in South Africa and Angola.

Millet is an important grain source in dry agropastoral areas, largely because of its tolerance of drought. Overall, the area of millet changed little during the 1990s. However, there were large proportional and absolute increases in area in Angola and Namibia with the former having a slight increase and the latter a large fall in yield. Production fell sharply in Zimbabwe as both area and yield fell. The expansion of the millet supply is steady and uniform across the countries with drier climates, except for Zimbabwe where it has fallen rapidly. The region's trade in millet is negligible.

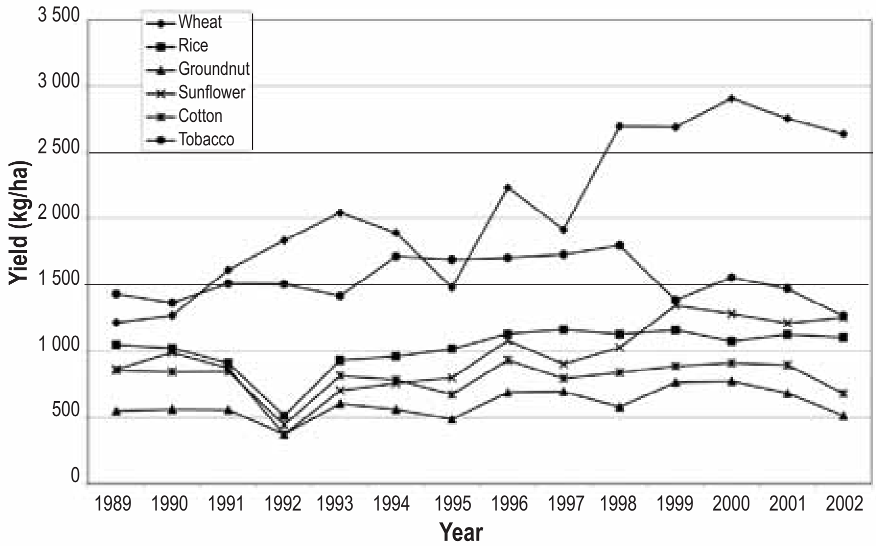
Roots and tubers are a major user of land and a critical source of food. Total area is expanding considerably, especially in Angola, Mozambique and Zambia, in all of which production is rising steadily.

Cash crops. Recent changes in the area cropped and the output of major cash crops have been more pronounced than those for food crops (Annex 3 for selected cash crop production data). There is considerable variation in production between countries and between crops for selection cash crops (defined here as grown exclusively or primarily for sale). The total output of all the selected crops rose between 1990 and 2000 although their total cropped area fell from 4.6 to 4.0 million ha.

The major shifts in production patterns between 1990 and 2000 were:

- Total area fell by about 0.6 million ha.
- Total area declined in Lesotho, Mozambique and South Africa.

FIGURE 2
Average yields of cash crops



- Reduced wheat area accounted for almost all of the reduction in the total area in South Africa (about 0.8 million ha).
- Total production (by volume) increased in all countries except Swaziland.
- Total production of each crop increased.
- Average yield for each crop increased by 2-106 percent.
- South Africa recorded very high increases in wheat, groundnut, sunflower, cotton and tobacco yields.
- Malawi increased wheat, rice, groundnut and sunflower yields substantially.
- Mozambique increased rice, groundnut, cotton and tobacco yields.
- Zambia had large increases in wheat, groundnut and cotton production and a large reduction in that of sunflower, owing to changes in both yield and area.
- Zimbabwe had large increases in output of cotton and tobacco (mainly from expanded area) and a large reduction in sunflower area and production.

Crop yields vary substantially from year to year (Figure 2) although less than for food crops. Much more exhaustive and detailed analysis would be required to draw valid conclusions about the changes in area, yield and production for cash. However, it is apparent that the incentives and opportunities for cash production are leading these crops in a different direction to that of the food staples.

THE NATURE OF RURAL POVERTY

Many studies have shown that poverty is widespread in most of the ten countries and considerably higher in rural than in urban areas. Statistics and analysis on income, poverty, food supply and composite measures on poverty are available from many sources including FAO, the World

Bank, the International Monetary Fund (IMF), the United Nations Development Programme (UNDP), the International Fund for Agricultural Development (IFAD), other UN agencies, governments, non-governmental organizations (NGOs), universities and others. Despite their differing definitions and methods for measuring poverty and arriving at differing estimates of its incidence and extent, the studies are unanimous that poverty is widespread and entrenched. However, there is no unanimity on the immediate and underlying causes of poverty or on solutions.

Among the key indicators of the severe and chronic poverty suffered by the subregion are[1]:

- The proportion of the population with an income of less than US$2 per day (UNDP data) is below 50 percent only for South Africa (36 percent) and ranges up to 87 percent (Zambia).
- The proportion of the population below the defined national poverty line ranges from 40 to 87 percent of the total, and that of rural people from 54 percent for Swaziland to 88 percent for Zambia and 90 percent for Malawi.
- Between 9 and 55 percent of the national populations, a total of some 31 million people, are undernourished (FAO data). Undernourishment, which is worst in Mozambique, Angola and Zambia, increased in the 1990s.
- The UNDP's Human Development Indexes (HDI) of the ten countries range from 107 (South Africa) to 170 (Mozambique) of 173 countries ranked.

A more wide-ranging study on rural poverty by the IFAD (2002) gives useful working descriptions of the poor and of the reasons for their condition. Its conclusions make three important points about the location of the poor:

- The majority of the poor are concentrated in densely populated areas.
- Although the remote regions with marginal agricultural resources are poorer than other regions, these have a relatively low population and, hence, account for a relatively low proportion of the poor in most countries.
- Due to historical circumstances, the majority of the poor in Botswana, Malawi, Namibia and Zimbabwe are found in areas with low agricultural potential, but elsewhere in the region, the majority are in areas with moderate to high agricultural potential.

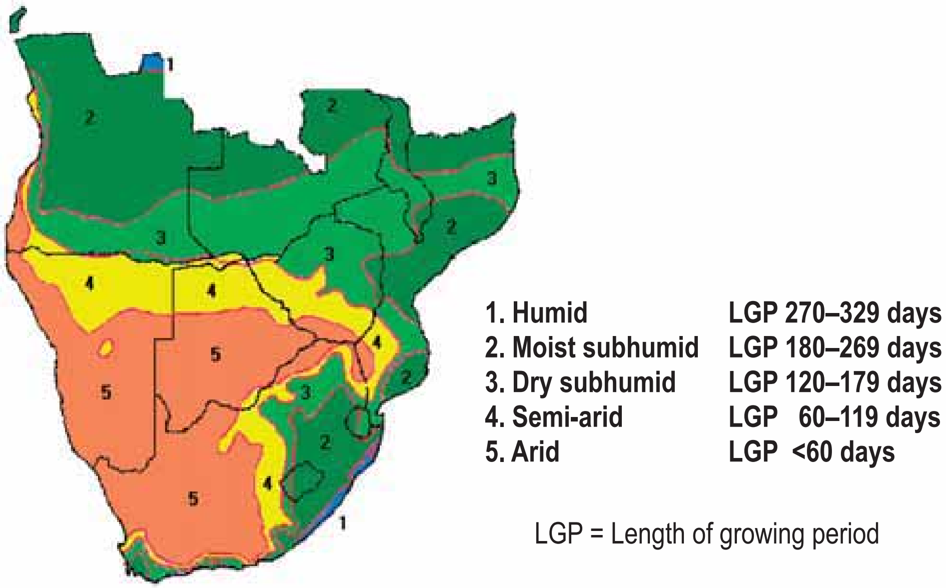
The IFAD assessment has two important conceptual findings:

- "The poor are, in general, very small entrepreneurs – their livelihoods are based on their operation of small businesses – in farming, trading, small services and small industry (and very often a combination of these within a household). Like small entrepreneurs everywhere, their success depends on their own access to capital, markets and technology."
- "The immediate causes of poverty may have been lack of access to assets and to free markets. The underlying cause has been lack of reflection of the interests of the rural poor in key political, economic and institutional processes."

These conclusion should come as no surprise but at the very least they point to the need to address two fundamental points when seeking to use improved water control as means for escaping poverty. First that stable systems of land tenure and water use rights are essential if

[1] Data on the indicators given here are not available for all countries.

MAP 1
Agro-ecological zones



Source: Global Agro-ecological Assessment IIASA and FAO, 2000

smallholders are to invest in water control infrastructure. Second that access to term credit needs to be carefully linked to markets and the availability of correct technologies to reinforce viable production chains. The policy environment to allow this to happen must also be in alignment with protection of fundamental rights in use, provision for their transfer and clear food and agriculture policies.

NATURAL RESOURCES AND AGRICULTURE

The region, except for the Cape in South Africa, experiences a single rainy season in the summer (November-March), in which mean annual rainfall varies from more than 1 000 mm in the Eastern Highlands of Zimbabwe to less than 300 mm towards the Kalahari Desert in the southwest. Mean temperatures are mainly in the range of 18-24 ºC.

The influence of climate on suitability for rainfed crop production is best described by **agro-ecological zones (AEZ.)** These are defined by the period (in days) when available water and temperature regime permit crop growth (Map 1). Moisture availability is expressed by the concept of length of growing period (LGP), which is the period (in days) during a year when precipitation exceeds half the potential evapotranspiration, plus a period required to evaporate an assumed 100 mm of water from excess precipitation (or less if not available) stored in the soil profile.

The most common cereal food crops need a growing period of at least 90-120 d, which makes the arid zone unsuitable for rainfed cropping and the semi-arid zone very marginally suitable to unsuitable.

The **soils** in the region can be grouped according to the overriding limitation they pose to cropping:

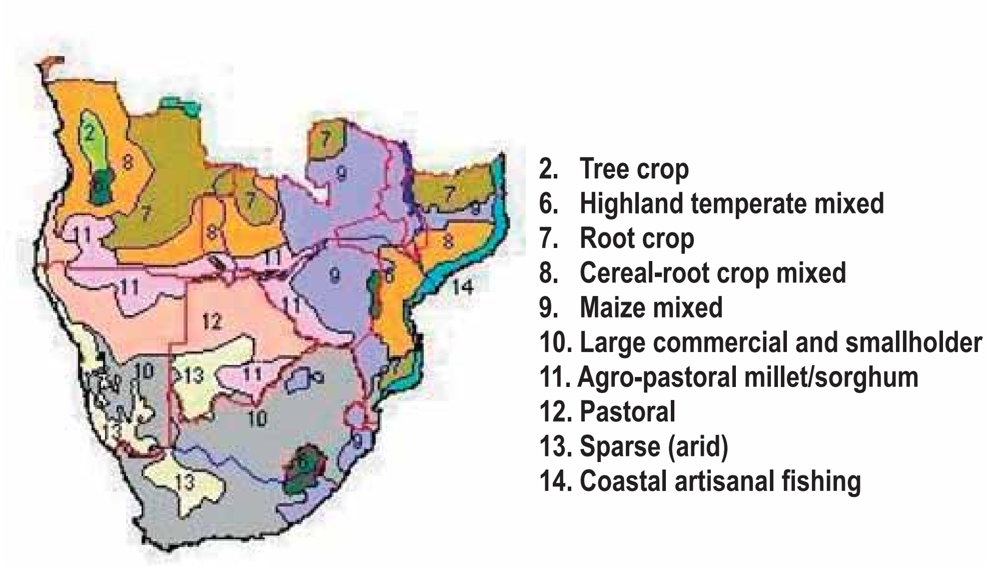
- Sandy and coarse gravelly soils: These cover almost half of the region and are especially extensive in Botswana, eastern Namibia, eastern Angola, western Zambia and southern Mozambique. The main production constraints are low waterholding capacity and high infiltration rate. Nutrient contents and nutrient retention are low.
- Poorly drained soils: Seasonally waterlogged soils or soils with high groundwater table occur along drainage lines throughout the region. Large expanses of poorly drained soils occur in the border area of eastern Angola and western Zambia and in the northwest of Botswana. Soils with impeded drainage are also common in South Africa (planosols). The agricultural potential of poorly drained soils varies greatly; they may be of great value in some localities within semi-arid and dry subhumid zones.
- Vertisols: These heavy clay soils are subject to shrinking (cracking) when dry and swelling when moist. A large area of vertisols occurs in eastern South Africa and minor areas in most other countries. Vertisols are not inherently unproductive but require special management as they are difficult to work and difficult to fertilize.
- Infertile soils (acid soils): This group of soils, characterized by low pH, low cation exchange capacity and low base saturation, is associated with areas of relatively high rainfall in western Angola, northern Zambia, Malawi and northern Mozambique. Acid soils may suffer from aluminium (Al) toxicity and generally pose difficulties for agricultural use.
- Steep lands: These are areas with slope inclinations in excess of 12 percent. Soils are often shallow.
- Saline/sodic soils: These soils contain considerable amounts of soluble salts. Salt accumulation may occur through natural processes in arid and semi-arid areas, or it may be a result of inappropriate irrigation practices. Salt-affected soils are particularly extensive in southeastern Zambia (Luengwa Valley).

Agricultural practices in the region can be described in terms of **farming systems**. FAO and the World Bank (2001) classified farming systems of developing regions from the available natural resource base and dominant pattern of farm activities and household livelihoods (Map 2).

Of the 14 major farming systems defined for sub-Saharan Africa, 11 occur in one or more of the ten selected SADC countries (Annex 1 details areas and populations of the farming systems in the ten countries). Four of the defined farming systems are considered to be of minor relevance to this study:

- Irrigated: This system comprises large-scale irrigation schemes, which would require individual studies. However, medium and small-scale irrigation, which occurs in many of the other systems, is considered.
- Tree crop, forest based, root crop and coastal artisanal fishing: The present study is mainly concerned with the use of water in areas experiencing recurrent droughts and water shortages. This largely excludes farming systems occurring in the subhumid parts of the region, i.e. central and northern Angola, northern Zambia, the extreme north of Malawi and Mozambique and the coastal zone of Mozambique.
- Large commercial and smallholder: This is an association of two types of farm: scattered smallholder farming adjacent to large-scale commercial farming. The present study focuses mainly on the smallholder component, without ignoring the possible interaction with the commercial farms.

Map 2
Major farming systems



Source: Farming Systems and Poverty by J. Dixon, A. Gulliver with D. Gibbon, FAO and World Bank, 2001

- Sparse (arid): With the exception of the Orange River in South Africa and Namibia, the arid zone has little water and few people.

The six farming systems that are the starting point of this diagnostic are:

- Highland temperate mixed: This covers most of Lesotho and nearby South Africa and the Eastern Highlands of Zimbabwe. The system covers mountainous terrain with a range of climate conditions with variable rainfall and extreme temperatures. The system is subject to drought and flooding. A diversity of crops is grown, including some temperate annuals and perennials. Livestock is important, as are off-farm incomes and remittances, particularly in Lesotho.
- Cereal-root crop mixed: This system predominates in the dry subhumid zone of Angola, Zambia and Mozambique at relatively low altitudes. The main crops are maize, sorghum and millet, together with cassava and yams. Livestock plays an important role in areas free of tsetse fly.
- Maize mixed: This is the most important food production system in southern Africa. It is predominant in the dry subhumid zone of Zimbabwe, Zambia and Malawi at relatively high altitude. The main crop is maize, grown for home consumption and cash. Cash crops such as cotton, tobacco and coffee are important in some locations. Livestock is an integral part of the system in Zimbabwe and Zambia. Some farmers may have access to wetlands and cultivate horticultural crops.
- Smallholder in South Africa (adjacent to large commercial): This farming system is typical for the former homelands in South Africa and also occurs in southern Namibia and Botswana. Climate conditions vary from semi-arid to dry subhumid. The system is largely mixed cereal-livestock. Off-farm incomes and remittances are important.
- Agropastoral millet/sorghum: This system covers large areas in the dry subhumid zones of Angola and Zambia and the semi-arid zones of Botswana, Namibia and Zimbabwe.

Agriculture is extensive and mainly for subsistence. The main staple crops are sorghum and millet, and livestock numbers per household are high.

- Pastoral: This system, especially in the semi-arid zones of Botswana, Namibia and Angola, is characterized by extensive cattle rearing. Although some commercialization has begun, animals are kept mainly for subsistence and traditional exchange.

The basis for analysing the crop and livestock farming practices and the constraints on and opportunities for improved water use to increase production is taken as the set of **resource management domains (RMDs)** across the region. RMDs are defined by farming system, AEZ, national boundary and degree of urbanization (as an indicator of access to markets). A total of 32 RMDs have been identified. Table 1 provides a summary of their features and their details are elaborated in Annex 5.

The RMD forms the basic unit of interpretation and is thus the minimum area of concern. An RMD is a complex tract of land that is relatively homogeneous in terms of its attributes defining farming systems and AEZs. Each RMD is a spatial unit that is different to all others in one or more of these attributes, which have been chosen as the delineation criteria for best reflecting their combinations of resources, farming systems and potential.

The natural resource constraints

The region possesses a set of base-depleted soils that have experienced millions of years of weathering and erosion and are combined contemporary sub-tropical annual rainfall regimes with long dry season. These natural realities set limits to what can and cannot be negotiated through natural resource management.

In general terms, **soil fertility** can be expressed by its ability to provide nutrients to crops (chemical fertility) and to provide a favourable environment for crop establishment and root development (physical fertility). Also important is the ability of the soil to hold and store added nutrients (nutrient retention capacity) and water (moisture holding capacity).

Most soils in southern Africa are inherently low in major crop nutrients, particularly nitrogen (N) and phosphorus (P) and many micronutrients, e.g. zinc (Zn), sulphur (S) and magnesium (Mg). More than half of the region has sandy or coarse gravelly soils with low nutrient retention and moisture holding capacities. Because the use of mineral fertilizer in smallholder agriculture is low and crop residues are often burned or grazed by livestock, soils are depleted gradually of some essential plant nutrients. This phenomenon, called ‘soil mining’, results in declining crop yields.

There are many variations of inherent nutrient status of the soil, natural nutrient replenishment and fertilization practices by farmers within each RMD and even within each farm. Wherever possible, farmers exploit all available ecological ‘niches’ around the homestead or further afield to produce various crops and livestock at different times of the year. Although adequate fertilization could double or quadruple maize and sorghum yields in the dry subhumid zone, recommended fertilization practices have to be location specific. Some consideration should be given to the following questions:

- Do the benefits of fertilization justify the costs (including labour)? Is there a ‘minimum threshold nutrient application rate’ below which the added costs for inputs exceed the added benefits from production?

Table 1
Resource Management Domains (RMD) – Defining characteristics

Farming system	Agro-ecological zone(s)	Occurrence by country	Rural/urban	Proximity to markets	Area (estimate) km^2	Population (estimate)	Pop dens. (rural) p/km^2	Domain symbol
Highland temperate mixed	Sub-humid (LGP 150 - 240 days)	Lesotho	urban	Maseru	29 000	800 000		1
			rural	near South Africa; poor road network		1 200 000	50-100	2
		Zimbabwe east	rural	remote; good roads	18 000	800 000	20-50	3
Cereal-Root crop mixed	Dry sub-humid (LGP 120 – 180 days)	Angola south-east	rural	remote; poor infrastructure	128 000	330 000	< 5	4
		Malawi south	rural	Blantyre	5 000	417 000	> 100	5
		Mozambique	rural	mostly remote	77 000	1 320 000	< 20	6
		Zambia central-west	rural	remote; limited road network	120 000	843 000	< 10	7
Maize mixed	Dry sub-humid (LGP 120 – 180 days)	Malawi central	urban	Lilongwe Blantyre	48 000	440 000 570 000		8
			rural	variable		4 600 000	50-100	9
		Mozambique north	rural	remote	143 000	2 327 000	5-50	10
		Swaziland east	urban	Mbabane	5 000	220 000		11
			rural	near		286 000	20-100	12
		South Africa north-west	rural	near	16 000	553 000	11-20	13
		Zambia central and south-east	urban	Lusaka	203 000	1 200 000		14
			rural	remote		2 700 000	5-50	15
		Zimbabwe central north and east	urban	Harare	177 000	2 000 000		16
			rural	variable		4 754 000	20-50	17
	Semi-arid (LGP 60 – 120 days)	Mozambique south-west	rural	remote	42 000	146 000	< 10	18
		Zimbabwe south-central & south-east	rural	remote	71 000	1 670 000	3-50	19
Smallholder in RSA (adjacent to Large Commercial)	Dry sub-humid (LGP 120 – 180 days)	South Africa central-north and central-east	urban	Gauteng	138 000	7 500 000		20
			rural	near		8 541 000 incl LCF	5-100	21
	Semi-arid (LGP 60 – 120 days)	South Africa central and north	urban	Bloemfontein	189 000	6 500 000 total, incl urban & LCF		22
			rural	variable			3-50	23
Agro-pastoral Millet/Sorghum	Dry sub-humid (LGP 120 – 180 days)	Angola south	rural	remote; poor infrastructure	86 000	390 000	< 10	24
		Zambia south	rural	remote	65 000	662 000	< 10	25
	Semi-arid (LGP 60 – 120 days)	Botswana south-east	urban	greater Gaborone	7 000	215 000		26
		Namibia north and north-east	rural	remote	146 000	965 000	< 10	27
		Zimbabwe west and south	rural	remote	72 000	1 436 000	5-20	28
Pastoral	Semi-arid and Arid (LGP < 120 days)	Angola south-west	rural	remote	50 000	172 000	< 10	29
		Botswana central, north, north-east	rural	remote	320 000	709 000	< 5	30
		Namibia central-north	urban	Windhoek	283 000	250 000		31
			rural	remote		182 000	< 2	32

- What soils are used on the farm and do they have different nutrient deficiencies?
- What does the farmer produce and what are the fertilizer requirements for each crop?
- Could one farming activity complement another (e.g. manure produced by livestock grazing crop residue, or intercropping cereals with legumes)?

Some important methods of fertilization and soil improvement are:

- Applying mineral fertilizers. The cost-benefit ratio is very important; composition and application rates must be very crop and site specific. Continuous application of mineral fertilizer may have negative side-effects (e.g. acidification caused by continuous application of N fertilizers).
- Applying lime on acid soils. Strongly acid soils may have toxic levels of Al and manganese (Mn) and deficiencies of Mg and calcium (Ca). Lime reduces soil acidity and improves fertilizer use efficiency (CIMMYT, 1998). Although liming could be a one-off intervention, large quantities are usually needed and are cost-effective only where the farm is near a source of lime.
- Applying locally available organic resources (manure and compost). On-farm manure and compost have low amounts of crop nutrients. However, they may improve physical properties of the soil, such as nutrient retention capacity and moisture holding capacity, substantially through the buildup of soil organic matter. Farms do not often produce enough manure and compost to satisfy requirements. Composting and the application of organic fertilizers are also labour-intensive.
- N fixation through the incorporation of legumes into the farm system (intercropping, relay-cropping, crop rotation and agroforestry). The capture and use of N from the air through the cultivation of N-fixing crops seems to have varying success. Problems are encountered with competition for water and light (e.g. with intercropping and alley cropping), high labour requirements (certain agroforestry practices), low value of legumes and interference from roaming livestock (e.g. with relay cropping and green manures).
- Crop adaptation. Rather than fertilizing, farmers may grow crops or varieties that tolerate the low nutrient status of the soil, or they make use of sites that are naturally enriched (e.g. compost sites near the homestead, and drainage lines and depressions receiving runoff and sediments).
- Combining mineral and organic fertilizers and appropriate crop rotation. A combination of various fertilizing practices seems the most logical strategy. However, such a strategy requires good management skills from the farmer, a good extension service and a flexible and diverse marketing system.

Generally, the maintenance and management of soil organic matter are central to sustaining soil fertility on smallholder farms. Various forms of conservation agriculture may be appropriate in this respect.

Soil moisture is replenished only periodically. Total seasonal rainfall is usually more than sufficient to grow an annual crop in all but the arid zone of southern Africa. However, only part of the precipitation is available for crop growth:

- Much of the rainfall comes as high-intensity storms whereby the soil is unable to absorb all the moisture, and runoff occurs.

- Rain falls in summer, when temperatures are highest, and some of the moisture evaporates before being used by the crop.
- Mid-season dry spells are a common feature of the annual rainfall pattern. Even in 'normal' years, it may not rain for ten or more days within the growing season.
- Poor cultivation practices have caused a deterioration of the infiltration rate, permeability and waterholding capacity of the soils.

These factors commonly result in moisture stress and reduced crop yields. Moisture stress in crops and lack of water for home use and livestock can be relieved by increasing the infiltration capacity and waterholding capacity of the topsoil. Key to such increases are the buildup of soil organic matter and, locally, the breakup of compact subsurface layers (e.g. 'plough pans'). Organic compounds in the soil have the ability to absorb moisture and retain nutrients, which crops can use at a later stage. They also encourage microbial activity and increase soil porosity. Decomposition of organic matter is higher under tropical and subtropical conditions than under temperate conditions. Conventional tillage by mould-board plough (turning the topsoil) or by hoe (loosening and shifting the topsoil) accelerates organic matter decomposition. In the arid and semi-arid zones, vegetative growth is limited and a meaningful increase of soil organic matter is not achieved easily. In the dry subhumid zone, there are possibilities for increasing soil organic matter through conservation agriculture.

Runoff is generally 'flashy' responding to high intensity rainfall events. The Rift lakes and extensive areas of wetlands on the higher erosion surfaces offer significant volumes of storage and attenuate and diffuse the otherwise flashy hydrographs from upstream catchments.

The recharge of shallow groundwater circulation on the saprolite soils developed over the Basement Complex is also significant. The deeper horizons on the higher elevation (older) erosion surfaces store significant volumes of groundwater but with low transmissivities. This groundwater is slowly released during the dry season, sustaining dambos and upland springs and seeps. The deeper groundwater circulation associated with carbonate rocks, for example in the Copper Belt, offer highly transmissive aquifers that are exploited for large scale commercial irrigation, as in Zambia.

Water use in agriculture

The importance of water storage in the region cannot be over-emphasised. The timely and adequate supply of water to crop roots during critical parts of the growing period is a main determinant of crop production. In much of the region, rainfall is not always adequate to enable crops to reach more that a small fraction of their potential yield, at least in the drier years. Rainfall is variable both from year to year and within the growing season. For some crops in some places, a dry period of a few weeks within an otherwise satisfactory rainy season can reduce production considerably. Droughts, or dry years, range from moderately dry periods, which occur about once in five years, to much more severe droughts of lower frequency. Annex 6 discusses the classification of droughts by frequency and the implications for risk management.

The key to successful water management for agricultural production in the region is water storage. In addition to the rain that falls directly onto the crop at the right moment, there is rain that falls at some other moment and can be stored and delivered to the roots some time later. The period involved can range from a few days to years. The main means of storing water are:

- soil moisture storage in the crop rootzone, especially valuable for storing on a time scale of days to weeks;

- storage as groundwater in accessible aquifers, which can operate efficiently for longer periods;
- surface water storage in tanks and in natural and artificial reservoirs, especially those formed by dams; they systems can be effective for the time-spans of weeks to years, depending on the ratio of storage volume to water throughput and on the relative rate of loss to evaporation and seepage.

Where water is stored some distance from the crop roots, it is necessary to convey and deliver it to the rootzone by various means. These range from buckets, through treadle and motorized pumps, to pipes and canals as found on irrigation systems of all sizes.

The great majority of cropping in the region is rainfed and will remain so. Therefore, **storing soil moisture in the crop rootzone is probably the most important of the three means mentioned above**. The basic ways of improving the amount of soil moisture available to crops have been researched, taught and practised for centuries. Soil water conservation techniques are linked closely to soil fertility management techniques. The present situation in the ten countries is mixed, with some farming systems more advanced than others.

Some 70-85 percent of rainfall in water-scarce farming systems is 'lost' from cropped fields through runoff, deep infiltration, evaporation and use by weeds and failed crops. The higher the transpiration, the higher the yield. In dryland farming especially the focus should be on minimizing water loss through runoff and evaporation and maximizing transpiration. This can be done either through *in situ* water conservation or through water harvesting.

In situ water conservation aims at preventing runoff and keeping the rainfall, as much as possible, where it falls and then minimizing the evaporation to the extent feasible. The goal of **conservation agriculture** is to maintain and improve crop yields and resilience against drought and other hazards while at the same time protecting and stimulating the biological functioning of the soil (FAO, 2002). Central to the concept of conservation agriculture is conservation tillage. Conservation tillage entails growing crops with minimum disturbance of the soil and with crop and weed residues covering at least 30 percent of the ground. Other essential practices include: crop rotation with legumes, optimum weed control and preservation of crop residues. The permanent soil cover inhibits the germination of many weed seeds. However, herbicides may be needed in the first few years.

The major advantages of conservation agriculture are: water and soil conservation, increased soil fertility, moderation of temperature extremes, more evenly-spread labour requirement and the opportunity to plant early. But a possible disadvantage is that conservation agriculture requires considerable management skills and, in many cases, a radical change in attitude. Livestock must be excluded from cropped fields throughout the year, which may be difficult in the dry season when grazing is scarce. Many of the benefits accrue only in the long term. Initial land improvement, such as liming, ripping or removal of persistent weeds and shrubs, is sometimes necessary.

Conservation agriculture has been promoted widely in southern Zambia (dry subhumid zone). During the dry season, permanent planting stations are prepared: organic matter and fertilizer are placed in holes where soil moisture also becomes concentrated. Crops are grown in rotation, including a legume (pigeon pea or cowpea). The system offers farmers the opportunity to raise yields and improve yield stability.Successful work on integrating conservation tillage and water management with soil fertility for smallholder maize-based cropping systems is ongoing in southern Africa and in Zimbabwe in particular (Waddington, 2003).

Water harvesting is the collection and concentration of rainwater and runoff and its productive use for irrigation. Water harvesting is more expensive than *in situ* water conservation, especially if in certain water harvesting structures, such as check dams, percolation ponds and irrigation tanks, need to be constructed. Some water is captured downhill of the crops, so necessitating lifting or pumping. In other forms of water harvesting it is captured and sometimes also stored uphill of the crop so that it can be brought to the crop by gravity. A comprehensive description of rainwater harvesting techniques is given in Hatibu *et al*. (1999). Although it is true, that the farmer has no control over the timing, since water can only be harvested when it rains, sufficient information is available nowadays to design water harvesting schemes that will improve crop production during the majority of years. However, the present situation in much of the region is water harvesting does not deserve sufficient attention, most probably because emphasis so far has been put on irrigation. However, some farmers have considerable knowledge and use traditional methods that are well adapted to local conditions. A few more innovative farmers develop their own methods by trial and error. However, there is little tendency for farmers to copy successful innovations and disseminate skills and knowledge. Some government and other agencies work to overcome this by projects or programmes aimed specifically at finding good techniques (‘best practices’), understanding the limits of their replicability and informing farmers about them. However, compared with the scale of the need, the extent of such work is small.

Wetlands are areas where water tends to collect in the rainy season even though they may not be wet throughout the year (FAO-SAFR, 2002). The use of wetlands is an important means of bringing water to crop roots. Such areas occur, usually as small patches, within many of the RMDs. Typically, in the natural state, the vegetated lower land in the middle of a shallow valley holds water during and after the rainy season and releases it slowly to a stream. This has some importance for the hydrology of rivers, but these wetlands (with various local names such as ‘dambo’ and ‘vlei’) are not always as vital for dry season river flows as has sometimes been supposed. One reason for this is that the water held in wetland soils interchanges in complex ways with groundwater in shallow aquifers, by normal seepage down the groundwater gradients or sometimes by springs on the fringes of the wetlands. For river hydrology, the groundwater may be the more important storage mechanism on a scale of several months.

With care, wetlands can be used sustainably for agriculture, at least at their fringes, and the cultivation of short-season annuals can be planned to follow the receding moisture from the fringes of a wetland towards its centre as a dry season progresses. This makes use of valuable seasonal water storage, over weeks or months, in the crop rootzone or within the range of capillary rise. Investing in simple earthworks can enable improved use of wetlands. There is some overlap with water harvesting. For example, the wetlands often benefit from water harvesting of a naturally occurring kind, where water runs off from immediately adjacent land that has shallow soils and high runoff rates (such as rocky interfluves).

In the past, some countries banned cultivation of wetlands on the grounds that it would destroy the valuable capacity for hydrological streamflow regulation or that it would expose soil to erosion (as ground slopes can be significant even within the wetlands, flow and erosion having been restricted historically by the lush natural vegetation). The administrative means for such prohibition were often crude, e.g. “no cultivation within 30 m of a streambed”, which is an erratic instrument when wetlands exist in tapering strips varying between ten and hundreds of metres. Modern research shows that, with appropriate practices, wetlands can often be used for cropping without unwanted consequences. In some areas, traditional practices have achieved this to a considerable degree, but there is considerable scope for expanded use of wetlands for harvested crops and for grazing to support livestock. At present, there does not appear to be any reliable quantitative estimate of the extent of this scope. Alternative modes of production,

TABLE 2
Irrigation systems in the ten countries

Country	Type of irrigation
Angola	Modern irrigation: 10 000-30 000 ha Traditional informal irrigation, inland valley bottoms
Botswana	Private and institutional schemes, mostly < 100 ha each Smallholder ('group') schemes, mostly < 10 ha with several farmers each
Lesotho	Small schemes (< 100 ha): 203 ha Large schemes (> 100 ha): 2 519 ha, no longer irrigated
Malawi	Wetlands, dambos: 61 900 ha Self-help smallholder schemes: 6 500 ha Government-run smallholder: 3 200 ha Private estates: 18 300 ha
Mozambique	Small schemes: < 30 ha, subsistence Medium schemes: 30–200 ha Large schemes, industrial
Namibia	Smallholder: plots about 1 ha each Medium-scale commercial farmers: blocks about 30 ha each Large commercial farms: private landowners and entrepreneurship Parastatal or state farming: national development corporation (state farms)
South Africa	Rural development programme schemes: 70 000 ha, irrigated community gardens Private schemes: 660 000 ha, private farmers Irrigation boards: 155 000 ha Government water schemes: 329 000 ha
Swaziland	Micro and small schemes: 1 000 ha, communal smallholder projects Large schemes: 66 400 ha, large-scale commercial farming
Zambia	Informal irrigation (wetlands): 100 000 ha, subsistence farming Small-scale farmer irrigation: Smallholder irrigation schemes: 16 000 ha Parastatal and semi-parastatal: 12 400 ha, large-scale farming Private commercial estates: 18 000 ha, large- and small-scale company estates
Zimbabwe	Informal irrigation: 20 000 ha, cultivated wetlands and gardens Formal irrigation: 116 600 ha, full/partial control irrigation

Source: Aquastat and other references quoted in the FAO report (FAO, 2003).

which are both environmentally acceptable and acceptable to local producers, to promote the conservation of wetlands should also be looked at.

Irrigated areas in the region are not a large proportion of the cultivated area, but they are important for crop production and the overall reduction of drought vulnerability. The main sources of information on irrigation are: (i) the FAO database Aquastat; (ii) the SADC Web site; and (iii) an IFAD report prepared in 2000 (IFAD, 2000b). A secondary source is an FAO internal draft report (FAO, 2003); its annexes offer a useful compilation of information on all the countries except Botswana. Table 2 evidences the considerable variety of irrigation schemes within the region.

Most irrigation systems are reported to be inefficient and poorly managed, with water losses averaging 40-60 percent. Irrigation is used primarily for high-value export crops that contribute significantly to foreign exchange earnings: sugar cane, tobacco, rice, maize, citrus, vegetables, wheat and cotton.

Estimates of irrigation potential (e.g. the Aquastat-derived figures in Table 3) should be regarded as orders of magnitude as the data derive from the early 1990s. FAO is working on an Aquastat update for the region. The information received to date indicates that not much more land has been brought under irrigation in the past decade. The SADC database has not yielded any more reliable data. The IFAD report (IFAD, 2000b) uses the same figures.

Table 3
Irrigated areas and potential

Country	Irrigation potential	Full/partial control irrigation	Total water-managed area		
			Area	Cultivated area	Irrigation potential
	(thousand ha)	(thousand ha)	(thousand ha)	(%)	(%)
Angola	6 700	75	425	15	6
Botswana	20	1	8	2	39
Lesotho	12	3	3	1	22
Malawi	162	28	90	4	56
Mozambique	3 300	107	107	3	3
Namibia	45	6	8	4	18
South Africa	1 500	1 270	1 270	10	85
Swaziland	90	67	67	35	75
Zambia	520	46	146	14	28
Zimbabwe	331	117	137	5	41
Total	12 681	1 720	2 261		18

Source: Aquastat.

Although not up to date, these statistics appear to indicate a considerable potential for further irrigation development: of the order of 10 000 000 ha. However, this is misleading because the available information does not indicate the probable unit cost and general economic merit of the nominally potential irrigation sites. Without reconnaissance level studies of most of the sites, and preferably full feasibility-level work, it not possible to draw a quantitative conclusion about the potential for economically attractive, financially viable and technically sustainable irrigation development.

The use of **groundwater** for irrigation is very limited in this region, especially in comparison with the large alluvial plains of Asia. There is some scope for its expansion, especially where groundwater is available at shallow depths and accessible by small dug wells, on the margins of wetlands sustained by groundwater flows. For such areas, there is considerable interest in foot-operated pumps (treadle pumps). However, the economic cost of human motive power is quite high even on a family farm. It requires many hours of human power to yield the same mechanical output as a litre of petrol or diesel used by an efficient motorized pumpset, or the equivalent for an electric pumpset. At best, treadle pumps are valuable for very small-scale vegetable growing or as a stepping-stone in a progression from pure rainfed cultivation to the use of a motorized pump.

Advances in climate science have enabled advances in indications of rainfall probabilities for three-month periods, which can be updated every month. This is done routinely in the southern Africa Regional Climate Outlook Forum process, with a main forecast for the region issued each September for the forthcoming summer-rains season, and an adjustment or update issued in December. These forecasts are interpreted routinely for national use by the Regional Remote Sensing Unit and the Drought Monitoring Centre (DMC) in Harare. The national agricultural authorities use these forecasts to guide agricultural practices such as planting dates and selection of varieties. However, for both those aspects, most farmers have little scope to change their actions so near the start of the cropping season. Forecasts are also used for early-warning purposes by those concerned with any shortages that may arise. The forecasters are aware that it would be more useful to issue forecasts on a finer time-scale, e.g. ten-day periods, and to do so early enough for well-informed rainfed farmers to modify their practices, or even their crop choice, so as to achieve the best results in a particular rainy season. However, the three-month forecast with monthly updates is currently the best that knowledge and technology can provide. While not perfect, the accuracy of forecasting is beginning to be useful and will probably become more so in the next ten years.

The policy environment

The national, sector and subsector policies that influence farmers' investment and management decisions range from those affecting the economy as a whole to those affecting only individuals. **National policy** is critical to all parts of society and plays a strong role in determining the profitability of enterprises. Coherent national policy is essential to establishing and maintaining macroeconomic stability, which in turn is a prerequisite for confident savings, investment and consumption decisions. However, the political stability needed to underwrite policy consistency has not applied widely or for long periods in much of southern Africa.

Different pieces of the national policy framework may influence all sectors, subsectors, groups and individuals. They may also discriminate against or in favour of particular elements of society to discourage or encourage behaviour that is judged against or in the national interest. Six areas of national policy are of special concern for agriculture and its subsectors: (i) fiscal policy; (ii) sector development policy; (iii) credit and savings policy; (iv) trade policy; (v) exchange rate policy; and (vi) institutions and governance. A matrix showing the stances of the ten countries to these six areas is presented in Annex 7 with a view to elaboration once individual countries begin to prepare bankable projects.

The progress being made in preparing water-sector, natural-resources and drought strategies can be used as the foundation for continuing work to create conducive sector and subsector policy. Six key areas of policy for improved use of water concern: (i) marketing; (ii) credit; (iii) security of land and water usage rights; (iv) institutions; (v) investment in infrastructure; and (vi) cost recovery and subsidies. This sector policy framework is much closer to the water subsector than national policy is, and its impacts on entrepreneurs are more tangible. While marketing chains and value added processing are crucial for countries committed to agricultural commercialisation, at a more fundamental 'productivity' level, it is important here to highlight the structural role of credit and land and water usage rights.

Capital formation (financed by savings, borrowings and equity contribution) is the *sine qua non* for sustainable increases in productivity, output, profitability and incomes in any enterprise. However, there is a widely held view that farmers in southern Africa are not able to create a surplus for saving and investment and that the only option for raising capital is borrowing. This rationale has underpinned the provision of a large volume of zero- and low-interest funds by donors and concessional financiers to financial institutions (primarily parastatal) for lending on to farmers. This approach has met with little success partly because farmers regarded loans as gifts from government and because loan approval, supervision and collection procedures have been weak. The formal private sector is the optimum conduit for credit for farmers and marketers and it ensures its rationing by commercial discipline. However, the low profitability and high risk of farming, together with high transactions costs, may render lending to agriculture unattractive to the formal lending subsector. Other approaches may be used. One is to stipulate quotas for commercial bank lending to farmers. This has the advantage of bringing some commercial discipline to loan appraisal and supervision, but the disadvantage of directing funds away from their highest earning potential. Private financiers (moneylenders) are widespread and often attractive to rural people. The apparent interest rates from these sources may be high but the real cost of funds less so when transactions costs and application procedures are considered. Other approaches include: savings and loan societies, where individuals' savings are pooled to create funds for lending to members; and group lending by commercial banks, where the members assume joint and several responsibility for all repayments.

There is evidence that farmers are more likely to invest to increase the productive capacity of their farms and increase their use of purchased inputs where they enjoy security of usage rights of land and water. Land rights can be conferred by customary practice or by more formal legislative means. Water rights, which are essential to ensuring that farmers can obtain water when needed, can be conferred by licensing with stipulated quotas. Transferability and inheritability are desirable features of good policy for securing resource usage rights. Provisions for these conditions should be built into sector policy reform and included in programme and project design.

Chapter 2
Improving water control in agriculture

Rationale

The rationale for a focus improved water control in southern Africa is self evident in a region that is dependant upon rainfed production and which experiences prolonged dry seasons. What is less evident is the need to fine tune a balance between rainfed and irrigated agriculture. Of primary importance is the need to stabilise the rainfed systems and then create the opportunities for targeted investment in the irrigated sub-sector without over-gearing the sub-sector through (capitalising).

Addressing poverty

Poverty in southern Africa is widespread and entrenched. It is especially severe in rural areas, where sustenance for the vast majority comes from chronically low and volatile income from agricultural production. At the same time, the HIV/AIDS pandemic is increasing the demands to take care of those afflicted, while greatly reducing the human resources available. In urban areas, falling household incomes may reduce the capacity to buy food.

Low and uncertain incomes lead to food insecurity and vulnerability to internal and external shocks. It is widely held that the climate in the region is becoming drier and that the incidence of drought is increasing. Major droughts can have a devastating impact in southern Africa, where agriculture generally accounts for 20-60 percent of national income and 30-70 percent of employment. The 1991-92 drought saw the output of maize, sorghum, millet and pulses fall by 60, 55, 35 and 25 percent respectively. Even in non-drought years, agriculture affords virtually no margin to permit saving for investment or for a buffer for bad years.

In recent decades, the average annual economic growth of the national economies (2.3 percent) has barely exceeded population growth (2.2 percent). The number of people depending on agriculture for a livelihood has risen by about 7.7 million (16 percent) in the last decade. In recent decades, the agriculture sectors have been able to increase output by about the same proportion as the increase in population that depends on them for livelihood. There has been little change in the overall production pattern, resulting in little change in the quantities of food, saleable produce and available income. However, some successes in increasing cash cropping suggest that resource, technical and market conditions can induce farmers to respond to opportunity for more valuable production.

Without significant options for moving people out of agriculture into other sectors with higher income-earning potential, the sole option for alleviating or reducing poverty for large numbers of rural people is to increase the output of farming. The scope for increasing farm size is limited though there is some scope for developing land for new settlement (e.g. in Angola, Mozambique, Zambia and Zimbabwe). Where new settlement and resettlement are not practical, improvement in living standards will need to come mainly from intensification.

Overcoming rigidity

The low value of production from farms is attributable to their small scale and low productivity of land and of water. The production problem is compounded by the impact of variability in climate. Farmers face a complex array of interacting factors (natural resources, climate, economics and policy) that limit their capacity to improve the productivity of land and water. Their efforts to maintain and improve resource productivity fall into four main management areas: enterprise selection; crop and livestock husbandry; investment to increase productive capacity; and marketing.

Farmers may not always select enterprises most suited to their natural and economic environment. There appears to have been little change in how farmers use available resources; in general, crop and livestock yields are not increasing and the mix of crops is changing very slowly. Very high proportions of cropped area are used for staple crops despite their high production risk in fragile environments. These crops are of inherently low productivity and fetch intractably low prices.

Farmers seeking higher productivity need to apply appropriate husbandry practices in terms of: land preparation; timing and method of planting, weeding, fertilizing, pest and disease control; and water use, harvesting and storage. Deficiencies in any of these lead to lower yields and limit the potential for gain by improved supply of water.

Investment in farm development and production technology appears to be generally low. The very low proportion of cropped area equipped with irrigation facilities reflects a lack of investment by farmers, the public sector and the private sector. Farmers appear to be either unaware of the possibilities or not motivated to invest in enhancing the productive capacity of their assets, e.g. by adding lime to improve acid soils or by harvesting local sources of water.

Farmers have been slow to develop marketing practices to take advantage of the opportunities for diversified and higher-value crops created by policy reform. Farmers have not developed skills to fill the vacuum left by the scaling-down or disappearance of parastatal organizations. There have been some successes in the development of market linkages between large groups of farmers and large buying and trading companies but there has been less success in linking small groups of farmers with medium- and small-scale trading entrepreneurs.

Improving the investment environment

A complex set of factors that apply beyond the farm influence efforts to improve the productivity of land and water. These affect how farmers tailor their investments and operations by determining the opportunities for and constraints on improved farm management. The business environment in which farmers operate is determined largely by the rate and nature of economic growth and by the policy stances of government.

In recent years, policy reform in most of the ten countries has reduced macroeconomic imbalances, encouraged the private sector and reduced the ‘crowding-out’ behaviour of parastatals. However, significant obstacles remain to improving farm productivity within the sector-specific policy frameworks. The areas of most concern for creating a conducive climate are: marketing, credit, land tenure and infrastructure.

In the ‘marketing’ of agricultural products, market development has been minimal. The economic growth achieved appears to have had little impact on farmer exploitation of domestic market opportunities. In order to create opportunities for diversification and shifts to high-value crops, market development must be supported by attention to infrastructure and services.

The slow development of marketing systems exacerbates the limited market demand. The response of the private sector to the increased trading opportunities, especially for staples, has been subdued. Farmers, intermediaries and petty traders can all play greater roles in facilitating transactions.

Policy on credit for agriculture needs to be set within the overall savings and credit policy. Inappropriate relationships between deposit and lending rates distort behaviour and may lead to unwise investments. The reduced role of parastatals in rural credit provision has left a void in services to farmers. The agriculture sector has little capacity for savings to finance investments. Low returns to enterprises, high risks and high transaction costs deter the formal credit subsector from serving farmers.

Land tenure has a major impact on farmers' investment decisions. If farmers are to be encouraged to invest in water and land management technology, they must be secure in the knowledge that they will remain its beneficiaries.

The several forms of infrastructure critical to farming and trading are not entirely adequate. Water storage and delivery facilities are vital to support crop and livestock production where technical and economic conditions are suitable. This is especially true for high-value crops with high and/or inflexible water requirements. Roads are essential to enable commercial intercourse. There is abundant evidence that farmers with reasonable access are more productive and better-off than those without. Crops requiring bulking and storage before delivery may need energy for cooling to prevent spoilage. Physical markets are required to bring larger volumes (especially of perishable and semi-perishable commodities) to large groups of purchasers.

In addition to investment and improved management within the farm, resolution of the problem of low productivity of land and water will require conducive policy formulation, institutional behaviour and investment beyond the farm for a long time. Nevertheless, there is considerable scope for improving the productivity of both land and water to raise incomes and reduce vulnerability to climate. This scope can be sought in the improved use of water resources to increase the productivity of land, with direct attention to the proximate and underlying problems being applied case-by-case. The methods for exploiting this scope vary and should be domain adapted.

A framework for guiding future water control programmes

The Regional Water Control Initiative for southern Africa is intended to lead to a range of investments by governments and private sectors, some with financial and technical support from external donors and concessional financiers. Achieving higher productivity depends not on such investments alone but on the interaction of all the factors mentioned above. It relies on: policy development; the application of clear, targeted strategies; and conducive structures and behaviour of all institutions concerned. Programmes for enhanced water control need to address all of these aspects.

Water use needs to be considered in the context of the overall development effort and rural development strategies. Water use programmes and projects need to consider it as both catalytic to the use of other resources and as an element within broader rural development efforts.

Setting priorities

Resolution of competing strategies. The diagnostic reveals that many conceptually linked strategies aim to reduce poverty or to increase income within a framework of management of natural resources. The strategies for any country or group of countries may conflict or compete for resources. Moreover, they tend to have many overlapping and duplicative features. The multiplicity of strategies causes difficulties for the intended beneficiaries. Further difficulty arises from confusion of purpose and from different strategies being domiciled in different institutions. Competition among donor and concessional financiers for high-quality programmes and projects and for 'thematic areas' exacerbates the difficulties.

Investing countries determine the highest priorities for their own attention and that of donors and concessional financiers so that project and programme action can be designed and targeted appropriately. Joint and individual action by the investing countries is essential for resolving competition among strategies and achieving unity of purpose, especially where donors and concessional financiers are involved. If mandated thus, the SADC would be ideally placed to initiate and coordinate the actions of its members in a drive to rationalize strategy formulation.

Priorities for agricultural production. It is not difficult to package technologies and techniques for improving the productivity of water and land into interventions in projects and programmes. However, interventions can succeed only if their targets and objectives are specified clearly in the formulation process. This requires that the goal of the proposed intervention be established very clearly. Different goals can lead to the specification of different targets and objectives, which are then reflected in very different programmes to influence farmers' behaviour.

Challenged by a goal of immediate or early increase in food production for the greatest number of people, programme designers would almost certainly select as the target the very large population in the maize mixed farming system and prepare projects to increase the maize yields of small-scale farmers. However, a goal of maximizing increase in incomes would almost certainly lead programme designers to promote peri-urban production of high-value crops. A goal of reducing the loss of food production by vulnerable people in dry years would lead designers to develop programmes to secure water in those RMDs where drought is most likely to cause crop failure.

It is important to the selection and design of water control strategies that the role of cropping and livestock be stated clearly. The key question is exactly which forms and extent of poverty are to be addressed as priorities. For success, the countries themselves must set the goals and identify the targets. This requires cooperation from donors and concessional financiers, who should design approaches that serve the domestic requirements rather than their own priorities.

Reaching the most vulnerable. Different kinds of droughts require different types of risk management (Annex 6). Farming practices must adjust to the variable rainfall of the semi-arid and subhumid zones of southern Africa. Farmers should be able to survive a single season with below average rainfall without resorting immediately to food aid or other forms of assistance. Traditionally, farmers have diversified their production systems, e.g. mixed farming of crops and livestock and the use of both uplands and lowlands (wetlands). Some farmers grow cereals and root crops, exploiting different crop water requirements.

The farmers most vulnerable to single-season droughts are those who rely on rainfed cereals and do not produce enough to keep carryover supplies. Farmers may not have enough land to diversify (e.g. RMD9 in Malawi), be too poor to venture into livestock (e.g. in the semi-arid zone of Zimbabwe, RMD28), or not have enough labour (child- and single-headed households). In addition, farmers in remote areas have fewer opportunities to earn off-farm income and to receive assistance from urban relatives. Water control programmes should give some priority to the needs of these and other most vulnerable groups, choosing from among the available instruments to design interventions for specific problems in specific domains. Farming-system development should build on traditional risk management strategies, including diversification in the case of subsistence farmers.

A sequence of dry years will affect nearly all agricultural enterprises, including irrigated farming. It is the task of government and farmers' organizations to act on long-term weather forecasts, advising farmers and adjusting policies. Examples are the timely offtake of livestock, promotion of drought-resistant crops and the close monitoring of water supplies for irrigation.

Elements of a programmatic approach: guiding principles

Guiding principles are the vital link between the setting of priorities and goals and the specification of objectives to be pursued by programmes and projects. Principles enable policy formulation, institutional actions and investments to be directed clearly to achieving subsector, sector and societal goals. However, adherence to principles is difficult and relies on firm direction-setting, scrutiny of action and supervision. Furthermore, it requires strong political commitment.

Diversity of interventions. The diagnostic reveals a vast array of 'cases' in which interventions may be made. Geographic areas vary in terms of natural resources, climate, population, access, economic opportunities, etc. Other cases in which interventions may be made include a special group within the society, a single commodity, a group of commodities, a specific market and a technology. The conditions applying in any two cases are unlikely to be so similar that a common remedy could be appropriate to any identified problem. For water control, a 'one size fits all' approach should not be attempted. Therefore, the first principle of programme design should be: statements of objectives and design of interventions need to be case specific.

Water and soil linkages. In most farming enterprises, water can be used effectively only as a complement to other land resources. Water and soil, together with light and a favourable temperature combine to provide a physical environment for crop growth. Ranching needs both water and pasture (or natural vegetation). Prevailing land forms influence the design of water supply systems. In crop production, the linkage between water and soil is particularly strong. Most of the water used by the crop comes from moisture stored in the soil. The water storage capacity of the soil is extremely important to productive water (rainwater and irrigation water) use. However, the infiltration capacity and permeability of the soil affect various production systems in different ways. For example, wetland rice requires soils with low permeability whereas most other irrigated crops require good infiltration and good permeability. Water brought to the farm may change the fertility status of the soil by salinization.

There is little point in improving water supply if limiting soil factors are not addressed. In some crop production systems in southern Africa, soil fertility is the main constraint on increased production. This is particularly true in the dry subhumid zone where most of the crop production takes place and where most of the people live (RMD9, RMD10, RMD15, RMD17 and RMD21). The guiding principle here is: measures to improve water use must always be accompanied by measures to increase and maintain soil fertility. In this context the role of conservation agriculture needs to be stressed. The goal of conservation agriculture is to maintain and improve crop yields and resilience against drought and other hazards while at the same time protecting and stimulating the biological functioning of the soil (FAO, 2002). Central to the concept of conservation agriculture is conservation tillage. Conservation tillage entails growing crops with minimum disturbance of the soil and with crop and weed residues covering at least 30 percent of the ground. Other essential practices include: crop rotation with legumes, optimum weed control and preservation of crop residues. The permanent soil cover inhibits the germination of many weed seeds. However, herbicides may be needed in the first few years.

The major advantages of conservation agriculture are: water and soil conservation, increased soil fertility, moderation of temperature extremes, more evenly-spread labour requirement and the opportunity to plant early.

A possible disadvantage is that conservation agriculture requires considerable management skills and, in many cases, a radical change in attitude. Livestock must be excluded from cropped fields throughout the year, which may be difficult in the dry season when grazing is scarce. Many of the benefits accrue only in the long term. Initial land improvement, such as liming, ripping or removal of persistent weeds and shrubs, is sometimes necessary.

Conservation agriculture has been promoted widely in southern Zambia (dry subhumid zone). During the dry season, permanent planting stations are prepared: organic matter and fertilizer are placed in holes where soil moisture also becomes concentrated. Crops are grown in rotation, including a legume (pigeon pea or cowpea). The system offers farmers the opportunity to raise yields and improve yield stability.

Private sector approaches. The success achieved in increasing farm productivity, output and incomes seems most associated with private sector approaches that treat the farmer as a critical role player, e.g. the various forms of nucleus estate, contract farming and outgrowing. The success of many government-supported 'market linkage' projects shows how well farmers can respond to incentives in a private sector framework. For example, by acting as a private-sector oriented link-maker, the Agrilink Project in South Africa (sponsored by the United States Agency for International Development) has made considerable progress in bringing farmers to markets and markets to farmers. Other evidence comes from irrigation schemes in Zimbabwe, where farmers who are free to select their own crops and have the appropriate water supply facilities and management have been successful in producing and marketing high-value crops. The role of government is to provide a policy and regulatory framework and to provide infrastructure and services to encourage the development of production and of marketing services with strong motivation and commercial discipline. However, there will still be a useful role for governments in providing some equity funds for irrigation schemes as a catalyst for private sector investment.

Market-led interventions. In addition to the general principle of private sector approaches, there is an imperative that intervention selection and design follow market demand rather than supply infrastructure and services. Project conceptualization should start from identification of possible demand rather than of resources and production possibilities. The guiding principle is: all interventions – be they public or private – should be demand driven.

Domain-adapted production. The diagnostic has made a start on what may become a useful analytical tool in helping to rationalize resource use by introducing the RMD concept. The RMD brings together ecological conditions, current farming systems, location and economic opportunity for consideration of production possibilities and enterprise selection. Much work will be needed to develop and refine the RMD concept into an effective planning tool. However, the preliminary work shows the need for specialized production. The emerging principle is: encourage and support domain-adapted crop and livestock enterprises.

Designing bankable projects

There is limited available analysis on the economic and socio-economic factors that are relevant to sound strategy formulation and subsequent investment decisions. In particular, there appear to be few rigorous, definitive studies of the costs of and returns to water applied for agriculture. There are comprehensive studies of the economic situations of rural people but the actual impact of water-oriented projects on rural income generation is rarely separated out and lumped in with other farm inputs. However, given the generally ‘lumpy’ nature of water infrastructure investments (as opposed to low intensity, dispersed investments in rainfed systems), such studies should be undertaken early in the formulation of water control programmes.

Any decisions on the use of water sources are best made in the light of accurate costing of the options. For example, as a major consideration in investment decisions, the unit cost of water from each possible source within each domain should be known. A particularly important case may be that of water harvesting, which is widely held to be ‘cheap’ because it requires mainly family labour. However, such labour may not be cheap in the context of other demands on families’ time.

A study of the costs of delivering water to farms in varying circumstances would be helpful in conceptualizing programmes and projects and subsequently in planning and decision-making. The study would estimate the unit cost of water by calculating: (i) the present value of the quantity of water supplied over the chosen evaluation period; and (ii) the present value of all costs of providing that quantity of water.

A group of international organizations (World Bank, the African Development Bank, the IFAD, the International Water Management Institute and FAO) is about to commission a set of seven studies related to water: (i) regional demand for products of irrigated agriculture; (ii) irrigation development planning; (iii) private sector investment; (iv) agricultural water use from a basin perspective; (v) pro-poor agricultural water use; (vi) costs of agricultural water use; and (vii) health and environment aspects. Care should be taken in writing the terms of reference for the costs study in order to ensure that it uses correct analytical methods and has adequate coverage of locations and water sources.

A rigorous analysis of the returns to water is needed to guide strategies, planning and investments. The analysis should estimate the value of output of a unit of water. For each crop, the study should calculate the present value of the output from a crop imputable to water, divided by the present value of the stream of water used.

Designing country programmes

Established techniques for project feasibility study and *ex-ante* appraisal are adequate to accommodate the prospective investments in water control in southern Africa provided that the problems being addressed are well identified and that correct practice rules in the analyses. The conditions apply equally for all resources in all countries. Institutions commissioning or undertaking studies should stress three points in their specifications:

- Target locations and groups. Studies should be conducted to derive ways of solving clearly specified difficulties for identified groups of people. The nature of the poverty problem should be documented prior to feasibility study in order to ensure that effort is directed clearly.

- Attention to specific regional and country difficulties. Of primary importance among the specific difficulties is the impact of HIV/AIDS. The pandemic will affect: (i) programme design through its impact on population and demand for food; and (ii) project design through reducing the capacities of families to produce food. Other major issues such as gender should also be set as requiring specific attention.
- Attention to markets. All project designs should include and specific analysis of whether there is real demand for the products and proposals for easing market constraints.

Policy issues affecting the outcomes of investment in water resource projects should be addressed at national and sector levels and within the design of projects. National and macroeconomic policies cannot be geared specifically to one subsector of agriculture. However, programmes for water control can incorporate attention to national and macroeconomic policy in two ways. First, policy dialogue and advocacy can encourage governments to accommodate the needs of the water subsector in framing policy. Second, donors and concessional financiers should give priority to assisting those investments in countries with conducive policy frameworks. The same principles apply to encouraging reform of agriculture sector policy.

Project design is an effective tool for bringing policy considerations into play. It is especially important to set obligations and regulations that encourage farmers to develop business approaches to their operations. A second vital issue within projects is the level of capital cost recovery and charges for annual costs. These have critical impacts on the profitability of farms and enterprises and on the viability of public-sector funded programmes.

Programme flexibility. The most important feature of country programmes is their internal diversity and their flexibility. Internal diversity comes from programmes being designed to address multiple difficulties in water control facing farmers. Each programme should deploy resources to address wide varieties of problems. The ‘menu’ should be one of cases to be addressed rather than of instruments to be applied. Flexibility should come from empowering programme managers, in concert with the investing governments, to change the problems being addressed, the approaches followed and the instruments applied as circumstances change.

Chapter 3
An outline strategy for southern Africa

Increased productivity of water depends on its improved use. In turn, this requires three groups of actors to perform effectively: (i) farmers need to improve the use of other resources to complement improved water use; (ii) those concerned with marketing need to facilitate the best use of products from farms; and (iii) governments need to create a framework that encourages the other actors to play their roles. Therefore, a water control strategy necessarily involves elements beyond the narrow confines of the application of available water.

The overriding goal needs to be higher productivity of land and water. Achieving the full potential for increased productivity depends on attention to the many factors that influence the incentives and opportunities available to farmers. These can be divided into two sets: (i) factors that apply primarily directly to farmers on their farms and should be addressed there; and (ii) factors that apply beyond the farm and need to be addressed in that sphere. A strategy to address these factors (Figure 3) therefore consists of two sets of tactics, for each of which a combination of instruments and activities can be designed to make up programmes of investments and policy reform packages.

The **first objective** of the strategy relates to farmers and farms directly and which would pursue the objective of productive and profitable farm operations would be: (i) improve farm management; and (ii) supply irrigation water. The focus for improving farm management would be on farmers and the resources they command. The focus on supply of irrigation would be on other actors bringing water to the farmers for their inclusion in overall input packages.

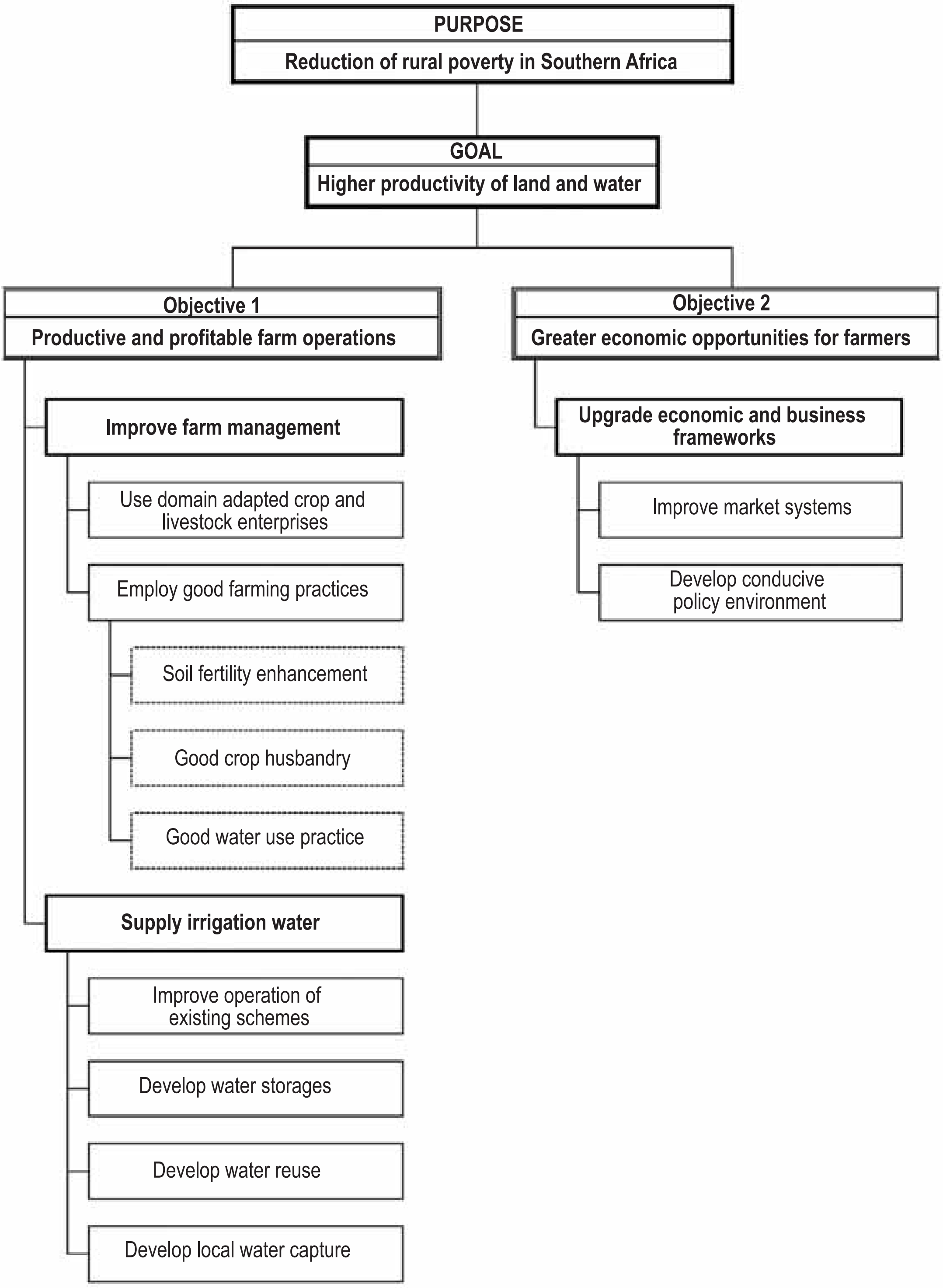
The **second objective** of the strategy addresses factors that hinder the creation of effective sets of incentives. The objective would be expanded economic opportunities for farmers. The tactics would be to upgrade the economic and business frameworks. The focus of these tactics would be on role players, such as governments, public institutions and private concerns in marketing.

Objective 1: improving the productivity of farm operations

The overall strategy is to guide identification, formulation and financing of water control programmes and projects, both regional and within countries. The central focus of these is on farmers and their farms and on the ways and means of improving productivity. The guiding principle of programmes and projects should be to improve the investment and enterprise choices of farmers and to increase their capacity to take advantage of market opportunities.

Farmers in different agro-ecological zones (AEZs) and farming systems growing different crops for different markets will use different sets of technologies and techniques. The selection of technologies and techniques will be for the farmers to decide within the business frameworks they face. It will be a responsibility of programme and project design to devise the instruments (e.g. investment and policy) that ensure that farmers are equipped to select and encouraged to use the best technologies and techniques, and that these are made available. The fields of

FIGURE 3
Strategy for best use of water for agriculture



technologies and techniques that are or might be available are extensive. They can be considered within the two sets of tactics for the first objective of the strategy.

Farm management

The critical determinant of production is the quality of farm management that combines available resources to deliver products that meet demand. Farmers are almost the sole role players (i.e. they participate in or influence the outcome of events) on their farms and the dominant stakeholders (i.e. they are affected by the outcome of events) in production. Therefore, efforts to increase productivity should focus on farmers, on the resources they apply, on how they combine inputs and on how they market their outputs. In short, the challenge is for farmers to select those enterprises most suited to their circumstances, to manage them efficiently and to trade their outputs to best advantage.

Farm management can be improved by selecting enterprises that are best suited to specific ecologies (the RMDs) and to economic opportunities and by applying the best farm practices in the use of fixed and variable inputs. The variable inputs include investments and practices for good crop husbandry and water use. Water managed by farmers includes that stored in the soil, that available by trapping runoff and that brought from outside the farm by irrigation schemes and technologies.

The strategy suggests techniques and technologies to improve management of farms in two groups: (i) use of domain-adapted enterprises; (ii) employment of good farming practices.

Domain-adapted enterprises. The RMDs are defined by farming system, agroclimatic zone, country and proximity to markets. The enterprises that are best adapted to a domain are those that give the best net return to farmers and the highest value added to the nation. Selection of the 'most profitable' enterprises should be a business decision made by each farmer on the basis of the available resources and market opportunities.

Factors determining the enterprise 'profitability' in a domain include: natural resource endowment, climate, farm size, infrastructure and proximity to markets. In each domain, the number of 'adapted' crop and livestock enterprises varies according to these and other factors. Ultimately, commercial judgement by the investing stakeholders (farmers) is the only mechanism for selecting profitable enterprises. However, analysis of the range of production possibilities is a prerequisite for the formulation of policy and strategy to support farmers' investments. Three examples show how domain-adapted production may be identified when compiling investment programmes:

- Pastoral farming system in the remote semi-arid zone of Angola, Namibia and Botswana (RMD29-RMD31). Soils are sandy, highly permeable and of low chemical fertility, and the topography is almost flat. The climate is not suitable for rainfed crop production. Water resources are limited to seasonal pools, a few perennial rivers and deep groundwater of varying quality and little recharge. Conditions are generally not suitable for rainwater harvesting. The most adapted enterprises would probably focus on extensive livestock production and possibly game ranching, while small-scale irrigated crop production could be considered near the perennial rivers and adjacent to homesteads. Elsewhere, water development would focus on providing drinking-water for livestock in balance with available natural pasture. The most likely source of water would be groundwater. Near perennial rivers, water development would include the development of cheap and reliable irrigation methods for gardening and improved flood recession farming.
- Maize mixed farming system in the relatively densely populated dry subhumid zone of Zambia and Zimbabwe (RMD15 and RMD17). Soils are of low fertility, and the topography undulating with wetlands (dambos). The climate is suitable for rainfed crop production

except in dry years. Water resources are abundant with perennial and seasonal rivers, dams and generally good groundwater reserves. Conditions are favourable for water harvesting. These domains have considerable potential for crop production. Maize is the dominant crop because it has proved well suited to the conditions and to the demands of accessible consumers. Moreover, maize offers opportunities to increase yields from the current 1 tonne/ha to 4 tonnes/ha, provided that markets can be found at prices that will induce farmers to raise output. Other crops could be grown here, with their profitability depending on market demand. The focus for water management would be on improving soil fertility and reducing vulnerability to drought. This can be achieved through various forms of minimum tillage and conservation agriculture, both of which improve the infiltration and waterholding capacity of the soil. In addition, simple water harvesting techniques could improve on-farm water supply. Irrigated farming of high-value crops (including winter crops) is possible at selected sites throughout the zone; its profitability would depend on markets and marketing.

- Maize mixed farming system in peri-urban areas (e.g. Greater Harare, RMD16). The proximity to urban markets suggests that high-value crops such as vegetables are well adapted to the domain. The focus of programmes to promote peri-urban production would be on investment in infrastructure, with facilities for the reliable supply of water as the centrepiece, supported by conducive policy, especially land zoning and municipality regulations, and securing land and water usage rights for farmers. Reliable sources of water might include existing storages and wetlands with perennially high water tables. Such sources have various users and would need to be managed communally or by an authority.

Traditional forms of agriculture are almost always domain-adjusted. In the case of new and improved systems, farmers need support from extension services and incentives from appropriate policies and support services. The focus of interventions linked to water would be its best use, with other elements of the strategy tailored to the needs of each domain.

Good farming practices. Good farming practices are critical to improving productivity and sustainability. Farmers will be motivated to improve the management of their enterprises where the returns to incremental inputs exceed their cost by an acceptable margin. The most important elements of improved crop husbandry are soil fertility enhancement and soil moisture conservation.

Farmers have many ‘tools’ to improve soil fertility (Chapter 2). Within each domain and each farm, there are many variations as to the inherent nutrient status of the soil, natural nutrient replenishment and fertilization practices. Recommended fertilization practices need to be location specific. Chapter 2 details some important methods of fertilization and soil improvement

Moisture stress in crops and a lack of water for home use and livestock can be relieved on-farm by increasing the infiltration capacity and waterholding capacity of the topsoil and by capturing and using on-farm runoff (Chapter 2). There are many techniques available, often combining water harvesting and soil conservation. Most techniques are location specific, depending on the physical characteristics of the farm, such as soil, landform and rainfall pattern, and on the farm water requirements. Some moisture conservation tools are:

- Adding manure, compost and leaf-litter to boost organic matter content of the topsoil. Common. Especially applicable in mixed farming systems. Most applicable in the subhumid zone.
- Zero or minimum tillage to conserve crop and weed residues in order to increase organic content in the topsoil. Most applicable in the subhumid zone.

- Agroforestry to increase soil organic content. Most applicable in the subhumid zone.
- Breaking compact layers through ripping or by growing deep-rooting crops (e.g. pigeon pea) in order to increase soil permeability.
- Digging planting holes, contour ridging, furrowing or other land improvements to reduce loss of rainwater through runoff. Various techniques applicable in all zones.
- Timely planting and weeding, and selection of drought-resistant crop varieties to enhance efficient use of soil moisture.

Improving irrigation service. There is a view that maintains that water resources are underused, that their development can increase the productivity of farmland and enable new land to come into production, and that there is no alternative if growing populations are to be fed adequately. However, there is another view that holds that irrigation water is expensive and that rainfed production should receive a higher priority in order to enable a higher number of people to be assisted by the limited resources available. These issues are compounded when set into the context of other demands for use of water resources.

The options pursued depend on, among many things, the particular objectives (e.g. maximum value of production, maximum number of rural people with food security, or greatest food supply of a nation) and the resource, technical and economic backgrounds. These and other determinant factors will vary among the RMDs defined in this study.

Farmers obtain water for livestock and crops from sources on or near their farms or from 'schemes' that convey it from further afield. Irrigation water from schemes supplies less than 15 percent of the cultivated area in nine of the ten countries and it is applied mainly to higher-value crops. An exception is Swaziland, where 35 percent of the cultivated area is irrigated for large-scale production, especially of sugar cane, pineapple and citrus fruits.

Irrigation practice ranges from large commercial farms drawing their own supply from rivers or storage to government-sponsored (or owned and operated) schemes to small private and informal schemes. Studies suggest that small-scale irrigation schemes are profitable to farmers, especially where: (i) cost recovery is modest; (ii) management is largely in their own hands; (iii) they enjoy considerable freedom to select their own enterprises; (iv) markets for high-value crops are accessible; and (v) land and water rights are inheritable or transferable. However, even where these conditions are satisfied, scheme management must be effective, especially in establishing and imposing discipline to collect and save funds for the O&M of facilities; this is often not the case. The continuation of large-scale commercial irrigation is an indication that such schemes are profitable.

There will be a continuing need for irrigation if higher-value crops (especially those with high water requirements) are to be expanded and cropping is to be intensified and/or diversified to exploit market opportunities. While it may be necessary and desirable to increase the irrigated area, it is also important to use water already under control more efficiently. The use of techniques such as drip irrigation reduces the amount of water applied and can permit the expansion of irrigated areas.

Feasibility studies of project proposals need to examine questions concerning whether and how irrigation should be supplied and who should supply it. These and other critical questions need to be answered on a case-by-case basis. Feasibility studies need to analyse whether water should be supplied by investment in schemes or by farmers developing local sources. The strategy places the options for improving water supply in four groups: (i) improving existing schemes; (ii) developing new storages; (iii) developing reuse of water; and (iv) developing local water capture.

Improving existing schemes. Most of the ten countries attach a high priority to improving and rehabilitating existing schemes. Exceptions are Namibia and Botswana, which have few schemes, and South Africa and Swaziland, where irrigation management and service levels are generally high. The improvement of existing schemes can result in increased water supply, increased reliability of supply and improved farming. Methods for improving schemes include:

- repair and upgrading of physical infrastructure (water delivery system, roads, storage and processing facilities);
- modification of physical infrastructure to suit new, more economic crops and produce;
- change of land tenure to give farmers more security and sense of ownership;
- change of management (e.g. from individual plots to outgrower schemes or cooperatives).

Not all schemes warrant improvement and fresh investment. Those that were poorly designed at the outset or have become obsolete under changed socio-economic conditions should not be pursued further. Individual schemes should be examined to determine the need and potential for improvement. Prior to any investment, the priority for improvement or new construction should be assessed in terms of technical and economic criteria.

Developing reuse of water. Where water is particularly scarce, the use of wastewater offers opportunities to increase supply:

- Some wastewater from households, farms (irrigation), mines and industries could be reused.
- Towns with a water shortage and an efficient sewage system often recycle wastewater (e.g. Harare).
- On a small scale, household wastewater can be used on gardens.
- Water from large buildings, such as schools, hospitals and office blocks, can be reused.

Water from industries may be polluted and expensive to clean. Some potential may exist for the use of water from mines (tailwater) unless polluted. Well-designed irrigation schemes have good drainage systems and may produce wastewater. Some of this water may have relatively high salt contents and should not be reused.

Developing local water capture. Certain locations provide opportunities for water harvesting, whereby rainwater runoff is collected from hillsides, road drains, roofs and specially prepared (sealed) pieces of land. The water harvested may be stored for later use or channelled directly to the crop. Increasing the infiltration and waterholding capacity of the soil and preventing runoff from the field are also forms of water harvesting. Rainwater harvesting during low and erratic rainfall may help overcome mid-season dry spells during the rainy season, or prolong the growing period. Local water capture is likely to fail in very dry years and is not a substitute for irrigation.

Recommended rainwater harvesting techniques vary according to the available natural resources (land, rainfall and soil), human resources (labour, capital and skills) and produce (crops, trees and livestock). However, few techniques have been subjected to economic analysis. Because of their higher inputs (especially labour), water harvesting techniques are most appropriate for high-value crops.

Objective 2: expanding opportunities for farmers

Farmers who select adapted enterprises, improve their management and enjoy greater access to irrigation may find their efforts to be to little avail if other parts of the framework in which they work do not improve. Markets need to deliver inputs and take outputs of the right quality at the right time and price. Further enhancement of the opportunities for and easing of the constraints on farmers needs to come from changes to the policy framework.

The development of 'business-oriented' approaches to farming and the provision of facilities and services to farmers should aim to bring greater efficiency to operations from production through to distribution. The most important way of applying business approaches is to bring commercial discipline to the allocation of resources throughout the production and marketing processes and especially in the allocation of funds for investment.

Attention needs to focus on two areas: (i) marketing; and (ii) policy frameworks.

Improvements to marketing

The most immediate 'off-farm' problem affecting farmers is that of the marketing of inputs and outputs in relation to quality, quantity, timeliness and price. Some marketing difficulties are addressable within programmes and projects, while others fall into the sphere of policy.

The marketing systems of the ten countries are in varying stages of development. Those where marketing was previously a function of parastatals have two problems: slow adjustment to the withdrawal or downgrading of parastatals (especially for staples); and slow development of the marketing skills of farmers and traders to assist the growth of higher-value and niche crops. Attention to these difficulties comes in two forms: (i) direct action within a project or programme framework; and (ii) policy development.

Marketing skills can be developed to enable exploitation of niche markets for specialist, high-value crops. However, there are increasingly successful attempts to improve marketing through various 'market linkages'. These can be pursued case-by-case for differing domains. Further support concerns the construction and operation of communications infrastructure (especially telecommunications and roads) and physical produce markets. This aspect is readily addressable in project interventions.

Policy frameworks

In addition to the national and macroeconomic policy issues discussed earlier, sector policy is also important. In sector policy, the issues are within agriculture and much closer to the water sub-sector. The progress being made in preparing water-sector, natural-resource and drought strategies can provide the foundation for ongoing work to create conducive sector and sub-sector policy. Chapter 2 examined the policy areas of crucial concern to improved water use. The analysis presented there provides the basis for some conclusions on sector policy:

Governments need to send clear and stable signals to producers on market opportunities and facilitate viable market chains in food and fibre production. Of fundamental importance is the guarantee of transparent, stable land tenure systems and water use rights through legal reform. Water law is being reviewed and revised across southern Africa, but often driven from the water supply and sanitation sector. The interests of agriculture have also to be articulated in this respect.

Market distortions need to be eliminated where possible and the private sector encouraged where it can provide expertise in marketing and the application of technology. The role of private irrigation suppliers in providing extension services as a package to smallholders is already significant in the region. But more importantly the void left by withdrawal of government marketing services has not been filled by a flourishing private sector. Therefore, much emphasis should be placed on 'market linkages' to improve both the supply of inputs to farmers and their access to profitable markets for the right goods of the right quality at the right time.

The facilitation of appropriate forms of credit will be key to reinforce local circulation of finance within land and water development. Term loans need to be geared toward the long term investment in irrigation hardware and appropriate forms of collateral accepted. Where the private sector is not prepared to take risk, the role of government credit agencies may need to be considered but not at the expense of crowding out private initiative.

Finally, the role of government agencies in promoting enhanced investment in improved water control needs to be clearly understood. Agencies dealing with agricultural extension will continue to be vital where no private agents are active. However, the role of government in owning and operating irrigation infrastructure has become more questionable, particularly when set against the performance of private irrigators – smallholders and large commercial concerns. In this respect it is important that government operational mandates do not crowd out private initiative and finance and that transfer of existing asset base to the farmer associations and commercial operation is considered when public irrigation schemes have become a burden on government budgets.

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