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Evaluating rainwater harvesting as a vulnerability reduction strategy that is relevant to sustainable development in rural, drought-prone Botswana.

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ABSTRACT

The dissertation will focus on evaluating rainwater harvesting as a vulnerability reduction strategy in rural, drought-prone Botswana. It poses the question of whether such technology is relevant for sustainable development in a country that is experiencing rapid urbanization, technological development and a changing agricultural base. Three different approaches are taken. The first considers ferrocement tank technology and its contribution to risk reduction in schools and rural households in south-eastern Botswana. The second evaluates the role of agroforestry in which rainwater harvesting and water conservation methods are practised in conjunction with growing and improving the yields of indigenous fruit trees and crops. The third considers community-based agroforestry in drought-prone communities in south-east and central Botswana where these strategies have been developed to improve food security and reduce people's livelihood vulnerability. By applying the 'pressure and release' conceptual framework that focuses on the root causes, dynamic pressures and unsafe conditions of drought-related vulnerability, the mitigating value of each initiative is assessed. The outcome of this assessment underlined three key factors that influence the effectiveness of rainwater harvesting as a drought vulnerability reduction strategy. These include the viability of rainwater harvesting for rural communities in the context of a declining agricultural base, especially in lands areas, and changing social employment patterns. Moreover, rainwater harvesting is itself vulnerable to recurrent drought, which limits its demand. A third prevailing factor is the social expectation of reticulated water supplies, rather than rainwater harvesting technologies.

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LIST OF ABBREVIATIONS

AD	Agricultural Demonstrator
AEC	Annual Equivalent Cost
ALDEP	Arable Lands Development Programme
ARAP	Accelerated Rainfed Arable Programme
BCA	Botswana College of Agriculture
BDC	Botswana Development Corporation
BDF	Botswana Defence Force
BHC	Botswana Housing Corporation
BNWMP	Botswana National Water Master Plan
BTC	Botswana Technology Centre
CBAP	Community Based Agroforestry Project
CBO	Community Based Organization
DIMP	Disaster Mitigation for Sustainable Livelihoods Programme
DWA	Department of Water Affairs
ECA	Economic Council for Africa
ENSO	El-Nino – Southern Oscillation
EO	Extension Officer
EU	European Union
EWTC	Early Warning Technical Committee
EWS	Early Warning System
FAO	Food and Agriculture Organization
FAP	Financial Assistance Policy
FED	Food Entitlement Decline
GDP	Gross Domestic Product
GNP	Gross National Product
GPSS	Gabane Private Secondary School
HIV/AIDS	Human Immuno-Deficiency Virus / Acquired Immune Deficiency Syndrome
HDI	Human Development Index
HPI	Human Poverty Index
HYV	High Yield Varieties
ICJ	International Court of Justice
ICRAF	International Centre for Research in Agroforestry
IK	Indigenous Knowledge
IMDC	Inter-Ministerial Drought Committee

IMF	International Monetary Fund
ITCZ	Intertropical Convergence Zone
ITDG	Intermediate Technology Development Group
LAWSS	Lands Area Water Supply Study
LBRPW	Labour-based Rural Public Works programme
MFDP	Ministry of Finance and Development Planning
MLGL&H	Ministry of Local Government Lands & Housing
MMR&WA	Ministry of Mineral Resources and Water Affairs
MoA	Ministry of Agriculture
MTCT	Mother to Child Transmission
NDP	National Development Plan
NGO	Non-Government Organization
OAU	Organization of African Unity
PAR	'Pressure and Release' model
PET	Potential Evapotranspiration
PPP	Purchasing Power Parity
PVI	Pelagano Village Industries
RAD	Remote Area Dweller
RDC	Rural Development Council
RIIC	Rural Industries Innovation Centre
RWCS	Rainwater Catchment Systems
SADC	Southern African Development Community
SAFIRE	Southern Alliance For Indigenous Resources
SO	Southern Oscillation
SSA	Sub-Saharan Africa
SST	Sea Surface Temperatures
STDs	Sexually Transmitted Diseases
TB	Tuberculosis
TL	Thusano Lefatsheng
TPR	Tripartite Review
UB	University of Botswana
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
UV	Ultra Violet light
VPR&D	Veld Products Research & Development
WMO	World Meteorological Organization
WWF	World Wildlife Fund
ZAB	Zaire Air Boundary

Chapter 1

Introduction to Botswana

1.1 Prelude

The rationale behind the research gives an overview of some of the main sociological issues that together form life today in Botswana. It initially guides the reader through an introduction to drought that is frequently perceived as a natural disaster, and the need to protect and exploit the country's available water resources. The Botswana presentation then sets the scene for an in-depth look at the country's geography, climate, economy and the agricultural sector. The chapter ends by considering the HIV/AIDS influence, coping and adaptive strategies during periods of drought and finally famine early warning systems.

Drought is a normal feature of climate and its recurrence is inevitable. However, there is much confusion in the policy and South African scientific community about its characteristics and the most effective drought management strategies to adopt. The severity of any drought depends not only on its duration, geographical extent and intensity, but also on the demands made by human activities and vegetation on a region's water supplies (Wilhite, 1999). The characteristics and impacts of a drought widely affect a region's society, economy and environment, and may be very difficult to identify and quantify.

There is wide institutional capacity to respond to drought emergencies in southern Africa. It is difficult, however, to sustain mitigation after a drought event has finished and more favourable conditions return, given the slow on-and-off nature of the hazard. Interest in planning ahead for drought quickly wanes in the post-drought period. Building up institutional capacity that provides continuous advocacy for drought mitigation is important in drought prone countries.

1.2 Introduction to natural disaster risk in southern Africa

"We in the villages like Chomuruvati are seen as knowing nothing because we are poor and we get drought relief. So those who give us things just treat us like that and we let them do it." Mr Gunge, Chivi district, Zimbabwe (Murwira, n.d., p.31)

Water issues are important for all peoples living in southern Africa. Water is not only a fundamental prerequisite for development but is also an essential basic human need for physical survival (South African Department of Water Affairs and Forestry, 1994). Drought is one of the greatest constraints to adequate water supply in southern Africa, and this recurrent natural event is responsible for depleting both surface and ground water resources. Some

parts of Sub-Saharan Africa, especially southern and eastern Africa, are particularly prone to severe droughts with 28 countries in the region experiencing more than two consecutive years of drought during the 1974 -1985 period (Sharma, *et al.*, 1996).

Water issues pose three challenges to policy makers in southern Africa. These are water shortage and availability, water supply, and water quality. In a regional context of rapid population growth, cross border migrations and urbanization, investing in a sustainable water supply has increasingly become a pressing development priority. There has been a proliferation of proposals for addressing water scarcity in southern Africa. These vary from the state regaining effective control over a country's water resources and investing in government Rainwater Catchment Systems (RWCS), to individual ownership and investing in private RWCS in the public interest.

Risks related to water scarcity are much greater in communities that are geographically located in arid and semi-arid areas. Much of southern Africa receives minimal rainfall. In South Africa, only a limited geographic area along the eastern escarpments and coastal regions receives more than the world average of 1000mm rain per year (Vogel, Laing and Monnik, 2000).

Over recent years, droughts in southern Africa have been perceived as natural disasters that simply necessitated large financial government handouts and subsidies. There has been an insufficient focus on protecting the rural poor against long-term risks that threaten their security. Increasing environmental, economic, social and political pressures are being exerted upon rural communities in southern Africa, making it harder for them to combat and recover from natural or human-induced shocks. People therefore find themselves more vulnerable to extreme weather events that impact their livelihoods. In order to consider the pressures exerted upon communities, drought mitigation needs to be an inclusive strategy that links the efforts of all sectors of society, from government to extension officers (EO), non-governmental organizations (NGOs), school teachers and tribal chiefs (Vogel, Laing and Monnik, 2000).

1.3 Background to this dissertation in Botswana

In a semi-arid, drought-prone country such as Botswana, there is great need to conserve as much water as possible, particularly when 94% of its fresh water originates from outside its borders. Water is such a precious resource that it is no surprise that the national motto, national greeting and the word for money are all '*pula*', meaning rain.

In Botswana, water conservation and carefully planned development, management and utilization of the available water resources are a matter of extreme importance. Water is a major factor in the socio-economic fabric of the country and is also a determining factor in the nation's development potential. At independence, Botswana was one of the poorest and least

developed countries in the world with 84% of the population living in rural areas. Its economy was sustained by migrant labour and beef exports, and it had a per capita income of about Pula60 per year (then equivalent to US\$80) (Moremi, 1987). Since independence, Botswana has experienced a rapidly growing population, a current trend towards rapid urbanization, and the increasing agricultural, industrial and mining activities are all exerting pressure on the provision of an adequate and safe water supply (Mbakile, 1999, pers com.).

Drought planning is part of Botswana's development history. Its institutional capacity is well defined and much local involvement occurs at district level. In 1998, the Director of Water Affairs in Botswana, Mr Khupe, expounded that:

"Competition for our (Botswana's) limited and diminishing water resources by different users in the country were causing problems, and conflicts are already emerging on the sharing of water resources between different users. However, it has become evident that additional planning tools and measures are needed in the quest to utilize the scarce water resources in the most beneficial and optimal ways. Collectively, these new measures can be grouped together under the term 'water conservation and water demand management' " (Khupe, 1998).

In light of increasing demands in the early 1990s for a framework for water development and to ensure the fair allocation of the nation's scarce resources, the Botswana National (BNWMP), was prepared. Up until then, the development of water resources in Botswana had been mainly demand-driven but a new strategy, that of matching water availability to projected demands in the foreseeable future, was emerging (Mbakile, 1999, pers com.).

The BNWMP, which projected the country's requirements over a period of 30 years, unfortunately over-emphasized water supply measures (Mbakile, 1999). An alternative, more sustainable approach would have been to address the problem from a resource orientated perspective that would have involved assessing the size of the available resource and then developing strategies to control the demand (Mbakile, 1999).

The Ministry of Agriculture (MoA) oversees the provision of water to people in the country's isolated and thinly populated settlements through the Arable Lands Development Programme (ALDEP), the Small Dams Unit and the Irrigation Unit. However, there is no co-ordinated domestic water supply programme for the lands and cattle posts areas (Bhebhe, 1994). The Lands Area Water Supply Study (LAWSS), commissioned by the government in 1991, noted the problem. The executive summary quotes:

"The water requirements of the towns and villages are currently dealt with by the Central Government and District Authorities (ie. Department of Water Affairs, Ministry of Local Government, Lands & Housing, and Councils) through formal policies and programmes such as the Rural Water Supply Programme. No such policies have so far been developed for the scattered rural population which constitutes a district problem, because of its dispersion and seasonality" (LAWSS, 1991, quoted by Bhebhe, 1994).

Some of the settlements which fell under this category have since been provided with complete village water supply systems, but the majority of isolated small settlements remain in need (Bhebhe, 1994).

1.4 Rationale for this study

In this thesis, drought is examined including drought as a natural phenomenon and risk reduction as a development strategy to better manage it. Drought may occur in practically any region of the world. In 1975, the World Meteorological Organization (WMO) first introduced the idea of drought as a water supply and demand phenomenon that is also related to other factors, principally the human demand for water for a whole wealth of activities (Cooke, 1978). Cooke suggested that a suitable definition of drought for Botswana might be:

"A lack of rainfall severe enough, of long enough duration, and of wide enough extent throughout the country to deleteriously affect plant growth, water supplies for stock use, domestic use, and for urban, industrial, and mining purposes" (Cooke, 1978, p.8).

In Botswana, the degree of susceptibility to water shortage stress, that is drought, varies from the low level islands in the Okavango Delta or Limpopo River valley, to the areas of deep Kalahari sand in the south-west of the country. Here, the coefficient of variability can be as high as 80% (Cooke, 1978). This susceptibility is inherent. In good years the land may have the appearance of a lush savanna, but in dry years it may resemble a desert and yet this may have no correlation with human activities. Over the last 100,000 years, Botswana has experienced alternating periods of savanna and desert, long before humans had any influence in the region (Cooke, 1978). Human practices can clearly aggravate or alleviate drought susceptibility. In arable areas, for example, poor cultivation and ploughing can lead to a breakdown in the soil structure, the excessive loss of moisture and very poor crop yields.

Good quality groundwater is available in many areas of Botswana and over 15,000 boreholes have been sunk throughout the country (Taylor, 1997). In some areas though, the groundwater is too deep, too unreliable or too saline to provide an acceptable supply for domestic use. In these areas alternative supplies have to be found or water trucked from great distances and at great expense.

As Botswana develops economically, its water need increases, placing it at risk from periods of prolonged water deficiency. At the same time, of course, a more developed society should have a greater ability to anticipate drought and to plan for mitigating its effects both in the short and long term. In the thesis, an evaluation, not only of the current mitigation programmes that are in operation in rural and village life in south-eastern and central Botswana, but of potential opportunities for the future are examined. An investigation is required both from a physical and

social viewpoint where drought mitigation strategies can be evaluated to determine their effectiveness and their potential.

1.5 Scope of research

A risk reduction approach is used to integrate an analytical framework of reducing communities' vulnerability to natural threats and incorporating mitigation strategies into the response. It specifically focuses on:

- The role of development programmes in rural and village communities in reducing drought risk.
- Water resources management of available supplies, particularly rainwater harvesting.
- Agricultural projects that seek to further people's livelihoods and initiate good environmental practices.

These are presented and evaluated amid a country backdrop of rapid rural-to-urban migration, an expanding successful economy and a consequently changing lifestyle for many Batswana. To evaluate the three areas mentioned above, also requires that three other major factors be similarly taken into account, those of climate and agricultural change and the current HIV/AIDS epidemic in Botswana.

1.6 Background on Botswana

Botswana is one of two countries in southern Africa, including Namibia, which has the greatest potential for rapid desertification and food insecurity, situated as they are within the naturally harsh arid and semi-arid environment of southern Africa. Eighty percent of Botswana's 582,000km² land surface area is classified as semi-arid Kalahari sandveld, a fragile ecosystem that is considered as marginal for most agricultural systems (Taylor, 1994).

Botswana is one of Africa's greatest success stories in terms of economic growth and democracy. Table 1.1 presents key development data for Botswana. According to the United Nations Development Programme's (UNDP) Human Development Index (HDI), in 1997 44% of the rural population lived below the Poverty Datum Line (the Human Poverty Index, or HPI) (Ross-Larson, 1999). In 1989, the figure was 64% (Taylor, 1994) and four factors were identified that contributed to this situation (Taylor, 1994):

- The semi-arid environment causes people to live precariously from one season to the next with the rainy seasons either bringing occasional rains, sporadic showers or drought.

- Fewer people are growing crops due to the diminishing returns from the exhausted soils. Fertilizers are often not worth investing in as, on average, crop failures occur one year in three.
- Overgrazing, drought and the sustained cultivation of marginal soils exacerbate degradation of the environment. People's food security is thus jeopardized as many rely on natural resources to provide food, firewood and medicines.
- There are limited opportunities to earn cash incomes for many rural women in particular and tremendous pressure is exerted upon them to provide for their families.

The HDI reflects achievements in the most basic of human capabilities; life expectancy at birth, the level of educational attainment (reflecting the adult literacy rate and the combined enrolment ratio) and income (adjusted per capita income in Purchasing Power Parity (PPP) in US\$). The HDI is a more comprehensive measure than per capita income as it looks at areas beyond income while treating it as a proxy for a decent standard of living (Ross-Larson, 1999). Botswana is also one of only five middle-income countries in the region that boasts a Gross National Product (GNP) of US\$3310 in 1997 (Ahmed, *et al.*, 1999).

Index	Value
Life expectancy at birth (years) 1997	47.4
Adult literacy rate (%) 1997	74.4
Combined first-, second-, and third- level gross enrolment ratio (%) 1997	70
Real Gross Domestic Product (GDP) per capita (PPP\$) 1997	7690
Human poverty index (HPI) (%) 1997	44
People not expected to survive to age 40 (as % of total population)	35
Population without access to safe water (%) 1990-1997	10
Population without access to health services (%) 1981-1992	14
Population without access to sanitation (%) 1990-1997	45
Underweight children under age five (%) 1990-1997	17
Population below income poverty line (%): US\$1 a day (1985 PPP\$) 1989-1994	34.7

Table 1.1: Key development data for Botswana

Source: Ross-Larson, 1999.

The HPI is a multidimensional measure of poverty and combines four basic elements of human life. First, a long and healthy life (% of people not expected to survive to age 40), second,

knowledge (illiteracy). Third, economic provisioning (% of people lacking access to health services and safe water) and fourth, social inclusion (% of children under five who are moderately or severely underweight). Poverty is going to be one of the most important challenges the Botswana government will face in the years ahead. A parallel to the poverty situation is an unemployment rate estimated as high as 21% and an AIDS infection rate which is estimated to have increased from 4.35% in 1992 to over 17% in 1998, with 85% of those infected in the age group 15-49 (Ahmed, *et al.*, 1999). HIV and AIDS is attributed as the primary cause of this decrease in life expectancy from 67 years to 47 in 1997 as noted in the 1999 UNDP Global Human Development Report (Ahmed, *et al.*, 1999). If the situation remains unchecked, the UNDP projects a negative population growth by the year 2010.

Botswana's human poverty index dropped from 32.2% to 22% between 1991 and 1996 as a result of higher progress in human development and less deprivation for people in urban areas than for those in rural areas. The rural-urban divide is, therefore, markedly high in Botswana. Poverty still exists today though at very different levels in urban and rural areas with the urban population being better off, with a HPI of 11.7%, compared to rural areas where the HPI is twice as high at 27% (Ross-Larsen, 1999). Botswana is considered to be a lower middle-income country and has avoided the recent economic recessions that have affected other countries in the region (Bollinger and Stover, 1999). Table 1.2 presents a breakdown of the labour force structure in Botswana by industry.

Sector	Economically active labour force: 1991 ¹		Employment by industry: 1986 ²	
	'000s	%	'000s	%
Agriculture				
Agriculture, hunting, forestry & fishing	97.6	25.69	6.0	2.64
Industry				
Mining & quarrying industries	13.3	3.50	7.7	3.38
Manufacturing	27.5	7.24	25.6	11.25
Services				
Electricity, gas & water	6.4	1.68	2.6	1.14
Construction	58.0	15.27	33.7	14.81
Trade, restaurants & hotels	35.2	9.27	40.9	17.98
Transport, storage & communications	11.5	3.03	10.2	4.48
Finance, insurance, real estate & business services	13.4	3.53	17.6	7.74
Community, social & personal services	106.7	28.09	83.2	36.57
Total	379.9	100.0	227.5	100.0
Source: ¹ - Europa World Year Book, 1999.				
² - United Nations Statistical Yearbook, 1995, Table 29.				

Table 1.2: Labour force structure in Botswana by industry

Source: Bollinger and Stover, 1999.

The Botswana economy relies upon the mining industry for approximately 33% of its GDP, while agriculture, manufacturing and construction each contribute between 4 and 5%. Diamond mining accounts for the majority of the mining sector, helping to give Botswana an average economic growth rate averaging 7.3% between 1970 and 1995 (Bollinger and Stover, 1999).

1.7 Geographical information

Botswana is a landlocked country that straddles the Tropic of Capricorn and lies between 18°S and 29°S of the equator with an area of 582,000 km² (Taylor, 1997), see Figure 1.1. Botswana shares its borders with South Africa, Namibia (including the Caprivi Strip), Zambia and Zimbabwe.

The country is vast and flat, with an elevation predominantly between 800-1200m with occasional rocky granite hills rising from the plain. It is divided into three geographical areas. First, the 10,000km² Okavango Delta in the north-west, an extensive swamp rich in wildlife and vegetation. Second, the eastern hardveld where the Limpopo River Valley gradually descends from 900m in the south to 500m at its confluence with the Shashe River. Here, the climate favours settlements, agriculture and fertile soils, in comparison with the rest of the country, though arable land is scarce with only 5% of Botswana's land being cultivable. Third, the western sandveld making up 85% of the country and comprising Kalahari Sand up to 120m thick. This supports vegetation of scrub and grasses but with almost no surface water. Some underground aquifers are recharged by heavy rain but most rainwater is trapped in the top few metres of sand and then lost through evaporation and transpiration (Moremi, 1987).

Vegetation patterns are closely related to climate and soil type. The main types of vegetation are arid scrub savanna in the extreme south-west, mopane woodland in the north and north-east, dry deciduous forest in the extreme north-east, and tree and bush savanna over the rest of the country. Grass savanna occurs around the Makgadikgadi Pans and aquatic grassland and swamp in the Okavango Delta (Taylor, 1997).

The population of Botswana was estimated to be 1.5 million in 1995, with more than 20% living in the urban areas of Gaborone (population 150,000), Francistown, Selebi-Phikwe, Lobatse, Jwaneng and Orapa. A further 20% live in 17 major villages and the remaining 60% inhabit small rural villages and settlements (Taylor, 1997). Traditionally, the Batswana adopted a tripartite migration system moving between their village, cattle post and lands area (where crops are grown) at different times of the year depending on rainfall.

People are today opting for more permanent settlement in urban areas that are supplied with water from dams and large villages that have reticulated borehole supplies (Taylor, 1997). To live permanently in the lands areas many people transport water considerable distances from boreholes or sand rivers by donkey cart, or occasionally by vehicle, often in 200 litre oil drums. Most households, however, are very poor with around half owning no cattle. Due to people's remote households and the lack of easily accessible ground or surface water resources the cost of providing piped water supplies to individual households is prohibitive (Taylor, 1997).



Figure 1.1: Southern Africa

Source: Dalal-Clayton, 1997

1.8 Climate

1.8.1 Climate patterns over Botswana

Rainfall over semi-arid Botswana is erratic, with the rainy season normally lasting between October and April. The mean annual rainfall varies from less than 250mm in the south-west of the country to more than 650mm in the north-west, see Figure 1.2. Figure 1.3 shows the river system that exists over the country, though the water within the Okavango Delta comes, not from rainfall over Botswana, but from the mountains in Angola. Evaporation on the other hand, is predictable and rates exceed 2000mm/year over most of the country (Taylor, 1997). Permanent surface water in Botswana is rare, and although a few dams have been built on ephemeral rivers to create reservoirs, the lack of suitable rivers and dam locations mean that surface water resources are generally not suitable for providing for rural settlements.

Southern Africa's weather is effected through tropical control and temperate atmospheric systems. The tropical easterly airflows consist of easterly waves and lows, while the temperate systems occur as disturbances in the westerlies that occur as westerly waves and lows (Preston-Whyte and Tyson, 2000). More locally, there are also west-coast troughs and smaller-scale coastal lows.

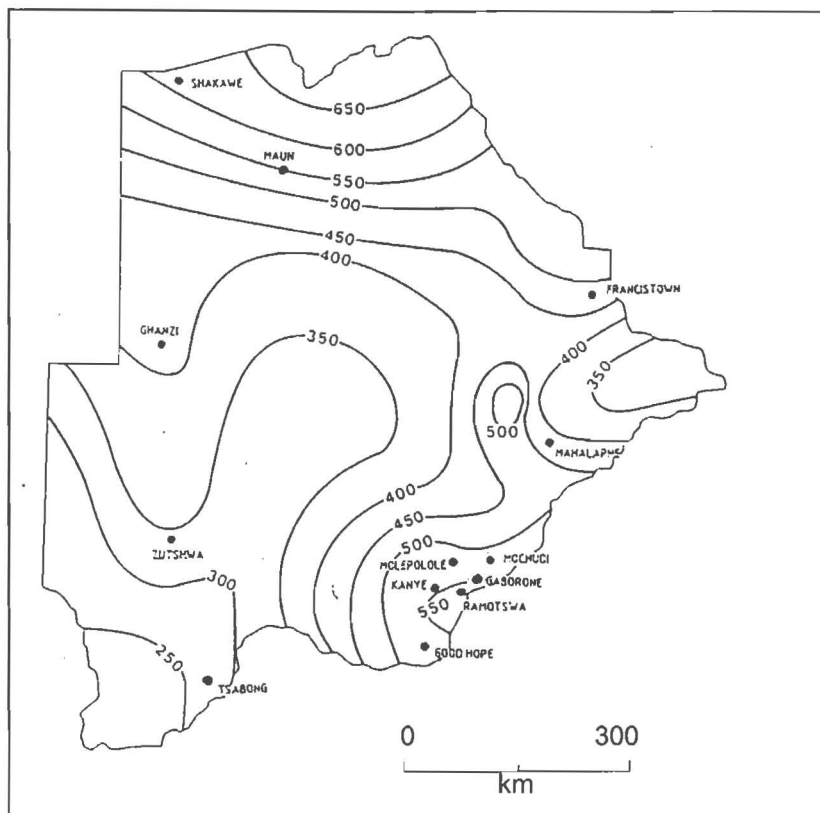


Figure 1.2: Mean annual rainfall map of Botswana (mm)

Source: Taylor, 1997

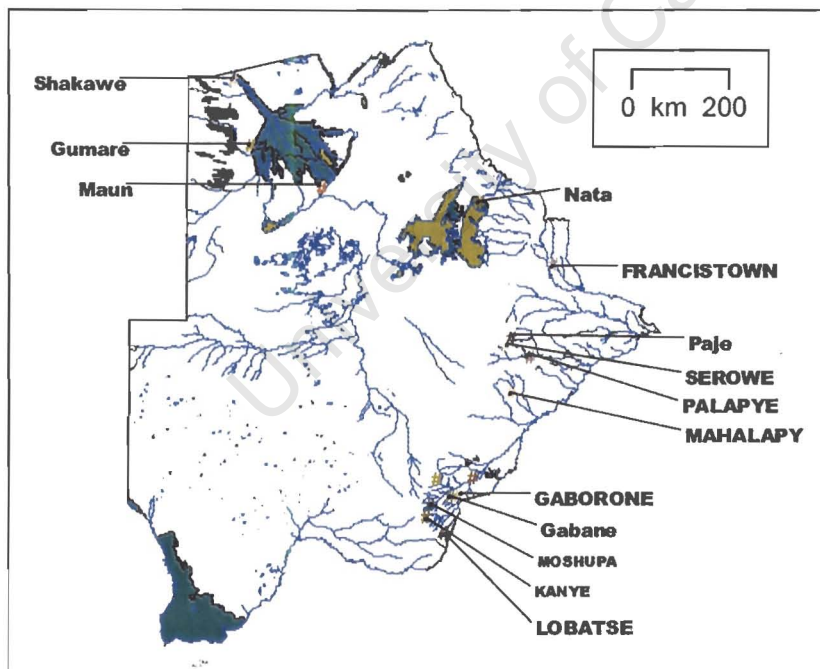


Figure 1.3: Botswana's river systems, the main urban centres and the villages of Paje, Gabane and Moshupa where fieldwork was carried out. The major water systems shown are the Okavango Delta in the north-west, the Makgadikgadi Pans by Nata in the north-east and the Kalahari Gemsbok National Park in the extreme south-west.

Source: World Resources Institute, 1995.

Southern Africa has an extremely variable climate. The Intertropical Convergence Zone (ITCZ) is responsible for most of the rain that falls over the region where cloud build-up forms as a result of the south-east Trade Winds converging with the north-east Monsoon Winds. The movement of the ITCZ southward away from the equator marks the onset of the rainy season in the Southern Hemisphere and it can fluctuate in position between mid-Tanzania and southern Zimbabwe, see Figure 1.4 (Chenje, *et al.*, 1994). Summer rainfall is associated with easterly disturbances in the north of the region and westerly disturbances in the south (Preston-Whyte and Tyson, 2000).

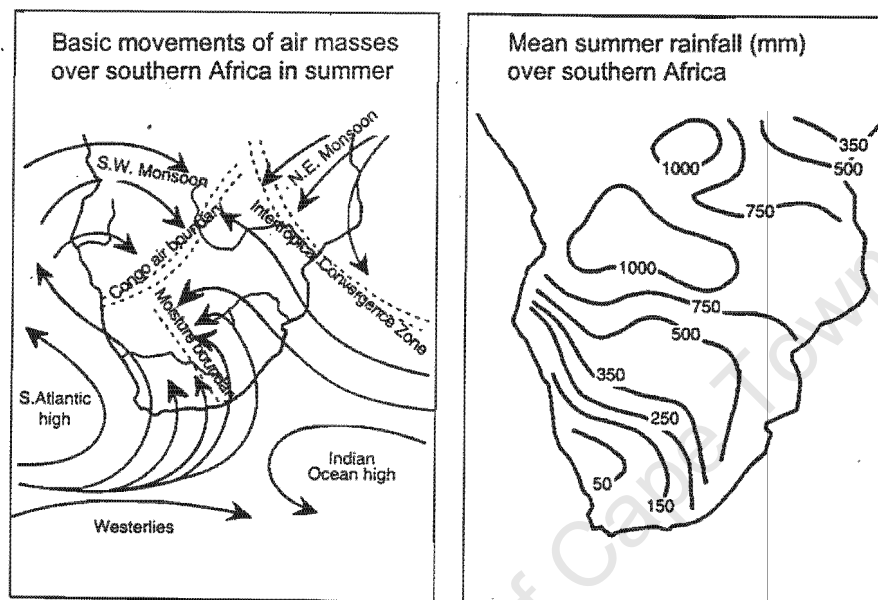


Figure 1.4: Basic movements of air masses and rainfall over southern Africa in summer

Source: Chenje and Johnson, 1994

An atmospheric condition known as the Botswana Upper High (a high pressure centred over Botswana -hence the name -between three and six kilometres above sea level associated with strong subsidence) is also responsible for creating poor, unfavourable precipitation conditions. Its frequent occurrence during winter almost always brings drought conditions to some countries in the region. The rain-bearing winds that flow in from evaporation over the Indian Ocean are deflected away from southern Africa by the Botswana Upper High together with the eastern seaboard mountain range that stretches from the Drakensberg right up to Tanzania (Chenje and Johnson, 1994).

The mean circulation of the atmosphere over the region is anticyclonic in nature and in the July winter this intensifies and moves northward in response to the northward movement of the ITCZ. As a result, the upper-level circumpolar westerlies expand and displace the upper tropical easterlies equatorward. During July, the low-level average pressure field at 850 hPa is strongly anticyclonic (Preston-Whyte and Tyson, 2000).

In January, the near-surface circulation at 850 hPa comprises a weak low pressure that is centred over the region's central interior and is connected to a tropical low pressure system north of Botswana by a trough across the northern Cape and Botswana. This feature traverses in an east-west direction along the southern branch of the ITCZ in the region of the Congo Air Boundary and it occasionally digresses southward towards Botswana, Namibia and Zimbabwe. The change over to a single high pressure cell usually occurs by March and this change brings with it a northerly flow of moist air from the tropics over western parts of southern Africa. During this period, moist air still lingers over Zimbabwe, Zambia, northern Botswana and Namibia, see Figure 1.5. This influx of moist air produces the late autumn rain maximum in western parts of the region.

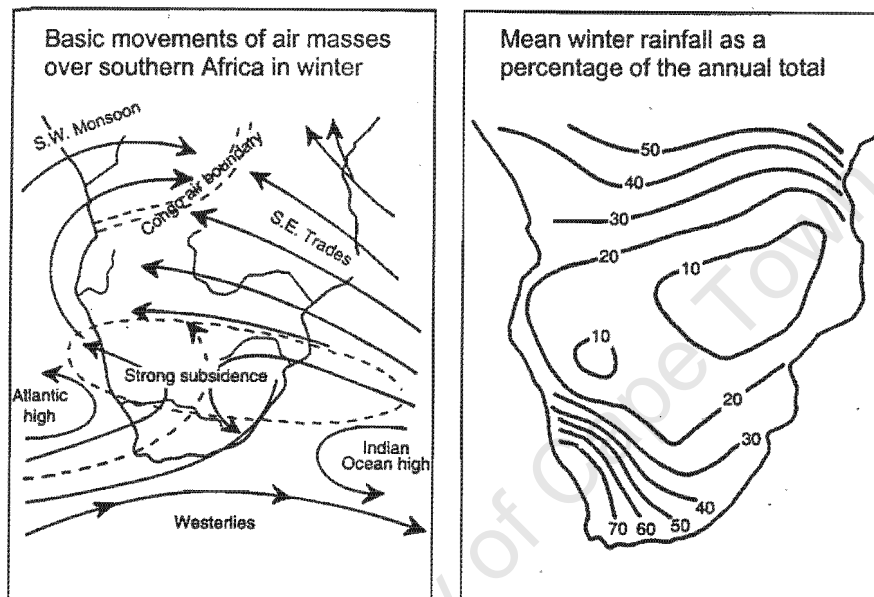


Figure 1.5: Basic movements of air masses and the mean rainfall over southern Africa in winter

Source: Chenje and Johnson, 1994

To gain a picture of Botswana's weather patterns, a consideration is required of the region's synoptic weather patterns based on their circulations at the surface and at 500 hPa. The weather comprises three systems (Preston-Whyte and Tyson, 2000). First, fine weather and mildly disturbed conditions that are associated with the generation of anticyclonic vorticity in large subtropical anticyclones that centre themselves over the region, see Figure 1.6. The anticyclones produce severe heat waves and desiccation in summer and their effects are even felt in coastal and adjacent regions as a consequence of the subsidence and warming effects from Berg winds. Berg winds form as a result of subsiding air on the edge of the front that diverges and warms as it descends and moves offshore in conjunction with the airflow of the anticyclone, see Figure 1.7. Adiabatic warming of the air as it descends off the interior upland plateau, which comprises Botswana, eastern Namibia and Angola, and western Zimbabwe and Zambia, also occurs, increasing the warming effect on the surrounding lower lying areas. The winds occur in late winter and early spring and can carry large dust plumes out to sea. The

coastal lows on the other hand normally develop on the west coast and propagate southwards towards Cape Town, thereafter moving eastwards and then north-eastwards around the coast. These are Kelvin waves that are trapped vertically under the strong subsiding air over the interior and bring localized fine mists or drizzle to the Cape mountains and into the Natal Midlands. They are not, however, major precipitation-producing features.

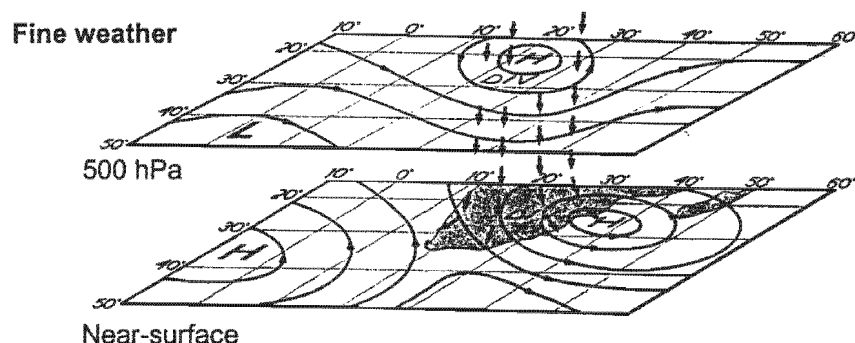


Figure 1.6: Representation of the near-surface and 500 hPa fine-weather circulation associated with high pressure systems over southern Africa.

Source: Preston-Whyte and Tyson, 2000, p.185.

Berg winds and coastal lows

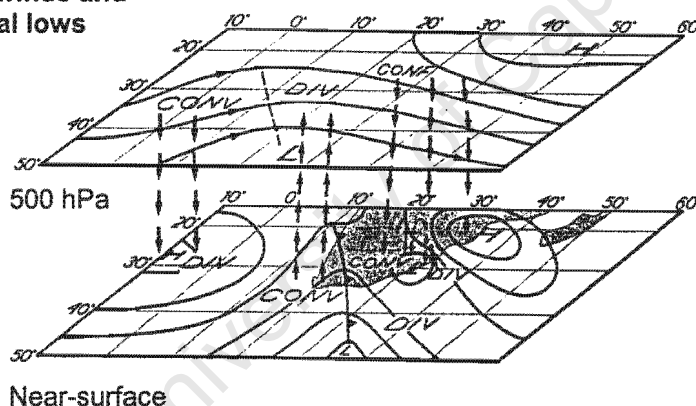


Figure 1.7: Schematic representation of the near-surface and 500 hPa circulation associated with Berg winds and coastal lows

Source: Preston-Whyte and Tyson, 2000, p.190.

Second, tropical disturbances in the easterlies. These disturbances take the form of waves and lows that are associated with the ITCZ and the warm humid easterly winds that travel around the northern edge of the subtropical anticyclones, between the ITCZ and the subtropical high pressure belt (Preston-Whyte and Tyson, 2000). The easterly waves are semi-stationary in nature and form in the region of an easterly jet stream; though they are confined to lower levels as a ridge of high pressure occurs above them in the upper troposphere, see Figure 1.8. The low-level wind convergence and hence strong uplift in the east of the trough brings rainy spells of a few days length with the presence of unstable air. The descending, divergent wind in the west of the trough brings with it clear skies, hot conditions and no rain. In comparison, easterly

lows cross the region in a northward direction and bring large quantities of rain to the interior upland plateau, including Botswana, and they are often responsible for turning the year into an abnormally wet one. Surface convergence occurs to the east of the lows with divergence at higher levels, with commensurate subsidence occurring to the west of the system, see Figure 1.9 (Preston-Whyte and Tyson, 2000).

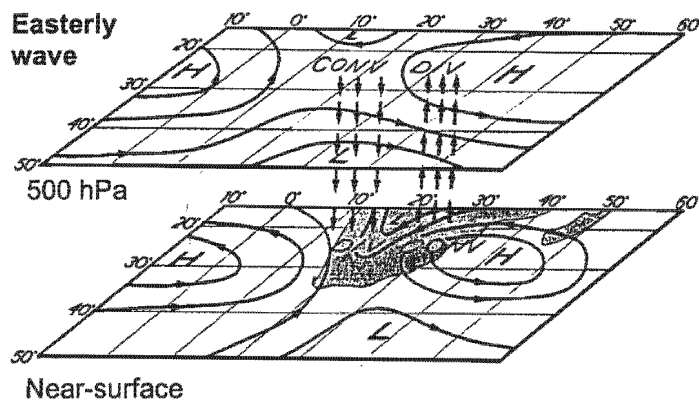


Figure 1.8: Schematic representation of the near-surface and 500 hPa circulation associated with an easterly wave.

Source: Preston-Whyte and Tyson, 2000, p.193.

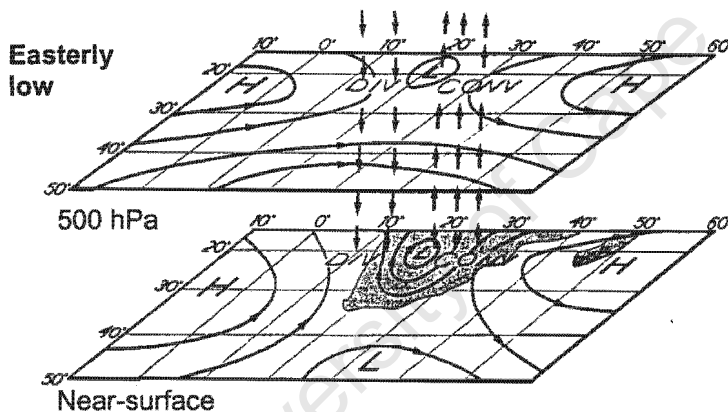


Figure 1.9: Schematic representation of the near-surface and 500 hPa circulation's associated with an easterly low

Source: Preston-Whyte and Tyson, 2000, p.193.

Both the easterly waves and easterly lows are essentially summer phenomenon and occur between December and February. They often determine how much rain actually reaches the continental interior.

Third, temperate disturbances in the westerlies. Figure 1.10 shows six types of westerly disturbances though on a daily basis one type may often change into another. Westerly lows frequently affect South Africa's coastal region seaward of the Escarpment and bring heavy rains between October and April. Cut-off lows, on the other hand, are unstable, more intense forms of westerly troughs that are characterized by strong vertical motions and convergence. They bring flood-producing rains to South Africa, particularly in March to May and September to

November, such as those in Laingsburg in 1981 and Natal in 1987. Southerly meridional flows and ridging anticyclones bring rain to Mpumalanga and eastern South Africa respectively, while west coast troughs and cold fronts bring rain to the western parts of South Africa and southern South Africa respectively.

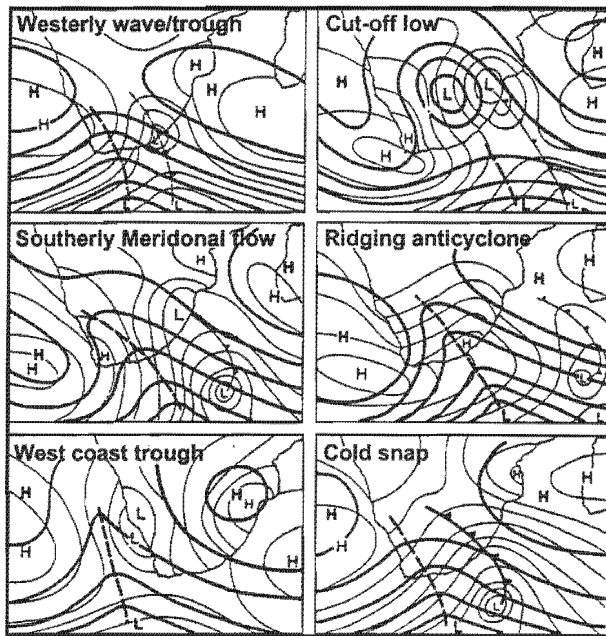


Figure 1.10: A schematic classification of temperate disturbances in the Westerlies in southern Africa based on circulation patterns at the surface (light) and 500 hPa (heavy lines).

Source: Preston-Whyte and Tyson, 2000, p.184.

1.8.2 The Walker Circulation and the Southern Oscillation (SO)

No consideration of southern African weather can ignore the effects of El Niño. The Walker Circulation and SO are two atmospheric conditions that have major impacts upon the climate of southern Africa and their effects will be described. The Walker circulation is the name given to a series of linked atmospheric cells between South America, Africa and Indonesia that have an important influence on the atmosphere in the southern hemisphere. The cells respond to changes in the temperature of the surface waters across the east and west Pacific Ocean and major pressure oscillations in the atmosphere become established as a result. This oscillation between the Pacific and Indian Oceans is called the SO and is observed by measuring the pressure differences between Tahiti and Darwin. When the difference is 'positive', the SO is in a 'high phase' (La Nina), and this means that over Indonesia sea surface temperatures (SST) are high and the pressure falls, while over the eastern Pacific SST are low and the pressure rises.

During the 'low phase' (El Niño) of the SO, SST over the eastern Pacific increase, reversing the pressure gradient between that region and Indonesia. The surface pressure over Indonesia is now comparatively higher than over the eastern Pacific and the Walker Circulation weakens in strength and may even reverse. This is accompanied by weakening westerlies and a movement of the South Pacific cloud-band convergence zone eastwards, bringing arid conditions to the western Pacific and rain in the eastern Pacific.

What is important for Africa though, is that contemporaneous changes in the cell positions also occur over the Indian and Atlantic Oceans. Over Africa, the 'normal' high phase zone of convergence and uprising over eastern Africa moves eastwards offshore, bringing below-normal rainfall conditions and drought to Africa. The differences are shown schematically in Figure 1.11. El Niño events (sometimes referred to as El Niño-Southern Oscillation or ENSO events) move the cloud band convergence zone offshore over the Indian Ocean and with it the highest rainfalls. However, the link between the SO and southern Africa's rainfall is not always clear and only explains 25% of the rainfall decrease (Preston-Whyte and Tyson, 2000).

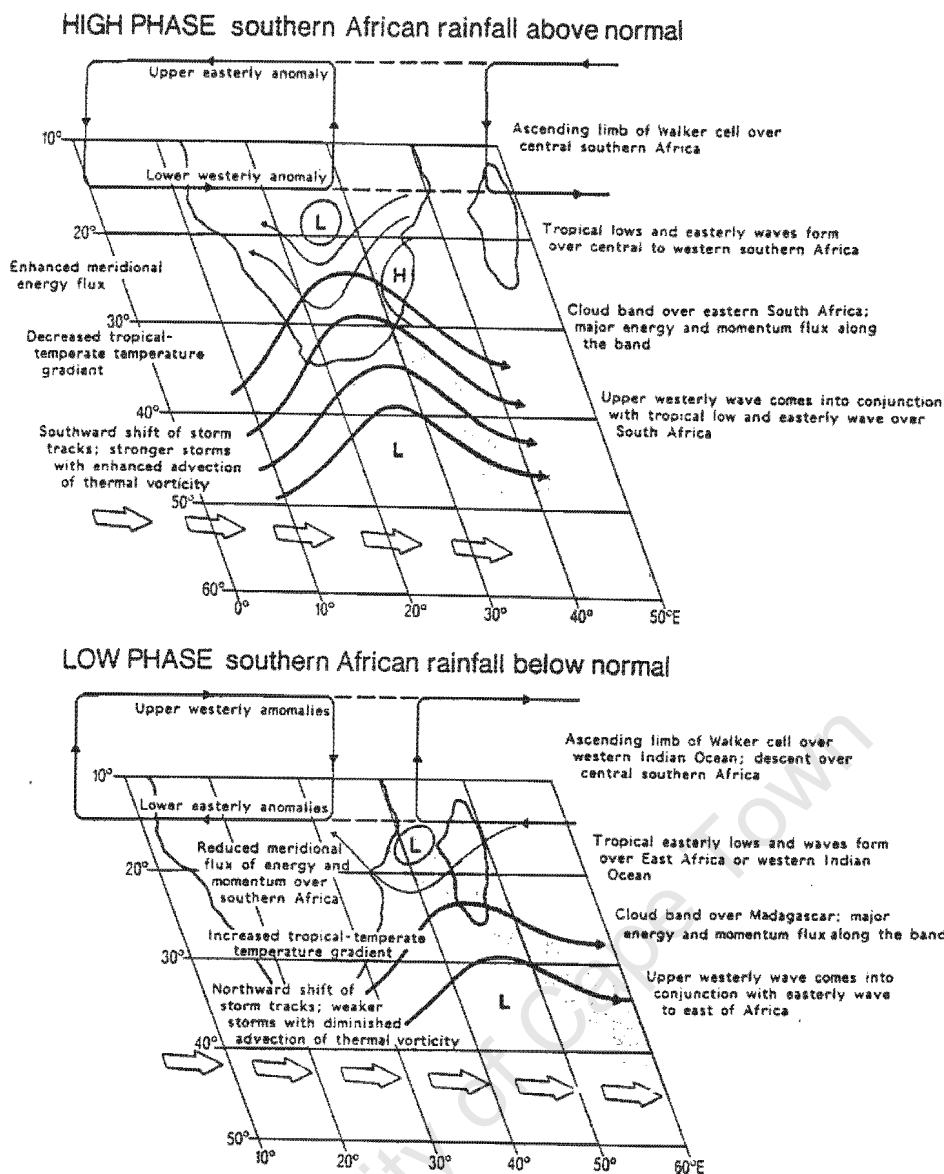


Figure 1.11: Schematic representation of the anomalous Walker Circulation over Africa.

The situation in the upper diagram occurs during the high phase of the SO and results in above-normal rainfall over southern Africa, while the lower diagram occurs during the low phase and results in below-normal rainfall in southern Africa. Light lines indicate surface flow while heavy lines denote upper tropospheric conditions.

Source: Preston-Whyte and Tyson, 2000.

From 1890 to 1990 there have been eight approximately nine-year periods of generally wet, above average rainfall years, followed by periods of dry, below-average rainfall years (Preston-Whyte and Tyson, 2000). For example, wet spells have occurred over southern Botswana, South Africa, Namibia and Zimbabwe during the period from 1971/72 to 1980/81 with a corresponding drier period between 1962/63 and 1970/71. These periods have affected most of southern Africa though not always in the same place or to the same extent. The wet periods are linked to the atmospheric conditions in the part of the Walker Circulation cell positioned over Africa. During the wet cycle, the ascending limb of the African Walker cell, that contains the

area of maximum tropical heat release and cloud band formation, is situated over tropical central Africa. Whereas during the dry cycle, this limb moves eastwards offshore and is replaced by a dry descending limb over tropical Africa (Figure 1.12).

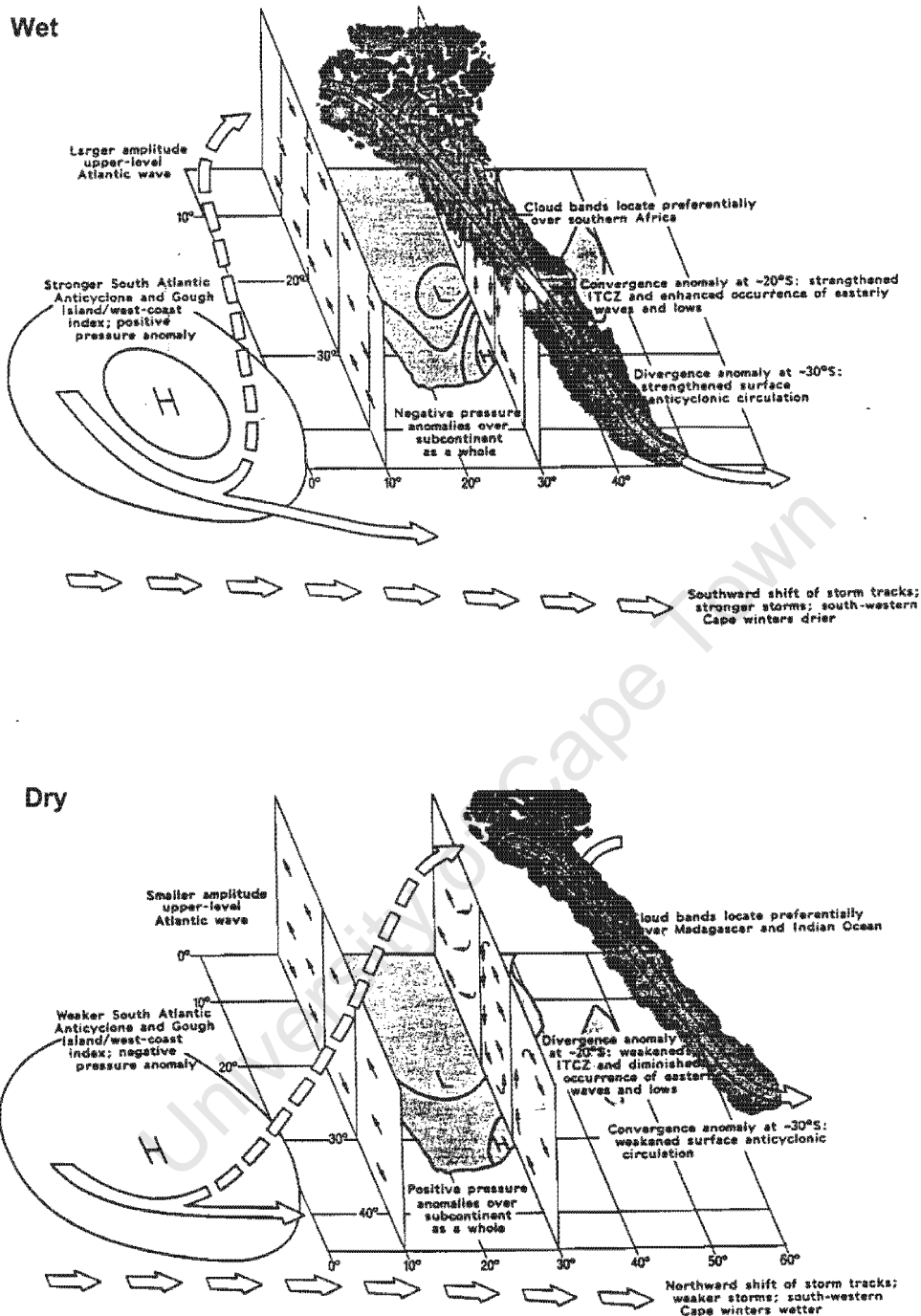


Figure 1.12: Model of the anomalous meridional circulations over southern Africa during spells of years of predominantly wet or dry conditions.

Also shown are the relative positions of the upper-tropospheric Atlantic wave, preferred zones for cloud formation, the surface manifestations of the South Atlantic Anticyclone and the location of storm tracks.

Source: Preston-Whyte and Tyson, 2000.

1.8.3 Climate change implications for Botswana

During the period 1980 to 1996, the Southern African Development Community (SADC) region experienced four major droughts; during 1982-83, 1987-88, 1991-92 and 1994-95. The first and latter two were severe droughts on a regional scale while the one in 1991-92 was the worst in the region's living memory (Ncube, *et al.*, 1999). All of these were associated with the ENSO phenomenon in the Pacific Ocean. Figure 1.13 shows the percentage departure from normal rainfall in arable areas in Botswana (from October to April) between 1920/21 and 1980/81, El Niño years are shown in white. Current scientific knowledge suggests that the region will become more prone to low rainfall conditions. Periods of drought are going to become more frequent and greater in magnitude, with the climate becoming drier and warmer as we enter the new millennium (Ncube, *et al.*, 1999).

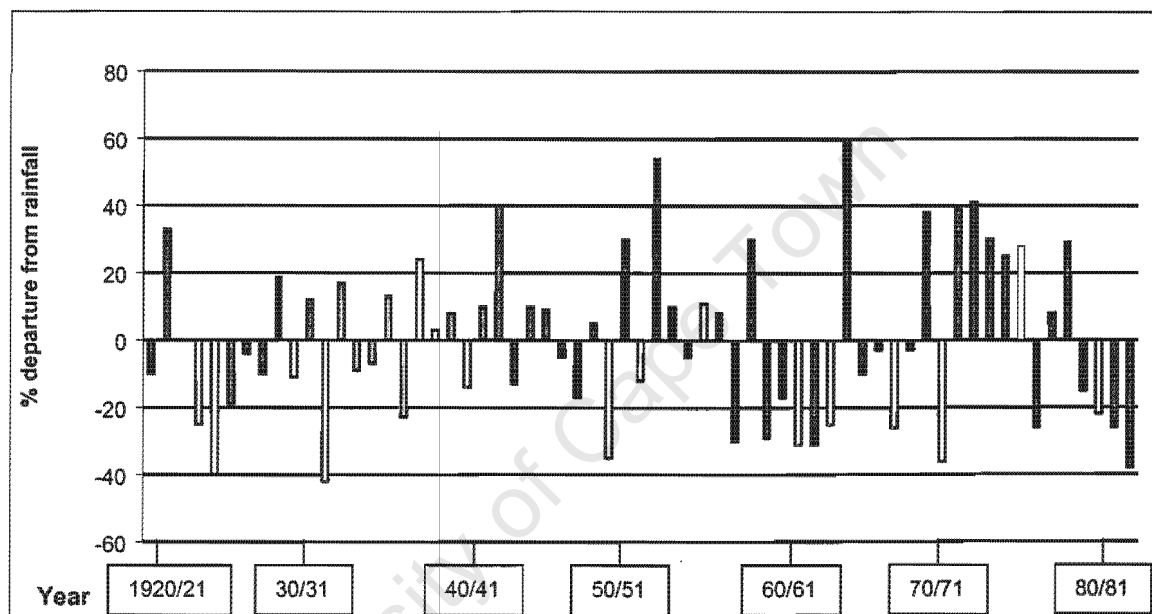


Figure 1.13: Percentage departure from normal rainfall in arable areas from 1920/21 to 1980/81 (October – April). White bars are El-Niño years.

Source: Bhalotra, 1987

Botswana rainfall has varied greatly since the late 1960s as Figure 1.14 illustrates. Data prior to 1959 are very meagre but droughts appear to have occurred during 1969/70, 1972/73, 1978/79 and 1981/82 through to 1986/87. The drought in the early 1960s took the country by surprise, peaking after five years in 1965 (Bhalotra, 1987).

Seasonal rainfall during the course of the rainy season between October and April is variable, for example, over Gaborone between 1925-80 (Figure 1.15). Rainfall usually peaks at pentad 17th-21st December followed by a striking dip that extends through to the 6-10th January. This decline is due to the decreasing frequency with which westerly troughs affect Botswana due to the more southerly latitude they take with the advance of the summer season. The increase in rainfall in mid-January is due to tropical influences from the ITCZ and Zaire Air Boundary (ZAB) that descend upon the region from the north, peaking at pentad 26/30th January in Gaborone.

The third peak in rainfall occurs between the 2-6th March and is the result of westerly troughs again extending further northward and interacting with tropical systems that are still over central Zambia; causing these systems to advance temporarily southward (Bhalotra, 1987).

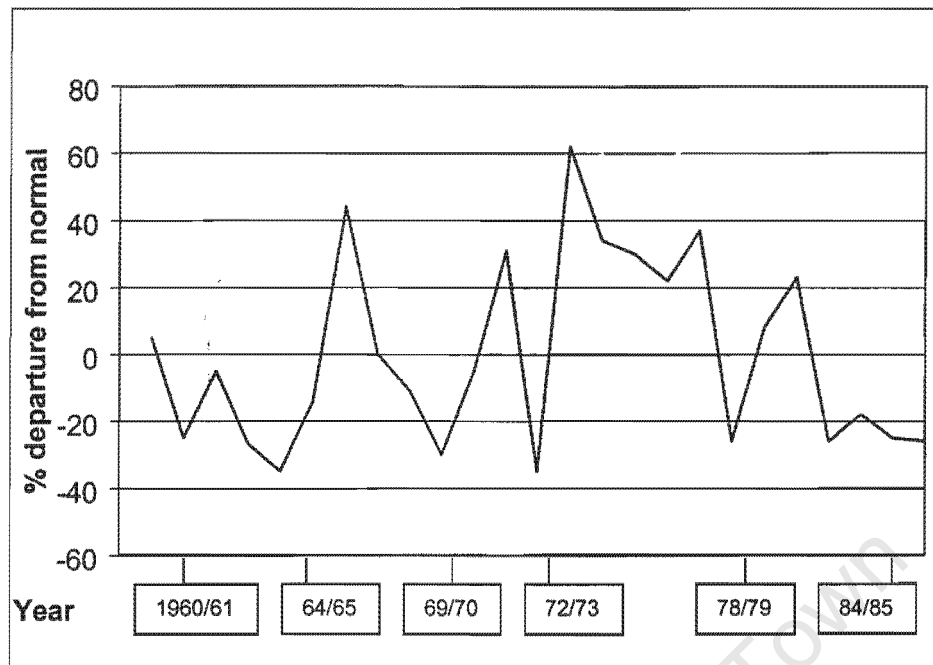


Figure 1.14: The departure from normal rainfall in Botswana rainfall from 1969/70 to 1984/85 (mean of 34 stations)

Source: Bhalotra, 1987.

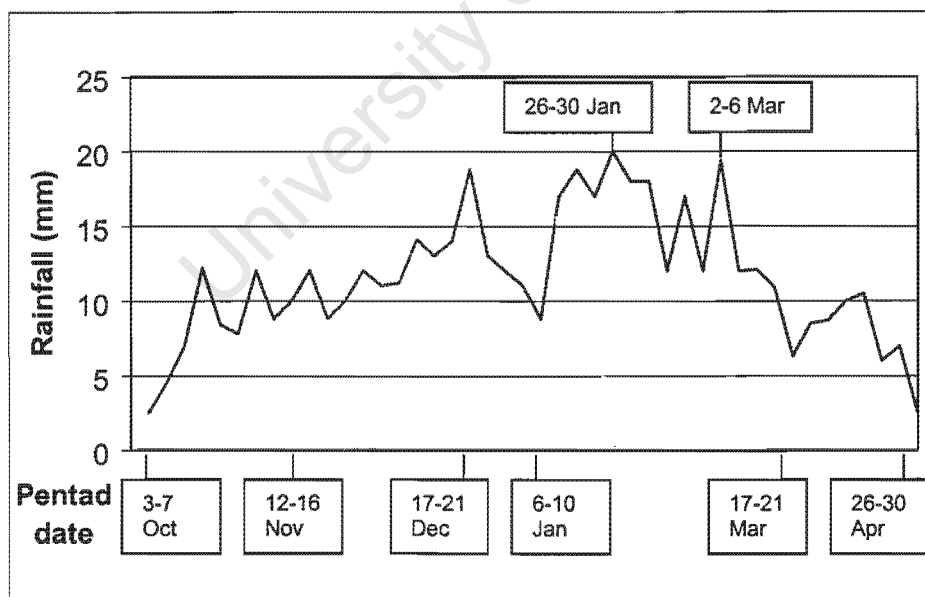


Figure 1.15: Mean pentad rainfall in Gaborone between 1925-80 (mm).

Source: Bhalotra, 1987.

There is much worldwide debate, concern and uncertainty about climatic changes in light of greenhouse warming and its possible impact upon southern Africa and Botswana. Predictions

of regional increases in temperature between 0.8-1.7°C depending on the location have been suggested (Dalal-Clayton, 1997 and Hulme, 1996). Rainfall, however, appears harder to predict. Estimates suggest that it will fall between 6-13% by 2030 while others suggest an increase between 7-14%. Southern Africa has experienced a temperature increase of 0.5°C since the 19th century (a pattern similar to global changes) (Dalal-Clayton, 1997). The warmest years this century have occurred since 1980 and the warmest and driest decade was between 1985-94. The World Wildlife Fund (WWF) predict a further warming of 1.7°C by the 2050s (Dalal-Clayton, 1997).

Three patterns of possible climate changes have been proposed. However, the wide range of possible outcomes is typical of the current generation of climate models, and narrowing this range in order to predict regional rainfall changes is still some years away (Hulme, 1996). The three scenarios are (Hulme, 1996):

- A 'core' scenario that envisages a modest drying over much of the region together with changes in variability and an increase in temperature.
- A 'wet' scenario where most of the region gets wetter and warmer.
- A 'dry' scenario in which rainfall decreases over the region by up to 20%, and temperatures increase.

In the 'core' scenario, a rise in the mean surface air temperature of 2°C, particularly during the dry season, would occur over the southern Africa interior upland plateau that encompasses Botswana, eastern Namibia and Angola, and western Zimbabwe and Zambia. The rate of warming between 1961-90 and the 2050s, about 0.2°C per decade, is four times what the region has experienced on average during the last century. Small increases in the average annual diurnal temperature range would occur, though this would decrease by a few tenths of a degree Celsius during the peak wet season (December to February) (Hulme, 1996).

The 'wet' scenario forecasts annual rainfall increases of up to 20% or more over the interior upland plateau, with the maximum increases over eastern northern Botswana, Angola and Zambia. Under the 'dry' scenario most of the region experiences a drying with annual rainfall decreases by 10% or more over Zimbabwe and surrounding areas.

1.9 Economic and social dimensions

Botswana boasts one of Africa's highest levels of economic growth with an average growth rate estimated at 6.9% in 1998, this nevertheless represents a decrease from an average of 13% between 1966-1991 (Ahmed, *et al.*, 1999). The drop is largely the result of a slow down in the diamond market in which Botswana holds the world's second highest supplier position from

mines such as Orapa and Jwaneng. The decrease in the demand for diamonds caused an acceleration in the Botswana Government's commitment to encourage new industries and this led to a policy called 'Sustainable Economic Diversification' that gained the focus of the Eighth National Development Plan (NDP) from 1997-2002 (Ahmed, *et al.*, 1999). Much progress has since been made in further developing the motor vehicle industry, manufacturing, livestock and tourism industries. A higher emphasis is also being placed on regional trade and economic co-operation where both SADC, and the Economic Council for Africa (ECA) based in Addis Ababa in Ethiopia, are leading the way into new approaches to development. The Mid- Term Review of NDP8 is currently ongoing to determine whether implementation of the plan is on course, or whether some adjustment action is required in addition to determining the focus areas for NDP9 that will run from 2003 to 2009 (Ahmed, *et al.*, 1999). Indications suggest that HIV and AIDS, poverty eradication, gender equity and information technology are likely to form the government's focus at the start of the new century.

One consequence of this development has been a significant increase in the level of effective demand for goods and services. Sustainable agriculture has for many years formed the backbone of rural communities but many people suddenly began to experience a transition. They have realized that agriculture can no longer provide for them an acceptable form of employment and that the standard of living it provides is not as high as they would like. Before the sudden diamond prosperity, sustainable agriculture was acceptable as one of the few available livelihood mechanisms for the majority of the population, but the expanding country's wealth and infrastructure base opened up for many people easier and more lucrative forms of employment (Ahmed, *et al.*, 1999). This development created a rapid wave of rural-urban migration and urban growth as the urban population figures from the UNDP's Human Development Report in Table 1.3 illustrate:

Year	Total Population (millions)	Urban Population (as % of total)	Annual population growth rate (%)
1975	0.8	12.0	3.3 (1975-1997)
1997	1.5	66.1	1.4 (1997-2015)
2015	2.0	88.7	-

Table 1.3: Population statistics in Botswana from 1975 to 1997 and projected to 2015

Source: UNDP, 1999

1.10 The agricultural sector

Farming in Botswana comprises both modern and traditional agricultural practices (Ndege, 2000). Modern practices constitute 10% and include sprinkler irrigation farming, micro-jet, drip irrigation and gravity irrigation through furrows, basins and border strips. Traditional farming makes up the remaining 90% and consists entirely of rainfed agriculture. Botswana's predominant soil type is the sandy loam, but clayey soils are also found at Pandamatenga and rocky soils in the country's hilly areas. There are approximately three million cattle in Botswana that are reared both for economic and social reasons. They are traditionally reared in communal farms but in estates for more modern agriculture. Botswana's small stock comprises 2.1 million goats, sheep and pigs, while other reared livestock include donkeys, horses, ostriches and camels. Vegetable crops grown include potatoes, sweet potatoes, carrots and beetroots. Cereal crops comprise maize, sorghum and millet, while cash crops consist of sunflowers, groundnuts and cotton (Taylor, 1997).

A similar scenario is, and has already, developed in Botswana today. Many Batswana are viewing the easier availability of food, particularly that imported from within SADC but also further afield, as an adequate and relatively easier alternative to that of developing the country's domestic agriculture or participating in sustainable agriculture. With foreign agricultural commodities being imported relatively easily into Botswana, this either depresses or stabilizes the rate of price increases in the home-grown food market, which in turn reduces the wage earnings for those employed in the agricultural sector (Allan, *et al.*, 1973). Simultaneously, the wages being earned in urban areas are rising in relation to the income generated in rural villages and lands areas.

Economic development in Europe, the United States and Japan was borne out of technological innovation and increased productivity in agriculture (Allan, *et al.*, 1973). The pursuit of wealth and success usually brings with it a sudden increase in the demand for food and materialistic possessions. The expanding urban population and higher disposable income among Batswana, and neighbouring South Africans now living in Botswana, increased this demand. Under normal conditions, such demand for goods and produce would trigger a strong resurgence in the agricultural domain. However, as a result of the climate, previous years of drought and the resulting despondency in farming, coupled with the low state of agricultural technology, such a comeback has not occurred.

Another reason could be the higher profits on investment in the trade and service sector of the economy (Allan, *et al.*, 1973). One of the consequences of droughts in Botswana; 1968-70, 1974-75, 1979-80, 1981-87, 1990-91 and 1991-92 (Thompson, 1993) has been that the risk of repeated drought has undermined livelihoods and possibly squeezed people out of farming.

1.11 Presenting HIV/AIDS

Droughts are not the only risks that communities are confronting in Botswana. HIV/AIDS is fast becoming one of the greatest social crises to affect not only Botswana but also the whole of southern Africa. Its effects and extent are far reaching. HIV/AIDS is not constrained to a particular racial group or livelihood status, but has the potential to impact people in every social class and in every form of employment from agriculture to economics.

"The HIV/AIDS epidemic in Botswana is the deadliest emergency and the biggest social and economic crisis facing the country today. After three decades of sustained economic growth, HIV is threatening to wipe out hard won gains in social development, including improvements in child health, nutrition and education" (UNICEF, 1999).

Impact on agriculture and water resources

The impact of AIDS on agriculture has been studied extensively in Tanzania where it has had adverse effects such as the loss of labour supply and remittance income (Bollinger and Stover, 1999). The loss of workers particularly affects the periods of planting and harvesting, and significantly reduces the size of the harvest. This causes farmers to switch to less labour-intensive crops, and often from export crops to food crops, in turn affecting the country's export earnings (Bollinger and Stover, 1999). In Botswana, many households rely on subsistence agriculture, so the impact of HIV/AIDS will be felt severely with a decrease in labour supply and production.

On a household level, the death of an adult represents a lost input to the household's productive activity. This has the result of pushing more and more people closer to the poverty line. In Botswana, this is set to increase as 48% of the population is under the age of 18, and most deaths from AIDS occurs in the sexually active age groups (Bollinger and Stover, 1999).

One of the effects of the epidemic on society will be lower food production, increasing people's risks to malnutrition, both to infected people and their associated non-infected family members (Goma, 1999). Poor nutrition is one of the factors that contribute to a shortening of an AIDS patient's life. The issues of food productivity, however, are complex and are certainly not the only contributing factors to lowering people's tolerance to illness. The recognition and addressing of HIV and AIDS in agriculture will set a precedent for development campaigns.

HIV and tuberculosis (TB) unexpectedly attack the human immune system producing a silent impact on a community, including productive subsistence farming communities who are the main producers of agricultural goods (Goma, 1999). AIDS weakens a person's activity and prevents them from leading a normal life thus leading to a reduction in the agricultural workforce. Households and communities may consequently have to abandon their agricultural

lifestyle, inviting poverty in if many people are affected. People may also experience disruption of the family unit, isolation from society and financial burdens as they search for treatments. The AIDS crisis is, and will continue to, directly impact the heart of people's food security, the labour force, community life and sustainable development. In order to reduce the effects, it is essential that mitigation skills be incorporated into sustainable development projects to reduce the effects of the virus in Africa (Goma, 1999).

The loss of even a small number of highly trained engineers could place entire water systems and large quantities of investment at risk. Such people are required for the constant maintenance and development of wells, dams and water pipelines. They are also, however, particularly susceptible to HIV because of the need to spend long periods away from their families, increasing the likelihood of multiple sexual partners. The same is true for people who operate transport services, such as truck drivers and train crews. The government faces the dilemma of improving transport, as an essential component of national development, while protecting the health of the workers and their families.

Impact on macroeconomics

AIDS has the potential to severely impact the Botswana economy because it is different from other diseases in that it strikes the most productive age group. There are two major economic effects. There will be reduction in the size of the labour pool and labour supply from among the country's young adult population that will affect the overall economic output, particularly if it includes the economic elite. Moreover, costs will increase. The direct costs of AIDS include capital for funeral expenses and medical care and drugs, whereas indirect costs include lost working hours due to illness, higher recruitment and training costs to replace workers, and caring for orphans. If these costs are borne out of people's savings, then their decline in investment could significantly reduce economic growth, see Figure 7.2 (Bollinger and Stover, 1999).

AIDS, it is forecast, will reduce economic growth by an average of 1% per year (Barnett, 1999). Estimates of the macroeconomic impact of AIDS is difficult to assess as it involves assumptions about how AIDS affects savings and investment rates, as well as whether it will affect the better-educated employees more than others. The impact may be small, especially if there is an unlimiting supply of labour and worker benefits are small (Bollinger and Stover, 1999). The macroeconomic impact of HIV/AIDS in Botswana may not be substantial, at least not at first. This is also because labour-intensive economic sectors such as agriculture and certain industrial sectors, do not contribute to GDP as much as the mining sector does (Botswana produced one-third of the diamonds mined in the world during 1998 (Barnett, 1999)), which is not labour-intensive (Bollinger and Stover, 1999). Table 1.2 showed that agriculture comprises

25.69% (in 1991) of the economically active labour force compared to the mining and quarrying industries that employ 3.50%.

AIDS also brings implications for income distribution and government budgets. Factors that require consideration include a reduction in the number of available workers and productivity as less experienced workers replace those currently at work. The population growth rate was 3.4% per year in 1987 (Moremi, 1987). It has been estimated that AIDS will reduce the current population growth rate in Botswana from 2% to 1% per year and consequently the current 20% unemployment rate will also fall because of the lower population growth rate (Barnett, 1999).

The result can be higher domestic production costs as the shortage of workers leads to higher wages, as people become more valuable. Higher production costs can lead to a loss of company competitiveness and, internationally, a loss of foreign exchange earnings. As a result of greater health care costs and a loss of worker income, the decrease in private savings and government revenues may mean that less capital is available for employment creation in the formal sector, which is particularly capital intensive. As a result, some workers may be pushed from their high paying jobs in the formal sector to lower paying jobs in the informal sector.

HIV/AIDS prevalence in Botswana

There are three main reasons for the high rate of HIV/AIDS prevalence. First, denial about the existence of AIDS is widespread. Second, there has been little change in people's sexual behaviour, and Third, the high rate of sexual activity among young people (UNICEF, 1999). In major urban areas, more than 30% of all pregnant adolescent women are infected with HIV.

Botswana has one of the highest regional adult (15-49 years) prevalences of HIV infection in southern Africa, standing at almost 25% (Zawaira, 1999) (note a figure for South Africa was not given), see Figure 1.16. Awareness and commitment to fighting the AIDS crisis has been prevalent in Botswana since the first AIDS case was diagnosed in Gaborone in 1986 (Moffat, 1999, pers com.). However, Government commitment to education, unemployment and AIDS has not brought the commensurate results. Education programmes have included billboards around the country showing slogans such as 'The ABC of living: Abstinence, Be faithful, Condomise,' and these have helped to educate the population but not stem the rising tide of infections.

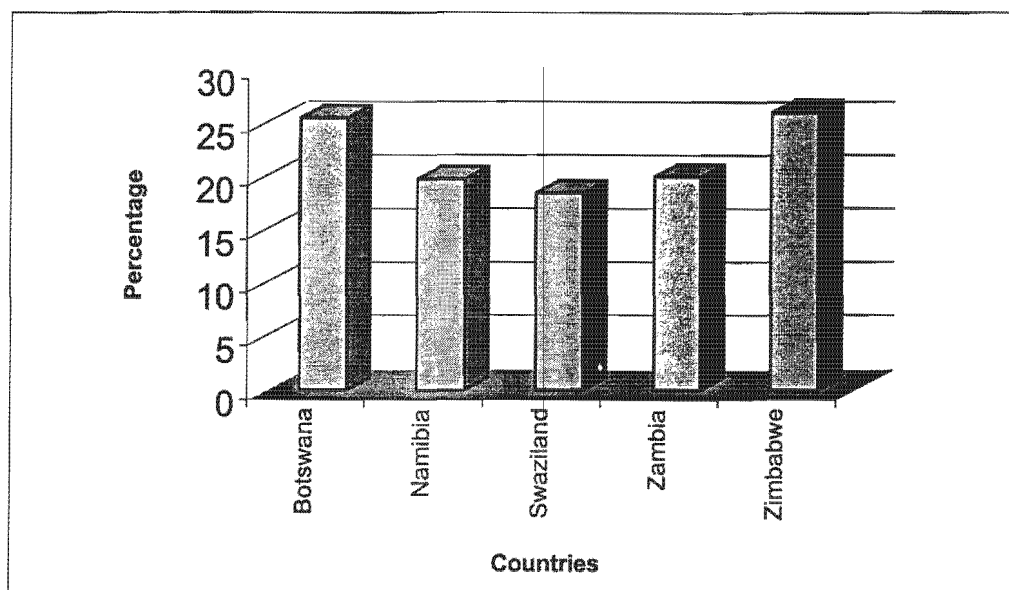


Figure 1.16: Estimated adult (15-49 years) HIV prevalence in most affected southern African countries (%)

Source: Zawaira, WHO Annual Report, 1997

The Botswana have shown a delayed acceptance of AIDS as a national emergency and this has seriously hindered the impact of the Government's response (Ahmed, *et al.*, 1999). The issue of HIV and AIDS is a critical component of Botswana's poverty eradication programme. A Botswana Government Tripartite Review (TPR) of the AIDS programme was completed in June 1999 and was attended by the Permanent Secretary. The evaluation acknowledged that:

"The commitment of Government, which is increasingly present to treat AIDS as a national emergency with enormous socio-economic consequences requiring the direct involvement of a broad range of Ministries, has not been effectively translated into impact at programme level" (Ahmed, *et al.*, 1999, p.5).

The majority of Botswana have not accepted AIDS as an issue they can impact through changing their behaviour (Moffat, 1999, pers com.). Some of the continued scepticism has been blamed on a lack of reliable, up-to-date information. Botswana has known that an AIDS crisis was coming to the country since 1986 when rates were less than 1%, and even then "this represented a 'voice calling in the desert' (from John 3 vs.4) for recognition and immediate action" (Moffat, 1999, pers com.).

Increase in orphans

During the year 2000, it was predicted that AIDS would be responsible for 64% of deaths of children under five years old in Botswana that year (UNICEF, 1999). A similar forecast was made by the Ministry of Health which predicted that the number of AIDS orphans under the age of 15 in Botswana would be 65,000 by the end of that year (Barnett, 1999). The rate at which children were orphaned quadrupled between 1994 and 1997; in 1997 around 4% of all Botswana's children under 15 had been orphaned because of AIDS (UNICEF, 1999).

By the end of 1992, extended members of the family, including those who had themselves been orphaned, were caring for 95% of these orphans. It is not clear, however, whether this coping pattern will continue given the increased number of AIDS orphans (Bollinger and Stover, 1999). A National Orphan Programme was established in April 1999 to respond to the needs of orphaned children. It is run by the Ministry of Health (through the National AIDS Control Programme), the Social Welfare Division of the Ministry of Local Government Lands & Housing (MLGL&H), as well as NGOs, Community Based Organisations (CBOs) and the private sector. The NGOs and CBOs who have taken the lead in supporting foster families include the Botswana Christian Council, the Botswana Christian AIDS Intervention Programme, Tirisanyo Catholic Mission and Childline Botswana.

The programme is responsible for co-ordinating the registration of orphan data through a national database, identifying and addressing the needs of foster children and parents, training community volunteers in basic childcare, providing HIV/AIDS counselling and reviewing and developing government and child protection policies. However, the country's high-level officials have only recently begun to speak about the problem and make it a national priority (UNICEF, 1999). NGOs and CBOs are newly working together in the area of childcare and children's rights in Botswana, and the programme is a first critical step towards halting the spread of AIDS and mitigating its impact.

Botswana has experienced a 400+% increase in the number of children being orphaned by AIDS over the last three years (Mukwaya, 1999). Botswana also lies 6th in a compiled table of the number of children orphaned by AIDS in Sub-Saharan African nations where 390 out of every 10,000 under-15 year olds have lost their mother or both parents to AIDS. This compares with Uganda with 1100, Zambia with 890, Zimbabwe with 700, Malawi with 580, Togo with 400, Mozambique with 180, Namibia and South Africa both with 110, and Lesotho with 100 (Mukwaya, 1999). Projected percentage of under-five child mortality due to AIDS between selected African countries for the years 2000-2005 illustrates that Botswana is expected to have a 65% under-five child mortality compared to the next highest countries of South Africa and Zimbabwe with 50%, see Figure 1.17.

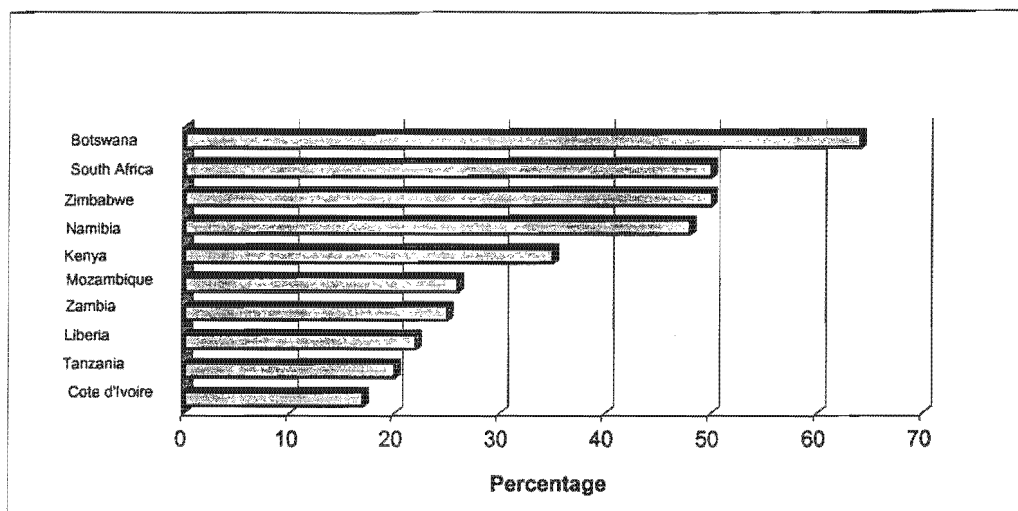


Figure 1.17: Percentage of under-5 child mortality due to AIDS, projected for 2000-2005

Source: Mukwaya, 1999

The mounting number of orphans in Botswana is increasing calls for a wider fostering enterprise where members of the extended family or community tend for the orphaned children aided by government assistance (Moffat, 1999, pers com.). However, the host families use much of the money given at present and little benefits the children themselves. Two 'SOS' villages currently exist in Botswana, one in Gaborone near Tlokweng and the other in Francistown, but these only house between 80-100 children each. Spread of the virus could be arrested in the new generation if they changed their behaviour and there have been campaigns all the way along but they have failed as the knowledge has not altered habits (Moffat, 1999, pers com.). Children who have lost their mother or both parents are society's most vulnerable members. Socially isolated because of the AIDS stigma, they are less likely to be immunized, more likely to be malnourished and illiterate, and more vulnerable to abuse and exploitation (Mukwaya, 1999).

1.12 Coping and adaptive strategies

Having illustrated the risks that the rural population in Botswana face, attention now shifts to examine responses to such risks and hazards. For generations, many traditional farming systems in southern Africa conserved their soil and water in arid regions, and people and livestock moved to find water and grazing areas depending on the rains. Population pressures and rapid political changes are breaking down many of the strategies that naturally enabled societies to adapt to their multi-faceted changing environments, and this is resulting in human hardship, occasional tragedy and environmental degradation. There are two different strategies that societies appear to use that enable them to overcome stresses placed upon them. First, coping strategies that are defined as short-term responses to an immediate and habitual decline in access to food. Second, adaptive strategies, that signal a permanent change in the

variety of ways that food is acquired, irrespective of the year in question (Davies, 1996). 'Coping' essentially means acting to survive within the particular system's prevailing rules but when adaptation occurs, the rule system (or the moral economy) itself changes.

The idea of cycles of food insecurity and recovery is central to the understanding of change within food-security systems. But within these cycles, distinctions need to be made between habitual seasonal variations and more unusual, unseasonal disruptions or shocks. While coping strategies help analyse how food-insecure households adapt to changes over time, one must recognize the transition from coping to adaptation. Coping strategies by themselves cannot alone explain system change (Davies, 1996). Unlike many parts of the world, many adaptive strategies in southern Africa remain deeply rooted in society and are of great strength in times of hardship. The need to be aware of, understand and build upon these adaptive strategies is, and must continue to be, a feature of initiatives across the region.

1.13 Botswana's past response to drought

Botswana gained its independence after the height of a severe drought that gripped the country from 1961 to 1965, and further droughts followed in 1968-70, 1974-75, 1979-80, 1981-87 and 1991-93 (Manamela, 1993). The new independence leaders had little opportunity to prepare for the drought crises, not least because they were trying to reduce large budget deficits and establishing their authority (Holm and Morgan, 1985). The frequency of drought has had a major impact on the way that policy and programmes have been developed to cope with drought, and, indeed on the country's performance as well. The challenge for Botswana's drought effort has been to bring about more rural development with less rain, that is, to 'drought-proof' the economy and to reduce poverty in rural areas, apart from drought relief. Poverty renders a large proportion of the country's population vulnerable to the adverse impact of drought, and recurrent droughts further entrench poverty (Manamela, 1993).

Drought affects the rural economy in two principal ways. First, it reduces income for many rural households who are dependent on income from rain-based activities, such as arable production and wage employment in agriculture. Second, drought erodes rural productive assets such as livestock and other assets that are liquidated in order to replace lost incomes (Manamela, 1997). Food production is not only a source of food supply, it is also a major source of income and livelihood for many people in southern Africa. As a result, any decrease in the food output per head also tends to be associated with a reduction in the overall income. Botswana experienced a decline in food production per head over the decade 1974 to 1984 of 44%, compared with Zimbabwe at -23%, Zambia at -24%, and Mozambique at -30% (Dreze and Sen, 1989). The extent to which this decline affects the country's population though, is determined by whether there is an expansion of alternative incomes usable to acquire food

from other sources, such as through imports from abroad. If the country fares well despite the decrease in food production, it is also because agriculture is not a primary source of income and entitlement (Dreze and Sen, 1989).

Economic growth in Botswana has followed a very uneven pattern and has not been spread equally across the population. Much of the growth since the 1970s was initiated by the expansion of diamond mining, but which is a productive sector with little direct relevance to the rural population. The 1970s saw increasing rural unemployment and falling rural incomes, declining in real terms at the rate of 5% per year during the period 1974-81 (Dreze and Sen, 1989). The year 1981-82 marked the start of a severe drought that lasted through until 1986-87. This would have seen an even larger decline if it were not for the mitigating effect of direct public support measures such as an entitlement protection system that was exemplary in its scope and integration (Dreze and Sen, 1989).

The entitlement approach to drought management considers the ability of people to command food through formal means in society. They include production possibilities, trade opportunities, entitlements handed out from the state, and other means of acquiring food. There can also be own-labour entitlements where a person owns his own labour power for the purposes of trade and production, and inheritance or transfer entitlements that people give him (Sen, 1981). A person's ability to have food at his command, or indeed, any commodity, depends on the entitlement relations that govern the possession and use in that society. It depends on what he owns, what exchange possibilities are offered to him, what he is given free, and what is also taken away from him (Sen, 1981). The entitlement protection system established in Botswana during the drought of 1982-87 involved three areas of action. First, the restoration of adequate food availability, Second, the large-scale provision of cash wages, for example, through cash-for-work schemes, and Third, direct food distribution to selected groups (Dreze and Sen, 1989).

The famine relief offered during the 1979-80 drought was an example of the 'strategy of direct delivery', that is, the transportation and distribution of food. The operation was logistically difficult though a considerable improvement occurred after the transportation was subcontracted to private truckers (Dreze and Sen, 1989). While the 1982-87 drought was far more severe and prolonged than that during 1979-80, the distress it caused to the population was comparatively small despite the large disruption to the rural economy. This demonstrates the effectiveness of the drought relief programme that was put into operation.

In 1981 the total national income from agriculture was Pula 121 million. As a result of the drought, by 1983, the loss of livestock and crops was almost Pula 34 million, almost one-third of the income produced by agriculture (Holm and Morgan, 1985). During the same year, the government stopped the construction of all new housing in Gaborone in order to conserve water in the capital, resulting in overcrowding, inflation in real-estate prices, and unemployment

in the building industry. During the 1980s the government's relief programme had four elements that helped to protect the poor against the effects of drought (Holm and Morgan, 1985):

- An effective system of food distribution. Almost 60% of the rural population had been fed on a regular basis by 1984, in contrast to only 25% during the droughts of the 1960s. Feeding programmes were stepped up in schools and health centres dropped their criteria for medical selection and fed all pre-school children, pregnant and lactating women, and tuberculosis patients.
- An increased employment scheme to provide short-term supplementary income. Adults were paid at a rate of Pula 2 per day during 1984-85 for their involvement in labour intensive public projects that used traditional skills. For example, stamping sorghum grain into flour for school needs, and improving local infrastructure. These labour-based projects provided several million Pula each year in added rural income.
- Water was supplied through local councils whenever sources of domestic water failed, and a rural drilling programme for small settlements was also speeded up.
- Agricultural projects were initiated to increase recovery from the drought. These included a free basic seed package, low-cost draught power to those with few or no animals, stock feed sold at highly subsidized prices, and cash grants given to farmers to clear and prepare arable land.

As a result of these relief efforts and implementation of the above programmes, the 1985-86 period, for example, saw 384,000 people in vulnerable groups of the rural population reached with supplementary feeding from a total foodstuffs supply of 53,000 tonnes. Food was also provided to 18,000 Remote Area Dwellers (RAD) and 222,000 primary school children received supplementary food to take home during school vacations (Moremi, 1987).

During the 1980s, Botswana's relief programme was directed at replacing lost incomes. The average annual wage during this period was between Pula35-250 per household, depending upon the variation in demand by region (Moremi, 1987). One line of argument followed that the reliance of rural employment in Botswana on uncertain rainfall, together with the pre-existing high levels of rural under-employment and unemployment and low levels of rural income, helped to aggravate the 1980s droughts (Hay, 1988). These factors enhanced the vulnerability of the population, increasing their susceptibility to reduced rainfall. Vulnerability is at least partly expressed by income instability, and this was why income stability was a major objective of drought relief as well as rural development strategies. Uncertain rural employment creates conditions for rural people to become vulnerable to rain failure (Hay, 1988). Resultantly, one of

the main lessons that Botswana offered other drought-stricken countries was an employment and income famine management theory. This aimed to replace lost sources of income (though not explicitly permanently) and offer short-term employment for those temporarily out of work (Hay, 1988).

The Ministry of Finance and Development Planning, through its Rural Development Co-ordination Division, is responsible for co-ordinating drought-related activities, which include the early warning of drought and the implementation of relief activities. Other ministries that play a part include the Ministry of Agriculture, the Ministry of Health and the MLGL&H (Manamela, 1993).

During the 1992 drought, the Food Resources Department of the MLGL&H had a much-reduced role in supplying food compared with previous years. This was the result of a government decision, following the droughts of the 1980s, to reduce the level of food hand-outs and to instead concentrate on trying to create income-earning opportunities through a programme of labour-based public works (Manamela, 1993). There was also an attempt to further link drought relief to regular development programmes by ensuring that ministries were continuously developing projects that were amenable to labour-based approaches. So should drought occur again, they could accelerate the implementation of these projects with the aim of creating additional income-earning opportunities for rural areas.

The 1992 drought came just three years after the long drought of 1981-87 and resulted in a poor crop performance from farmers in Pandamatenga, the country's commercial breadbasket region. Only 12,676ha were planted, which constituted 70% of the farms baseline area of 17,500ha (Manamela, 1993). The impact further included between 5-30% mortality in cattle countrywide; cattle being the main determinant of wealth for the rural household. During this period, the number of people involved in agriculture dramatically declined. In 1981 the number of people employed in non-cash family agriculture was 143,805, and this had decreased to 76,085 people in non-cash employment in family business and farms by 1991 according to the 1991 population census (Manamela, 1993). The impact of drought on agricultural production in Botswana was strong during the early 1990s, particularly during the drought years of 1990/91 and 1991/92, see Table 1.4. (*The normal level of agricultural production is assumed to be the four year average for the most recent non-drought years, 1987/88 to 1990/91, approximately 44,000 million tonnes).

Year	Output (million tonnes)	Output as % of normal*
1987/88	78,900	175%
1988/89	48,900	108%
1989/90	27,000	60%
1990/91	24,900	55%
1991/92	5000	11%
1992/93	34,800	77%
1993/94	39,900	88%
1994/95	9600	21%

Table 1.4: The impact of drought on crop production –total production estimates in the communal sub-sector between 1987/88 and 1994/95.

Source: Manamela, 1997

With crop production during 1991/92 down to 11% of normal levels, as Table 1.4 shows, the government responded to the cereal shortage by releasing 20,000 million tonnes of sorghum and maize into commercial stocks from the Strategic Grain Reserve (Manamela, 1997). The World Food Programme has been working in co-operation with Botswana since 1977, and they helped establish the country's Strategic Grain Reserve in recognition of, and response to, the recurring drought problem. This became a very important part of the overall drought contingency planning effort (Moremi, 1987). The release of this sorghum and maize then enabled the private market to re-establish itself during and after the drought (Manamela, 1997).

The Labour-based Rural Public Works Programme (LBRPW) was also upgraded during the 1991/92 drought and this was a major avenue for employment creation and providing relief. Between June 1992 and June 1993 more than 3000 projects costing approximately Pula 267 million were started creating between 90,000 and 100,000 jobs (compared with 1987/88 when Pula 13.1 million was spent creating 61,000 jobs) (Manamela, 1993). A labour-based relief programme that operated during the 1982-87 drought 'replaced' almost one-third of all rural incomes lost from crop failures between 1983 and 1985, that is, about three million person-days of employment to 74,000 labourers (Dreze and Sen, 1989). The productive value of these works constitutes a considerable contribution towards national investment.

The actual ground implementation of the labour-based projects lay with the District Councils, who have limited technical and managerial capacity to supervise the programmes (Manamela, 1997). As a result, the range of projects initiated have been limited to infrastructural

development, at the expense of more directly relevant drought mitigation projects such as water harvesting, soil conservation, land reclamation and veld fire control. The labour-based cash- or food-for-work schemes could dissuade young men from migrating and thus reinforce local capacity for environmental rehabilitation, but they could also increase dependence on donor support (Critchley, *et al.*, 1992). Food-for-work schemes can also be a discentive to building water harvesting systems as some farmers may not continue to build or maintain them without food aid. Food distributions in years with good harvests can also have similar effects. There could be a policy to diversify incentives such as having, fertilizer-for-work, tools-for-work or community infrastructure-for-work. However, villagers may not automatically accept these alternatives, particularly after food- or cash-for-work schemes have been introduced (Critchley, *et al.*, 1992).

During the 1994/95 drought, emergency relief was provided in the form of food aid, water and sanitation, and transport with logistical support. The cost of these operations totalled over US\$25 million. A breakdown of these costs is shown in Table 1.5.

Requirement	Observations	Cost (US\$)
Targeted food aid	Almost 0.5 million people in need of food relief	9,950,000
Water & sanitation	Urgent need for water bowzers Need to urgently interconnect supplies and to rehabilitate boreholes Urgent need for water quality monitoring and training on water purification	4,975,410
Transport & logistical support	Increased demands for internal transport and logistics support for the feeding and labour-based programmes Urgent need to create employment for at least 35,000 people	10,978,200
TOTAL		25,903,610

Table 1.5: The emergency requirements of the 1994/95 drought in Botswana

Source: Manamela, 1997

Botswana's remarkable record of reducing risk to drought has been called "Africa's best kept secret" by Eicher, a leading expert on Africa (Dreze and Sen, 1989). Its past success in drought management can be attributable to many factors. Botswana has immediate access to South Africa's highly developed foreign trade and domestic transport system for securing food and other supplies for the relief effort. Many households can also obtain an income, for

example, from Batswana working in South African mines; work that persists throughout the years of drought. Some people are also involved in local trading, small-scale industries or are employed by the Botswana government. Drought relief has been made easier through the concentration of the population into large villages that ranged in size from 5000 to 35,000 inhabitants in the 1980s. The opening of major diamond mines in Orapa and Jwaneng, meant that the government has been able to finance a substantial portion of the relief programme on its own without relying totally on international support (Holm and Morgan, 1985).

The government knows that Botswana is a drought-prone country and been able to plan accordingly. It has also come to view drought relief as a very effective means of reinforcing its rural support (Holm and Morgan, 1985). Drought relief has also been an object of rival promises and actions on behalf of competing political parties. Drought management is intimately the result of accountability of the ruling party to the electorate, the active opposition parties, the vigilance of the press, and the strong demands for public support for affected peoples (Dreze and Sen, 1989).

During the 1980s, western democracies were eager to supply food to Botswana to help reinforce the political stability of one of the few functioning liberal democracies in southern Africa. For example, in 1984, almost one-fifth of its total cereal consumption came from foreign donors (Holm and Morgan, 1985). Other reasons for Botswana's success include a national drought prevention strategy, a Presidential commitment that has prompted the quick release of resources, a competent civil service and an effective early warning system (Hay, 1988). This early warning system will now be considered.

1.14 Famine early warning systems

Much of the literature on reducing risk to drought impact has focused on formal systems of early warning of famine threats. The advantages of instituting an early warning of drought are very beneficial, but they are not a crucial requirement of an effective anti-drought strategy (Dreze and Sen, 1989). Countries such as Botswana and Zimbabwe have had remarkable success in the past in preventing negative drought impacts as a result of timely public action and not necessarily because they have made much use of formal early warning systems (EWS) (Dreze and Sen, 1989).

Botswana's relief-development strategy placed disaster preparedness high on the political agenda. Systems that provide advance warning of crop failure and income collapse are important, though the lack of this information was not a limiting constraint to the relief response that occurred in Africa during the 1980s (Hay, 1989).

In addition to indigenous or traditional adaptive strategies, many external agencies have developed warning systems to anticipate periods of acute food insecurity. This has included the evolution of early warning systems that are particularly focused on preparing for famines and droughts, and famine EWS will now be considered. These are concerned with predicting the failure of food systems, in order that any intervention carried out can be in a timely manner to mitigate the effects of a system failure and so safeguard food supplies. A 'rough and ready' national balance can be calculated using population estimates and *per capita* needs by monitoring key indicators of pending system failure (typically staple food production, national stocks, import availability) (Davies, 1996).

Most EWS have evolved beyond this to also monitor 'upstream input determinants of production' such as rainfall, and 'downstream outcome indicators of the effects of the national (im)balance on sub-national supply and demand' such as market prices for food and the nutritional status of under-fives (Davies, 1996). Early models of EWS are top-down and famine orientated rather than focused on access to food as the key determinant of food security. Conventional scientific EWS are concerned with short time frames (maximum of a year); with symmetry, between supply and demand, deficits and food aid; and with the data they have, rather than what they do not know (Davies, 1996).

In contrast, however, more recent EWS are increasingly concerned with the distribution aspects of food insecurity, which now comes under the term of 'vulnerability mapping'. In practice though, most EWS cannot identify vulnerable groups within food-insecure areas with any precision. Coping strategies can explain how poor households deal with food stress and these could be incorporated in EWS, particularly local-level food monitoring systems. These strategies would then help to indicate what appropriate and sustainable interventions would mitigate the crisis. The following list suggests local early-warning indicators that need to be assessed (Davis, 1996):

- Chronic and transitory food shortages, essential in order to interpret indicators of stress and help people overcome them. For example, does a particular pattern of migration signify a normal or abnormal activity?
- The degree of insecurity. For example, if the harvest fails, are there sufficient fallback options to meet needs?
- Appropriate response measures. For example, do people need food to eat or help in retaining their productive assets?

Monitoring these processes will improve famine EWS as well as guide interventions for increasing farm productivity. Indigenous coping strategies could therefore be reinforced, in preference to imposing external, often late, inappropriate and, above all, unsustainable

solutions, epitomized by emergency food aid distributions. Food aid assists producers only when they have lost the ability to feed themselves, whereas monitoring coping strategies has the potential to identify ways of protecting and reinforcing system success and adaptation before it collapses. If successful, such interventions would warn earlier of drought. The long-term effects of livelihood vulnerability to food shortages that persist once the crisis is over could be reduced. EWS could therefore simultaneously predict famine and aid its prevention (Davies, 1996).

Coping strategies employed by communities during drought can be thought of in terms of their sequential uptake, shown in Table 1.6. The table distinguishes between *insurance strategies*, which are activities undertaken to reduce the likelihood of failure of primary production, and *coping strategies*, which are employed after the sources of production have failed to meet expected levels and producers then have to 'cope' until the next harvest (Davies, 1996).

Monitoring coping strategies should ideally accompany with disaster preparedness action. Such contingency plans can be put in place prior to the onset of drought, including plans that identify potentially viable alternative employment opportunities for people in at-risk areas. Often such ideas are hard to put into immediate effect 'on the day', though many local people will be able to effect some degree of response. In addition, consultation should occur with local people who are vulnerable to water stress to establish what their own plans and views would be if rainfall failure occurred. Moreover, there should be greater integration between rural development strategies, disaster preparedness, and drought recovery strategies. Famines result from low rural incomes and income instability, so the objectives of rural- and relief-development are therefore the same (Hay, 1989).

Stage	Coping strategies
Stage 1 –insurance mechanisms	Changes in cropping and planting practices Sale of small stock Reduction of current consumption levels Collection of wild foods Use of inter-house transfers and loans Increased petty commodity production Migration in search of employment Sale of possessions (for example, jewellery)
Stage 2 –disposal of productive assets	Sale of livestock (for example, oxen) Sale of agricultural tools Sale or mortgaging of land Credit from merchants or moneylenders Reduction of current consumption levels
Stage 3 –destitution	Distress migration

Table 1.6: The sequential use of coping strategies

Source: Davies, 1996

Botswana's famine EWS was established in 1978 when an Inter-Ministerial Drought Committee (IMDC) was set up for monitoring drought conditions. The committee was also responsible for making relief policy recommendations to the cabinet, securing relief aid from domestic and international sources, and monitoring the effectiveness of relief measures. At local government level, district drought committees were encouraged to plan and co-ordinate the relief measures (Walker, 1989).

An example of the government's increasing concern with drought was the decision in 1978 to develop the Nutritional Surveillance Programme that would help to determine the effects of drought on vulnerable groups of the population (Moremi, 1987). Then in 1980 the government adopted three indices for a drought declaration (Manamela, 1997). The first was applied when rainfall dropped to the 1st and 2nd decile on a rainfall monitoring deficiency system. The second criteria focused on harvest output greater than 30% below normal, while the third emphasized declining nutritional status among children, focusing, when at least 40% of the under-five year old children attending Child Welfare Clinics were less than 80% of their standard age weight. Greater emphasis was placed on the first index, in tracking actual rainfall deficiencies and their distribution during the rainy season.

In 1984 a small Early Warning Technical Committee (EWTC) was established. This provides monthly reports to the IMDC and suggests to them what actions should be taken, while simultaneously monitoring the country's strategic grain reserve. Since this time the EWTC has received information from two separate sources (Walker, 1989). First, subjective monthly reports from agricultural field staff on crop production, the expected harvest, the cattle situation and grazing and water conditions. Second, meteorological data that are collected on a weekly basis and analyzed every month by over 50 stations around the country. The meteorological department combines this information with data on soils and crop moisture requirements to produce an index of the potential drought stress for the main food crops. Harvest failures for crops such as sorghum or maize, can therefore sometimes be predicted earlier than agricultural staff in the field.

Botswana also places a high emphasis on collecting and analyzing anthropometric data on the nutritional status of the country's children. Children in the zero-five age group are measured and weighed each month and the data are passed on to the EWTC. In 1984, 60% of the total number of children in this category were measured (Walker, 1989). Information on the nutritional status can identify areas that are more prone to drought stress so the government's response can be targeted.

During February of each year, members of the EWTC tour the country as part of a 'drought assessment tour' and meet with District Drought Committees at district level to assess the current situation (Manamela, 1997). The IMDC then decides whether Botswana will face a food shortage that year. The year's agricultural and rainfall cycles usually make it possible to forecast what will happen from June/July onwards. During March the IMDC, together with the Rural Development Council (RDC), advises the cabinet on the household food situation outlook for the rest of the year, including the need or otherwise for a declaration of drought by the 1st April. If food scarcity is predicted, the IMDC will make a request to the cabinet for funds, and the cabinet may then also decide to make a formal crisis declaration and appeal to the international community for help (Walker, 1989). Intervention in the form of cash-for-work schemes and food handouts is controlled and targeted by the nutritional survey data. The programme is orientated towards reacting to a symptom of distress rather than addressing the underlying causes.

The following government departments are responsible for co-ordinating drought-related activities (Manamela, 1997):

- The Ministry of Finance and Development Planning through its Rural Development Co-ordination Division, is responsible for drought monitoring, resource mobilization, and overseeing the actual implementation of relief activities.

- The Ministry of Local Government, Lands and Housing, primarily through District Councils, is responsible for the implementation of relief programmes on the ground.
- The Ministry of Agriculture is responsible for implementing the agricultural assistance packages and some agriculture-related, labour-based projects.
- The Ministry of Mineral Resources and Water Affairs is responsible for human water supply, including water-related, labour-based projects.
- The Ministry of Works, Transport and Communications, through its Central Transport Organization, provide transport to the various government agencies.

During 1997, non-routine early warning information was received concerning the phenomenon of El Nino. There was at first some uncertainty about how to interpret the information in absence of a regional (southern African) consensus position, and then whether or not to issue a public statement before the existing EWTC structure could process the ground information (Manamela, 1997). This example illustrated how confusion over non-routine information like El Nino could potentially result in an undue delay in responding to an emerging drought crisis.

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Botswana's past responses to drought together with its famine EWS, have concentrated on reducing the impact of drought through schemes such as food-for-work and aid handouts. Rainwater harvesting, which has been developing seriously in the country over the last 25 years, offers a mitigating component to lowering the effects of drought. It is a potentially viable technology that would lower communities' vulnerability to drought, and bring income-generating mechanisms and food security to rural areas. Rainwater harvesting, it can be argued, can be incorporated into, and should be incorporated more, into a rural development strategy that is also a relief development strategy. A definition of rainwater harvesting and history of its practice in Botswana is presented in the next chapter.

Chapter 2

Rainwater Harvesting as a Drought Mitigation Strategy in Botswana

2.1 Introduction to rainwater harvesting

In this chapter an overview of rainwater harvesting practices in an agricultural and domestic context is given. The potential for further development of rainwater harvesting within Sub-Saharan African countries is also argued. A brief history of rainwater harvesting is given followed by a detailed examination of organizations involved in Botswana.

2.1.1 Rainwater harvesting as a drought mitigation strategy

"We should look upon water with the eye of a Bedouin; cherish it like a treasure, remembering that even to have it in limited quantities is a privilege which is not given to all" (Ardito Desio, cited in Allan et al., 1973, 34).

"Everyone should hear about rainwater harvesting, promoting it in every village. The current situation is like the gospel, 'many are called, but few are chosen'" (Opelo, 1999, pers com.).

Drought is very difficult to define. Four different types of drought; meteorological, agricultural, hydrological and social drought have been identified:

- Meteorological drought is a 'reduction in rainfall supply compared with a specified average condition over some specified period.' In an African context this period is normally a year or more (Benson and Clay, 1994).
- Agricultural drought is defined as a reduction in moisture availability below the optimum level required by a crop during different stages of its growth cycle and resulting in impaired growth and reduced yields. It should also be noted that other factors also influence crop yields, such as reduced fertilizer inputs, a lack of weeding, pest and crop diseases, a lack of labour at critical periods in the growth cycle, and unattractive producer prices and market conditions (Benson and Clay, 1994).
- Hydrological droughts result from the impact of a reduction in precipitation on surface or sub-surface water and may, therefore, lag behind periods of agricultural or meteorological drought.
- Social drought relates to the impact of drought on human activities, but this depends upon the characteristics of a particular agro-ecological zone or the economy.

From an economic perspective, 'agricultural drought' results in large reductions in agricultural production and employment, reduced export earnings, and the widespread loss of assets and other losses associated with declines in rural income. Meteorological drought may bring about hydrological conditions that directly impact non-agricultural activities such as hydroelectric power generation and human water supply (Benson and Clay, 1994). The presence of armed conflict in several African countries has greatly exacerbated the effects of drought and has been responsible for turning drought into famine.

Good development practice needs to be balanced with the country's political goals because in general it is accepted that community-based approaches are the only mechanisms that produce lasting sustainable development. There is also an enormous demand for the basic services of water and sanitation to be provided for under-privileged people who expect rapid delivery and their needs to be met. Traditionally, drought mitigation strategies have been defined in terms of improving food security at the national and household level. Strategies often also relate to larger-scale investments in water resources but there has been little attention given to mitigating economic impacts, for example, through drought insurance policies (Benson and Clay, 1994).

Academics, practitioners and policy makers are continually searching for low-cost techniques of water supply and management. Techniques that build on traditional knowledge and have a good chance of being replicated on a large scale are particularly beneficial. The focus in rural development has shifted over recent years towards human resource management and development, self-help and farmer initiation and participation. Rainwater harvesting, it is argued, fits –and should fit more –into these integrated approaches. It therefore has the potential to be a form of drought insurance policy.

Most governments would prefer to invest in large-scale infrastructure projects both for water supply and irrigation even though they are expensive to develop and maintain. For example, Botswana's Pula 1.4 billion North-South Carrier Water Project that carries water from reservoirs near Francistown, 350km south using pipelines and pump stations to Gaborone, Molepolole and their surrounding settlements (Mateke, Mbakile and Opelo, 1999). The need to find alternative resources ideally suited to community's needs has become imperative and the protection of existing water resources is crucial because water is scarce and tapping new supplies is becoming increasingly expensive.

During drought, additional burdens are placed upon women. A study of the 1992 drought in Malawi, Zambia and Zimbabwe by Save the Children Fund, found that when their usual watering sources dried up, women spent up to seven hours per day fetching water. They sometimes left home at around 2am and returned mid-morning. More time was also spent searching for wild foods and attempting to earn money to finance increased purchases of

maize-meal. The drought also increased the number of female-headed households, which were already numbered one-third of the total, as the men left to seek work elsewhere. Consequently, women comprised the majority of workers on 'food for work' projects, and would often go without food to ensure that their children received enough (Eldridge, 1998).

2.1.2 Definition of rainwater harvesting

Rainwater harvesting is one strategy to address issues of water scarcity. A commonly used definition of rainwater harvesting is, 'the collection of runoff for productive use'. Rainwater harvesting is an umbrella term for a whole range of methods for concentrating, storing and collecting surface runoff water in different mediums, for domestic and/or agricultural use, see Figure 2.1. The domestic use mainly refers to the collection of drinking water for the household and for livestock while the production use mainly refers to the cultivation of crops, trees and fodder.

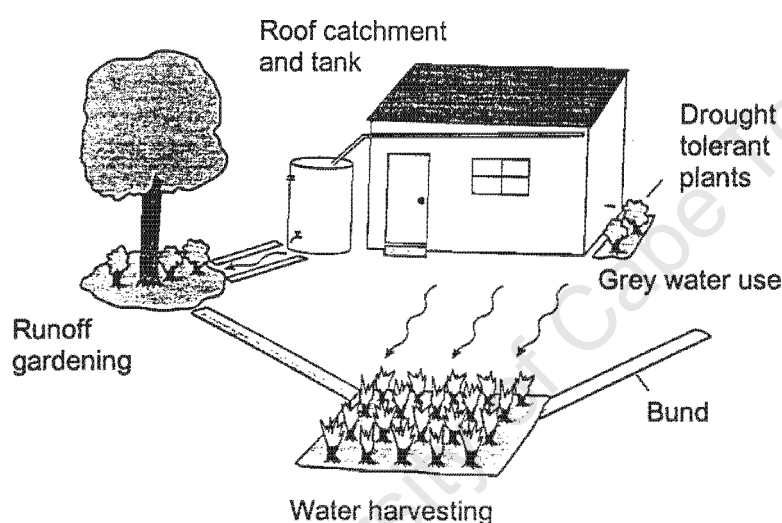


Figure 2.1: Runoff gardening techniques used in rural Africa

Source: Gould, 1999

2.1.3 Rainwater harvesting for domestic purposes

The most common water harvesting technique found in eastern and southern Africa are roof water tanks built with concrete or bricks. Simple techniques of storing runoff in reservoirs developed from old traditional and indigenous practices. The most commonly found methods for agriculture are within field runoff systems (runoff harvesting) for in-situ conservation, using for example, fanya juu, contour ridges and pot holing. Water can also be harvested from channel flow (floodwater harvesting). Less prevalent systems include small dams that capture external catchment water for irrigation purposes.

Many domestic rainwater harvesting techniques are spontaneously carried out in Botswana without government or NGO involvement. For example, in the village of Kumakwane (10km west of Gabane, see Map 1, Appendix E), roof catchments, buckets, drums and small dams are

used. Moreover, in Metsimotlhabe (70km north-west of Gaborone, just before Molepolole, see maps 1 and 2, Appendix E) a rock catchment feeds water into a small pond and catchments channel runoff into buckets (Ndege, 2000).

2.1.4 Rainwater harvesting for agricultural purposes

"Food needs to be grown where the people are and the high costs of transport and storage have to be avoided, and that will exclude expensive pipelines."
(Nilsson¹, 1993, 54)

Water harvesting was originally developed in the arid Negev Desert three to four thousand years ago where farmers shaped hill slopes and surfaces to channel rainfall from large catchment areas onto their fields (Harrison, 1987). Today, water harvesting in Africa is more likely to take the form of micro-catchments where rainfall is concentrated into small basins or depressions where crops and trees can be grown. This is particularly effective on soils with an impermeable surface crust where the amount of runoff from catchment areas is increased.

A small farmer or horticulturist must have water security to grow a minimum amount of crops so that he or she can maintain his/her business through periods of low rainfall until the rains resume. Crops require approximately 1m³ of water per 1m² of land per year, which corresponds to 1000mm of rainfall (Nilsson¹, 1993). This figure is based upon year-round production and it represents the average water need for many different crops. A farmer, therefore, would like to be assured of some degree of 'security water' before he/she undertakes to plant crops.

By combining rainwater harvesting with erosion-preventive, tree planting, Botswana could be vegetated at the same time as obtaining enough water for horticulture, dryland farming and small industries. Water must also be prevented from running away, as it can take large quantities of the soil with it (Nilsson², 1993). The greatest potential for rainwater harvesting lies in the agricultural sector where available technologies have been developed successfully but not properly utilized. The promotion, therefore, of practices at a rural community and household level is of extreme importance and requires careful thought and follow-up. Rainwater harvesting techniques often have multi-purpose uses within farming systems. In semi-arid regions of Kenya, for example, the diversion of runoff from roads into ditches might at first sight only offer a limited advantage through increased soil moisture retention around the diversion ditch. But often this concentration of sub-surface water produces a substantial local recharge of groundwater and so allows for the construction of shallow wells on the land.

The cheapest way to store water for agricultural purposes is as moisture in the soil. Providing wheat, for example, with a larger soil volume from which to absorb moisture will help carry it through periods of drought. One of the first steps in increasing soil volume, therefore, is to reduce the number of plants, as this increases the drought-resilience of the crop in any given

field and creates a 'uniform plant stand' (Nilsson¹, 1993). To further reduce farming costs and supply plants with more secure water, the permanent strip method can be introduced. This involves the deep ripping of permanent strips 50cm wide and 50cm deep, using a single shank ripper. The strips are 2m apart and the surface graded to encourage runoff to drain towards the strips where moisture can be stored in the loosened or ripped soil. To increase the yield and reliability of the harvest, planting approximately 12,000 maize plants per hectare is recommended (Nilsson¹, 1993). However, it is the volume of the wetted soil in the strips, which is the key to successful permanent strip cultivation.

One variation to the permanent strip method is the 'wavy pan variation'. For example, in a very heavy soil where the depth of cultivation is 50mm deep in the middle of the strips, this can be deepened to 100mm close to the edge in order to take advantage of a subsurface pan for water harvesting to the strip. Shallow soils and shallowly ploughed soils may contain water in excess of their field capacity for several days after rains. In this soil environment, the roots of plants may turn brown and diseased, and be attacked by pathogens that operate in saturated or slowly drained soils. This lack of oxygen is a common cause of plant disorders and poor plant growth. Whereas the excess water poisons roots by reducing nitrate to nitrite, and producing free manganese ions from oxidized manganese.

Initiating crop growth before weeds become a major problem is one of the basic goals of farming in Botswana. Using supplementary irrigation, this can be achieved by feeding previously harvested water into the permanent strips to initiate early crops growth. One single application of water to a given area planted with seeds in September or early October would bring the crops into the rainy season in most years (Nilsson¹, 1993). Even salty water can be used in water harvesting schemes as some crops can still grow well, for example, spinach, redbeets, fodder beats, tomatoes and melons.

Storing water in the soil reduces the amount of evaporation, making it available to trees and crops. This is cheap and effective, and ensures the use of local resources for local use. Cultivation along contours is also immensely beneficial, as well as contour bunding, vegetative bunding, gully plugging, building microcatchments with crescent bunding, and building up a rich organic soil with a good storage capacity (Keve, 1997). The importance of water conservation similarly needs to be stressed, as this is a natural follow-on after the water has been harvested. To help the soil absorb and store water, common measures include practising multi-cropping, using mulches, watering at night (during the morning in winter), and making watering heavy and less frequent. Also, using methods of drip and pot irrigation, drought-resilient crops and trees, and using composts, farm wastes or other biodegradable materials all help to absorb and store water (Keve, 1997).

More rainfall is harnessed using zero-tillage as a conservation practice (Oldreive, 1993). How the soil is tilled affects the amount of rainfall that will infiltrate and a large amount of water and soil is lost through full tillage that immediately results in poorer crops. The benefits of zero-tillage with a mulch cover include cushioning the impact of raindrops that simultaneously reduces surface sealing, reducing lateral water movement that minimizes soil erosion and improves infiltration, and reduces evaporation. The practice also moderates temperature extremes for the plants, encourages soil fauna activity, reduces surface crusting and compaction and develops a better root system closer to the surface, facilitates a more efficient fertilizer use and also allows for a more efficient oxygen exchange with the roots (Oldreive, 1993). Mulching and minimum tillage reduces the proportion of rainfall lost in runoff by as much as 85%, increasing the level of water infiltration and reducing soil erosion (Harrison, 1987).

One very effective technique similar to agroforestry is that of 'alley cropping', where food crops are grown between pruned hedgerows of fast-growing, nitrogen-fixing trees (Harrison, 1987). The leaves are used as mulch and also act as a tree fertilizer, improving soil structure and increasing crop yields. This principle is seen in the agroforestry trial plot where indigenous trees are incorporated into the sorghum-growing microcatchments and bunds. The trees used in alley cropping must be carefully selected to have deep roots so that they do not compete with food crops for water and nutrients. Useful attributes include quick growth after pruning, mulch from their leaves, and firewood or stakes from their stems. The leguminous trees fix their own nitrogen, providing protein rich leaves for livestock and nitrogen-rich organic matter for the soil.

In alley cropping, the trees are pruned just before the rainy season to a height of between 25cm to 2m, so that they do not shade the growing crops. The larger stems are used as firewood or for stakes, while the leaves are spread on the soil as mulch. Although the tree stems may take up 5-10% of the available land, there is usually no loss of crop output, as the fertilizer-properties of the leguminous leaves substantially increase the yields (Harrison, 1987). The mulch also suppresses weed growth, reducing the labour required to look after the field area. Trees such as *Leucaena* grow well in areas with an average rainfall of 600mm per year, though *Sesbania* can tolerate as little as 350mm per year, also withstanding acid soils, waterlogging and flooding (Harrison, 1987).

Rainwater harvesting practices should, preferably, be cheap and simple, and show reasonable benefits in the short-term to rural homes, villages and schools. They should be small in scale and flexible, known locally and be viable for adoption into the local farming system. As with a piece of agricultural technology, if a specific rainwater harvesting project does not fit into the overall farming system, it will not be adopted. Factors such as climate, rainfall, available natural resources, available labour and capital, off-farm labour opportunities, and household preferences and priorities, are among many of the elements that decide whether or not a

'system fit' is reached. Rainwater harvesting by whatever technology and at household level is therefore of extreme importance, either as the sole source of water or to enhance the existing water supply systems so people's basic needs can be met.

Commitment is required for on-going activities and long-term water development plans that seek to make local livelihoods more resilient and sustainable. Examples of such activities include those of engineers who drill boreholes to the appropriate depth to ensure that water continues to be supplied during times of water stress. However, communities should also become involved in gardening and water harvesting activities that provide food and water during times of well being, and this will increase their capacity to survive, their resilience, and their ability to sustain themselves through periods of drought.

Many types of agricultural activity using rainwater harvesting are carried out in Botswana without government or NGO involvement. For example, rainwater is used for livestock watering in the villages of Goodhope (~10km south of Lobatse), Nswazwi and Makaleng (north-west of Francistown, on the road to Nata), and Mosu (north-east of Orapa, near Boteti). Additionally, crop production and livestock watering can be seen in Kumakwane, Metsimothabe and Manyana, south-west of Mmankgodi (see Map 1, Appendix E) (Ndege, 2000).

2.2 Tapping into the potential of rainwater harvesting

"I remember particularly at one of the discussion meetings when I asked about traditional pesticides. There was one farmer whose tomatoes were never attacked by red spider mite. But he could not tell everyone what he was using. He was probably afraid of being laughed at or even being accused of not using 'modern methods'" (Murwira, n.d., p. 33)

"The government doesn't look at the poor people's views. It thinks that when one is poor in money one is poor in mind. But it is the poor people that know the most about rainfall" (Scoones, 1996, p.160).

In order to utilize the untapped potential of rainwater, through 'an increased use and/or adoption of small scale, flexible, site-specific rainwater harvesting practices, through participatory approaches' (Van Veenhuizen, 1999), the policy and institutional environment in most Sub-Saharan African countries will require some change. Both government and privately supported institutions need to mobilize existing local institutions and motivate them to adopt and participate in water harvesting techniques. In order to pursue this goal, activities need to be planned to raise awareness of water harvesting and how these are and can be integrated with soil conservation and irrigation.

African countries will need to use water more efficiently in agriculture. This ranges from traditional water harvesting and moisture control practices to modern irrigation systems. These practices have the potential to increase food security in southern Africa. Figure 2.2 illustrates

the capacity for cereal production using rain-fed and irrigated practices in Sub-Saharan Africa and the contribution that rainwater harvesting can make to a region's food security. In the chart, the effects of using High Yield Varieties (HYV) of crops in conjunction with irrigation schemes are compared with rainfed crops (Sharma, *et al.*, 1996). (Food security, however, can also be affected by many risk factors such as war and economics).

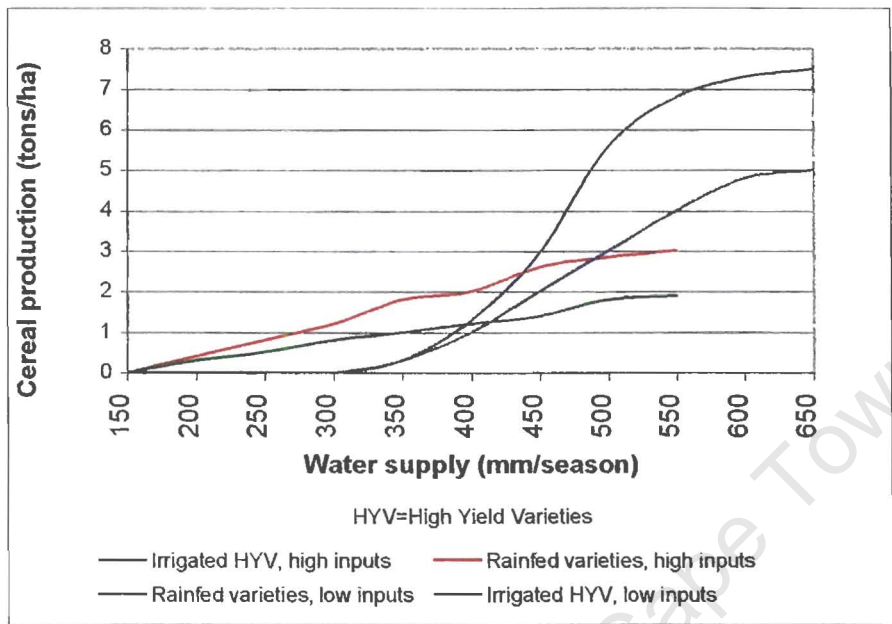


Figure 2.2: Comparison of yield-productivity for rainfed and irrigated crops

Source: Sharma, *et al.*, 1996

Irrigation schemes combined with HYV and high inputs from, for example, the use of improved technology and agricultural services, offer the most productive solution to improving food security, (Figure 2.2). However, the contribution to cereal production that rainfed crop varieties make is large enough to be a powerful supplementary source of food. Food security means not only availability but also stability and access to food.

Rainfed production needs to be addressed in conjunction with problems of high variability from inadequate water control, uncertain incomes, and the scarcity of off-farm employment. Once established, however, agricultural productivity can provide a base for growth, income and employment in economically disadvantaged rural areas, which would in turn help to mitigate urban migration (Sharma, *et al.*, 1996). Investment for research into appropriate agricultural methods, training of local users, and developing programmes and products has been small when compared to infrastructure investment. Research investment is essential though, for increasing productivity and the ecological sustainability of rainfed crops.

2.3 Botswana's modern emergency drought responses

"In southern Africa's emergent democracies, drought mitigation is underpinned by and contributes to the process of responsible governance. In this context, drought is viewed as an expected threat to national economic security, and accompanied by a commitment to avert preventable hardship and financial loss, both of which compromise development opportunities" (Holloway, 1999).

Since the early 1980s, Botswana has regularly imported about 90% of its cereal needs. During the drought of 1992 the cereal crop was only 27% (15,000 metric tons) of the long-term average production of 55,000 metric tons, which was still low compared to the country's cereal consumption requirements of about 200,000 metric tons (Thompson, 1993). More than 100,000 people were seriously affected by the drought, particularly those who lived in smaller settlements and remote areas. By November 1992, the government had spent Pula 107 million (US\$54 million) of its domestic resources on emergency drought relief. In December 1992, 60% of the population had access to potable water, but only 20% of those in settlements with less than 500 people. Drought relief and rehabilitation cost 14-18% of the total government development expenditure during the drought of 1984-87. While evaluating that drought, one senior government official said that it "had become unaffordable" (Thompson, 1993).

Botswana's 1991 Sixth National Development Plan (NDP VI) reviewed the state of vulnerability to drought, and attributed the recent reduction in vulnerability to:

"Overall economic progress made since independence" and in particular, to the fact that "the country can now afford extra food imports, and the Government has administrative capacity to organize their distribution, using the improved road network that has been developed over the past 18 years (National Development Plan VI, 1985-91, p.21, para.1.76: Manamela, 1997)

At the national planning level, factors such as economic performance, institutional capacity and the state the country's infrastructure, are therefore seen as important for the reduction of long-term vulnerability to drought. Action on these fronts forms the basis of the Botswana's drought mitigation. In the 1997 NDP VII, the government established a new drought mitigation strategy:

"The diversification of the rural economy, the expansion of non-farm employment opportunities in rural areas, and improvements in agricultural efficiency, especially for smallholders, will reduce the vulnerability of the rural areas to drought." (National Development Plan VII, 1991-97, p.89, para.4.97: Manamela, 1997)

The economic diversification of rural areas is promoted as one of the government's main strategies in drought mitigation. A particular emphasis has been placed on improving the security of supply for water, food and pasture (Manamela, 1997). The socio-economic resilience to drought has increased over recent years through the relative efficiency of the domestic market with its serving infrastructure, and the well-dispersed food retail outlets that are found even in the remotest villages. However, of particular concern is the strengthening of household level vulnerability and involving the community in the monitoring of drought conditions that would improve local level preparedness.

Reducing the long-term vulnerability to drought will remain a central issue in Botswana policy debates, despite having arguably one of the best disaster response systems in the world. Botswana is much further ahead of its neighbours in integrating drought mitigation into its overall, long-term development plans. Programmes that regularly address poverty reduction, such as labour intensive public works projects, inputs to small farmers and water initiatives, offer the best insurance against increasing vulnerability to extreme weather events. Poverty is the root cause of vulnerability to drought in Botswana which makes poverty reduction one of the key development policy objectives (Manamela, 1993).

2.4 A brief history of rainwater harvesting in Botswana

At the moment there is no government policy in Botswana that specifically addresses rainwater harvesting (Ndege, 2000). However, various rainwater harvesting initiatives have taken place. Historical evidence for the use of RWCS is scarce but some rainwater tanks were used throughout the colonial period in Botswana. Traditionally though, people have collected the rainwater that ran off the eaves of their thatched rondavel roofs in pots and small containers and this practice to varying extents still continues today (Taylor, 1997). There has, however, been a considerable amount of interest in the use of RWCS over the last 25 years.

In 1976, Pelegano Village Industries (PVI) at Gabane village, 20km west of Gaborone and established by Taylor, built a rock catchment system on a large granite slab comprising low catchment walls 20-25cm high to catch runoff, a sedimentation chamber to remove solids and a 38m³ underground storage tank. The runoff was used for watering the vegetable gardens of

two families at a time when there was no piped water to Gabane village. The holding tank was never more than half full and the grey, soapy kitchen water was reused for banana and paw paw trees. Very few other villagers had granite outcrops in their yards, but the system was tried successfully elsewhere, in the villages of Oodi (for a weaving factory) and Thamaga. In 1977, PVI built a water collection microcatchment and a 33m³ underground igloo reservoir to store drinking water for a local poultry farm. However, a water reticulation system was installed in the village soon afterwards, so the scheme was not copied either (Taylor, 1997).

Many of Botswana's older buildings were built with rainwater tanks such as Primary Schools in Nata during the 1940s and many of the Botswana Housing Corporation (BHC) high cost houses built during the 1960s had corrugated iron tanks (Gould and Jay, 1993). The first documented project in 1969, later supported by the Intermediate Technology Development Group (ITDG) and Oxfam, involved collecting surface runoff in ground tanks at 12 primary schools in eastern Botswana and using the water for irrigating vegetable gardens. This project provided the impetus for the development of similar schemes through the MoA's ALDEP initiative in the 1970s and 1980s (Cullis and Pacey, 1986).

Between 1979-91, ALDEP provided subsidies to small farmers enabling them to purchase sub-surface ferrocement ground tanks, see Figure 2.3. More than 700 of these were built and most used traditional threshing floors or compacted surfaces as catchment aprons. They were originally designed to provide water for draught animals in the lands areas to facilitate early ploughing when the rainy season started. However, people also used the water for domestic purposes including drinking. The water, however, was unsuitable for drinking because of contamination and a high bacteria content from the excrement of animals and small children.

A new ALDEP roof catchment system was thus designed and developed and this was the 7m² polyethylene surface tank connected to a 40m², iron roof catchment system. It became available in 1991 and more than 200 of these have been installed since (Gould and Jay, 1993), see Figure 2.4. Providing the roof catchment is kept clean and the surface tank has a cover and tap, the water is generally suitable for drinking.

Farmers in Botswana who owned less than 40 cattle could apply for an ALDEP roof and tank system and they received an 85% subsidy from the government for it which cost a total of Pula 2500 each. However, some farmers still found the remaining 15%, or Pula 800 (the cost of a calf), prohibitive to their participation in the scheme, which therefore remained under-subscribed (Gould and Jay, 1993). The 40m² roof catchment supplying a tank between 7-10m³ in size, was found, during a 1994-95 field survey, to be too small to supply the needs of an average family's requirements (Gould, 1997). The average daily consumption was 107 litres, and the RWCS could only provide for between one-third to half of the required demand.

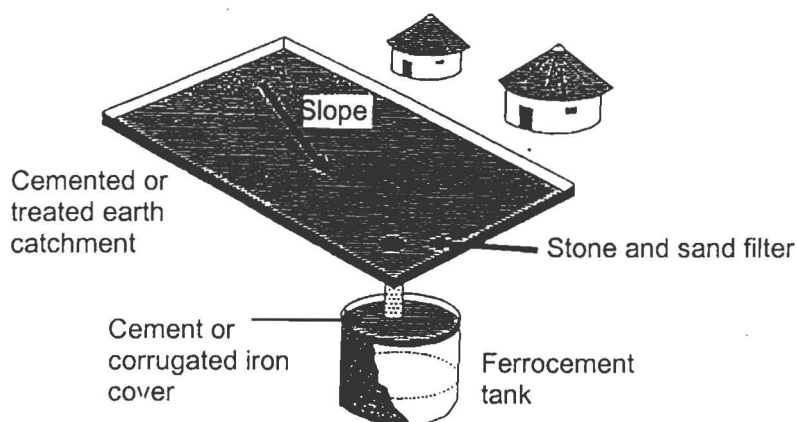


Figure 2.3: The original ALDEP ground catchment system design using a traditional threshing floor as the catchment apron

Source: Gould, 1999

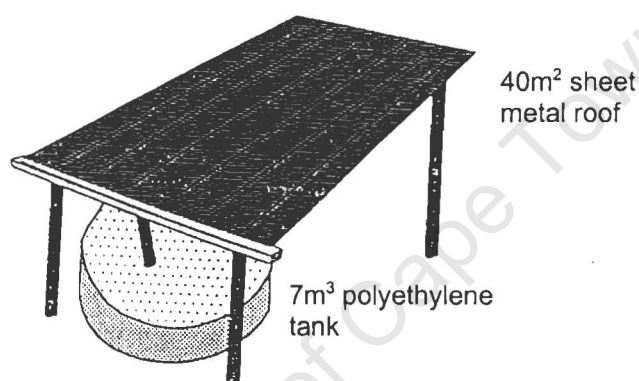


Figure 2.4: The upgraded ALDEP rainwater catchment system design

Source: Gould, 1999

Approximately half of the 800 primary schools in Botswana have had rainwater tanks built of corrugated iron, but since these have an average life expectancy of only five years, many of them are now either leaking or disused. The average school has a roof surface area of 1300m^2 , and yet an average of only two tanks totalling 12m^2 were built for each, capturing at best only one-tenth of the available rainwater (Gould and Jay, 1993).

After the upgraded ALDEP rainwater catchment system design, the next variation proposed involved a combined roof and ground catchment system (Gould, 1997), see Figure 2.5. The 40m^2 roof would be equipped with a 5m^3 surface tank and a 15m^3 sub-surface tank, which itself would also be fed from a $100+\text{m}^2$ ground catchment apron comprising cement or treated earth. This combination offered the opportunity to collect between 20,000 and 50,000 litres of water per year (between 55 and 135 litres per day), in the driest and wettest areas of the country respectively (Gould, 1997). The higher quality water in the surface tank would be used for drinking and cooking while the ground water tank would be used for washing, cleaning and watering stock.

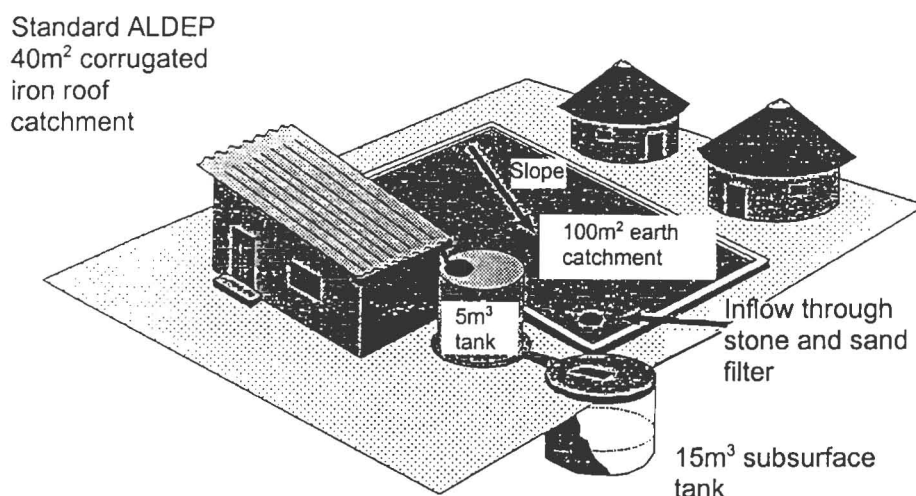


Figure 2.5: The ALDEP combined roof and ground catchment system

Source: Gould, 1999

During the 1980s, ferrocement water tank technology was tried and over 100 tanks were built in rural schools and clinics (Chishimba, *et al.*, 1993). However, only just over half of those later inspected (26 out of an inspected 46) were still structurally sound and watertight. The others had either never been filled or were badly leaking at the joint between the wall and the basal slab, the most vulnerable part of the tank as a result of stress concentrations (Chishimba, *et al.*, 1993). Since 1994 the Botswana Technology Centre (BTC) has been experimenting with improved ferrocement technology based on a design originally from Kenya, and a pilot training project has also been established.

Today, corrugated iron roof catchment tanks remain a common sight at primary schools in villages throughout Botswana. Surveys conducted by the BTC revealed that about half of the 800-plus primary schools in the country possess corrugated iron tanks (Gould, 1996). However, since they have an average life expectancy of only five years, many schools have leaking tanks. Despite the average roof size of a primary school in Botswana being 1300m², the average total tank storage volume is only 12m³ per school, compared with a potential mean annual roof runoff of 495m³ (with an annual rainfall of 220mm) (Gould, 1996).

Another interesting rainwater harvesting technique developed was by the Rural Industries Innovation Centre (RIIC) at Zutshwa. This small, remote bushman (basarwa) settlement lies 65km south-west of Hukuntsi in the Kgalagadi District, and 600km west of Gaborone. The people in this RAD settlement lack access to locally available water, a feature that characterizes most RAD villages. Zutshwa contains around 250 people whose water is collected off the side of a salt pan that is used as a catchment surface.

A series of three 68m³ brick, sub-surface tanks were constructed (5.8m diameter by 3.1m high) to collect the runoff and provide a water source for the people and their livestock (Petersen, 1993). Once the first tank is full, water spills over into the second and then the third tank. The system was working well after construction in June 1992, though there was a problem of high turbidity due to the presence of very fine clay particles which were suspended in the runoff, giving the water a milky appearance (Gould, 1998). The water is pumped by an operator from one of the water-containing tanks using a suction mounted on a specialized donkey cart. The operator then makes three to four trips to the village centre 2km away, to deliver around five litres per person per day (Petersen, 1993).

The catchment apron was found to be between 60-80% effective in collecting water during rainfalls between 21st December 1992 and 28th January 1993. Interestingly, during one intense rainstorm on 30th January 1993, where 21mm fell in 45 minutes, the catchment was not durable enough to withstand the high rainfall impact. Blocks from the apron were swept away in some places causing the loss of an estimated 50% of the available water. Nevertheless, 88m³ was collected during the storm, over one-third of the total storage capacity. The system should collect over 200m³ per year, with over 450m³ being needed to supply each person with five litres per day (Petersen, 1993). This illustrates the potential quantity of water that the pan can catch as a part solution to Zutshwa's water requirements.

Three interesting observations were made in 1994 regarding the Zutshwa rainwater catchment scheme. First, a modern pipeline was constructed to the village from a borehole 10km away, where a reverse osmosis system was installed to remove dissolved solids, the year after the rainwater catchment system was installed in Zutshwa. After installment, however, the system had twice temporarily broken down within the following couple of years, leading the people to rely exclusively on rainwater (Gould, 1997). Second, despite the presence of the new piped system, the people still highly valued the rainwater system, with the collection of rainwater off all modern roofed buildings in the village being ubiquitous (Mateke, *et al.*, 1999). Last, the villagers still use the water despite its high turbidity (Mateke, *et al.*, 1999).

The MoA is keen to replicate this rainwater technology elsewhere in the Kgalagadi, such as at Tshane, but so far it has met with only limited success due to the implementation of inappropriate designs (Mateke, *et al.*, 1999). Projects such as this require careful monitoring and evaluation so those lessons for future rainwater harvesting schemes are correctly advocated to the people and implemented. At Zutshwa, however, rainwater harvesting is the most practical technological solution to ensure its long-term sustainable development.

The MoA's soil conservation unit has attempted to introduce the use of demi-lune microcatchments for plant production through some field trials at the villages of Mogobane in the south-east of Botswana and at Masunga in the north-east. Ordinary farmers, however, have

not adopted the practices and cite excessive labour requirements and pests such as pigeons eating the early maturing crops as inhibiting factors.

The development of rainwater harvesting initiatives for plant and tree production in Botswana was initiated in 1981 when F. W. Taylor established Veld Products Research & Development (VPR&D). This is an NGO involved in the sustainable utilization and management of veld products and natural resources for environmental and economic development. VPR&D is located in Gabane village and the 50-acre site boasts research sites and nursery facilities. In the mid-1980s, a trial orchard of exotic deciduous fruit trees was established including apricot, almond and peach trees and demi-lune microcatchments to collect surface runoff. Despite the trees growing well, there was insufficient residual moisture present at budbreak (3-4 months after the rainy season) so the flowers either aborted or produced very small fruit (Taylor, 1997). This knowledge was subsequently built upon when in 1990 research and planting trials were carried out to domesticate indigenous fruit trees of economic importance using both macro- and microcatchments. Indigenous trees included for example, Morula (*Sclerocarya birrea* subsp. *caffra*), Morulta (*Strychnos spinosa*), Mogorogorowane (*Strychnos cocculoides*), Mmilo (*Vanguaria infausta*) and Morojwa (*Azanza garckeana*). The end of 1997 had established some 23 planting trials, each involving several hundred trees.

In 1994 a Morula trial was established to compare its growth in plain microcatchments and in stone-lined microcatchments, though no definitive results are available yet. During the rainy season in 1995/96, VPR&D established an agroforestry trial that comprised indigenous fruit trees intercropped with traditional crops, such as cowpea and watermelon.

New innovations and approaches to RWCS are desperately required in Botswana where the rapidly growing population is increasing the pressure on limited water resources and 10% of the population still lacks adequate and safe water supplies. The potential for rainwater harvesting has yet to be fully realized despite that potential, for example, being clearly demonstrated in several other countries. For example, intermediate water technologies have been practised for thousands of years in the Negev Desert in Israel which receives as little as 100mm of annual rainfall. Other examples include Thailand where over 12 million ferrocement roof tanks have been built since 1985 and many roof, ground and rock catchments are also common over much of semi-arid Kenya (Taylor, 1997).

A 155m³ galvanized steel tank with a plastic inner lining was built on the VPR&D site on the edge of a granite hill in 1996. After negotiating land rights, the tank, which will purely be used as a storage facility, will be connected to the mains supply from Gaborone Dam and other local dams in late 1999/early 2000. Water will be pumped up into the tank from which it can then gravity flow down to the houses and buildings on the NGO site.

ALDEP Phase II was introduced with the aim of assisting small farmers to increase and improve crop production by providing them with technological packages, according to Mr Mmofswa, ALDEP Co-ordinator (Toto, 1998). ALDEP's current emphasis is on technology transfer, strengthening extension services, training, and encouraging previous beneficiaries to efficiently and effectively utilize the packages they received during phase I of ALDEP. Phase II involves providing farmers with silos, threshing machines, animal draught power, fencing materials, water tanks, chuffcutters, fodder seed, fertilizers, animal drawn implements (ploughs, harrows, donkey cart planters and cultivators). Under this scheme, female-headed households are required to pay 10%, and male-headed households 15%, of the total cost of the package they require (Toto, 1998).

Another NGO, Thusano Lefatsheng (TL) is similarly involved in agroforestry research in Botswana. It is studying plant genetic composition, growth patterns and yields of various exotic and indigenous fruit trees, for example, the Morama bean (*Tylosema esculenta*) (Taylor, 1994).

2.5 Applications in Botswana

The BTC and VPR&D are now focused upon to describe each organization and its initiative.

2.5.1 The Botswana Technology Centre (BTC)

Botswana largely depends on expensive underground water development (about 90%) and is exposed to periods of drought marked by severe shortages of water when boreholes dry up (Opelo, 1998). In response to this, the MLGL&H, together with the MoA and the BTC, are co-ordinating efforts to try to alleviate the current water crisis. They investigated the possibility of using ferrocement tank technology in rainwater harvesting at primary schools and lands in the Southern District. Only areas within a radius of 80km around Kanye were chosen at first for easy observation. The BTC sub-contracted RIIC, based in Kanye, to train the builders and the construct the tanks. The project is known as the Ferrocement Tank Development Project – Phase II State II, since it followed other previous projects that had similar objectives.

The project was established as a pilot project for a water conservation initiative. It is also meant to help provide water at arable lands through ALDEP as well as a water supply augmentation scheme at various primary schools around Kanye.

The BTC's objectives of the ferrocement water tank project were (Opelo, J. 1998):

- To introduce a durable, reliable and cost effective rainwater tank design suitable for widespread use throughout the country.
- To run an intensive training course in ferrocement tank construction to teach trainers and builders from brigades, technical officers from councils, and contractors.

- To draw up standards and introduce a graded system of certification to ensure the tank builders meet minimum levels of workmanship and competence.
- To produce a design manual and draw up design criteria to assist in effective and consistent construction methods.

For the BTC, the project was divided into two phases. Phase I consisted of a feasibility study that examined what tanks might be suitable, what capacity was required, what the conditions of the villages were, and a literature review of the technology currently in use in other southern and east African countries. Phase II then comprised the training and construction of the ferrocement tanks, chosen as a result of their durable qualities. Phase II is presently still in operation. If the project is well received by the Botswana Government, then Phase III will take effect: piloting the tanks into households on a district and countrywide scale (Opelo, 1999).

A total of eight tanks were built between 1996 and 97 instead of the initially estimated 16 tanks as a result of the low turnout of trainees. The training was designed to build on the theoretical background that the trainees had already and expose them to the practicalities of building the tanks. This part of the project was carried out by RIIC where a total of 11 trainees, with varying degrees of qualification, formed two groups, with each group additionally being backed up by two casual labourers who assisted during the construction of the tanks.

The trainees came from the Botswana Government and parastatal and private sectors for the project. The participating organizations included South East District Council, the Botswana Defense Force (BDF), Kweneng District Council, Tswelelopele Brigades, Madiba Brigades, Moramosi Construction and the MoA. The training programme, which commenced on the 2nd July 1996, covered a period of 24 weeks with the first four weeks being theoretical and the next 19 weeks practical, with a one week evaluation course held at the end on 12th December 1996. Both the contractor (RIIC) and the consultant (BTC) gave lectures in theoretical training with additional participation from The University of Botswana (UB), Department of Environmental Science. RIIC took 70% of the project's work in the training of the artisans and construction of the tanks, while the BTC took the remaining 30% of the work on a consultancy and technical basis (Opelo, 1999). It is also intended that trainees write an examination after the course is completed, and then awarded certificates as a means of verification and course completion.

Funding for all the tanks in the pilot project came from the Botswana Government through the MLGL&H, the MoA, the Ministry of Finance and Development Planning (MFDP) and the United Nations Children's Fund (UNICEF). Funding for the entire programme totaled 529,340.92 pula (Opelo, 1999). It was the role of the government through the MLGL&H and the MoA to identify people and schools who required either a supplementary or primary source of water. This was carried out through the agricultural EOs who talked to local farmers and accessed their

willingness to become involved in the project and their requirements and needs. This was also examined in recognition of socio-economic aspects of the villages and lands areas. It was the role of the BTC, in light of this information, to come up with the technology to support it.

A total of 11 ferrocement tanks were built, at six primary schools in Moshupa, and two tanks in the Moshupa Kgotla Lands and Polokwe Lands. Tanks were constructed at the following sites:

- Bakoko Primary School
- Kgabophuthi Primary School
- Mosielele Primary School
- Moshaneng Primary School
- Lotlhakane Primary School
- Kebonyekgotla Primary School
- Moshupa Kgotla Lands –1 tank
- Polokwe Lands –1 tank

2.5.2 Constructing a ferrocement tank

There are several problems with the materials used in the rainwater harvesting ferrocement tanks. For example, it is perceived to be a poor reinforced concrete and a second-class technology developed for Third World countries (Hasse, 1989). Ferrocement is a building material similar to concrete, and is produced by applying cement mortar composed of fine aggregate and cement onto wire reinforcement using plasterer techniques. There are as many as four to five wire frames, each with varying mesh sizes and orientations that are superimposed upon each other before the ferrocement is applied on either side. While of similar durability to reinforced concrete, the ferrocement is more elastic and flexible with high impact resistance properties. The width of the roll of mesh or mats will determine the height of the tank wall, usually up to 1.80m high. RIIC has developed tank sizes of 11 m³, 23 m³ and 46 m³ for use in the pilot project.

Joseph Monier produced flowerpots made of cement mortar reinforced with chicken wire and he showed this new product first to a world exhibition held in Paris in 1867. During the First and Second World Wars, ferrocement boats were successfully built in the UK, US, New Zealand and Australia as builders tried to save shipbuilding materials such as steel plates and timber. One such ship even circumnavigated the world without problems (Hasse, 1989). The building process is highly labour intensive and while this is now considered a disadvantage in industrialized countries, it remains an appropriate technology for countries where labour costs are low and the labour pool is large. The organization, 'Christian Action for Development in the Caribbean', which has used the technology, comments that it is ideal where only a few tanks or even just one are required, where prefabricated moulds are not considered and welded reinforcement mesh is not available (Hasse, 1989).

2.5.3 Veld Products Research and Development (VPR&D)

VPR&D is governed by a board of directors drawn from farmers in Gabane village and senior officials in the MoA, the Department of Agricultural Research and other NGOs. Funding and

support for the VPR&D's projects have been received from international donor agencies. These include the GTZ (Germany), SNV (Netherlands), the European Union, IDRC (Canada), the United Nation's Food and Agriculture Organization (FAO), NORAD (Norway), DANCED (Denmark), the Royal Netherlands Embassy, the British High Commission and the Canada Fund for Botswana (Sunstrum, 1999, pers com.). Field activities around the country include community-based projects as well as research work on indigenous tree planting trials and agroforestry trial plots located throughout Botswana. VPR&D's mission statement and goal is:

"To undertake research and development projects in partnership with rural communities and households to improve their quality of life through the sustainable utilization and management of natural resources. In order to achieve this VPR&D aims:

- *To engage in innovative research*
- *To promote Human Resource development on the basis of equal opportunity*
- *To promote systems enabling communities to develop their own strategies to successfully utilize their natural resources on a sustainable basis*
- *To be an international centre of excellence in the utilization and management of veld products"*

2.5.4 The Agroforestry Project

VPR&D established an agroforestry trial plot at its site in Gabane in 1995 where the growing of indigenous fruit tree species together with traditional crops with rainwater harvesting practices is experimented and demonstrated. The trial was established to show the potential rainwater harvesting has to produce more stable and reliable yields in the erratic rainfall climate and poor soils in Botswana. One of the crucial aims of the project is also to make the techniques accessible and adaptable to local farmers (Mateke *et al.*, 1999).

A five-year old Morula orchard (planted in 1990) formed the basis of the trial. The trees were planted on contours 12m apart with 12m between the trees on each contour. The semi-circular bunds were lined with stones that serve as a mulch and each tree had a microcatchment of 6m², with the upper line of trees having a macrocatchment of between 3-400m². In 1995, species of Morutla (*Strychnos spinosa* -wild orange family) and Morojwa (*Azanza garckeana* - snot apple) were planted in between the Morualas, later joined by Mmilo (*Vanguaria infausta*, wild medlar) and Mogorogorwane (*Strychnos cocculoides*, wild monkey orange family). The project was then presented to farmers who were encouraged to adapt it for themselves. Prizes are given every year to innovative farmers in the Kalahari to encourage the adoption of the viable practices.

Under the heat of the summer sun, any soil or sandveld that is left bare experiences a depletion and killing of its microflora, so there is a great need to keep the ground cool. Consequently,

intercropping between the indigenous trees is a common practice and sorghum and cowpeas are the predominant crops planted. Their decayed remains later form a good mulch on the soil during the dry season. Watermelons are also planted and their wide, shallow roots expand out across the catchment areas. As do Morama beans (similar to soya beans), which have a 2m spread across the ground and whose tubers can weigh up to 300kg and live for 100 years! Traditionally, no reploughing is ever done at the lands areas if the first rains and crops fail, but with the agroforestry method, crops can be replanted if the first crop fails.

The attraction of birds to the trees and crops is a major problem in Botswana and VPR&D have tried various methods of scaring them away in the past. Methods include a plastic bird on a six-foot pole elevated above the crops; temporarily effective but the birds soon return. One method recently tried in England involves a pyramid of mirrors that creates shafts of light that disorientate the birds as they fly in towards the crops, thus scaring them off. One pyramid can control an area approaching two hectares but its cost, 3,000-4,000 pula, is prohibitive in Botswana though plastic bottles filled with water have a similar effect (Taylor, 1999, pers com.). A future design might include a pole with strings tied on it, and at the end of each string is small mirror for the purposes of reflecting light and scaring birds away.

2.5.5 The Community Based Agroforestry Project (CBAP)

The Community Based Agroforestry Project was started in June 1997 and the main objective is, "to support communities in the development of appropriate low-input and sustainable agroforestry systems that will increase food and household security for subsistence farmers in semi-arid Botswana." (Makete, and Taylor, 1999). VPR&D aims to use the experience that it has gained from the agroforestry initiative and take this out into communities in Botswana. The objective is to create an interest in agroforestry, to develop viable and appropriate methods of rainwater harvesting, and alternatives to traditional agriculture. CBAP currently operates in villages in the eastern Hardveld, those of Gabane, Paje, Thabala, Letcheng and Tsamaya. In this thesis, VPR&D's work in the first two villages, Gabane and Paje, will be analysed.

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Rainwater harvesting is the term used for a wide range of methods for concentrating, collecting and storing surface runoff for domestic and agricultural use. Through utilizing the technology, the potential exists to lower vulnerability to drought. The projects established by VPR&D and the BTC will be examined through a framework of lowering vulnerability and reducing the risk to drought. Blaikie's 'pressure and release' model and 'access' model are both used and through which the potential that rainwater harvesting has for drought mitigation can be evaluated.

Chapter 3

Conceptual Framework

3.1 The conceptual framework

Drought mitigation can be conceptualized within a framework using various models. Two models of vulnerability to hazards are considered. People face risk due to a combination of both their vulnerability and a hazard. A hazard is *“an extreme event which may affect different places singly or in combination, at different times...with varying degrees of intensity and severity”* (Blaikie, et al., 1994, p.21). When a hazard affects a group vulnerable to that particular hazard a disaster may result.

“A disaster occurs when a significant number of vulnerable people experience a hazard and suffer severe damage and/or disruption of their livelihood system in such a way that recovery is unlikely without external aid” (Blaikie, et al., 1994, p.21).

Vulnerability encompasses the capacity of a person or people group to anticipate, cope with, resist and recover from the impact of a natural disaster (Blaikie, et al., 1994). It includes factors that determine the degree to which people's livelihoods are put at risk and disrupted by a discrete natural or social event. Vulnerability can also be associated with the word capability; the ability to protect one's family, home and community, and to rebuild one's livelihood after a hazard. The most vulnerable in society are those who find it hardest to reconstruct their lives after a disaster has struck them.

3.1.1 The 'pressure and release' model

Two models that help to explain vulnerability are the 'pressure and release' (PAR) model and the 'access' model (Blaikie, et al., 1994). The PAR model is a simple tool for illustrating how disasters occur when vulnerable people are subjected to pressure. Their vulnerability is often rooted, not in the severity of the disaster, but in the social processes and underlying factors that may be far removed from the disaster itself but have heightened vulnerability to risk or a hazard. The idea behind the PAR model is that a disaster is the intersection between two opposing forces; those producing vulnerability on one side, and actual physical exposure on the other. The 'release' component involves relieving the pressure and so reducing the effects of the disaster through reducing people's vulnerability through, for example, mitigation measures. This model has the tendency to separate the hazard from the conditions that create vulnerability, making a distinction between them.

The impact of any hazard is related to social factors that generate a state of vulnerability. There are three categories of vulnerability-inducing factors, as illustrated in Figure 3.1:

- Root causes of vulnerability
- Dynamic pressures, and
- Unsafe conditions

Root causes of vulnerability may be economic, demographic (affecting the allocation and distribution of resources between people groups) and political (such as control by the police or military). Economically marginal people are particularly vulnerable, for example, those living in semi-arid marginal environments or in sparsely populated lands areas. Their access to jobs and resources is less secure and government aid during periods of hardship can sometimes take time to reach their communities when compared to larger urban centres.

Dynamic pressures, on the other hand, translate the above effects into the vulnerability of unsafe conditions. For example, having reduced access to resources may arise from rapid population growth, urbanization, deforestation, epidemic diseases, foreign debts and monetary adjustments, wars, and mining and hydropower development. People's basic health is also important as it often determines their ability to survive disruptions to their livelihoods and their resilience. For example, the old and the very young living in a marginal environment are more susceptible to infections and drought through living with malnourishment or poor nutrition.

Unsafe conditions are generated when people live in insecure or dangerous places. People may live in areas highly susceptible to crop or rainfall failure, in unsafe buildings, in economically poor settlements or with prostitution and health risks.

These three factors are interlinked. For example, farmers displaced from their land during colonial times (the cause) may subsequently experience reduced access to resources (pressure) and may now be living in a marginal environment where rainfall is erratic, low and very variable (unsafe conditions).

The progression of vulnerability

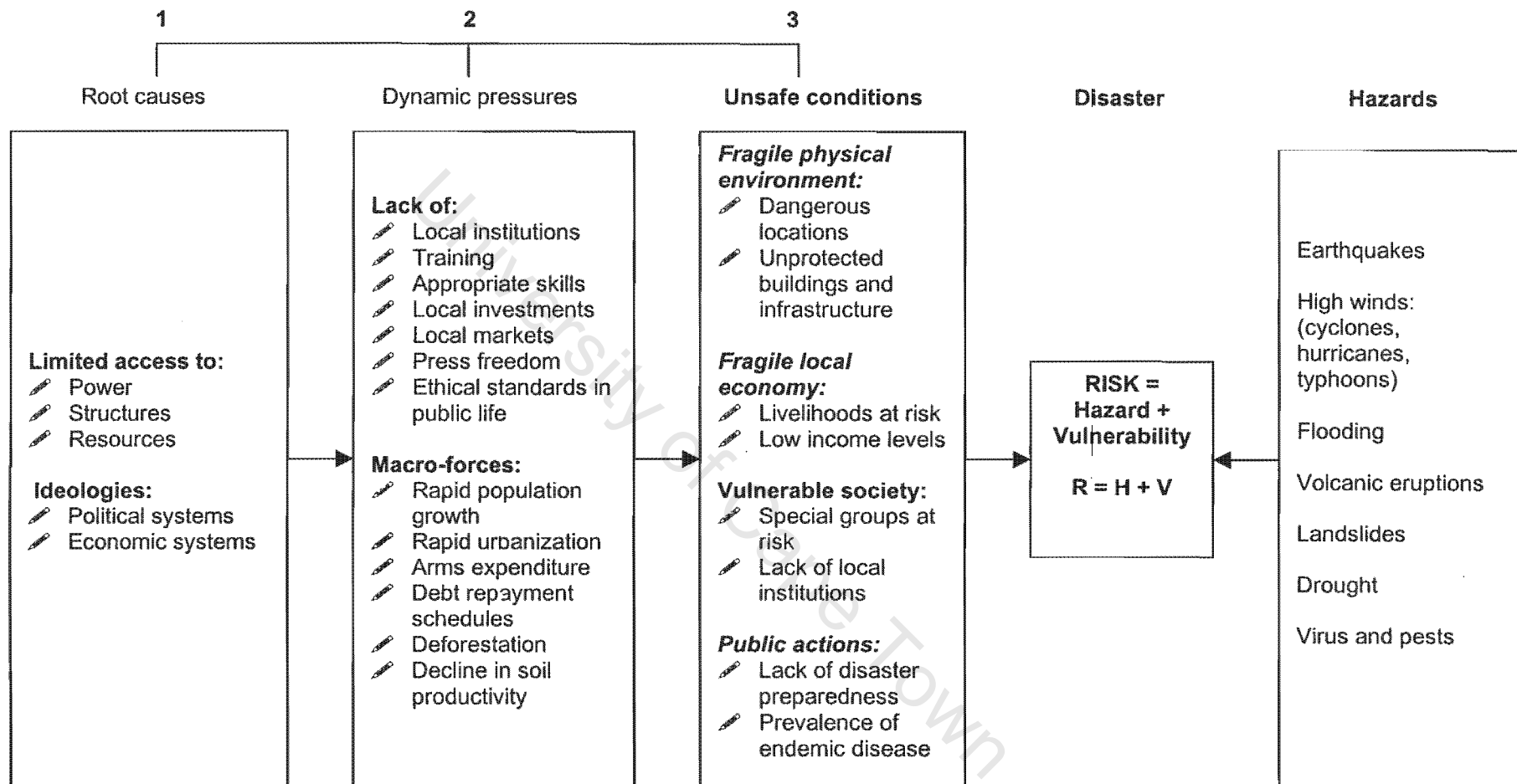


Figure 3.1: 'Pressures' that result in disasters: the progression of vulnerability

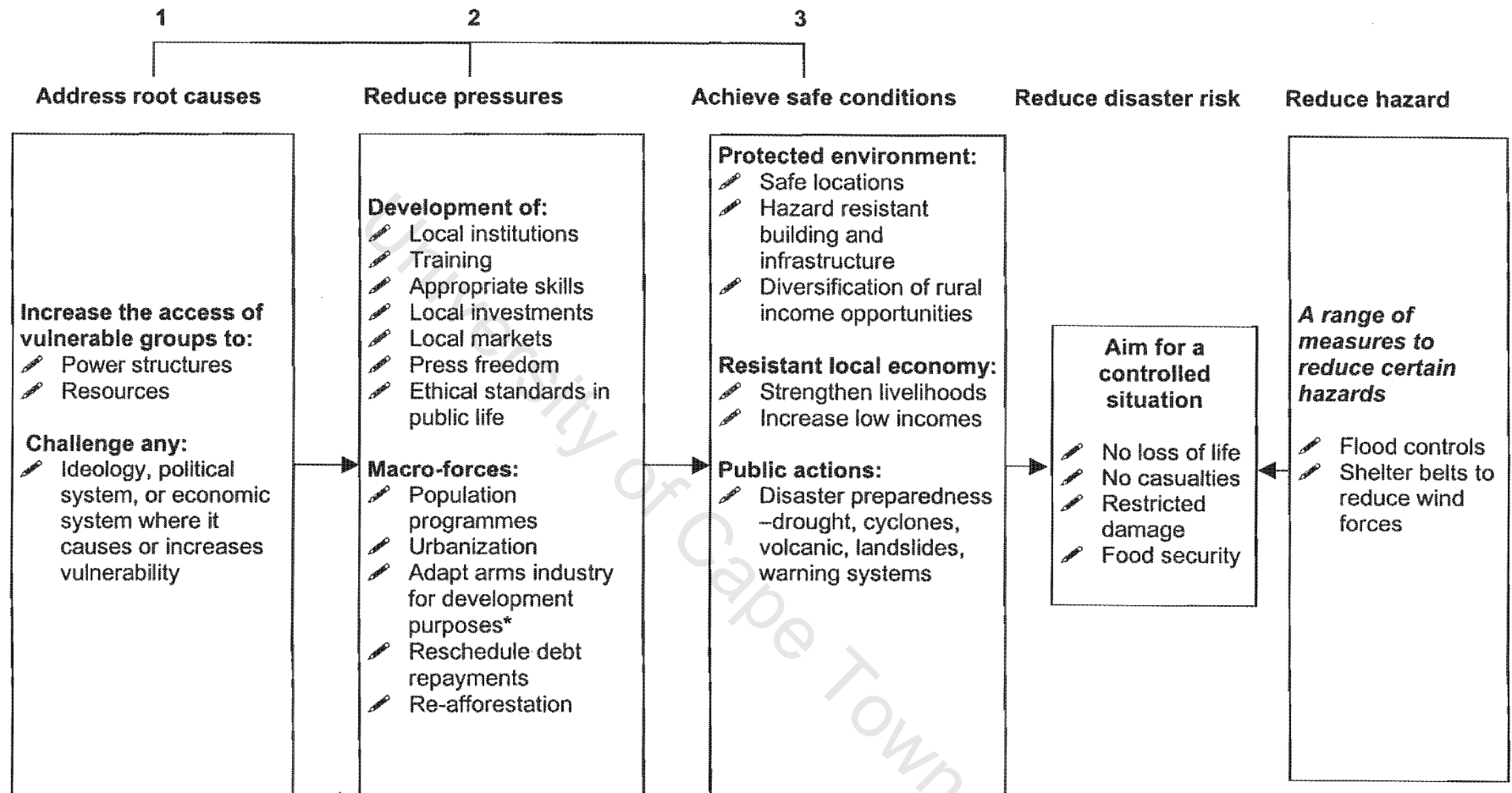
Source: Blaikie, *et al.*, 1994

Figure 3.2 summarizes the 'release' process as a reversal of disaster 'pressure'. For example, the introduction of primary health care, child immunization and community water supply and sanitation at village level dramatically improves protection against some diseases and reduces vulnerability to other hazards. Such mitigating actions relate to the middle of the 'release' model where the mechanisms that translate root causes into unsafe conditions are reversed. Root causes, or global pressures, can be changed, and should not be considered as permanent or inevitable. For example, reducing debt and environmental degradation would allow for more development into rural areas, which would eventually be translated into less vulnerability to hazards. Vulnerability analysis is therefore important to ensure that any mitigating feature that is introduced does have the desired impact and does not create other forms of vulnerability (Blaikie, *et al.*, 1994).

NGOs and governments have an important role to play in helping to establish an enabling environment where the progression of safety is seen within the communities with which they are working. Vulnerable people groups that are experiencing unsafe conditions and unstable or fragile livelihoods can, through organizations working with them, develop a more resilient and sustainable livelihood where they are more capable of responding to shocks and stresses placed upon them. The emphasis, however, should lie in working 'with' the people, rather than working 'to' the people

In this context, the theoretical orientation for this study views semi-arid Botswana at particular risk from the impacts of recurrent drought. This level of risk is further exacerbated by such factors as declining soil productivity, accelerated urban migration, HIV/AIDS that, along with others, increase vulnerability to drought and other shocks.

The progression of safety



*Particularly crucial in post-conflict situations

Figure 3.2: 'The release of 'pressures' that reduce disasters: the progression of safety

Source: Blaikie, *et al*, 1994

3.1.2 The access model

The access model expands on the principles in the PAR model and analyses how economic and political pressures generate vulnerability. It suggests how conditions need to change in order to reduce people's vulnerability and therefore increase their protection against hazards and their capability and capacity to recover (Blaikie, *et al.*, 1994). Unsafe conditions may arise through economic and political pressures that unfairly allocate assets, income and resources in society. Hazards then change the set of resources that households rely on and alter the recovery patterns of different people groups. Some hazards actually intensify people's vulnerability, but may also improve their coping strategies in the long term by encouraging them to invest more in, for example, good building infrastructure, disease or drought-resistant crops and insurance policies. We must therefore include nature, with all its extremes, in the working out of social processes as the two are invariably linked. For example, given a country's economic situation, a wealthy family may suffer greater losses in absolute terms in a hazard, but less in relative terms as they have the ability to recover more quickly than a poorer family. People's access to resources therefore varies, and therefore the potential loss and recovery rate.

Access is the ability to use resources that are directly required to secure a livelihood and can be influenced by class, age, gender and ethnicity. Women generally have less access and less control over income. Lower levels of access increase a person's vulnerability and as resources are not spread evenly, a spatial dimension is introduced. For example, it may be too expensive to travel to collect water every day. This spatial inequality of access reflects economic and social inequalities. To improve this situation, people may move to the towns or cities to find work and secure their livelihoods, inducing rural to urban migration. Recovery may be subsequently impaired by no alterations to the access to resources within a country. Different people are also vulnerable to varying degrees to the same hazard and some will be vulnerable to more than one hazard.

During periods of drought in Botswana, people's level of vulnerability may be determined by their food supplies, entitlements, market behaviour, goods exchanges, or their prospects for earning enough to buy food. Their access to resources is determined by where they are spatially located in relation to their requirements. For example, a family with a lands area 20km from a village and with no water cart is more disadvantaged than a family immediately outside the village and close to a standpipe.

Section 1.13 developed the concept of entitlements, and here it is carried forward into Sen's model of entitlement failure and food entitlement decline (FED) (Blaikie, *et al.*, 1994). FED is the failure of effective demand (or pull failure) which can cause famines, rather than the market failure (or response failure). Despite people needing to buy food, they might not have the necessary cash or other

exchangeable resources to purchase it. In this case, therefore, effective demand has failed and is absent and so does not exert an upward pressure upon food prices. In the access model, entitlements are conceived of as socially derived resources that can be called upon by individuals according to the prevailing 'rules of the society' (Blaikie, *et al.*, 1994). Sen's entitlement relationships, such as production entitlements, trade opportunities, own-labour entitlements, inheritance and transfer entitlements, and extended entitlements (those that exist outside the legal rights of, for example, ownership), are similar principles to those in the access model. However, Sen's work, rather than being a theory, is a structural approach and a structural checklist of factors that affect access.

Entitlements can either be owned by a person (Sen described this as a person's endowment) or can be exchanged by that person for other commodities (called 'exchange entitlement') (Blaikie, *et al.*, 1994). The exchange entitlement depends upon the legal, political, economic and social characteristics of the society in question and the person's position in it (Sen, 1981). People become more vulnerable to drought and famine if their endowment does not comprise adequate food or resources to produce food, and/or if their capacity to exchange labour or other goods and services cannot be translated into enough food. This can occur without a reduction in aggregate food supply and without any breakdown of the market (Blaikie, *et al.*, 1994).

When a person's entitlements change, they can suffer two things. First, they can experience a decline of endowments, such as crop failure, livestock deaths or loss of labour power due to ill health. They also face a decline in exchange entitlements, such as when food prices rise, wages fall, loss of employment occurs, a decline in self-employed production, or the demand for their own goods and services falls at the market (Dreze and Sen, 1989). By considering how endowments and exchange entitlements change, a more comprehensible explanation for why drought occurs can be reached.

3.1.3 Risk reduction framework

Risk can be said to be the sum of hazard plus vulnerability (Blaikie, *et al.*, 1994):

$$RISK = hazard + vulnerability (root causes + dynamic pressures + unsafe conditions)$$

When risk is sufficiently high a disaster may result. In order to reduce disaster the pressure must be relieved upon the people group that will lessen their vulnerability. The PAR model can thus be set within the context of a risk reduction framework. Reasons for adopting a risk reduction framework are:

- To set vulnerability analysis within the broader context of disaster planning and mitigation
- To link disaster mitigation into its wider contest of creating a more sustainable environment

One of the ways of reducing pressure and vulnerability is through community-based projects and schemes that aim to reduce poverty, increase food security and raise up the level of people's livelihoods. Anti-poverty programmes are designed to raise incomes or consumption, and may be in partnership with anti-vulnerability programmes that aim to increase household security and reduce the chances of a hazard having a serious and detrimental impact (Blaikie, *et al*, 1994). Existing anti-vulnerability and community-empowerment programmes need to be evaluated in order to develop good working models for future development and investment. Similarly, to successfully mitigate drought through reducing the dynamic pressures that are exerted upon people's lives.

Water conservation with good management strategies and collection systems in both urban, but particularly rural areas, is an essential component of mitigating the effects of drought ahead of time. A water conservation strategy could include financial measures (such as seasonal peak pricing), technical measures (such as curbs on inefficient water-using appliances and advice on watering) and social measures (such as persuading people to grow indigenous trees instead of the more water-demanding exotic varieties).

Drought increases the pressure on limited land resources and many practices may not directly cause drought but amplify its effects. These practices include over-grazing, poor crop management, deforestation and harmful soil and water conservation techniques (Blaikie, *et al.*, 1994). There is therefore a huge need to mitigate the risks by better, sustainable agricultural land use practices, for example, planting tree shelter-belts to lower the wind velocity and thus its erosive capability at ground surface. The BTC and VPR&D are two such organizations that are actively researching and promoting these strategies.

Many urban areas benefit from the construction of impressive water systems and reservoirs that are designed to provide a predetermined minimum level of supply. With elements of over-design and careful crisis management, many of these can perform well during fairly high magnitude droughts (Chenje and Johnson, 1996). However, it is also the rural towns, villages and lands areas that water providers must not neglect. Governments and NGOs must also consider sustainable development in rural areas. Failure to provide or offer even basic risk reduction mechanisms to rural people could mean the difference between the sustainability of rural livelihoods or accelerated migration to urban settlements in search of increased job and livelihood security.

New attitudes may be called for to help decrease the dynamic pressures upon people's lives as investing both money and resources in rural areas and in community-based projects may go against the normal funding priorities and may not show a conventional return on investment. Above all, there

is a great need to establish more local initiatives in order to produce more self-reliance in communities who depend on drought aid during periods of hydrological or agricultural drought stress.

3.2 Problem statement

Drought conditions are prevalent in Botswana and have a major impact upon people's livelihoods. Reducing the risk of drought and lessening people's vulnerability to drought in villages and rural communities is necessary in order to promote sustainable development and make livelihoods more resilient. Rainwater harvesting presents, at least theoretically, an appropriate technology to minimize the impact of meteorological drought in at-risk households. Despite its potential role as a useful risk reduction strategy, the appropriateness and effectiveness of rainwater harvesting in rural Botswana has not yet been evaluated.

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The PAR model illustrates how disasters occur when vulnerable people are subjected to pressure. A disaster is the intersection between two opposing forces; those producing vulnerability on one side, and actual physical exposure on the other. The 'release' component involves relieving the pressure and so reducing the effects of the disaster through reducing people's vulnerability. The access model analyses how economic and political pressures generate vulnerability, suggesting how conditions need to change in order to reduce vulnerability and increase people's capacity to recover from a disaster. Risk is the sum of hazard plus vulnerability, and in order to reduce risk the root causes and dynamic pressures that contribute to vulnerability must be reduced. The next chapter presents the methodology of how rainwater harvesting will be analyzed in order to evaluate it within a vulnerability-reduction framework.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 Aims and objectives of the research

Rainwater harvesting has the potential to contribute to the reduction of drought-related vulnerability in rural communities. The effectiveness that rainwater harvesting has, as a risk reduction strategy, to lowering vulnerability in selected rural communities in Botswana is examined using three major objectives:

1. *To determine whether rainwater harvesting enhances livelihood resilience in village lands areas and rural communities, as the result of the installation of ferrocement water tanks.*
2. *To determine the degree to which drought-related vulnerability has been reduced in the Paje and Gabane villages due to agroforestry community-based interventions.*
3. *To determine whether rainwater harvesting and drought-resistant agricultural practices are feasible options and should be further supported in Botswana, as a rapidly urbanizing country.*

4.2 Research methodology

To explore the risk reducing potential of existing community-based rainwater harvesting projects in drought-prone areas of Botswana, three primary data collecting methods were used:

- Key informant interviews
- Focus group interviews
- Direct as well as participant observation techniques.

In the following section, an outline of each research method will be given. The methodological paradigm for this dissertation is predominantly qualitative in nature, where the data collected are integrated and subsequently analysed. This approach was chosen based on the objectives mentioned above and in order to establish a well-rounded, fully coherent objective view of the Botswana livelihoods and the country's future potentials.

4.3 Field research

Information gathered for this dissertation has been collected through a literature review at the Disaster Mitigation for Sustainable Livelihoods Programme (DiMP) at the University of Cape Town. Two separate field visits were also undertaken. The first comprised a rainwater harvesting workshop for southern Africa in Harare and Masvingo, Zimbabwe, in February 1999. The second involved eight weeks of field research carried out in southern and central Botswana during July and August 1999. Research was undertaken while based at the VPR&D site in Gabane, 20km west of Gaborone, and during this time targeted random case studies were carried out and the majority of interviews with communities and key stakeholders undertaken. Fieldwork was undertaken in the villages and lands areas of (see Figure 4.1):

- Moshupa and Polokwe, where the Ferrocement Tank Development Project had been established
- Gabane, where an agroforestry trial plot had been developed
- Paje, where the agroforestry practices had been introduced into a local community context

Detailed maps of village locations are given in Appendix E. Map 1 shows the location of Gabane, Map 2 of Moshupa (written 'Mosopa'), and Map 3 of Paje.

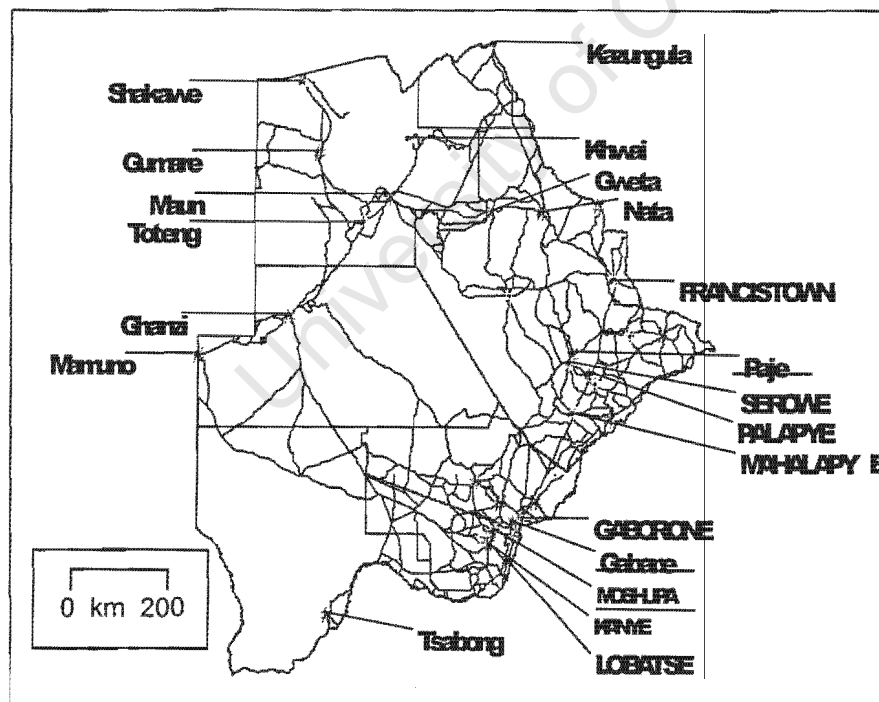


Figure 4.1: The villages of Paje, Gabane and Moshupa where fieldwork was carried out are shown (underlined) on the map of Botswana. Also shown are the district boundaries, the road network and the locations of main towns.

Source: World Resources Institute, 1995.

4.4 Key informant interviews

Four locations in which ferrocement tanks had been built were visited with members of staff from the BTC. These were Bakoko Primary and Kgabophuti Primary Schools in Moshupa and two tanks in lands areas, those of Moshupa Kgotla lands and Polokwe lands. A survey was carried out at all these areas where the pilot project was taking place. The exercise was carried out to get feedback from the users of the water tanks, and on their perceptions and impressions on their water situation since the tanks were built. People were also given the opportunity to voice any problems or concerns that they had experienced or come across.

Conducting rapid appraisal techniques such as key informant interviews offer systematic ways of obtaining information quickly and at low cost. An effective sampling strategy is to identify knowledgeable individuals who can accurately present the layout, practices and history of the school or farm in question; such people are called key informants. The interviews were structured to allow information input in a non-threatening environment. Questions were framed spontaneously, probing for information following some key themes:

- 1. *Introduction and setting of the ferrocement tank locations.***

This introductory section describes the location and arrangement of the ferrocement tanks.

- 2. *Root causes of drought-related vulnerability that increase drought risk***

The root causes of vulnerability that make communities susceptible to drought are presented.

- 3. *Lifestyle, situation and dynamic pressures of drought-related vulnerability at schools and rural households.***

This section presents some of the dynamic pressures that influence the livelihoods of the school or family concerned.

- 4. *Drought-mitigating benefits of the rainwater collecting tanks.***

Successful aspects of the drought mitigation programme are given.

- 5. *Problems encountered and unsafe conditions created by drought-related vulnerability.***

These contribute in helping to create some of the vulnerability and unsafe conditions that people experience.

- 6. *Desires for the future of the risk-reducing, tank development programme.***

Finally, people's hopes are presented for the risk-reducing rainwater harvesting programme.

Guided walks around the school and farm ground presented the opportunity to observe, listen and identify different practices, and to identify problems and possible solutions. Key informant interviews were adopted for this pilot project evaluation work for the following reasons (USAID, 1996):

- The qualitative, descriptive information was sufficient for decision-making.
- There was a need to understand motivation, behaviour and perspectives of the key informants. In-depth interviews of the pilot project participants concerning their attitudes and behaviours about an NGO's activity can be used to help explain its successes and failings.
- One of the main purposes of the research is to generate recommendations and obtaining information can help improve a programme's performance.
- The key informant interviews helped to provide the how and why of what happened and the quantitative data collected can be used to complement data collected from other sources and methods.

Advantages of key informant interviews include that they provide information directly from knowledgeable people, they are inexpensive, and provide the flexibility to explore new ideas and issues that were not anticipated during planning. Some disadvantages of key informant interviews include the fact that they may be biased if the informants are not carefully chosen. The interviews are also susceptible to interviewer biases and it may be difficult to prove the validity of the findings (USAID, 1996). Knowledge is a source of status and wealth and some indigenous peoples fear that their indigenous knowledge (IK) will be misused, and lacking the power to prevent such abuses, they choose to remain silent (Grenier, 1998). This knowledge can also represent power and for this reason some individuals may not be willing to share it with outsiders or even each other.

The selection of key informants included representatives of a wide spectrum of groups, for example, educationalists, women's groups and male-headed households. A teacher at each of the primary schools; at the Moshupa Kgotla lands the women who headed the household, as the other members of her family were living in the nearby village; at the Polokwe lands area, the head male automatically assumed responsibility for answering all the questions.

The interview started with an explanation of its purpose, the intended use of the information and with assurances of confidentiality. The questions started factually followed by those that required opinions and judgements from the interviewees. In general, questions were started in the present and moved onto the past and then the future. While interviewing, it was important to avoid giving the impression of having strong views on the subject under discussion. This neutrality was also beneficial to the

informants, because, while trying to be polite, some of them might simply have said what they thought the interviewer wanted to hear.

The interviews, conducted through a competent Setswana and English-speaking interpreter from the BTC, added further dynamics and difficulties. For example, differences in status between the translator and informant may inhibit the conversation. Using a translator who was not known to the informants minimized this obstacle, and the translator was briefed before the informal interview on the need to repeat the informant's comments word for word. Notes were taken during the interviews and developed in detail immediately afterwards to ensure accuracy. While talking, the reliability of the key informants information was assessed, and notes made of their knowledge, credibility, impartiality, willingness to respond, and the presence of outsiders or NGO staff who may have inhibited any of their responses. A conscious effort was made to look for evidence that questioned other previously received information, thus bringing out issues that may have been overlooked.

4.5 Focus group interviews

These were carried out in the village of Paje, near Orapa, with members of the community whom VPR&D are working with on the CBAP programme. A focus group interview was carried out with four women participating in the project along with the area's EO and an independent translator. The location of the interview was in the office of the EOs house in Paje and it lasted about two hours. Having some degree of privacy, the interview avoided arousing curiosity from other members of the village and reduced the risk of uninvited participants. It was decided on this basis that, for the purposes of the interview, an open-space in the village was not going to be beneficial to the discussions.

A focus group interview is a form of inexpensive, rapid appraisal technique that provides a wealth of information on the performance of the development programme and activities. The author played the part of the facilitator and guided between seven and eleven people in a discussion of their experiences, feelings and preferences about the risk-reducing CBAP programme. The technique was excellent for allowing the facilitator to explore unanticipated issues and it also encouraged interaction among the participants. In a group setting, interviewees provided checks and balances, thus minimizing false or extreme views.

A few limitations of the focus group interviews could include a susceptibility to facilitator bias, which can undermine the validity and reliability of the results (USAID, 1996). A few vocal individuals might also dominate the discussions so every effort was made to include everyone in the conversation. Another limitation was that despite relevant qualitative information being gleaned from the interview,

no quantitative data were gathered from which generalizations can be made for a whole population. Comments were thus analysed in the context of the group setting.

However, for the purposes of the dissertation, focus group interviews are excellent as they:

- Help identify programme implementation problems
- Extract recommendations and suggestions from the participants that are required by analysts and evaluators working in conjunction with an NGO.
- Identify people's attitudes, preferences and requirements.

All of the interviewees were homogenous, that is, they were from a similar socio-economic and cultural background, and all had in common agricultural issues that were relevant to the discussion. The purpose and format of the discussions were outlined at the onset, thus setting the group at ease. The participants were also told that everyone was expected to contribute, that divergent views were welcome, and that the author was independent of VPR&D, so they should feel free to express their views and opinions.

A second focus group interview was carried out with participating members of NGOs in Gaborone as the potential for, and future of, rainwater harvesting in Botswana was discussed. This was held in the offices of the BTC and involved one representative from each organization that the author was working with. It was held during the final week of fieldwork in Botswana once all other material had been gathered, in order that the author had could speak from a position of knowledge and authority.

4.6 Direct and participant observation techniques

Direct and participant observation techniques allow for a systematic, structured process of gathering information in its natural setting, and build up a richer understanding of the subject in question. They also reveal conditions, problems or patterns that were not brought up during the key informant interviews or the focus group interviews, or issues that the informants may not have been able to describe adequately (USAID, 1996). One limitation of direct observation techniques is their susceptibility to observer bias, thus every effort was made to bring impartiality to the observations. This was made easier through conversation with the translator who himself was aware of the aims and objectives of the days discussions.

Direct observation was seen as a useful tool to use for the following reasons (USAID, 1996):

- When problems are suspected with implementation of the projects, but are not understood. Direct observation can help identify whether the project requires more inputs or it is being poorly implemented.

- When an activity needs to be evaluated according to whether it has reached a standard required for effectiveness.
- When a physical inventory or list of inputs is required that cannot be obtained from another source.
- When an interview is unlikely to provide the required information, either because the interviewees don't know or are reluctant to divulge it.

Direct observation was a tool used to complement each interview in the field. Field-based interviews were preferred as these provided on-hand evidence of the projects that were being evaluated, and the observations also complimented or contradicted information gleaned from the interview. Before conducting the field observations, the researcher engaged in informal, friendly conversation to reduce any anxiety that the interviewees may have had. They were also told that the object of the observation was not to evaluate their own performance, but to determine what kinds of successes and problems are being encountered. Time was spent with the targeted interviewees during the week prior to their interview and friendly conversation enabled people to become less self-conscious and natural. The author observed with the help of the Motswana translator as a team can develop more comprehensive, higher quality data, and eliminate individual bias. Non-experts can become good trained observers given an outline of the aims and objectives of the exercise and an understanding of what information was required. All observations were recorded promptly on site using the team of observers (author plus translator) to ensure that all collected data were reliable and valid.

This technique was employed while interviewing:

- Staff workers on the VPR&D farm site
- Participants of VPR&D's CBAP project in Gabane and Paje
- Participants of the BTC's rainwater harvesting programme in Moshupa and Polokwe

4.7 Limitations

As with most surveys and interviews, a number of limitations may arise. The schedule for fieldwork in Botswana was determined by when staff and workers from the NGOs, and governmental and EO personel, were available for consultation and site visits.

Objective 1

To determine whether rainwater harvesting enhances livelihood resilience in village lands areas and rural communities, as the result of the installation of ferrocement water tanks.

Limitations:

- At the ferrocement tank in the Polokwe lands area, the whole family was present though as the Batswana culture dictated, with the men present the women did not take part in the discussions. They remained around the campfire with most of the children. This brought a male bias into the interview.
- Only one member of the family (the head women) was present at the Moshupa lands area for discussions as her family were then living in Moshupa village and she had simply returned to the lands area for one day to clean the rondavels and yard. The family would move there at the start of the ploughing season. This introduced female bias.
- No health data were available from the local clinic on the study areas despite repeated searching.
- Kgabophuti Primary School in Moshupa was visited (on the same day as Bakoko Primary School) but during a school holiday so no face-to-face interview could be carried out. The interview was undertaken later, however, through a phone conversation.

Objective 2

To determine the degree to which drought-related vulnerability has been reduced in the Paje and Gabane villages due to agroforestry community-based interventions.

Limitations:

- Fieldwork was carried out during the dry season winter months of July and August when the effectiveness of the water catching and retaining capacities of the agroforestry trial project microcatchments could not be viewed. Information on this particular aspect, therefore, came through guided walks and consultation with VPR&D staff and workers.
- The two farmers interviewed in Gabane were, at the time of the fieldwork, the only two to have volunteered to participate in CBAP. Since then, a further 6 farmers have become involved (Mateke, 2000, pers com.).
- As a result of holding the focus group interview in the office of the local EO (the interviewees deemed this preferable to sitting underneath a village tree where all the village could gather, which was the alternative meeting place), an element of bias could have crept in. The presence of the EO during the interview could also have influenced to some degree the interviewee's answers.
- Interviews were carried out with an interpreter that inevitably exerted a language challenge, though as near as possible direct translation was carried out.

Objective 3

To determine whether rainwater harvesting and drought-resistant agricultural practices are feasible options and should be further supported in Botswana, as a rapidly urbanizing country.

Limitations:

- Those people who were available both for formal interview and for informal conversation determined the resource base of knowledge accumulated.
- The author acknowledges that there are other NGOs in operation in Botswana, such as Thusano Lefatseng (mentioned in section 2.4) and the Forestry Association of Botswana, that are also involved in drought-resistant projects that were not evaluated in this thesis.
- The Botswana Government minister in the MoA who was available for consultation was a hydrogeologist and he thus brought his particular bias to this key informant interview.
- The thesis is set within the conceptual framework of drought mitigation and the 'pressure and release' model. It is equally possible that the subject matter could be set within the context of other conceptual frameworks such as climate change, environmental impact assessment, rural-to-urban migration and population demographics or the future potential impact of HIV/AIDS.
- One of the challenges for the thesis is to use the available information and apply it on a countrywide level, thus determining whether rainwater harvesting and/or drought-resistant agriculture should be further developed in Botswana.

Despite these limitations a wealth of information on drought mitigation through rainwater harvesting has been obtained, for example, ferrocement tanks in lands areas that provide water into the dry season, stone mulches in agroforestry that aid water conservation, and indigenous and exotic fruit trees that contribute towards food security. These are expanded upon in Chapter 5.

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The research methodology focuses on three main data-collecting mechanisms, key informant interviews, focus group interviews, and direct as well as participant observation techniques. Fieldwork was carried out in the villages of Paje, north north-west of Serowe, and Gabane, Moshupa and Polokwe between Gaborone and Kanye. The next chapter presents the three projects that were evaluated, the ferrocement tank development project, agroforestry and the community-based agroforestry project. They are presented from the perspective of the vulnerability-reduction framework, recognizing the root causes, dynamic pressures and unsafe conditions involved in each project situation.

CHAPTER 5

IMPACTING SEMI-ARID LIVELIHOODS THROUGH DROUGHT MITIGATING APPROACHES

5.1 Introduction

Rainwater harvesting technologies have the potential to impact livelihoods and mitigate drought. The fieldwork visits and key informant interviews focus on the livelihood impacts of ferrocement tank technology in Moshupa and Polokwe (Section 5.2 and Appendix A), the drought-reducing impacts of agroforestry (Section 5.3), and the impacts of community-based agroforestry (Section 5.4 and Appendixes B, C and D).

5.2 Focus on ferrocement tank rainwater harvesting in Moshupa and Polokwe

The impact of ferrocement tank rainwater harvesting was explored at the following sites (see Figure 4.1 for the location of Moshupa; Polokwe is approximately 20km from Moshupa):

- Bakoko Primary School, Moshupa
- Kgabophuti Primary School, Moshupa
- Kgotla Lands Area, Moshupa
- Polokwe Lands Area

As mentioned in Section 4.4, both Bakoko and Kgabophuti Primary Schools, and the Kgotla and Polokwe lands areas were explored under the following six headings:

- Introduction and setting of the ferrocement tank location.
- Root causes of drought-related vulnerability that increase drought risk.
- Lifestyle, situation and dynamic pressures of drought-related vulnerability at schools and rural households.
- Drought-mitigating benefits of the rainwater collecting tanks.
- Problems encountered and unsafe conditions created by drought-related vulnerability.
- Desires for the future of the risk-reducing, tank development programme.

Summaries of the interviews can be found in Appendix A with corresponding plates below, while the findings are also consolidated and summarized in table form in Section 5.2.1.

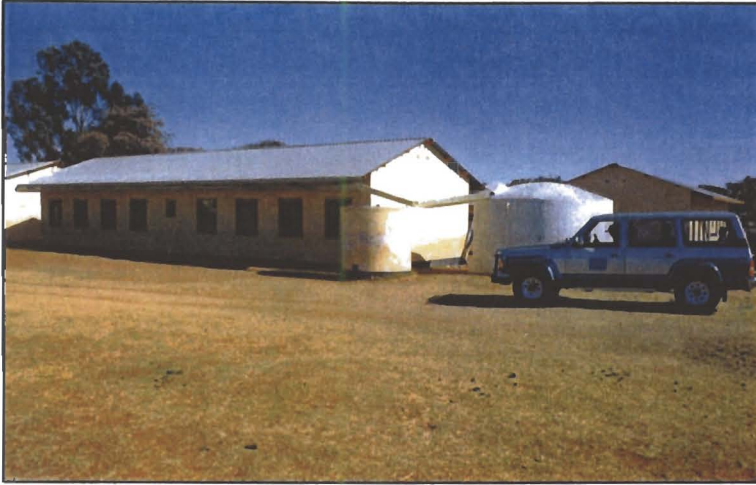


Plate 5.1: Ferrocement tank and old galvanised steel tank at Bakoko Primary School

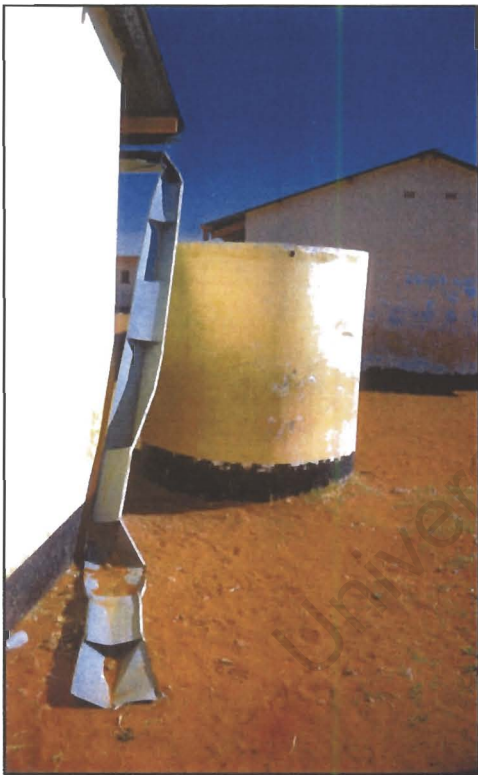


Plate 5.2: The broken aluminium gutter between the school roof and the ferrocement tank, Bakoko Primary School



Plate 5.3: Bakoko Primary School vegetable garden fed by rainwater collected from the RWCS

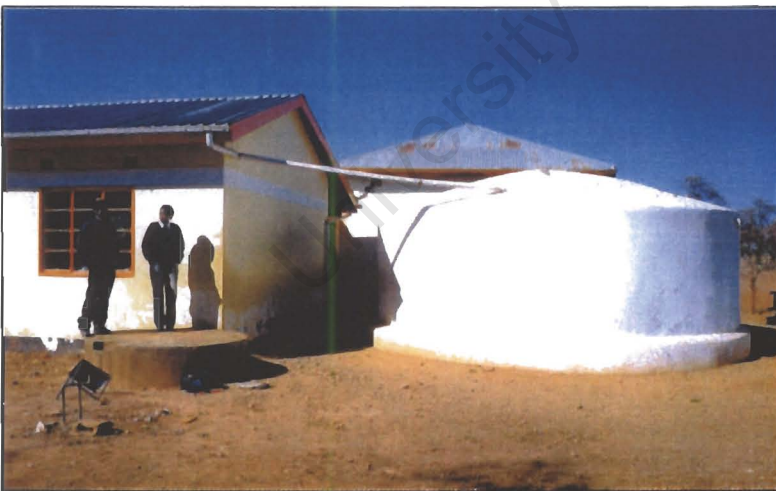


Plate 5.4: Members of the BTC beside Kgabophuti Primary School's ferrocement tank



Plate 5.5: Mrs Ntebogang (centre) with members of the BTC beside the rainwater catchment roof and ferrocement tank, Kgotla lands area



Plate 5.6: Members of the BTC beside Mr Kgopiso's (centre) rainwater catchment roof and ferrocement tank, Polokwe lands area

5.2.1 Summary table for the Ferrocement Tank Development Programme: Table 5.1 summarizes the site visits.

Location	Setting & root causes of drought-related vulnerability	Lifestyle, water uses & dynamic pressures of vulnerability	Drought- mitigating benefits of the tanks	Problems & unsafe conditions of drought-related vulnerability	Desires for the future and risk reduction
Bakoko Primary School, Moshupa	500 pupils from Moshupa, served by one 23 m ³ tank built in 1996. Counteracts against a commonly dry or broken standpipe and supplements supply.	Cooking, washing, drinking, bathing, vegetable garden. If no water: 1km walk to Moshupa twice a month. Health improves, teacher reported less cases of diarrhoea.	Improved health evident from washing after the toilet. Good tasting water, non-rust, robust tanks. Agricultural garden mitigating low food security.	Flimsy, broken aluminium guttering, leaks, thus no rainwater collected creating unsafe conditions. No food could therefore be cooked, or cleaning or washing done.	More tanks are desired –crucial role in reducing drought risk as the village standpipe often runs dry or has problems. Improves livelihood.
Kgabophuti Primary School, Moshupa	600 pupils, 96% from Moshupa, 4% from the Lands. Two 46 m ³ tanks, built in 1996, though one not connected up. Failure of standpipes and water insufficiency.	Kitchen washing and gardening. The tanks and school/village standpipes reduce dynamic pressures on water provision.	Gardening and spinach sales to community; money subsidizes activities. Rain heavily relied upon; sole supply for cooking, drinking if village reticulation supply breaks down.	Tanks too small for demand, creating unsafe conditions. 10m section of plastic guttering warped in the heat and not collecting water. Asymmetrical roof, so water can only be collected off one side.	Scheme should be expanded into an official programme on top of the Government's reticulated supply. Teacher's quarters also in need of facilities.
Moshupa Lands Area	Root cause; great distance from water, 5km to a natural spring, 15km to Moshupa. 11 m ³ tank, serves one female-headed family of 11. Built in 1996.	Water used for vegetable gardening, domestic use and watering animals. Unreliable, erratic rains; no crops planted in 1999. Low food security, people vulnerable.	Rain the only source of water during the ploughing season. Supply has never run out since installation. Neighbours also often use supply.	Tank never full as a result of poor rains. Before installation, the spring was 5km away. No activities for children at the lands, females dominate while the men work in town.	Great demand among neighbours for the same technology. Survival on the lands would be virtually impossible without it.
Polokwe Lands Area	Drought conditions prevailed, but contact with a farmers group brought in RIIC to install the 11 m ³ tank. Male-headed family of 23 of which 15 are children.	Tank currently empty so a donkey cart travels to Polokwe 4km away to collect water. Pressure on the family (5 adults, 8 children) to collect water 3 times a week.	Full tank lasts 6 months. Children do not suffer the same illnesses they had before the tank, e.g. diarrhoea. Water more palatable; is not chemically treated.	No grate on the gutter intake opening means leaves enter. Cleanliness cannot always be guaranteed though tank cleaned out when empty.	Tank is helping to reduce the risks of unsustainable living at the lands area and is highly prized and sought after.

Table 5.1: Fieldwork visits for the Ferrocement Tank Development Project, analyzed through the conceptual framework

5.2.2 Rainwater harvesting as a risk-reducing technology in Moshupa and Polokwe

In each of the four locations visited, the recipients have benefitted when rain has been present in the tanks and the RWCS has worked correctly. During these periods their vulnerability to breakdowns of the nearby village reticulated water system and standpipes is lessened. At Bakoko and Kgabophuti Primary Schools, the presence of on-site, available rainwater enables activities such as cooking, washing and vegetable gardening to be carried out with ease, without having to either rely on the local standpipe or, if that is out of order, fetch water from the village. Bakoko Primary School has seen a decrease in cases of diarrhoea resulting from children washing their hands in water provided by the rainwater tanks after they visit the toilet.

In the lands areas where the ferrocement tanks are being piloted, there would be no on-site water supply if it were not for the RWCS. Water at the Moshupa lands area would have to be collected either from an underground spring 5km away or from Moshupa itself 15km away. The village standpipe in Polokwe is 4km away from the lands area visited. Communities feel that their vulnerability to water stress has been lessened with the tanks and that this has enabled them to continue living in drought-prone areas.

There are several problems associated with the pilot project. The aluminium guttering installed at Bakoko Primary School is experiencing structural problems and has been blown down, rendering the RWCS currently inoperable. At Kgabophuti Primary School a 10m section of the plastic guttering has warped in the heat and this has been responsible for wasting otherwise collectable rainwater.

The tanks in all four locations have never been totally full of rainwater as a result of the erratic and unreliable rainfall. There was no rainwater at the Polokwe lands area during July and August 1999 when the site was visited. Therefore, risk reduction in terms of food security and water availability only operates during and for a period after the rainy season, depending on how quickly the water is used. However, food insecurity and drought-risks can again return during extended dry periods. A predominance of women and children occur at the lands areas and this is because many of the men work in town and so are not available to offer their skills, labour and time to their family's agricultural farms.

5.3 Agroforestry Initiatives

"Let us look at innovative agriculture to improve the agricultural potential for subsistence farmers," (Taylor, 1999, pers com., quoting the Ministry of Agriculture)

One approach for increasing soil moisture retention in semi-arid and drought-prone communities involves a suite of microcatchment technologies. These methods aim to effectively catch and conserve water thus increasing the yields of the crops or trees planted and soil productivity. This in turn improves the sustainability of agriculture in areas that experience erratic rainfall. In exploring the role of the rainwater harvesting practices that help to mitigate drought, the following microcatchment technologies were analysed and examined:

- Agroforestry Initiatives featuring microcatchment bunds lined with stone mulches
- Effectiveness of the agroforestry catchments
- Microcatchments with earth-constructed bunds
- The Trickle system
- The Serpentine irrigation system
- Spherical microcatchments with earth bunds

5.3.1 Agroforestry Initiatives featuring microcatchment bunds lined with stone mulches

A Morula (*Sclerocarya birrea* subsp. *caffra*) orchard planted in 1990 at VPR&D in Gabane was adapted to incorporate an agroforestry trial plot during 1995/96. The plot is shown in Plates 5.7 and 5.8 and Figure 5.1. During the first year of the project, the semi-circular microcatchment bunds around the indigenous fruit trees remained at a diameter of 1m and without any form of mulch on them. For the second year, stones were added to the inside of the microcatchment and their diameter was increased to 1.5m in diameter. The flat stones, each approximately 4-500cm², were put in with 30mm gaps between them. There are two reasons for the use of a stone mulch. First, it keeps the weed growth down resulting in less competition for moisture for the crops and trees. Second, the stones reduce the levels of evaporation from the soil. The stone mulch must be laid on the outside edge of the drip line, in order that water running off the tree will feed the roots.

For a grass mulch, when a hand is put over it during winter, it feels cool and contains dampness from the movement of water out of the soil. During summer, however, the mulch keeps the soil cool which is extremely important for the microflora that provide nutrients to the feeding roots (Taylor, 1999, pers com.). No grass mulch is currently used in the agroforestry trial, but it could potentially be present during summer and then removed during winter.

There are two major disadvantages of stone bunds. The first disadvantage involves small or young trees that have narrow drip lines and thus narrow shade areas. During the summer, the

stone mulch heats up the soil as a result of there being no or very little shade, and the hot soil then kills the microflora upon which the roots are feeding. It is therefore proposed that stone mulches should only be used when there is an adequate amount of leaf cover. For vigorous growing trees, this could be as early as the second year of growth. During the first year of Morula growth, a grass mulch is used which is then replaced with a stone mulch at the start of the second year. The second disadvantage arises after 3-4 years when a large quantity of nutrient-rich silt has built up on the stones and the roots cannot utilize this. This silt is prone to desiccation, nutrient leaching and colonization by weeds. Consequently, stone mulches should be removed after five years (Taylor, 1999, pers com.). An example of a stone mulch around a citrus tree is shown in Plate 5.9.

At present, when holes (dimensions: 70 x 70 x 70cm) are dug to plant trees in, the topsoil is used to construct the surrounding bunds. This effectively takes nutrients out of the system and an alternative method is proposed. When the trees are planted, the nutrient-rich topsoil from the hole is put in at the bottom of the hole around the roots to kick-start their growth, while the subsoil is used to construct the bunds. This would be important in marginal soil areas where soil nutrients are scarce.

In 1991, stone mulches were constructed around the trees and they grew very vigorously in comparison to a nearby Morula tree planted in 1988 that had a plain earth bund and a 6 x 12m catchment area (approximately the same area as the orchard Morulas). By 1993 this lone Morula tree had significantly stunted growth and it was one third of the size of those trees planted in the orchard. One variable to be taken into account, however, was the fact that the earth-bunded tree was not grafted, whereas those in the orchard were. Grafting is when a seedling is joined with a piece of stem from the choicer superior tree to ensure the transfer of preferred characteristics and that the sex of the resulting seedling is female. This is important as trees planted for fruit production need to be female. A grafted tree normally produces twice as vigorous growth compared to an ungrafted tree. However, within one year of adding a stone mulch to the ungrafted tree, its growth had increased by 50% and within two years it was almost 100% higher than from the time of mulch addition. Its growth was thus significantly enhanced with the stone mulch, reaching double the height than with the earth bund (Taylor, 1999, pers com.).



Plate 5.7: The agroforestry initiative; stone-lined microcatchments 1.7m wide around Morula and Morutla trees, with tied ridges surrounding holding bays 1.4m wide by 1.0m deep.



Plate 5.8: The agroforestry project; contoured rows of fruit trees and tied ridges where traditional crops such as sorghum and cow peas are grown.



Plate 5.9: Stone mulch around a citrus (lemon) tree.

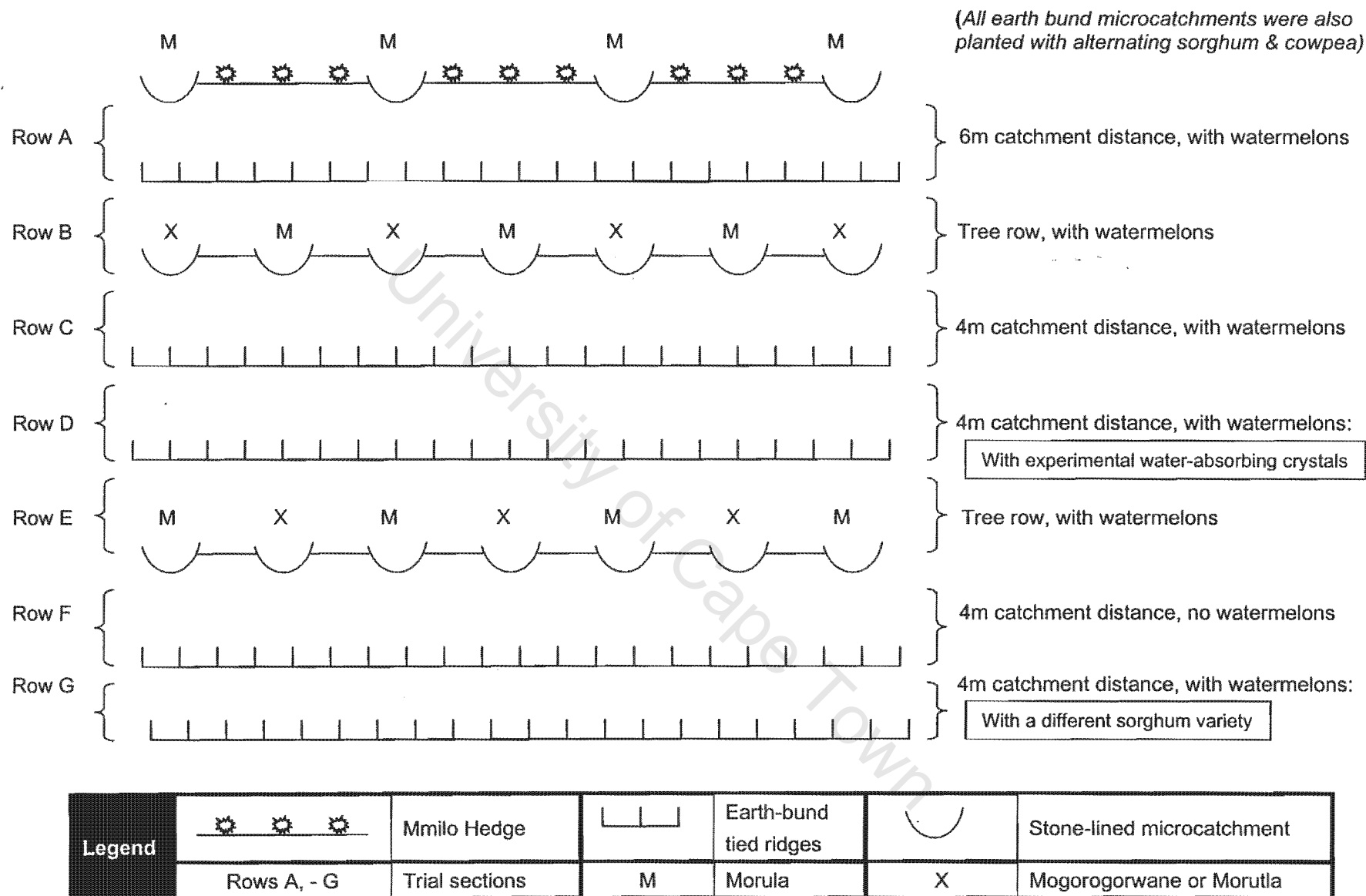


Figure 5.1: Layout of the Agroforestry Trial Project

Source: Berkhout, 1997 and Taylor, 1997

5.3.2 Effectiveness of the agroforestry catchments

With 10 mm of intense precipitation over 20 minutes, both the macro- and microcatchments overflow and the overflow channels between the trees would begin to operate. With 10 mm of rainfall over 4-5 hours, only the macrocatchment overflows and the microcatchments fill up to within 50-75% of full capacity. Soil water penetration is thus more effective with longer, more prolonged rainfall, and after 1.5 hours of rainfall cessation most of the water in the tree holding areas has soaked away. In order to maximize the volume of runoff, the catchments should be kept free from any significant plant growth.

Traditional crops such as sorghum and cowpea were also planted in the tree holding areas and on the bund sides, see plate 5.10. The crops grew well during the good rains in the first year of the experiment compared to those in a nearby control plot (Taylor, 1997). A probable significant factor in the relatively high yields was the high concentration of nutrient-rich soil on the bund sides (no fertilizers are added to the trees). This accumulates through the mulching of crop residues and through nitrogen fixation from the leguminous cowpeas. After the harvest, crop residues are slashed and left as a mulch on the cropping area, in which the next year's crop will be planted. Sorghum and cowpeas are grown in a yearly rotation and through mulching both the leguminous crops and tree leaves, the soil structure and fertility improves. By growing watermelons, the productivity of the agroforestry system is increased, but the trade off may be a decreased runoff to the main crops.

Evidence of the effectiveness of the agroforestry system is presented in section 7.3.1 where the yields of cowpeas and sorghum crops grown in the microcatchments are compared with a control plot comprising only ploughed land.

5.3.3 Microcatchments with earth-constructed bunds

Many farmers do not have stones on their lands and so resort to the use of earth bunds. The establishment of earth bunds in the original Morula orchard turned it into an agroforestry site. The earth bunds form tied ridges on the earth bund contours that join the indigenous fruit trees. Tied ridges are contour ridges with cross ties, these comprise short earth bunds constructed perpendicular to a contour bund or ridge on the upslope side and protruding at least 2m upslope. These are normally spaced at 2-10m intervals on the contour ridge or contour bund to subdivide them into microcatchments and ensure even storage runoff (Gould, 1999).

During heavy rains, the water-retaining bund walls can experience overflows and breakthroughs. Therefore, by increasing the height of the retaining wall or by decreasing the height of the tied ridges, the water is encouraged to flow laterally. Stones should also be put on the end corners of the contour ridges thus ensuring the water does not erode back into the ridge.

Four native tree species: Morutla (*Strychnos spinosa*), Morojwa (*Azanza garckeana*), Mmilo (*Vanguaria infausta*) and Mogorogowane (*Strychnos cocculoides*), were also incorporated into the agroforestry project and one of these was planted in each holding area delimited by the tied ridges. The earth bunds, initially built to a height of 40cm, subsequently self compact to 30cm. Plate 5.11 similarly illustrates an Early Peach tree with an earth microcatchment area on the VPR&D site. The drip line of the tree corresponds to the circumference of the microcatchment and the earth bund surrounding it.

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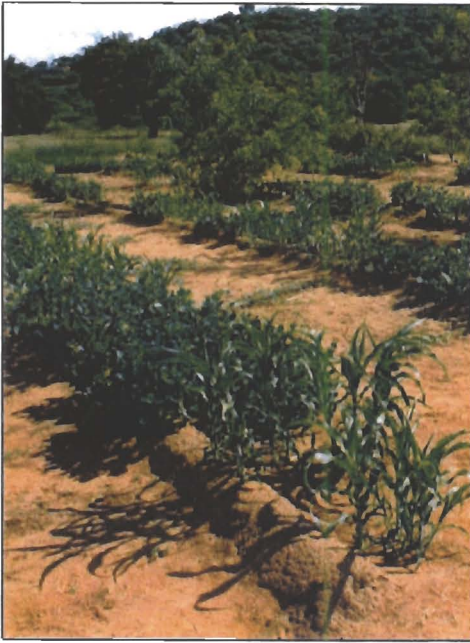


Plate 5.10: Traditional crops such as sorghum and cowpeas grow on the microcatchment bunds of the agroforestry project during the wet season.

Plate courtesy of VPR&D.



Plate 5.11: Earth microcatchment around an Early Peach tree.

5.3.4 The trickle system

This is a method widely practised on the VPR&D site and involves inserting clear, 2 litre plastic bottles into the topsoil by the stem of the exotic or indigenous fruit tree. The bottle is positioned 20° off the vertical and water is allowed to trickle out of a small bore made in the side of the bottle. While evaluating the system, three problems have arisen.

- The top shoulders of the bottles were found to have broken and decomposed in the ultra-violet (UV) light. This can occur after only 6-8 months of use before the cracked bottles require replacement. However, the system remains immensely valuable, as the bottles are only necessary during the first year of growth until the start of the first rainy season.
- Some bottles were found lying on the ground surface where they had remained since the last heavy rains. When the bottle is initially buried at the start of the first rainy season, the soil around them requires proper compaction because after good rains with a holding area full of water, the empty bottle can pop out the ground. However, if the soil is compacted too much the bottles can be compressed.
- Evidence was found of water in the topsoil around the bottle after filling. When replenishing the bottle with water, skill is required so not to incur any wastage, but this is difficult without a siphoned hose that was not currently in use on the site.

Farmers viewing the practice at the Gabane site obtain the opportunity to view and compare the trickle system at work in both indigenous and exotic trees. It has been found by VPR&D staff that the indigenous trees grow more effectively with the trickle system, and this experience is brought to the attention of visiting farmers and communities (Taylor, 1999, pers com.).

5.3.5 The Serpentine Irrigation system

This newly developed irrigation system was built during the 1999 dry season and consists of a continuous stone-lined, S-shaped irrigation channel 15m long with multiple bends. (The original Serpentine Irrigation System was earth-lined and was developed during the 1996 wet season, see plate 5.12. It was constructed around a line of indigenous Mmupudu (*Mimusops zeyheri*) trees, planted on the 13th November 1995, that predominantly grow on granitic soils).

The earth-constructed sides of the system were then lined with flat stones, each separated by a width of 1-2 fingers (15-30mm) to allow water to soak into the soil, see plate 5.13. The irrigation canal is fed from a macrocatchment that essentially comprises a gravel road with a gentle downslope gradient. This road is not only effective in transporting runoff but unfortunately also gravel that is swept into the system and the upper six holding bays. These have consequently become swamped in gravel with the resulting burial of the young Mmupudu seedlings. However, a sand trap or settling basin built at the top end of the system would effectively eliminate this

problem. Two Mmupudu trees currently growing on a flat sandveld area near the lower farm net house are experiencing vigorous growth so perhaps they would also grow well if established on the sandveld.

5.3.6 Microcatchments with earth bunds

Spherical microcatchments have been established around *Combretum* species near the site of the first large orchard on the farm site, see plate 5.14. The microcatchments are approximately 0.85m in diameter and 0.10m high, with each species planted 1.45m from the next one. A narrow break in the bund wall occurs on the upslope side of the microcatchments to allow the flow of water by gravity towards the plant. The microcatchments work successfully for small shrubs that have a high planting density (species 1.45m apart) and have a narrow drip line.

Semi-circular microcatchments occur nearby and are each 1.20m deep by 2.0m wide, with earth bunds 0.20m high. They receive runoff from a nearby orchard and off a catchment area between 2-3m long that has been cleared of vegetation, see plate 5.15. Note within this plate, that new tree seedlings in black plastic bags are being raised for sale to community residents and farmers. Behind them is a net house offering shade to various degrees (25%, 50% and 75% depending upon the weave of the net) to younger saplings that are being propagated.

5.3.7 Agroforestry initiatives contributing to drought mitigation

The agroforestry initiatives have established an environment for the growth of both indigenous and exotic fruit trees in the semi-arid hardveld setting of Gabane. Through the agroforestry project, indigenous trees planted in earth-bunded microcatchments, together with crops such as cowpeas and sorghum, are grown. Microcatchments that are lined with a stone mulch offer the best water-capturing method for growing fruit trees.

Agroforestry technologies include building earth- and stone-bunded microcatchments with upslope rainwater catchment areas, serpentine irrigation systems, and using the trickle system as a means of regulating the watering of fruit trees. These demonstrate the potential for farmers to improve their rainwater capture, soil moisture conservation and tree-watering practices. The potential exists to improve food security through practices such as mulching and intercropping that increase the level of nutrients for both leguminous crops and trees.

The initiatives demonstrate that an increased level of food security could be provided not only for farmers but also village residents who wish to supplement their food source with fruit harvested from trees planted in their yards. Through the adoption of such practices, the potential exists to lower people's vulnerability to periods of reduced rainfall through successfully capturing, conserving and then utilizing the rainfall that does occur.



Plate 5.12: The original earth-bunded Serpentine Irrigation System during the wet season in 1996.

Plate courtesy of VPR&D



Plate 5.13: The earth-bunded Serpentine Irrigation System in 1999; with the added stone catchment system.

The water channel is 0.25m high, between 1.3-1.5m wide, and there is a 0.05m height decrease between each circle in the plate. The water flow direction is from right to left. Note also the aloes within spherical stone microcatchments behind the irrigation system.



Plate 5.14: Spherical microcatchments each 0.85m in diameter with openings facing upslope to catch runoff for the *Combretum* species (Dry season, winter photograph)



Plate 5.15: Semi-circular microcatchments holding (from far right to left): *Anona* (Custard Apple), *Vangueria* sp. (Wild Medlar) from Tanzania, White Sapote (Mexican Apple), *Mmupudu*, *Vangueria* sp.

5.4 Community-based agroforestry initiatives

"There is a great need for VPR&D's agroforestry project knowledge to be transferred into village communities, to primary and secondary schools, and to innovative farmers around Botswana" (Miriam Kobo, VPR&D's CBAP coordinator, 1999, pers com.).

5.4.1 Introduction

The community-based approach works on the principle of encouraging farmers to have their own 'on farm plots', 50m x 50m in size, where VPR&D works with them to establish an agroforestry project on their land. VPR&D promotes their own practices as well as acknowledges the farmer's own experiences. The agroforestry project is also practised at schools where plots similar to the trial plot are established with trees and intercropped maize, sorghum and cowpeas. The CBAP project is currently being run at schools in the villages of Gabane, Paje, Thabala (south of Serowe) and Lecheng (south-east of Palapye).

The project's objective is to support households and communities and after harvest time, to increase food security and provide families with a means of income generation. Meetings are arranged where all the farmers, school representatives, EOs and village headmen meet and discuss what would be appropriate for the community. It is envisioned that the children taught at the schools will transfer the information to their parents who will themselves in turn improve their food security by learning about the techniques available.

For example, one of the indigenous trees that CBAP's participants are encouraged to grow is a grafted Morula that VPR&D supply to them. With propagated, grafted Morulas, the fruit's taste and quick maturation period can be accurately determined. The fruit produced can be used both to increase the family's food security and for selling any surplus to community members, a local trading store or a marketing network. A grafted female Morula tree will start producing fruit three to five years after being planted in the field whereas an ungrafted female tree can take 10 to 12 years (Sunstrum, 1999). The trees that are planted are usually scarce in the villages and this community-based approach therefore aims to reintroduce particularly many indigenous species. They are grown for their fruit, market value, and medicinal use, as well as for crop windbreaks. The uses of selected indigenous fruits are given in Table 5.2.

Tree species	Scientific name	Use
Neem	<i>Azadirachta indica</i>	Used to control pests and for shade
Moneperepe	<i>Cassia abbreviata</i>	Medicinal role, antibiotic for body diseases
Mmupudu	<i>Mimusops zeyheri</i>	Fruit tree
Moretlwa	<i>Grewia flava</i>	Wild berry tree
Mogagwa	—	Mogorogorwane family; wild monkey orange family
Morama	<i>Tylosema esculenta</i>	Ground creeper planted between bunds that has a peanut-like fruit and is often eaten roasted, contains a higher oil content than a peanut.

Table 5.2: The uses received from a selection of indigenous fruit trees

Source: Taylor, 1999, pers com.

This section will present the results from the following:

- Group interview with Paje farmers (Section 5.4.2)
- Direct and participant observation of the Paje lands plots (Section 5.4.4)
- Key farmer interviews in Gabane village (Section 5.4.6)

5.4.2 Group interview with Paje farmers

Four women farmers that VRP&D are working with under the CBAP scheme in Paje were interviewed along with the village's Agricultural Demonstrator (AD), Masego Kalakawe. The women who have developed 'on farm plots' are:

- Dilwana Keibonge
- Bareri Radithipa
- Flora Olwedswe
- Keikotlhae Osupile.

The interview was carried out with prepared questions with openness to new topic areas that were explored as the interview took place. A VPR&D site worker provided interpretation of the interview from Setswana to English and vice versa. The following questions were asked during the group interview:

- How did you meet VPR&D and when?
- What provides your source of water?
- Has watering become an inconvenience? Has interest in the project been maintained?
- What is your assessment of the work that VPR&D is carrying out? Is more input required?

- Would you like VPR&D to help with the drought-mitigating aspect of the project?
- What do other villagers think of these livelihood risk reduction projects? Are they likewise keen to become involved?
- Have you heard of, or applied for, the ALDEP rainwater collection scheme?
- To the AD: what is the root cause of people's problems and is there a future in lands agriculture?

Summaries of the interviews can be found in Appendix B, while the findings are consolidated and summarized in table form in Section 5.4.3.

5.4.3 Table of the Group Interview with Paje Farmers

Table 5.3 summarizes the results of the group interview with the farmers in the village of Paje.

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Question	Responses
How did you meet VPR&D and when?	VPR&D held a meeting for the village at the Kgotla in 1998 and presented the CBAP scheme. The 'on farm plots' were introduced and the participant's role and ownership were discussed. Great deal of initial interest shown but few project commitments due to active participation required.
What provides your source of water?	1. Village standpipe 15km away; collected by donkey cart. 2. Village standpipe 10km away, water also collected by donkey cart. 3. Hires a donkey cart at 10 pula for 210 litres of water taken 5km to the lands area. Expensive and infrequent watering. Under the impression that bottles were to be provided for the trickle system. 4. Hires a donkey cart to transport water 25km; great inconvenience as one night's sleep at the lands is required and it clashes with village social occasions.
Has watering become an inconvenience? Has interest in the project been maintained?	1. The large transportation distance is inconvenient and expensive. Pressure not to allow the project to deteriorate. Real interest, anticipation and love for the project. Concerned about collapsing thatch shelters and ants. 2. Distance is not a problem and she fills up the 2-litre trickle system bottles. Would hire out her donkey cart to other farmers for a fee. 3. Watering carried out twice monthly as VPR&D recommended, and the drought-resistant qualities of indigenous trees benefit over exotics. 4. Watering twice monthly but recently more irregular due to moving to the village from the lands.
What is your assessment of the work that VPR&D is carrying out? Is more input required?	Great benefit obtained from a workshop held by VPR&D in Gabane and from an organized field day in Paje itself. Very positive experience, with contact details given should issues arise.
Would you like VPR&D to help with the drought-mitigating aspect of the project?	An appeal was made for water assistance and for labour- and time-reducing mechanisms. With more water the trees would grow better as the farmers believe they grow well in the area. A solution to a white ants problem is also required.
What do other villagers think of these livelihood risk reduction projects?	Some villagers are amused and sceptical, while others turned down the offer of assistance upon hearing that active participation was required. Others started the project well and then withdrew.
Have you heard of, or applied for, the ALDEP rainwater collection system?	Applications have been made to ALDEP for fencing materials and ploughs (1 st and 2 nd priorities). Three of the women had heard of RWCS and were making them their next priority.
To the AD; what is the root cause of people's problems and is there a future in lands agriculture?	"Farming is not dying out but the problem is that there is no rain. People are resultantly not interested in farming any longer". The AD had been in Paje for the last three years, though finds her work very difficult with 750 farmers to attend to and no vehicle has been provided to assist her.

Table 5.3: Summary table of the group interview with Paje farmers

5.4.4 Direct and participant observation of the Paje lands plots

Informal conversational interviews were held with each farmer on their lands 'on farm plot'. The results are presented in Appendix C for each of the four women, with their corresponding plates below, and their responses are summarised in Section 5.4.5.

5.4.5 Table of the alleviation of drought-related vulnerability from the Paje lands plots

Table 5.4 summarizes the results of direct observation from the 'on farm plots' in the Paje lands area.



Plate 5.16: A Morojwa tree with cleared microcatchment on Dilwana Keibonge's plot. From left to right: Dilwana Keigonge, Vuyo (translator), Flora Olwedswe, Bareri Radithipa, Masego Kalakane (AD), Keikotlhae Osupile and J Tsapisa.



Plate 5.17: A Mogorogorwane tree protected under a thatch shelter on Dilwana Keibonge's 'on farm plot'. From left to right: Dilwana Keibonge, Bareri Radithipa, Johanna Tsapisa (driver), and Keikotlhae Osupile.



Plate 5.18: Flora Olwedswe on Dilwana's 'on farm plot' by an indigenous tree fed by a trickle system bottle and within a circular earth microcatchment.



Plate 5.19: Bareri Radithipa (front) on her 'on farm plot' by an indigenous tree protected from the winter cold by a hessian sack. The trees were planted in a line to form a windbreak for an adjacent field.

Farmer	Summary of the problems associated with the alleviation of drought-related vulnerability of the 'on farm plots' in the Paje lands area.
Dilwana Keibonge	The trees were successfully growing with semi-circular earth bunds around them, receiving water via the trickle system. This works well apart from the bottlenecks cracking in the intense UV light and the water-refilling hole becoming clogged with grass and soil. Some problems are arising from re-shooting Mopane trees previously cut down and grass growing on the catchment areas (a dynamic pressure). Food security will be enhanced though diurnal temperature extremes and a lack of rain (root causes) are contributing to unsafe conditions for the trees.
Bareri Radithipa	Chairperson of the farmers committee, the trees were in excellent condition and benefit from a nutrient-rich, black earth and winter cold protective measures such as white hessian sacks and thatch shelters (winter mitigating features). No microcatchments or trickle system water bottles were present. Instead, runoff flows off adjacent fields. The last good rains occurred in 1996 and the land is currently under great pressure to provide for the family and give them food security. Poor rains fell during the 1999-planting season, and were insufficient to warrant a planting of any vegetables. This has increased the family's vulnerability and could translate the drought-prone land as a root cause into unsafe living conditions for the family
Keikotlhae Osupile	The farm plot was discovered overgrown with grass with signs that a small animal had entered under the fencing and eaten some of tree's leaves. The Mogorogorwane trees in particular appeared to be suffering from drought-stress (a root cause), though most of the trees were in the process of being planted. Signs of farmer disinterest as a result of a prolonged illness that has meant her children now maintain the plot. Illnesses can contribute to the dynamic pressures that people face meaning that less energy and motivation is available for normal activities and agriculture
Flora Olwedswe	The land was well cleared of grass allowing for the free flow of water towards the trees. The sandy soil has prevented the securing of the fencing materials and cattle, as a result, have been able to gain access to the plot and had eaten most of the trees. These are dynamic pressures that are in need of attention so the project can continue and no unsafe conditions, such as reduced food security, will develop. Assistance from VPR&D would be welcome. Monthly visits are made to the site though no microcatchments or water bottles have been installed yet.

Table 5.4: Summary table from direct observation of the 'on farm plots' in the Paje lands area

5.4.6 Key farmer interviews in Gabane village

VPR&D are currently working with two innovative farmers in Gabane:

- Mr Nnwi
- Mr Sekgee

VPR&D approached farmers in the village, indicating that they wanted to do some research on people's land and the above men indicated an interest in the project. VPR&D personnel provided translation. At the start of the interview, it was stressed that the interviewer was coming as an independent researcher and was not there on behalf of VPR&D. This encouraged the interviewee to speak openly and truthfully about the project, and to voice any fears or problems they had.

The questions asked during the interviews were as follows:

- How did you become involved in CBAP?
- What watering regime do you work with?
- What maintenance work is carried out on the plot?
- Do you think the project will succeed and lower vulnerability to drought? (It was explained to the farmer that by growing fruit trees, he was increasing his food security, and so lowering his vulnerability to drought).
- Where is the water source and is watering an inconvenience?
- Is VPR&D supporting or monitoring you throughout the project?
- What do other community residents think of the drought-resilient enterprise?

The results, contained in Appendix D, are also presented in summary table in Section 5.4.7

5.4.7 Summary table of the key farmer interviews in Gabane

Table 5.5 summarizes the results of the 'on farm plot' interviews with Mr Nnwi and Mr Sekgee from Gabane.

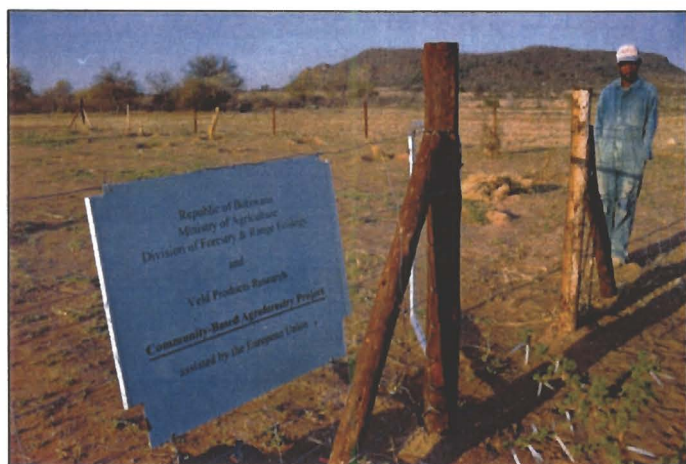


Plate 5.20: Mr Nnwi beside his 'on farm plot' in Gabane



Plate 5.21: Moses Ketshabile by a banana tree on Mr Sekgee's 'on farm plot' in Gabane. A citrus tree (orange) grows in the foreground with a white grape vine growing under the wooden frame.

Farmer	Mr Nnwi	Mr Sekgee
How did you become involved in CBAP?	Mr Nnwi, who held some land in the village and worked as a builder for VPR&D, became involved in Nov. '98 when he was invited to take part. The plot, 35 x 30m in size, had 30 indigenous trees planted on it. If the project is successful, the farmer can keep possession of the trees.	VPR&D's CBAP representative for Gabane approached Mr Sekgee in Nov. '98 and proposed the idea. An exotic orchard was already being planned so a combined orchard with indigenous trees in as well was initiated. An open day at VPR&D's site was attended before starting.
What watering regime do you work with?	No strict regime is worked to, and watering is done when signs of wilting appear. The trickle system has just been introduced and more bottles are required, despite disintegration due to intense UV-rich sunlight.	Watering is carried out three times a week with each tree receiving 15litres of water. This continues for the first year until the trees are established.
What maintenance work is carried out on the plot	Catchments were constructed around trees with openings facing upslope to catch runoff. Thatched tree shelters are built, weeding is carried out, and vegetables such as water melon and sorghum are intercropped with the trees.	Mr Sekgee frequently inspects the plot and has also planted exotics and white grape cuttings taken from VPR&D stock. Intercropping, a self-initiative is also carried out in or around the semi-circular catchments.
Do you think the project will succeed and lower vulnerability to drought?	Great potential to succeed, but some of the trees are already dead from suspected parasites and ants. Increased food security during low rainfall periods.	Proceeding very well, the exception being the death of the Mogorogorwane trees; a difficult species to propagate. Increased food security.
Where is the water source and is watering an inconvenience?	The free village standpipe, used when the project began, was always busy with queues, so the private water source was considered more attractive. Water bills are 25 pula per month; considered expensive but a worthwhile investment. No watering inconvenience or pressures as family members lend assistance.	Water (communal and therefore free) is collected by donkey cart from a standpipe in Gabane 5km away. The work is strenuous, as the donkeys are often not fit enough as a result of the poor grazing.
Is VPR&D supporting or monitoring you throughout the project?	VPR&D monitors once a month and have suggested maintenance ideas. A binding agreement indicating the length of time VPR&D would like to carry out research for would be useful.	More regular visits are required as some of the trees die and it is hard to get word to VPR&D. Monthly visits occur during the growing season.
What do other community residents think of the drought-resilient enterprise?	The community is interested and would like the project on their land but is simultaneously cautious, thinking that their land might end up in the NGO's hands.	A great deal of interest has been shown and other farmers are very keen to participate. They would like to reap the benefits of effective water harvesting techniques in the drought-prone land.

Table 5.5: Key farmer interviews in Gabane village

5.4.8 Community-based agroforestry

The CBAP programme has been introduced to members of the farming community both in Paje in central Botswana, and Gabane in the south-eastern Botswana. Microcatchment technology has also been introduced to the lands areas and evidence of semi-circular and spherical microcatchments (though not stone lined) were present on the plots. The trickle system was similarly in use in both villages.

The project participants were found to be enthusiastically committed to their 'on land plots' and to the raising up of fruit trees to increase their food security. Some of the difficulties encountered include the large distance from the village water source to the lands area, and the cost of hiring a donkey cart to transport water if the owner does not have one. In one case, the donkey's health was put into question as a result of the poor grazing from a lack of rain. Other villagers not involved in the project, however, remain sceptical about its possibilities for success and the active participation that would be required on their part such as the transporting of water to their lands areas.

The trickle system, where utilized, has proved a useful standard for watering but problems have arisen with the disintegration of the bottlenecks as a result of the intense UV radiation. The lack of rain, according to the AD in Paje, has been responsible for people's disinterest in continuing farming at the lands. Minor difficulties also require overcoming, for example, white ants, securing fencing materials in sandy soils and unwanted animal access to the plots. Residents in Gabane also feel that more follow-up from NGO staff would better aid the adoption of the technologies introduced. They also feel that the monthly visits should continue throughout the dry season as well as the summer wet season.

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Rainwater harvesting has the potential to offer drought mitigating benefits to farmers through ferrocement tank technology and agroforestry practices. These benefits would include:

- A supplementary or sole supply of water after rains that can be used in schools for cleaning, cooking and washing, and in lands areas for watering stock and all domestic activities. The benefits extend when the RWCS is working correctly and during these periods people's vulnerability to the breakdown of the nearby village reticulated water system and standpipes is reduced.*
- Community's vulnerability to water stress is lessened with the presence of the water tanks at their lands areas and this has enabled dwellers to continue living in drought-prone areas.*

- *The agroforestry practices have the potential to increase food security through practices such as intercropping, maximizing catchment runoff and conserving soil water through mulching.*
- *The introduction of CBAP into the villages of Paje and Gabane has encouraged members of the community to invest in lands agriculture by planting indigenous fruit trees and practicing microcatchment technology.*

Hindrances to the adaption of RWCS and agroforestry technology include the following:

- *The unreliable and erratic nature of the rainfall in filling the ferrocement tanks. There was no rainwater in the tank at the Polokwe lands area during July and August 1999 when the site was visited.*
- *Risk reduction through improved food security and water availability only operate during, and for a period after, the rainy season, depending on how quickly the tank water is used. Food insecurity and drought-risks can again return during extended dry periods.*
- *The aluminium guttering installed at Bakoko Primary School experienced structural failure and had been blown down, while at Kgabophuti Primary School a section of the plastic guttering had warped in the heat, wasting rainwater runoff.*
- *More effective solutions to community-based agroforestry problems are required, such as water transport, white ant infestations, and sandy soils with unstable fencing,*

In the next chapter, the ferrocement tank development project, agroforestry and the community-based agroforestry project will be analyzed using the conceptual framework. The projects will be examined through a drought vulnerability framework and their potential in reducing risk.

CHAPTER 6

QUO VADIS RAINWATER HARVESTING AS A DROUGHT MITIGATION STRATEGY?

In this section the findings generated by the field research are examined against the backdrop of the conceptual framework introduced in Chapter 3. It intends to apply a drought vulnerability and risk reduction framework to results obtained from interviews and site visits conducted in Botswana. Analyses will be given of:

- Ferrocement tank development project (section 6.1)
- Agroforestry initiatives (section 6.2)
- Community-based agroforestry project (section 6.3)

Section 6.4 summarizes and compares the three approaches in terms of their strengths and weaknesses with respect to drought-related vulnerability and implications for risk reduction.

6.1 Analysis of the Ferrocement Tank Development Project

Field research on the ferrocement tank development project showed the following findings.

Benefits:

- At the four locations where ferrocement tanks have been built, the recipients have benefitted when rain has been present in the tanks and the RWCS has worked correctly. When a supply of rainwater is present, people's vulnerability to the breakdown of the nearby village reticulated system and standpipes is reduced.
- The rainwater tanks have provided an enabling environment for a wide variety of activities in the schools such as cooking, washing and vegetable gardening (Appendix A, Bakoko Primary School).
- The children's health has also improved and the schools have reported a decrease in cases of, for example, diarrhoea from children washing their hands in water provided by the rainwater tanks after they have visited the toilet.
- If the ferrocement tanks were not installed at the lands areas, there would otherwise be no on-site water supply and water would have to be collected from the nearest village up to 5km away (Appendix A, Moshupa and Polokwe lands areas). Communities feel that their vulnerability to water stress has been lessened with the tanks.

Problems:

- The aluminium guttering installed is experiencing structural problems and has been blown down at Bakoko Primary School, rendering the RWCS currently inoperable.
- The plastic guttering at Kgabophuti Primary School has warped in the heat and has led to rainwater wastage.
- The tanks in all four locations have not been totally full of rainwater as a result of the erratic and unreliable rainfall. But only at one location, the Polokwe lands area, was there no water present in the tank during the fieldwork period in July and August 1999 (Appendix A, Polokwe lands area).
- Risk reduction with good food security, therefore, operates during and immediately after the rainy season, given good rains, but food insecurity and drought-risk return during extended dry periods.
- Most of the men work in town and this has meant that they are not available to offer their skills, labour and time to maintaining sustainable agriculture at the lands.

Cost benefit analysis of roof catchment systems in Botswana

The following equation can be used to obtain an estimate of the approximate mean annual runoff from a roof catchment system (Gould, 1999):

$$S = R \times A \times C_r$$

Where:

S = Mean rainwater supply in cubic metres (m³)

R = Mean annual rainfall in millimetres (mm/a)

A = Catchment area in square metres (m²)

C_r = Runoff coefficient of 0.8 (assuming water losses through evaporation, leakage and overflow)

The mean annual rainfall in the area of Moshupa and Polokwe is 500mm/a (see Figure 1.2) and at the Moshupa and Polokwe lands areas the size of the roof catchment areas is 40m² (5 x 8m). The approximate mean annual runoff is:

$$S = 500 \text{ mm/a} \times 40 \text{ m}^2 \times 0.8$$

$$= 0.5 \text{ m/a} \times 40 \text{ m}^2 \times 0.8$$

$$= 16 \text{ m}^3/\text{annum} = 16,000 \text{ litres/annum}$$

This translates into 0.044 m³/day, or 44 litres/day.

Rainfall, however, varies greatly from year to year, and the actual amount captured will also depend upon the rate of water use and the volume of the tank. The lands areas tanks are 11 m³,

with a calculated potential of supplying 16 m³ per year. The RWCS at the Polokwe lands area was serving 5 adults and 8 children with water (see Table 5.1), which is equivalent to (44 litres per day / 13) 3.38 litres/person/day. This falls well below the 10 litres total domestic water use /person/ day estimated for rural southern Africa, see Table 6.1. Table 6.1 also provides estimates of the total water use per capita for various standards of living in rural and urban Africa.

	Semi-arid			Humid		
	Rural Poor	Rural Poor	Rural Wealthy	Standpipe	Urban House connec. poor	Urban House connec. wealthy
Drinking	3	3	3	3	3	5
Cooking	2	2	5	5	7	10
Dish washing	1	3	6	4	10	15
Body washing	2	6	8	6	20	30
Laundry	1	5	8	6	15	20
Cleaning house	1	6	10	6	10	20
Garden	-	-	5	-	10	30
Sewage	-	-	-	-	-	30
TOTAL	10	25	45	30	75	160

Table 6.1: Total domestic water use per capita in rural and urban Africa (in litres/person/day)

Source: Finkel and Segerros, 1993

The actual volume of water consumed will depend upon the exact range of activities carried out, who collects the water and the mode of transport used. If a donkey cart is used to collect water from a standpipe or spring, then more will be carried than a women or child carrying a container. For example, fieldwork carried out by a SADC Land-Use Planning Workshop in Botswana found that rural people living at a distance of 20km from the town of Ramotswa fetched between 10-15 litres/person/day for their domestic consumption. In rural Malawi, when a source of piped water was supplied to communal water taps within a short walking distance of people's homes, the per capita water demand doubled from between 12-15 to 27 litres/person/day (Finkel and Segerros, 1993). There is a strong correlation between the mode of water delivery and the distance over which water is fetched (determined by standard of living) and water demand. The amount of water utilized would dramatically increase, for example, if a water-borne sewage system was installed or the house was connected to a water mains supply.

The average volume of water that people living in poor, rural lands areas, such as around Moshupa and Polokwe, would utilize is 10 litres/person/day (see Table 6.1). During a drought, a full water tank 11 m³ in size would last a family of 13 members (11,000 litres / (13 x 10)) 85 days, or approximately three months. If the family were in the humid, rural poor category, then according to the table each person would consume 25 litres per day. A full 11 m³ water tank would last for a duration of (11,000 litres / (13 x 25)) 34 days, or approximately one month. The dry

season in Botswana lasts at least from May to September, a period of 5 months, implying that a full 11 m³ lands area tank would act as a supplementary water supply rather than a sole supply.

The same calculation can be carried out for a school such as Bakoko Primary School in Moshupa that has 14 classes each with 35 children in giving a total of 500 pupils (see Appendix A). The 23 m³ ferrocement tank is fed off a roof catchment approximately 132 m² in size. If, each day, every child just received enough rainwater for drinking (3 litres/day) and body washing (2 litres/day), as suggested by Table 6.1, then a full water tank would last (23,000 litres / (5 x 500)) 9.2 days. This excludes water taken out for cooking and dish washing and assumes that the tank was full to begin with. The ferrocement tank water would, therefore, be a useful source of water for a period no longer than 10 days if the village supply temporarily broken down or ran dry. At Kgabophuti Primary School, assuming that both of its 46m³ tanks were being utilized and full of water, they would yield sufficient water to supply a school population of 600, at a rate of 5 litres per person per day, for 30 days (92,000 litres / (5 x 600)). Again, this calculation does not take into account water taken out for cooking and dish washing.

How rainwater harvesting at primary schools and lands areas has made a difference to drought mitigation will now be discussed using the conceptual framework and Blaikie's PAR work as a model. Some of the dynamic pressures such as standpipe breakdown that communities face are relieved and reduced through the presence of the tanks. The water tanks have in this way reduced the vulnerability that people face when their yard or village standpipe breaks down. The tanks enable with ease a variety of activities to be carried out, for example, washing, cooking, watering trees and vegetable gardening. Verbal reports from the school's teachers also suggest that the children's health has improved through rainwater being available for washing after visiting the toilet.

Rainwater, as far as preference is concerned, also has a more pleasing taste and produces a better lather when washing, compared to standpipe supply. A wide variety of unsafe conditions have therefore been reduced or eliminated. These include poor hygiene and no available water for cooking school meals. Vegetable gardening at schools and lands areas increases food security for both the children and their parents but also other neighbours and community residents who similarly buy the vegetables. Through learning about gardening techniques, children can also pass on their knowledge to their families who can also increase their food security.

Technically, the RWCS theory is good and the water helps to mitigate the impact of drought as well as food insecurity. There have, however, been problems in the technology such as broken or warped guttering and installing tanks where only one side of an asymmetrical building can be utilized for water collection. A lack of grates over intake openings and the appearance of leaks if the standard of workmanship is not high enough are two further issues that require investigating. The underlying vulnerability is therefore heightened again in communities. This is seen, for

example, in Bakoko Primary School where the broken guttering and no resulting rainwater led to the return of unsafe conditions and vulnerability to the school as staff could not cook meals for the children or clean the school. Water then had to be collected from Moshupa village.

People's reduced access to resources in the lands areas may have developed from their distance from the developing urban centre around Gaborone, deforestation, living in a drought-prone semi-arid area, epidemic diseases such as TB from poor hygiene, or a low level of income from crop failure. Rural lands areas have, therefore, seen a migration into villages and urban centres in order to escape the poor standard of living and lack of work and income through agriculture. The drought-prone vulnerability that can remain in rural areas further questions whether investment in rainwater harvesting is economically viable given the semi-arid climate, a declining interest in agriculture and heavy rural-to-urban migration. For example, despite the introduction of the ferrocement tank to the Polokwe lands area, male members of the household remain living and working in Moshupa.

Using the Access Model, it can be seen how drought and the poor distribution of resources and jobs in lands areas when compared to urban centres, has been partially responsible for an increase in people's vulnerability. Spatial dimensions are present in that it can be too expensive or time consuming to travel to collect water every day due to the large distance concerned and other activities fall by the wayside. A family with fewer resources, therefore, has a greater potential loss and longer recovery rate when a hazard strikes. The female-headed household at the Moshupa lands area has less access and less control over her income when compared to the male-headed household at the Polokwe lands area with his extended male family members also using the farm as their base. During periods of drought, people's level of vulnerability may be determined by many different factors. These include access to adequate food supplies that result from whether the rains were good that season, the ability to raise income by other means, family entitlements and coping strategies.

In the context of risk reduction, when a vulnerable community is exposed to a hazard, such as drought, its risk increases and if sufficiently high, a disaster may result. Ferrocement tank technology has the potential to help reduce the pressure upon communities, lessening their vulnerability to periods of reduced rainfall and creating a more sustainable environment. Rainwater harvesting could, therefore, be incorporated within the broader context of disaster planning and mitigation.

6.2 Analysis of agroforestry initiatives

Field research investigating agroforestry initiatives generated the following findings:

- The agroforestry project has demonstrated its effectiveness in the successful establishment of both indigenous and exotic fruit trees.

- Indigenous trees in particular grow well in the drought-prone, semi-arid environment through the wide variety of practices adopted on the farm.
- Stone-lined microcatchments offer the best growing environment for the fruit trees and intercropped vegetables.
- Through the sustainable management of the land's resources, it has been demonstrated that an increase in food security, and therefore also livelihoods, can be offered to those who similarly wish to participate in the project. These include not only farmers but also village and city residents who wish to supplement their food source with fruit harvested from trees planted in their yards.
- The innovative agricultural techniques, such as the trickle system and the microcatchments constructed from earthen bunds and cross-ties, demonstrate the potential that exists to improve the agricultural livelihoods of subsistence farmers.

Through the adoption of such practices, it is feasible to lower people's vulnerability to periods of crop failure or food shortage through the careful management of the soil, the available water, and other natural resources. In the risk reduction framework, risk is the sum of hazard plus vulnerability. In order to help avert or reduce the effects of a disaster, the pressure must be relieved upon a particular people group that will lessen their vulnerability. The drought mitigating, rainwater harvesting and water conservation techniques that are demonstrated in the agroforestry project directly aim to reduce people's vulnerability.

The agroforestry project integrates indigenous fruit tree production and the intercropping of traditional crops with rainwater harvesting. This is offered as an alternative to arable agriculture in Botswana, and has great potential to succeed as the traditional crops and trees are not only well adapted to the country's environment but they are also familiar and acceptable to subsistence farmers.

Sustainable agricultural land use practices mitigate the risks that drought poses to communities. For example, most indigenous fruit trees produce fruit even during drought years and the fruit is consumed by both urban and rural dwellers. However, as a result of overgrazing, the natural regeneration of these fruit trees is substantially reduced. By buying and growing trees farmers could not only improve their household nutrition and food security, but also sell surplus fruit as a means of generating an income. This would benefit women in particular, as it is they who are predominantly involved in arable agriculture. One mechanism to reduce the dynamic pressures that act on the semi-arid veld is to encourage people to grow indigenous trees so communities will be less inclined to remove them from the veld.

Rainwater harvesting practices provide the opportunity for the maximum amount of rainfall to be collected for a crop that will improve its yield and could prevent a total crop failure during years

with below-average rainfall. Furthermore, intercropping, for example, sorghum and cowpeas with Morula trees allows nutrients and water to be tapped from more than one soil level, which maximizes the available soil resources. Soil erosion is simultaneously controlled by the interception of runoff during heavy rain showers. The trees and rainwater harvesting practices similarly have a positive effect upon the soil's structure and fertility. Such practices reduce the dynamic pressures that act upon communities and that translate root causes into unsafe conditions. The higher crop and tree yields would go further to meet household food requirements than traditional arable agriculture does.

Trees also act as drought insurance, with their deeper roots going further into the ground, and may resultantly be more likely to yield fruit during dry years when more conventional food crops fail. One of a tree's most crucial roles is in the recycling of nutrients, particularly in climates where heavy rains can quickly leach them down below the reach of crop roots. They also help to maintain the level of organic matter in the soil where high summer temperatures cause the organic matter to break down too quickly. Trees are also more likely to survive and thrive because farmers invest a lot of time in tending and guarding the seedlings, particularly from goats, cattle and people collecting firewood.

Crop water requirements

The water requirements of a particular crop are a function of the actual evapotranspiration of the plants, though this is estimated through the potential evapotranspiration (PET) of the crop. In order to obtain water requirement data for water harvesting practices, one technique that is often used is the Blaney-Criddle method (Finkel and Segerros, 1993). This states that PET can be represented by the following equation:

$$PET = 0.46P (T + 17.8)$$

Where:

PET = potential evapotranspiration in mm/day (the mean value for the given month).

P = the mean daily percentage of maximum possible daylight hours, a factor of latitude.

T = the monthly mean temperature in °C.

To convert the monthly PET value thus determined to actual evapotranspiration, the estimate of the crop water requirement for a specific crop, it is necessary to multiply it by a crop factor that is experimentally determined. A further modification of the Blaney-Criddle formula takes into account the three interrelated climatic factors of relative humidity, the sunshine ratio and daytime wind speeds. Relative humidity (the monthly daytime minimum average), the sunshine ratio (or cloud ratio: the actual number of sunshine hours divided by the maximum possible sunshine hours) and daytime wind speeds (the monthly average of daytime wind speeds measured at a height of

0.2m). These correction factors are experimentally determined. Low humidity is associated with high wind speeds and high sunshine ratios, where as high humidity is associated with low wind speeds and low sunshine ratios. Table 6.2 compares the water requirements of a variety of crops, including their total growing period and sensitivity to drought.

Crop	Total growing period (days)	Crop water requirement (mm/growing period)	Sensitivity to drought
Bean	95-110	300-500	Medium-high
Maize	125-180	500-800	Medium-high
Melon	120-160	400-600	Medium-high
Millet	105-140	450-650	Low
Onion	150-210	350-550	Medium-high
Rice (paddy)	90-150	450-700	High
Sorghum	120-130	450-650	Low
Sunflower	125-130	600-1000	Low-medium

Table 6.2: Crop water requirements, growing period and sensitivity to drought for a variety of crops.

Source: Anschutz and Nederlof, 1997

The water requirements of a particular crop depend on both the crop type and the climatic conditions under which the crop is cultivated (Anschutz and Nederlof, 1997). The required size of a crop's catchment area is expressed by the *C:CA ratio*, where C is the amount of water harvested in the *Catchment* area and CA is the water needed in the *Cultivated Area*. In order to calculate the crop water requirements under certain climatic conditions, grass is taken as a standard or reference crop. The water requirement of the reference crop is called the reference evapotranspiration, (ET_0) which is expressed in mm of water depth per day, (mm/day). Values of ET_0 vary according to the mean daily temperature. In a semi-arid environment they are: 4-5 mm/day for a low mean daily temperature ($<15^{\circ}\text{C}$), 6-7mm/day for a medium mean daily temperature ($15-25^{\circ}\text{C}$), and 8-9mm/day for a high mean daily temperature ($>25^{\circ}\text{C}$). Exact data on the ET_0 are best obtained locally. By using the water requirements of the reference crop as a starting point for calculating the crop water requirements, the climatic influence has already been taken into account.

In order to relate the water requirements of the reference crop to those of the crop to be grown a crop factor K_c is used. This is a factor by which the water requirements of the reference crop are multiplied in order to obtain the water requirements of the crop to be grown. This is expressed by the following equation (Anschutz and Nederlof, 1997):

$$ET_{\text{crop}} = K_c \times ET_o$$

Where:

ET_{crop} = the crop evapotranspiration in mm/day

K_c = the crop factor (For example, cotton = 0.82, groundnuts = 0.79, legumes = 0.79, maize = 0.82, millet = 0.79, sorghum = 0.78)

ET_o = the reference evapotranspiration in mm/day

An example calculation for the crop water requirements of sorghum in a hot, semi-arid climate such as Gabane or Paje, with a growing season of 120 days and an average K_c of 0.78 is as follows:

Value of ET_o (obtained from the local meteorological service or estimated):

Month	1	2	3	4
ET_o (mm/day)	9	8.5	8	8

Calculation of average ET_o for the growing season: $ET_o = (9 + 8.5 + 8 + 8) / 4 = 8.375\text{mm/day}$

Calculation of ET_{crop} : $ET_{\text{crop}} = 0.78 \times 8.375 = 6.533$

Average crop water requirement for the growing season: $6.533 \times 120 = 784\text{mm}$.

The following steps and formula are used to calculate the C:CA ratio (Anschutz and Nederlof, 1997):

1. Water needed in the Cultivated Area (CA) = water harvested in the Catchment area (C)
2. $CA = (\text{crop water requirements} - \text{design rainfall}) \times CA \text{ (m}^2\text{)}$
3. $C = \text{Runoff factor (R)} \times \text{design rainfall} \times \text{efficiency factor} \times C \text{ (m}^2\text{)}$
4. Therefore: $(\text{crop water requirements} - \text{design rainfall}) \times CA = R \times \text{design rainfall} \times \text{efficiency factor} \times C$
5. $C:CA = (\text{crop water requirements} - \text{design rainfall}) / (R \times \text{design rainfall} \times \text{efficiency factor} \times C)$

The design rainfall is the quantity of rainfall for which a water harvesting system is designed. For example, while the average annual rainfall may be 500mm, there will be years both above and below this total. If the actual amount of rain is less than the design rainfall, the catchment area will not produce enough runoff to satisfy the crop water requirements. If the actual rainfall is greater than the design rainfall, there may be more runoff than the system can cope with and the structure may be damaged. The runoff factor (R) is dependent upon local conditions, but is generally

between 0.2 and 0.3 on slopes of less than 10%, and may be as high as 0.5 on rocky catchments. The efficiency factor expresses the part of the harvested water that can actually be used by the crop, and values range from 0.5 to 0.75, with values being higher when the cultivated area is flat and smooth.

An example calculation is given of the C:CA ratio for a sorghum crop in a semi-arid environment, where the crop water requirement is 550mm, the design rainfall is 320mm, the runoff factor is 0.5, and the efficiency factor is 0.7.

$$\text{C:CA} = (550 - 320) / (320 \times 0.5 \times 0.7) = \underline{2.05, \text{ or } 2:1}$$

In conclusion, the catchment area in this example must be approximately twice as large as the cultivated area. A C:CA ratio of 3:1 is generally used as a rule of thumb for small scale water harvesting systems. This is due to the fact that the runoff coefficient on common short catchment slopes is higher than expected, and the efficiency factor is also higher because runoff water does not often become ponded in the cultivated areas. Calculating the C:CA ratio is useful primarily for where crops are to be grown. The ratio for trees is harder to determine, and catchment areas vary between 10m² and 100m² depending upon the climate and species grown.

The sizes of the holding bays (or cultivated areas) used on the agroforestry trial project for growing crops (as illustrated in Figure 5.1 and Plates 5.7, 5.8 and 5.10) are 1.4m x 1.0m in size, 1.4m². These are fed with runoff from upslope catchment areas 4m in length, approximately (1.4m x 4m) 5.6m² in size (assuming all water flows downslope perpendicular to the contour into each holding bay). The ratio between the size of the catchment area and the cultivated area is thus 5.6: 1.4, or 4:1. Where the upslope length of the catchment area is 6m between the agroforestry rows, the size is (1.4m x 6m) 8.4m². The C:CA ratio is therefore 8.4: 1.4, or 6:1. The C:CA ratio is larger here than is suggested above in order to increase the amount of rainfall caught and so satisfy crop water requirements during years when rainfall is below average. The system is therefore constructed for a design rainfall considerably less than the average rainfall.

The agroforestry project has intentionally reduced exposure to drought by designing catchment areas that assume that the annual rainfall is less than the average. This enables sustainable irrigation of trees, even through drought periods.

The crop water requirements vary with the growth stages of the crop. When designing a water harvesting system though, it is sufficient to calculate the total amount of water that the crop requires over the entire growing season. In drought prone agricultural areas such as Botswana's hardveld, where water is a limited resource, it might not always be possible to apply the amounts of water required for achieving maximum yields. However, applying water at critical stages within the crop growth cycle, when a shortage would otherwise cause plant stress, enables the crop to

continue its development and produce reasonable yields. The amount of water used is therefore less. For example, the critical period for maize is during pollination, assuming that is, that water had been present during the late vegetative period ending with the first tassel. Sorghum, however, is less sensitive to water deficits and is in general more drought resistant than maize.

Mean annual rainfall totals are important when planning agroforestry systems. Of equal consideration, however, are the rainfall characteristics of frequency, duration and intensity of rainfall events (Begemann et al., 1988). Particularly in arid and semi-arid zones, the variability of rainfall is very high. Minimum requirements for the frequency distribution of showers are very difficult to establish and also strongly depend upon other factors such as the length of the dry spell between showers. Runoff occurs only when certain thresholds are exceeded: either the rainfall intensity exceeds the infiltration rate, or the rainfall intensity and duration exceeds the storage capacity of the soil. The number of rainfall events producing runoff is a better indicator for the potential of water harvesting than the total amount of rainfall (Begemann et al., 1988). This is particularly significant in climates with lower than average rainfall intensities over a short duration.

The potential for water harvesting can be further given by the frequency of individual rainfall precipitation events and the probability of a certain minimum amount and intensity. The frequency influences the antecedent moisture condition, which indicates the decrease in soil storage capacity due to previous rainfall events (Begemann et al., 1988). Decreased levels of runoff are caused by a higher surface retention, a higher soil hydraulic conductivity (permeability) and a higher soil porosity. Runoff is characterized by two factors: the runoff threshold value, which is the amount of rainfall at which runoff starts, and the runoff efficiency, which is the percentage of rainfall that arrives as runoff. Some of the reasons for the failure of water harvesting schemes include an inaccurate hydrologic design, poor engineering construction and a lack of attention to agrotechnic details (Begemann et al., 1988).

6.3 Analysis of community-based agroforestry initiatives

There are both drought-mitigating benefits and problems associated with establishing community-based agroforestry with at-risk households in the villages of Paje and Gabane.

Benefits:

- VPR&D have established a range of practices for strengthening livelihood resilience and reducing the impact that a period of reduced rainfall or drought would have on both individual households and a community.
- The CBAP presentation received a favourable response from the Paje community.
- The project participants are committed to their 'on land plots' and to the raising of fruit trees to increase their food security and livelihoods (Appendix B).

- The introduction of microcatchment technology to village lands areas has facilitated the building of semi-circular and spherical microcatchments (though not stone lined). The trickle system was also in use in both Paje and Gabane.
- Despite only two farmers in Gabane participating in CBAP at the time of the fieldwork (Appendix D) (a further six signed up during 2000 (Mateke, 2000, per com.)) residents in the village have also shown interest. Many have purchased fruit trees and planted them in their yards, following other people's examples.
- The trickle system, where utilized, has aided watering but problems have arisen with the disintegration of the bottlenecks as a result of the intense UV radiation (positive but with negative side effects) (Appendix C, Dilwana Keibonge).

Problems:

- Difficulties encountered include the large distance from the village water source to the lands area, and the cost of hiring a donkey cart to transport water if the owner does not have one. In one instance, the donkey's health was put into question as a result of the poor grazing from a lack of rain and water had to be collected by donkey cart from a standpipe 5km away (Appendix D, Mr Sekgee). The family's vulnerability is increased through this dynamic pressure.
- Villagers not involved in the project remain sceptical about its possibilities for success and the active participation that would be required on their part (Appendix B).
- The poor, erratic and unreliable rainfall was often cited as hindering agriculture at the lands. According to the AD in Paje, the lack of rain has been responsible for people's disinterest in continuing farming at the lands (Appendix B).
- Residents in Gabane feel that more follow-ups from NGO staff would aid the adoption of the technologies introduced (Appendix D, Mr Sekgee).

CBAP takes the drought-mitigating practices from the agroforestry project and introduces them into rural and village community settings. In the context of the conceptual framework, these practices aim to reduce people's vulnerability, increase their capacity to anticipate, cope with, resist and recover from the impact of a threat such as drought. It takes a long time to build up sufficient capacity to overcome the root or underlying causes of drought-related vulnerability. In Botswana this is particularly prevalent where factors such as overgrazing have removed much of the veld and former indigenous fruit trees that used to surround rural villages.

Through communities initiating agroforestry projects, the potential exists to reduce the dynamic pressures exerted on people and mitigate the build-up of unsafe conditions. Food security is an essential component in mitigating the risks that drought poses, and in doing so preventing the

abandonment of farming areas when people move into town to find work or a more secure livelihood.

CBAP is an example of an anti-poverty and anti-vulnerability programme that aims to increase household security and reduce the chances of a hazard having a serious or detrimental impact upon a society. Pressure and vulnerability can be reduced by community-based projects. CBAP has thus the potential to become a model that can be exported not only to other communities in Botswana but also to other southern African countries. For example, the planting of tree shelterbelts to protect crops from excessive wind speeds at ground level is just part of a package of sustainable land use practices.

The CBAP scheme also has the potential to impact farmer's livelihoods. However, as is seen from some of the above points; the scheme does have its difficulties. The need to transport village standpipe water, sometimes over long distances to sustain lands farming plots could be prohibitive in encouraging the further widespread adoption of the project. Community attitudes similarly need to be targeted to persuade wider audiences that projects such as CBAP indeed help to mitigate dynamic pressures faced in the semi-arid environment.

Community-based agroforestry initiatives offer a potential mechanism for improving people's livelihoods and reducing the impact that a period of reduced rainfall or drought would have on them. The dynamic pressures exerted on people would be decreased and the build-up of unsafe conditions mitigated. Food security is an essential component in mitigating the risk that drought poses and preventing people from abandoning their farms and moving into town to find work and a secure livelihood.

6.4 Comparing the approaches with respect to drought-related vulnerability

Table 6.3 compares the strengths and weaknesses of the three approaches, looking at the drought-mitigation features through their root causes, dynamic pressures and unsafe conditions created. Risk reduction features and implications are also drawn together.

Project	Setting & root causes	Livelihood & dynamic pressures	Problems & unsafe conditions	Drought-mitigating benefits & risk reduction features
Ferrocement Tank Development Project	Established at schools and lands areas within a radius of 80km of Kanye. Built to counteract against dry or broken standpipes, and to be a sole or supplementary supply. Root causes include water shortages and drought-prone conditions enhanced by the economically marginal environment, the harsh living conditions and the uneven distribution of resources.	Water used for every activity including vegetable gardening, water animals, washing and drinking. The tanks reduce the dynamic pressures on water provision. Dynamic pressures, such as reduced access to resources for rural communities, epidemic diseases, and rapid urbanization with a reduced rural labour pool, translate the root causes into the vulnerability of unsafe conditions.	Structural problems with guttering blowing down or warping. The tank building procedure similarly requires further work on quality and recruitment. Low, erratic and unreliable rainfall mean the tanks are never full, and water still has to be collected from villages up to 5km away. Food insecurity and drought-risk return during extended dry periods. Most men live in town and do not contribute to lands agriculture.	People's vulnerability is reduced when their village or yard standpipe breaks down or springs dry up. Tanks supplies last between 2-6 months, and offer an enabling environment for a wide range of activities. The tanks comprise the lands area's sole water supply and are responsible for allowing an easier life to continue there. An improvement in children's health with reduced diarrhoea is evident.
Agroforestry Project	VPR&D's drought-mitigating and water conservation techniques directly aim to reduce people's vulnerability. The project practices indigenous fruit tree production with the intercropping of traditional crops with rainwater harvesting. The drought-prone environment is a challenging agricultural setting. The project offers the potential, through open days and farmer exchange visits, to raise community's livelihoods.	The agricultural practices are offered as an alternative to arable agriculture, with the trees and crops being familiar and acceptable to subsistence farmers. They are also sustainable in the semi-arid environment. Deforestation and overgrazing removes the natural regeneration of fruit trees in the veld, lowering food security. The growing and selling of trees with good management practices improves household nutrition and food security.	The low and erratic rainfall means that hand watering is essential, particularly during the tree's first year, to ensure establishment. Problems are experienced with the disintegration of plastic bottles that used for the trickle system by intense UV radiation, and invasions of the land from goats and cattle.	The introduction of good agricultural water harvesting and conservation strategies is part of the mechanism for reducing pressure upon people that will lessen their vulnerability. Risk reduction is enhanced. The project's practices can thus be set amid a context of sustainable planning and mitigation. Benefits include increased food security, particularly emphasising growing indigenous fruit trees.

Table 6.3: Comparing the impacts of drought-related vulnerability from the ferrocement tank initiative and the agroforestry and community-based agroforestry initiatives

Project	Setting & root causes	Livelihood & dynamic pressures	Problems & unsafe conditions	Drought-mitigating benefits & risk reduction features
Community Based Agroforestry Project	Development and community empowerment projects are carried out in partnership with rural communities and households to improve their quality of life through the sustainable management of natural resources. Practices are introduced to mitigate drought, low food security and depleting natural veld products and resources. It is into the declining agriculture base across Botswana, with its low and unpredictable rainfall, that community participatory projects are advocated and established.	Farmers visited in Paje and Gabane are successfully establishing 'on-farm plots' and growing trees with rainwater harvesting practices. Lands visits are made on average twice monthly. Dynamic pressures include water transport distances up to 25km, a lack of widespread interest and adoption in the scheme among rural dwellers, rural depopulation, overgrazing and poor rains inhibiting crop planting. Poor health from HIV/AIDS and TB would result in reduced energy, motivation and labour for investing in the plots. Many varying factors thus contribute to generating unsafe conditions.	Problems include social engagements that reduce time farming, village scepticism and unwillingness to engage in hard manual labour, white ants, cattle invading the plots, poor farmer health that prevents lands visits and the high costs of hiring donkey carts to transport water. Vulnerability increases and the mitigation of unsafe conditions is compromised. Unsafe conditions include living in areas highly susceptible to crop and rainfall failure, a small labour pool and HIV/AIDS, which result in communities remaining economically poor with lower health standards and more risks than their urban counterparts.	The anti-poverty and anti-vulnerability programme increases household food security and reduces risks. The technologies are easily adopted and offer both urban dwellers and rural subsistence farmers the opportunity to be more self-sufficient. They thus make maximum use of their rainfall and yard space or lands area for the purpose of increasing food intake and income-generating fruit sales. The indigenous nature of the trees compliments the semi-arid environment, more so than exotic trees.

Table 6.3 (Cont): Comparing the impacts of drought-related vulnerability from the ferrocement tank initiative and the agroforestry and community-based agroforestry initiatives

The three projects have been presented through identifying their causes of vulnerability and where they provide benefits that help to mitigate unsafe conditions. Ferrocement tank water availability has the potential to supply a lands area family for either 1 month or 3 months depending upon whether the climate is semi-arid or humid. This does reduce drought vulnerability, especially when there are five dry months, but it is not a complete answer to rainfall-induced risk. In a primary school, rainwater collected in a 23 m³ ferrocement tank would provide up to 10 days drinking and washing water supply for 500 children. At a school where two 46m³ tanks yielded water, sufficient supply could be provided for 30 days. This would be sufficient to outlast a temporary breakdown in the village standpipe but no longer.

An indication of the crop water requirements and the C:CA ratio provides agroforestry developers with the knowledge to establish local plots in village gardens or lands areas. For example, growing sorghum in a hot, semi-arid climate such as Gabane or Paje demands an average crop water requirement for the growing season of 784mm. Similarly, in this climate, sorghum requires a C:CA ratio of 2:1 but ratios of up to 3:1, or even up to 6:1 for trees, are used in order to ensure that crops are sustained through dry periods.

Disadvantages of the ferrocement programme include structural guttering problems, workmanship and training issues while building the tanks and the low, erratic rainfall which necessitates collecting water from villages up to 5km away. Benefits, however, include reducing people's and school's vulnerability by providing them with supplementary supplies of water, and health improvements.

Disadvantages of the agroforestry project include the disintegration of plastic bottles that are used for the trickle system and land invasions by cattle and goats. Benefits include increased food security, particularly from growing indigenous trees in the semi-arid climate. Problems associated with CBAP include village scepticism and unwillingness to engage in the 'on farm plots' and the high cost of transporting water up to 25km to these plots at lands areas. However, benefits reaped include improved food security and reduced risk to crop failure during extended dry periods.

The next chapter considers how each of the three projects contributes to protecting at-risk livelihoods and mitigates the effects of drought. It also discusses whether rainwater harvesting should be developed in Botswana as a risk reduction strategy.

CHAPTER 7

DISCUSSION ON VULNERABILITY REDUCTION IMPACT

7.1 Introduction

Chapters one and two introduced Botswana and many of the challenging issues that are currently facing the Batswana. Rainwater harvesting was also presented and the potential that lies within this field for technology expansion to better support rural livelihoods. The findings and their analysis reflect the three different approaches of ferrocement tank technology, agroforestry techniques and community-based agroforestry.

Each of the projects will be discussed within the context of sustainable vulnerability reduction. Botswana is a drought-prone but rapidly developing country and great strides are being taken in the manufacturing and service industries. Rainwater harvesting is consequently discussed within the context of changing economics, agricultural base and climate. Social economics and HIV/AIDS are also examined. The findings are related to the conceptual framework.

These issues are addressed as follows:

- The role of ferrocement rainwater harvesting technology in protecting at-risk livelihoods (Section 7.2)
- The role of agroforestry (Section 7.3) and community based agroforestry (Section 7.4) as drought mitigating strategies.
- Discussing rainwater harvesting as a risk reduction strategy for further development (Section 7.5)

7.2 The role of ferrocement technology in protecting at-risk livelihoods

This section will focus on the Ferrocement Tank Development Project and its contribution to sustainable development. The following issues will be considered:

- The Ferrocement Tank Development Project
- Economic analysis of ferrocement technology
- Construction material availability
- BTC's analysis of the Ferrocement Tank Development Project
- Evaluation of the training procedure
- The role of ferrocement technology as a strategy protecting rural livelihoods
- Potential expansion of the pilot project as a development strategy
- Applying the conceptual framework

7.2.1 The Ferrocement Tank Development Project

Many rainwater tank designs in Botswana are not as durable as the ferrocement technology. The early above ground pre-fabricated galvanized steel tanks, such as those at Bakoko Primary School, generally have a limited lifespan from corrosion as a result of the saline water. Similarly, the imported, black plastic 'Aquatan' tanks can also readily develop leaks and are not durable. Brick tanks have also been constructed in the past, but due to poor quality control and poor construction methods, they have not performed well (Enyatseng, 1997) and have experienced cracking and leaking (Opelo, 1999, pers com.). A well-built ferrocement tank will have a life span of approximately 25 years and therefore the training component is crucial to the project's long-term success and feasibility.

Evidence from Bakoko Primary School suggests that the downpipe and gutter design will require some additional work before it can be presented as a model to the country for widespread adoption. Many rural and village schools in particular would benefit from the technology as it would enable them to become self-sufficient in water especially during periods when boreholes dry up or the water pressure in the village articulated systems is not high enough to supply a community's needs. Members of local communities would also benefit from a school's self-sufficiency not only from collecting water there themselves but also from having their children attend school during periods of poor village water supply. One of the lessons learnt from the project has been the failure to identify groups at the schools to oversee and maintain the tanks, but being a pilot project no such arrangements were made (Opelo, 1999, pers com.).

In Botswana, it is the poor installation of gutters that is predominantly responsible for inadequate RWCS (Austin and Douthwaite, 1987). For the gutters to function properly, three factors need to be considered. First, that adequate care must be taken to ensure that they can collect the water running off the roof even in very heavy rain and can fill completely without bending and twisting excessively. Second, close attention must be given to gutter or bracket damage due to changes in temperature that cause the material to expand and contract. Third, efforts should be taken to ensure that there are no leaks, and that the water drains from the far end of the gutter all the way to the outlet (Austin and Douthwaite, 1987). Damaged or leaking gutters and brackets that come loose should be fixed or replaced immediately to ensure that the maximum quantity of rainwater is collected.

The aluminium gutter has only recently been available in Botswana and installation costs can be high. At 1987 prices, the approximate price per metre for the gutters was Pula 15 (cross-sectional area 100cm²). This was expensive, compared with costs of galvanised steel at Pula 2.75 per metre (cross-sectional area 60cm²), PVC at Pula 6 per metre (cross-sectional area 40cm²), and Asbestos cement at Pula 8.50 per metre (cross-sectional area 180cm²) (Austin and Douthwaite, 1987).

Rainwater cannot be collected off thatch roofs as a result of the high organic matter content (Opelo and Taylor, 1999, pers com.). This provides a challenge for houses that lack a corrugated iron roof and cannot collect rainwater in the traditional way. However, one possibility that is demonstrated at the current (1999) BTC headquarters involves collecting the runoff from a thatched rondavel. A trench is constructed around the drip line of the thatch perimeter and the water is directed into an underground catchment tank.

A scheme for the installation of these collection systems was administered in 1984 by the MoA through ALDEP and was designed to provide water in remote lands areas for the watering of draught cattle and for domestic use (Gould, 1984). Over 350 such tanks were built with the help of a major government subsidy, but the project, despite being technically successful, had serious water quality problems. The high bacteria count was "disturbing when it is realized that much of this water is used for drinking in an unboiled state" (Gould, 1984, p.33). However, the method does have huge potential if the water quality issue can be overcome, particularly in places where alternative sources are either too remote or uneconomic. Water quality is one issue that is frequently raised in relation to RWCS. The results of a bacteriological analysis carried out in 1985 by Gould of the water quality of ten, covered roof catchment tanks is shown below, see Table 7.1 (note: the names of four additional locations are unknown).

Location of tank	Total coliforms*	Faecal coliforms*	Faecal Streptococci	Tank type
Tutume	0	0	0	Covered corrugated iron tank
Nata	0	0	0	"
Francistown	0	0	0	"
Francistown	0	0	0	"
Tlokweng	0	0	46	"
Morwa	0	0	158	Partially covered brick tank
Morwa	0	0	165	Covered brick cement tank
Unknown	1	0	1	Covered tank
Unknown	0	0	44	"
Unknown	0	0	75	"
Unknown	0	0	90	"
Maximum WHO recommended concentration	<10	<1	<1	-
Local guidelines (for remote rural supplies)	<100	<10	<10	-

Table 7.1: Results of bacteriological analysis of stored rainwater in covered roof catchment tanks (* Per 100ml calculated from 5ml and 50ml samples)

Source: Gould and Jay, 1993, and Gould, 1987

Despite all the samples falling within WHO guidelines for total and faecal coliforms, the presence of large numbers of faecal streptococci show evidence of contamination by birds, plants or small animals. Although this is not a serious health hazard, the water could pose the risk of the consumer contracting a rare form of salmonella (Gould and Jay, 1993). The quantity of faecal coliform is the most important, however, as this indicates the presence of human excrement, of which none were found (Gould and McPherson, 1987).

7.2.2 Economic analysis of ferrocement technology

Water harvesting projects should not just be technically feasible, socially desirable or environmentally sustainable, they should also be cost-effective. Every project should take account both investment costs, including economic contributions made by government, donor and

community, and operating costs, such as maintaining the system and delivering water to the user. When comparing the costs and benefits of a system, the costs must be divided over the number of years which benefits will be gained from (the economic life). For example, the economic lives of roof catchments are 20 years, whereas ground tanks can last for 10 years and hand pumps five years (Finkel and Segerros, 1993). The costs of RWCS are presented for three southern African countries: Botswana, Namibia and Mozambique, in which the mean annual rainfall figures inevitably, vary widely from year to year.

Botswana

The comparative costs of rainwater harvesting tanks in Botswana at 1999 prices are shown in Table 7.2 (* = Annual Equivalent Cost).

Type of tank	Volume (m ³)	Cost (Pula)	Cost (per m ³)	Life expectancy	AEC* (per m ³)
Galvanised iron	2.25	998	609	5	121
Galvanised iron	4.5	1639	498	5	101
Galvanised iron	9	2717	413	5	83
Polythene (ALDEP)	7	1413	277	10	28
Brick (Council)	10	9420	645	10	65
Ferrocement (BTC)	11	4150	-	20	39
Ferrocement (BTC)	23	5100	-	20	28
Ferrocement (BTC)	46	8000	-	20	17

Table 7.2: Comparative costs (in Pula) of rainwater harvesting tanks at 1999 prices

Source: Mateke *et al.*, 1999

On a cubic metre (m³) basis, the table shows that there are economies of size. For both the galvanized iron tank and the ferrocement tanks, the cost per cubic metre decreases as the size of the tank increases. The AEC shows that the most cost-effective tank is the 46 m³ ferrocement tank (Pula 17 / Rand 25 per m³), equally followed by the 23 m³ ferrocement tank (Pula 28 / Rand 40 per m³) and the 7m³ polythene ALDEP tank (Pula 28 / Rand 40 per m³). The galvanized iron tanks are the most expensive. The calculation of the AEC is based on the assumption that there are no maintenance costs and there is only one rainy season per year. Tanks are therefore filled and emptied twice a year, supplying twice their capacity every year (Acquah, 1993).

A move from a thatch rondavel to a small corrugated iron house in Botswana would enable the installation of a RWH tank but with the following costs (Taylor, 1999, pers com.):

- Cost of the tank: Rand 4380 / Pula 3000 (Galvanized steel tanks rust very quickly and can wear out in 10 years so a plastic tank is recommended).
- For an average family, the monthly water tariff would be Rand 22 / Pula 15 per month, equivalent to Rand 260 / Pula 180 per year.
- Botswana's water consumers are currently paying a monthly tariff of Pula 0.6 per m³ for the first 5m³, thereafter a sliding scale up to Pula 5 per m³ if they consume more than 20m³ each month. Paying present water rates of Rand 260 / Pula 180 a year, it would take 20 years to pay back the cost of the tank and gutters: 20 x Rand 260 / Pula 180 = Rand 5250 / Pula 3600, without factoring in interest.

A plastic tank has a lifespan of only 20 years and therefore in this instance no saving is made on the installation of a RWCS. The costs to subsistence farmers and labourers can be particularly high as their income can be as little as Pula 50 per month (Scott, 1999, pers com.).

The comparative costs of rainwater harvesting tanks (Table 7.2) to the cost of providing water from alternative forms of technology from a borehole for a 1KW system operating at 50m depth are shown in Table 7.3. Note that 1KW systems will yield according to the system efficiency and the yield might vary during any day with the available power. To illustrate, the table shows a solar system where the DC system has a higher efficiency and therefore needs less power to provide the same output as an AC system. DC systems demand smaller photovoltaic arrays and have lower recurrent costs than AC systems, while AC pumps use conventional electric motors that are less expensive but they do have higher maintenance demands (Rydtun, 1994).

Technology	Investment Cost (Pula)	Annual recurrent cost (Pula)	Yield (m ³ per hour)	Expected yield	Maintenance
Engine powered	25,000	17,500	3-10	High	High
Wind pump	28,500	1500	0-8	Low / medium	Low
Solar powered AC	49,800	3900	0-10	Medium / high	Medium / high
Solar powered DC	45,000	2100	0-10	Medium / high	Low
Handpump	6500	5500	1-2	Low	Low

Table 7.3: Comparison of technology alternatives

Source: Rydtun, 1994

Moreover, to compare rainwater harvesting costs with those of recasing wells and sinking boreholes, an example is given from the Central and Northeast Districts in Botswana, centred on Maun. Here, the MoA, the Ministry of Health and the Department of Water Affairs (DWA) are currently involved with casing some of the boreholes, according to a hydrogeologist from the Ministry of Agriculture, Mr Mmutle. Many of the wells have collapsed as a result of the shifting loess and dune sands, the absence of a solid bore casing, and a high water table just 1-1.5m below ground level. A high organic matter content in the wells is producing 'black water' and water contamination and diarrhoea are also problems. A solid base is planned for the boreholes to prevent the sands from rising up the bore, together with an inner perforated casing surrounded by rock packing. Costs, however, are expensive. Borehole construction costs amount to Pula 51,870 and are based on three months labour work at an additional cost of Pula 16,445 (Mmutle, 1999, pers com.). Materials planned for the first test well casings include concrete rings, hand pumps (Bush), GI pipes, 100mm channel irons, 4mm steel sheets, cement, aggregate, sand, and skilled and casual labour.

The following example in Table 7.4 shows the actual construction, operation and maintenance costs of a typical roof catchment in both Botswana and Namibia (Finkel and Segerros, 1993). The original 1993 figures in Rand have been corrected to the year 2000, assuming an average annual price increase of 10% compound interest.

Costs		Botswana	Namibia
		Tank size 7m ³ , supplying 10m ³ /year	Tank size 40m ³ , supplying 50m ³ /year
Investment costs:	1. Tank	R390	R9700
	2. Gutters	R970	R3900
Economic life:	1. Tank	15 years	15 years
	2. Gutters	5 years	5 years
Annual investment cost:	1. Tank	R570	R1420
	2. Gutters	R270	R1080
Annual operation costs		R0	R0
Annual maintenance costs		R50	R50
Total annual costs		R940	R2600
Cost of water		940/10m ³ = Rand 94/m ³ (=Pula 64/m ³)	2600/50m ³ = Rand 52/m ³ (= Pula 36/m ³)

Table 7.4: The construction, operation and maintenance costs of typical roof catchments in Botswana and Namibia.

Source: Finkel and Segerros, 1993

For both tanks in Botswana and Namibia, the annual maintenance costs are the same despite the difference in size: 7m³ and 40m³. The total cost of water is significantly cheaper in the larger volume tank, making any investment in the larger tank size more attractive in the long term.

A 7m³ PVC (polyethylene) Aquatan tank had been in use at the Kgotla Lands area before the building of the ferrocement tank. Aquatan tanks were introduced in the early 1990s at a cost of Pula750 each (in 1992), and were designed as a cost effective, off the shelf solution to meet the growing demand for tanks given the shortage of skilled builders for constructing sub-surface ferrocement tanks. The Aquatan tanks were also built to improve the quality of water compared with the sub-surface tanks that were rainfed off catchment aprons and which resultantly contained high levels of bacterial contamination from birds and animals. A decision was eventually taken to stop using the Aquatan tanks. They suffered problems such as leakage from around the tap, the thin plastic sheeting cover was easily ripped by the wind and they were in overall poor condition after an average of only three years of use (Mateke, Mbakile and Opelo, 1999).

An economic analysis of RWCS technology should also take into account the advantages and disadvantages of the tanks. Table 7.5 compares ferrocement tanks with four alternative types of tank.

Type of tank	Advantages	Disadvantages	Estimated life expectancy
Ferrocement	Long life expectancy. Can be built much larger than corrugated tanks, up to 46 m ³ . Uses local labour and materials.	Requires special construction moulds. Requires trained builders.	10-20 years
Corrugated iron	Readily available. Ready to install. Low labour costs.	Short life expectancy. Rusts easily. Needs to be transported to site. Maximum size 9m ³ .	2-10 years
Brick and cement	Can be built to any size. Can be built above or below ground.	More expensive than equivalent sub-surface tank.	20+ years
Plastic	Relatively cheaper. Low labour costs.	Short life expectancy. Difficult to fix in specified location. Punctures easily.	1-10 years
Masonry	Long lifetime. Can be built to any size.	Requires skilled stonemason. Restricted to areas with abundance of rock. Uses local labour and materials.	20+ years

Table 7.5: Advantages and disadvantages of different types of RWCS tanks.

Source: Van Duuren, n.d.

Ferrocement technology has the advantage over other types in that it has a long life expectancy of between 10-20 years and tanks can be built both from locally available material and much larger than other tanks. However, special construction moulds and trained builders are required, relative to tanks made from, for example, plastic or brick and cement.

Namibia

A feasibility study was carried out in Namibia to assess the potential for efficient rainwater harvesting at a farm near Kudubis in the Erongo Region, in an area where the Spitzkoppe Farmer's Association operates (Van Someren, 1997). Rainfall figures are very low in Kudubis with the last 10 years having an average of 86mm of rainfall per year. It is therefore very important to catch every drop of water, requiring an efficient RWCS.

Two examples are given of what installing a RWCS would mean for one person and then a family of five. In the first example, one person requires a roof catchment surface of 9m² (3m x 3m) to catch 630 litres (equivalent to three oil drums) of water in one average rainy season (assuming an average rainfall of 70mm per year). With a dry season lasting ten months, the person would have 2 litres of rainwater available each day. Note that if the roof is bigger then more water can be harvested, and if the number of people increases, then the roof size must similarly increase or the daily amount available per person will be less, see Table 7.6. In the second example given, in order for each person in the family of five to have 2 litres per day in the dry season, the roof surface must be 45m² (5m x 9m) to harvest 3150 litres of water, see Table 7.6.

During the feasibility study it was also identified that further exploration of the ground water was not recommended as a result of its severely limited quantity and quality, and the flat topography did not facilitate for the construction of dams. This leaves rainwater harvesting as the only viable alternative to improving the supply of drinking water to rural households. Twenty families from the Kudubis Farming Community expressed an interest in upgrading their existing systems in order to bring drinkable water near their homes. The water tanks can also provide the families with a drought preparedness strategy, since the tanks can also be filled by a tanker service during drought (one of the government's emergency relief responses). Some of the component manufacture, assemblage and installation for the RWCS could be carried out within the community itself. This would help make the scheme cheaper and easier, provided that the appropriate training was made available to selected craftsmen from the community (Van Someren, 1997).

Structure	PVC (Rand / Pula)
Example 1: for one person with a 9m² (3 x 3m), single pitch roof, and with one gutter of length 3m	
3m gutter and down pipes	R230 / P160
Ferrocement tank (built by a trained community builder) or galvanized corrugated tank (treated inside)	R320 / P220
Total estimated cost	R550 / P380
Example 2: for a family of five with a 45m² (9x 5m), two pitch roof and with two gutters of length 9m	
18m gutter and down pipes	R900 / P615
Ferrocement tank (built by a trained community builder) or galvanized corrugated tank (treated inside)	R1600 / P1100
Total estimated cost	R2500 / P1715

Table 7.6: Estimated cost to make rainwater harvesting efficient from existing roofs

Source: Van Someren, 1997

Historically, Namibia was almost totally dependent upon rainwater harvesting technology utilizing pans, low lying areas and springs accessed through hand-excavated wells. Colonizers subsequently built boreholes, windmills and catchment dams (RISE, 2000). Today, the official view of the Government of Namibia is that rainwater harvesting is not feasible due to the cost involved, and any significant future advances in developing appropriate technology will be reliant upon individuals and NGOs (RISE, 2000). The technology is perceived as expensive compared with building boreholes or a pipeline network. However, through demonstration of the technology in neighbouring countries, it is hoped that interest will be re-ignited.

While it is possible to establish up front the high capital costs for constructing and maintaining RWCS, no comparison costs are usually given of what the costs would be if RWCS were not constructed. For example, costs from drought-affected farmers or those borne by government when extreme drought conditions require the transport of emergency water supplies. Or, for example, the cost of water increases for farmers. What we do see is the cost of establishing sustainable technology but what we can't compare it with is the costs of not doing it. Do the state or the poorer farmers manage these losses?

Mozambique

To further widen the regional perspective, an example is given from Mozambique. The average cost of a cistern is between Rand 550-840/capita / Pula 375-570/capita, which consists of a hole dug manually in the ground and lined with 2-3 layers of cement mortar and stones or bricks (Matsinhe, 2000). The net volume of the unit ranges from 4-33m³. This cost assumes a water demand of 20 litres/cap.day with 180 days of dry season, 600mm of average annual precipitation and losses due to evaporation of about one-third of the total volume. The equivalent cost of a borehole up to 60m deep and equipped with a handpump is Rand 190/capita or Pula 130/capita. Despite the cistern requiring high investment costs, it can be operated for many years without intensive maintenance, thus making it economically feasible on a long-term basis. Additionally, because the cistern adopts traditional technology, maintenance can be carried out by local labour.

However, the technology is not affordable to the majority of households in rural communities in Mozambique, and attempts to establish it will have to be accompanied by a credit system run from an NGO or government. Villagers then apply and get the initial capital outlay to start their construction. Moreover, this approach is only feasible in semi-arid regions where water is limited (Matsinhe, 2000). With the exception of cement, which constitutes 70% of the cistern investment cost, local materials are used as much as possible. Despite this though, costs remain unaffordable to the majority except where they can be heavily subsidised by government or NGOs.

7.2.3 Construction material availability

Another attractive feature of the ferrocement technology is the opportunity to use locally derived building alluvial sediments. Botswana does not have a plentiful supply of natural aggregates but an abundance of mineable sand deposits occurs within the country's river courses. Settlements adjacent to river courses, such as Metsimotlhabe (a collection of lands areas 20 years ago near Molepolole but now a thriving settlement village) and Mahalapye, thus have great potential to use these resources in constructing the tanks. The pilot project was limited to the Southern District within an 80km radius of Kanye and the sand was extracted from the Metsimotlhabe River and its tributaries. No analysis of the sand deposits has yet been carried out outside the Southern District (Opelo, 1998).

7.2.4 BTC's analysis of the Ferrocement Tank Development Project

Quality control management is the central focus that requires addressing for the ferrocement tank development project (Inger, 1999, pers com.). The implementation of a high quality control needs to be enforced but this is unlikely without an expensive inspection system. He stressed that initially, rainwater harvesting, and not ferrocement tanks, needs to be advocated to the Botswana Government. Practices such as installing gutters, downpipes and tanks on all government buildings, staff houses, schools and clinics should be standard procedure, especially in settlements with low and unreliable rainfall.

A monitoring exercise carried out by the BTC of the ferrocement tanks after occasional rainfalls revealed a varying storage of between 50-90% full and at some locations people had indicated that they were 100% full (Opelo, 1998). The time it takes for the tank to empty depends upon the capacity of the tank, the number and frequency of water drawers and the activities the water is used for. At both the schools and lands areas it takes on average between 2-6 months before the water is consumed if there are no rains in between. The BTC quoted the project participants an example construction cost of a ferrocement tank of Pula 6,000 and the school indicated that, if they were required to fund the tank, the raising of finances should not be a problem.

One review of the ferrocement tanks around Moshupa was carried out on the 15th September 1997, and included water sampling from the tanks and an assessment of general aspects of water quality by the Ministry of Mineral Resources and Water Affairs (MMR&WA). Specific comments by the MMR&WA on the water's analytical results are given in Table 7.7 (note, actual figures are not available from the MMR&WA).

Location	Specific comment from the Ministry of Mineral Resources and Water Affairs
Bakoko Primary School	Analyzed (chemical and mineral) parameters are of an acceptable quality. High bacterial contamination so cleaning and disinfecting of the reservoir is advisable.
Kgabophuti Primary School	Analyzed (chemical and mineral) parameters are within acceptable quality. Bacteria contaminate water, though cleaning and disinfecting the reservoir will improve this situation.
Moshupa Kgotla lands	Acceptable (chemical and mineral) quality. Acceptable (microbiology/biochemistry) quality.
Polokwe lands	Bacterially contaminated, but the quality is chemically acceptable.

Table 7.7: Analyses of the ferrocement tank water supplies

Source: Opelo, 1999

The MMR&WA concluded that in each case the analytical results for chemical and mineral content were found to be generally low and acceptable for human consumption. The results are also reasonable considering the rainwater is not filtered through any mineral media such as quartz sand. Except for the Kgotla lands tank, all the other samples indicated bacterial contamination above the recommended limit of 10 counts per 100ml for drinking and other human consumption processes. The source of contamination was traceable to bird excreta from the roofs off which the rainwater runs into the tanks. Birds also sit on the gutters that lead to the tanks. If the water is consumed, it may therefore be necessary to boil the water or filter it first through sand, charcoal or filter paper at the household to remove or reduce bacterial infection. Alternatively, the water could be blended with non-contaminated water, especially since the contamination is not severe or from human faecal pollution. One solution could be to make a sand compartment within the tank itself (BTC, 1998). The tanks were found to be in good condition except for a few that had superficial, hairline cracks on the outside walls. This was attributed to poor workmanship (BTC, 1998).

An example of a technology that failed to achieve even localized adoption and status was the construction of haffirs in the early 1970s (Inger, 1999, pers com.). Vernon Gibberd constructed two demonstration haffirs in Serowe, each 25m³ in size (Taylor, 1997). One was an open reservoir, intended for irrigating agriculture, and had a floor and sloping walls lined with 'sausages' that were lengths of plastic tubing filled with a weak soil/cement mixture. The other haffir was similarly constructed and contained a porous beehive-shaped structure of coiled plastic tubing in the middle of the base with an opening at ground level. The haffir was then filled with river sand, and a raised bund put around the downslope edges of the haffir to catch and hold runoff water

while it filtered through into the open beehive. This haffir was used for filtering household drinking water. While local Batswana showed interest in the projects, no-one seemed prepared to copy them, possibly because of the high labour input required to dig the holes, make the 'sausages' and transport the river sand (Taylor, 1997).

7.2.5 Evaluation of the training procedure

There are limitations to the expansion and development of the ferrocement water tank project. Various technical and training difficulties require addressing and ironing out before the project can be successfully advocated to communities and the government. From a training standpoint, it was difficult to get trainees all with a uniform qualification and their employers were concerned about the cost of releasing some of their highly qualified personnel for an extended leave of absence for the training period. There was also a low attendance of trainees that was unexpected. In addition, problems arose in designing a balanced construction programme that catered for their wide range of qualifications and backgrounds (Opelo, 1998). The reduced number of trainees led to a rescheduling of the number of tanks built from 16 to 11 and then to eight.

The trainees believed that because the training programme had no accreditation, it would not help them at their work centres and therefore was of dubious benefit. They also held the view that the project was more of a commercial exercise rather than a training programme and that it merely capitalized on their cheap labour as indicated by the number of tanks that were built with no added provision to learn more about the process (Anon, 1996).

Some NGOs such as RIIC took part in the construction of the tanks and in the training of the artisans with a view to improving the quality of workmanship. However, the major obstacles to rainwater harvesting are a lack of funds and adequate knowledge to build appropriate systems (Ndege, 2000). One of the problems experienced with the project has been the training of the artisans (Opelo, 1999, pers com). In practice, the ferrocement tanks do not represent a simple technology and a thorough understanding is necessary of the idea behind the tank construction before the artisans can become proficient builders. Poor workmanship during some of the construction stages led to the development of very small, superficial yet visible cracks. More importantly, however, is that despite the problems present, the tanks that were constructed are now serving the purpose for which they were built and the project has provided either a supplementary or sole source of water to the communities involved.

Well-skilled artisans are required at the lands areas for building the ferrocement tanks. But as the agriculture teacher from Gabane Private Secondary School (GPSS) pointed out, if a person is skilled enough to build the tanks, they would not remain at the lands but would be working in the towns (Scott, 1999, pers com.). The prosperity of the country's economy appears to discourage these kinds of rural initiatives. The government and NGOs should rather be concentrating on

RWCS at schools, clinics and government buildings instead of expecting and relying on local people to take up a RWH project's reins (Scott, 1999, pers com.).

RIIC also encountered some difficulties with the varied trainee qualifications with only three trainees meeting the criteria for the programme. The trainees also did not receive adequate briefing during the selection about the accreditation and nature of the programme and this had detrimental effects on the motivation of the trainees (Anon., 1996). RIIC also discovered that the conventional belief that ferrocement is a simple technology that requires no previous specialized skills was not entirely accurate, and it did prerequisite well trained artisans.

7.2.6 The role of ferrocement technology as a strategy protecting rural livelihoods

The installation of ferrocement technology through the pilot project has made a valuable contribution to protecting rural livelihoods at both the schools and lands areas selected through enabling a wider range of activities to be carried out and with relatively more ease. The project is benefiting the present participants through providing them with a better source of water than, for example, collecting from below the water table in a dry stream bed, or taking a donkey cart up to 15km to a village standpipe.

At the lands, the time and distance that would otherwise be spent fetching water is reduced to a minimum unless, due to the erratic nature of the rains, the ferrocement tanks lie empty for short periods between rainy seasons. The rainwater does have an advantage over water taken from natural springs that may be contaminated by animal waste, and which may, therefore, not be fit for human consumption. The family practising subsistence agriculture at the Polokwe lands area, for example, has therefore been able to remain and live there all year round.

The rainwater has enabled, for example, school staff to enjoy the benefits of good-tasting water, washing, cooking and cleaning when water is present in the tanks. Children also benefit from the close proximity to the water supplies and have improved sanitation facilities. The potential exists to increase livelihood resilience in these communities.

7.2.7 Potential expansion of the pilot project as a development strategy

Additional work is required on artisan training and the building programme before ferrocement technology could supercede conventional water tanks, such as the plastic 'Aquatank' tanks. At present, the technical difficulties stand in the way before the advantages of installing ferrocement technology can be widely promoted and experienced. Development priority should, it could be argued, then be given to rural settlements where a range of appropriate technologies could be demonstrated at household and community level. Pilot demonstrations of the tanks could be built at schools, clinics or at individual households in order to advocate the technology.

The greatest potential for demonstrating rainwater harvesting countrywide lies in the construction of water tanks at schools, clinics and with farmer 'co-operatives' in rural and village areas, particularly where alternative water resources are too unreliable, distant or saline. With the average price of a tank being Pula 4000, individuals would find it hard to pay for the tanks themselves. The BTC recommend that farmers organize themselves into groups or co-operatives in order to pay for the technology (Opelo, 1999, pers com.). Cattle farmers in particular should be able to fund tank construction, as the value of four livestock is equivalent to about Pula 4000.

Despite positive opportunities in rainwater harvesting and other appropriate technologies, speculation exists as to whether subsistence agriculture will be sustained in Botswana with the passage of the older generation and continuing urban migration (Inger, 1999, pers com.). This clearly has implications for future levels of rural investment and support for rainwater harvesting.

7.2.8 Applying the conceptual framework

Vulnerability, as defined by Blaikie's 'progression of vulnerability' in section 3.1.1, increases as dynamic pressures translate the root causes into unsafe conditions. A disaster may eventually result if a hazard exploits people's vulnerability. The Ferrocement Tank Development Project aims to reduce the root causes and dynamic pressures and encourage a 'progression of safety' that contributes to achieving safe conditions and reducing disaster risk.

Dynamic pressures have been reduced through the teaching of appropriate artisan skills, investing in new technologies and in the development of local building teams in order to construct the ferrocement tanks. Members of the community are, therefore, being empowered to facilitate reducing the risk to vulnerable communities. The safe conditions achieved for the tank participants include a drinkable source of water that also enables a wide range of activities to be carried out with greater ease and a diversification potential for rural income opportunities. An increased food security potential from using the available water for vegetable gardening helps to reduce disaster risk, mitigating the impact of a hazard such as drought.

The AEC prices of ferrocement technology in Botswana, as Table 7.2 shows, are comparatively less than AEC prices of galvanised iron, polythene and brick tanks. The most cost-effective tank is the 46 m³ ferrocement tank, assuming there are no maintenance costs and only one rainy season per year. Ferrocement, therefore, offers the greatest opportunity to cost-effectively reduce vulnerability in communities. The cost of water from a 40m³ tank supplying 50m³/year (in Namibia) is Pula 36/m³ and from a 7m³ tank supplying 10m³/year (in Botswana) is Pula 64/m³, as shown in Table 7.3. Investing in the larger tank volumes is, therefore, more attractive in the long term. These figures can be compared with borehole construction costs of Pula 51,870 each comprising three months labour work at an additional Pula 16,445.

However, the difficulties encountered in the artisan training procedure and the resulting smaller number of tanks built, as well as structural failure of the guttering materials, has not adequately advanced the 'progression of safety'. The underlying vulnerability of the tank's susceptibility to periods of drought means that the root causes of drought have not been mitigated. Tanks at schools offer only a temporary water source if the village standpipe breaks down, provided of course that the tank is full when the breakdown occurs. Tanks in lands areas could provide water for a family for up to three months during a dry period. The dynamic pressures can be temporarily mitigated, though not during a prolonged standpipe breakdown or drought.

7.3 Role of agroforestry initiatives as a drought mitigation strategy

This section examines the agroforestry initiative and focuses on the following areas:

- Strengths of the approach
- Limitations of agroforestry
- Opportunities for further development
- Constraints to future expansion
- Applying the conceptual framework

7.3.1 Strengths of the approach

The effectiveness of some of the agroforestry initiatives presented is collaborated by evidence from field trials carried out during the 1995-96 growing season by VPR&D. The yields from growing sorghum and cowpeas in agroforestry microcatchments of widths 4m and 6m are shown in Table 7.8. The 1995-96 rainy season was exceptionally good, with 709mm in Gabane compared with an average annual rainfall of 376mm over the previous 10 years (Mateke, 1997).

Location of crop	Row with a 6m upslope catchment area	Row with a 4m upslope catchment area	Row with a 4m upslope catchment (with w.a.c. *)	Control plot
Yield of Sorghum (kg/ha)				
Bay	92	63	316	
Ridge	311	349	269	
Total yield	403	412	585	579
Yield of Cowpeas (kg/ha)				
Bay	147	284	417	
Ridge	353	408	418	
Total yield	500	692	835	330

Table 7.8: Yields of sorghum and cowpeas (kg/hectare) from the agroforestry trial plot (w.a.c. * = water adsorbing crystals).

Source: Mateke, 1997

In order to artificially increase crop yields, water-adsorbing crystals were added to the soil. These adsorb up to 500 times their own volume in water, which is then slowly released to the plants. The crystals, which it is claimed help facilitate nutrient uptake by the plants, were included in the trial to assess their potential for crop production in Botswana. They are, however, quite expensive, and a cost-benefit analysis is required to reveal if their application is practical (Mateke, 1997).

The results indicate that there is very little difference in crop yield for microcatchment widths of 4m and 6m, though this can be attributed to the year's high rainfall totals. The crops grown in the row with the water adsorbing crystals seemed to be under stress, as expressed by early flowering, in their initial growth stages but this was thought to be the result of waterlogging (Mateke, 1997). However, the eventual yields were highest in this row. The following differences were noted between the bays and the ridges:

- Germination was better in the bays than on the ridges for both crops.
- Flowering was earlier in the bays for both crops, indicating stress from waterlogging.
- The yields on the ridges were higher than in the bays for both crops.

The differences in germination and flowering are explained by the fact that ridges are more prone to desiccation than the bays. However, as the ridges are constructed using topsoil from the bay areas, so soil fertility and structure is better here, they produce higher yields in the end. The control plot is just ploughed and it is usually expected that yields here are lower than the agroforestry system. The cowpea results illustrate this. Bays with a 6m-upslope microcatchment yielded 500kg/ha and bays with a 4m-upslope microcatchment yielded 692kg/ha, compared to the control plot with 330kg/ha. With the year's good rains, yields from the control plot were higher than expected for sorghum, even exceeding those from the agroforestry plot. It is anticipated though that during years with less rainfall, agroforestry yields will be higher (Mateke, 1997).

One of the strategies developed to promote some of the agroforestry practices has been through promoting the growing and sale of indigenous and exotic fruit trees. VPR&D tried this through employing one of their trailers to travel around Gaborone and Mogoditsane selling trees (see plate 7.1). The trailer was parked at the same site every week on a regular basis and sales were always very good at the start of the planting season, tailing off towards the end. People were very keen to plant their own trees and harvest the benefits, and this strengthened the agroforestry initiative.

To date, over 1000 trees have been voluntarily planted by approximately 140 households in yards in the Kweneng District with a 75% survival rate (Sunstrum, 1999). VPR&D staff assisted with this planting trial, just one of 18 around Botswana that has been aimed at improving community livelihoods through the planting of indigenous fruit trees. Projects such as these help to market the importance of the indigenous fruit trees to the younger generations and promote the trees protection and value. One of the tasks ahead, therefore, is to convert farmers and herders from 'passive' to 'active' agroforestry; from users of self-planted trees, to growers and farmers of trees (Harrison, 1987).

7.3.2 Limitations of agroforestry

One of the limitations of the agroforestry initiative is the Botswana preference to plant exotics, particularly paw paws, mangoes, apricots, oranges and grapes, rather than indigenous trees. When the trees are being sold, however, a slight improvement in the sale of indigenous trees occurs when both types are marketed together (Ketshabile, 1999, pers com.).

The financial costs of constructing water harvesting systems are highly variable between projects and difficult to compare. Available cost estimates do not always take into account the cost of labour for their construction and maintenance, or for the depreciation of equipment. The downslope effects of agroforestry such as less damage to crops, or upslope effects such as accelerated growth of trees in the catchment area, are difficult to quantify and so are therefore usually not considered in cost analyses. Also, a comparison between yields from different plots can be very difficult unless controlled by a researcher as cultural practices such as timely weeding, planting density and the use of inputs all have a big effect on yields (Critchley, *et al.*, 1992).

The viability of agroforestry techniques will also be determined by the rainfall patterns over Botswana and expected climate change in the region. The rainwater harvesting practices that suit agroforestry so well are themselves vulnerable to recurring drought, which will in turn lead to a decreasing uptake of the rainwater harvesting technologies.

Within a rapidly urbanizing country such as Botswana that has expanding opportunities for trade, the continuation and uptake of subsistence agriculture is likely to decrease. An expansion of the service and tertiary industries will place less emphasis on the country's primary agricultural base. Product consumerism begins, therefore, to replace a subsistence lifestyle and growing one's own fruit and vegetables.

7.3.3 Opportunities for further development

Field days actively advocate agroforestry and water conservation practices, and encourage people to invest in improving their own food and household security. Practices that have potential to be

promoted and expanded include the trickle system, intercropping and the reusing of grey wastewater.

The trickle system is an effective watering tool to combat the effects of drought in young trees while the practice of intercropping among trees taps into different rooting levels and can effectively open up and increase the supply of water and nutrients. One technology that has proven successful at encouraging the growth of fruit trees and vegetables is the use of grey wastewater. Grey water from a household shower can be diverted into a pipe system that feeds perforated plastic drums beside trees, and some trees have even been planted inside them, see Figure 7.1 and Plates 7.2 and 7.3

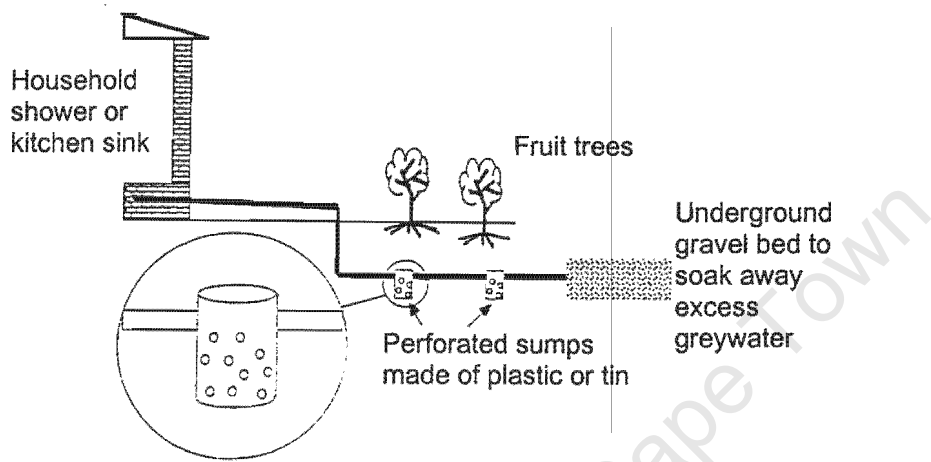


Figure 7.1: Schematic illustration of household greywater reuse
Source: Somarelang Tikologo, 1997



Plate 7.2: A perforated plastic drum with inlet pipes that carry waste grey household water, beside a paw paw tree in Gabane.



Plate 7.3: Series of perforated water drums with paw paw and citrus (orange) trees either planted beside or inside them, Gabane.

There is an important role for formal research in agroforestry, in selecting the most productive species, breeding improved varieties and testing out management methods (Harrison, 1987). For example, Kenya has one of the most well developed agroforestry research networks in Africa and operations are based at six Farmer Training Centres belonging to the Ministry of Agriculture, with the whole project run from the offices of the Ministry of Energy. This has ensured that agroforestry is viewed as a key area for both agriculture and energy, supplying not only crops but also wood for fuel. The centres' main functions are research and training, and demonstration plots have been established using volunteer 'model farmers' all of whom are innovative people likely to influence other farmers. Some of the centres work with as many as 1800 women's groups, farmer's clubs and schools (Harrison, 1987). Botswana could take encouragement from this Kenyan example, and establish more demonstration plots supported by its own government departments.

Reducing the vulnerability in rural communities could be seen as one of the keys to drought management, and understanding local indigenous water harvesting and conservation techniques could contribute to the promotion of effective practices. Agroforestry should be seen as an integral part of the business of farming and not just as a separate activity. An EO's role could be invaluable as they suggest ways how agroforestry could overcome people's difficulties and wrong perceptions. Another future emphasis could be on teaching farmers and farmer's groups to collect their own seed and raise their own seedlings. For example, seedlings could be planted in the shade of a family compound where wastewater is available, or directly into a cropped field at the start of the rainy season.

7.3.4 Constraints to future expansion

A common situation found among many rural Botswana farmers is their willingness to leave their lands areas and find employment in the towns or cities (Tsapisa, 1999, pers com.). Only the older generation and very young children are remaining at their fields. However, family members keep their fields as a security during periods of drought as neighbours and villagers will pay to collect the wild indigenous fruits on other people's land.

To illustrate, Johanna Tsapisa is currently working in Gabane but he owns lands areas 2 x 2km in size near the village of Kgari, 25km north of Francistown. Although living in the Gaborone area, he would like to return to his fields one day and farm them (Tsapisa, 1999, pers com.). Food, however, will remain a priority, and the land will have to be worked to help provide it. The past social norm in Botswana was for the over-50s and 60s to move back to their families' lands areas to farm after their working lives in urban areas. However, people's willingness to farm again will depend upon their health and levels of energy and motivation. At the end of people's urban working lives they would ideally have funds available to hire rural labourers to help work their fields. The majority of people want to return to their lands or villages after completing their lifetime of town work, so fields tend to stay within family inheritance groups (Tsapisa, 1999, pers com.).

However, this situation is changing. It is questionable whether the present working generation will want to move back to their families' lands areas and adopt agriculture after they retire from working in urban areas. For the majority of urban dwellers, the focus appears to be transferring more and more to that of a settled lifestyle rather than the traditional tripartite migration system. This will place less of a demand on agricultural practices and more on buying the agricultural products.

7.3.5 Applying the conceptual framework

Agroforestry directly aims to reduce risk by offering drought-resilient agricultural practices that mitigate a fragile local economy and the unsafe conditions of food insecurity, at-risk livelihoods and low income levels, as illustrated in Figure 3.1. Through strengthening livelihoods and increasing low incomes, a local economy resistant to risk can be developed.

The effectiveness of the agroforestry techniques was illustrated in Table 7.7 where it was demonstrated that the yields of cowpeas and sorghum can be effectively increased through adopting agroforestry practices. The yield of cowpeas, for example, from a row with a 6m upslope catchment area was 500kg/ha, compared with 330kg/ha from a control plot. Providing that crop water requirements are reached each growing season, enormous potential exists to decrease vulnerability through improving food security. An increased level of disaster preparedness is, therefore, built up in society.

The popularity of agroforestry is extending to other towns in Botswana such as Francistown where the city council has planted indigenous drought-resistant trees in the city's parks and gardens. Kweneng District has also recently planted 1000 trees in 140 households with a 75% survival rate. Through offering the sale of indigenous and exotic fruit trees to members of the community, people's food security is increased, reducing the pressures during periods of food shortage.

However, the viability of agroforestry techniques is dependent upon the often low and erratic nature of the rainfall over Botswana. During a severe drought when crop failure occurs the government is quick to provide food hand-outs and aid packages. This readily available and indeed expected humanitarian response from the government means that many people feel there is no need to strengthen their capacity to resist drought when it arrives. This attitude to receiving support during periods of hardship is limiting the 'progression of safety' within Botswana and maintaining the high level of rural vulnerability.

7.4 Role of community-based agroforestry as a drought mitigation strategy

This section discusses the community-based agroforestry initiative as a drought mitigating strategy and similarly focuses on:

- Strengths of the approach
- Limitations of agroforestry
- Opportunities for further development
- Constraints to future expansion
- Applying the conceptual framework

7.4.1 Strengths of the approach

Community-based agroforestry aims to increase the capacity base of rural communities to periods of drought, providing them with increased food security through the growing of indigenous and exotic fruit trees and intercropping. Some participants have enthusiastically adopted the techniques and have developed their own 'on farm plots'.

Fruit trees are just starting to make an appearance around households and community buildings in urban areas (see plate 7.4), though it will take a long time to achieve widespread adoption. One woman in Gabane, Mmagohaledi (meaning 'mother of star') has become the village's largest banana grower. She is actively advocating the planting of fruit trees and fellow village residents have followed her example and planted trees themselves (Mmagohaledi, 1999, pers com.). Interest is therefore growing despite no direct NGO promotion. Some young sapling fruit trees stolen once from a VPR&D net house illustrate the point that people regard the trees as valuable and marketable commodities. So despite the loss of the trees, this was an encouraging feature (Taylor, 1999, pers com.).

At the Gabane Private Secondary School, vegetable gardening constitutes a large part of the school curriculum for those who chose the agriculture option during their last two years at school (forms 4 and 5, aged 18-21, but 'pupils' can be as old as 35) (see plate 7.5). Children prefer the agriculture option out of all those offered as it is regarded as an easy subject because it is so practical (Taylor, M., 1999, pers com.).

The school is also currently applying to the government's Financial Assistance Policy (FAP) where up to Pula 2 million can be made available for single commercial projects such as pig/chicken/cattle rearing, vegetable growing or fish farming. The school would like to increase its pig rearing operation and build a slaughterhouse and larger chicken coops.

7.4.2 Limitations to community-based agroforestry

The transferring of agroforestry practices to innovative farmers in the community is challenging with some difficulties to overcome. Since the early 1970s, EOs have been introducing many

government agricultural policies to farmers. Each EO had his or her own group of 20-25 farmers with whom they worked closely over a concentrated period of two to three years helping to establish their farms and practices. However, 'progress' was then made and today EOs work with between 1000-1500 farmers at any one time, but this is not productive as the time committed to each farmer is very small (Ketshabile, 1999, pers com.).

Moses Ketshabile, before joining VPR&D, worked as an EO and he believed that many people used the droughts during the late 1970s and early 1980s as good reasons to leave their farms. At the same time, agricultural subsidies were introduced and other people were attracted to farming when they were not really farmers at all. Since 1982, many farms have been subsidized through ALDEP and people were given free donkeys, ploughs and even cattle, but without the people first being screened for farming suitability. As recently as 1994, many were given seeds and even paid between Pula 70-100 to plough and sow. Some people though, took the money from the EO back to their villages and did not invest it in their lands areas (Ketshabile, 1999, pers com.).

Some of the agricultural practices promoted and encouraged by the government appear to be politically motivated and are opposite to those recommended by their policy advisors, who remain reluctant to speak out against the new policies (Ketshabile, 1999, pers com.). During the coming season, 1999-2000, free seeds might be handed out by the government after an inter-ministerial drought committee recommended to the President that this year be declared a drought year across the whole country (Ketshabile, 1999, pers com.).

Government subsidies are available to help buy RWH tanks and gutters only if there is a direct agricultural advantage through the project. Under Phase II of ALDEP, as section 2.4 mentioned, female-headed households are required to pay 10%, and male-headed households 15%, of the total cost of the agricultural package they require. However, a privately owned vegetable garden would not qualify for inclusion in this category and it would not be economical as insufficient rain would be collected and it would only work during the summer wet season (Taylor, 1999, pers com.). Recipients of subsidies and materials from ALDEP that enable them to stay at their lands or rural villages directly benefit from government subsidies. Commercial crop growing and cattle rearing also qualify for subsidies as they produce marketable commodities. It is evident, therefore, that the MoA are keen to promote sustainable monoculture through their subsidy policies.

If permanent water sources could be provided at lands areas, many people would live there all year round and raise cattle and fruit trees. No growing of crops would be likely to occur though unless they are either close enough to a market centre or there are other skilled farmers available to similarly join a market co-operative. A village's agricultural lands extend for up to 5km around it, while the harvesting of veld products may occur up to 15-20km away (Taylor, 1999, pers com.).

Rainwater harvesting has received very little publicity in the lands thus far and it desperately needs promoting. NGO workers feel that EOs are not pushing the ALDEP scheme and consequently many rural people are not aware of the help that the government could offer them. At the lands, water tanks could carry water over into the dry season if enough was saved, but this could only be successful if it was not required for cattle watering as well as agriculture. The farmer's cattle post could be some distance away, perhaps up to 100km.

Tree planting as an agroforestry initiative is a new concept in Botswana, so the use of bunds, mulches and stones that are even more recent, will require some time to catch on (Taylor, 1999, pers com.). Subsistence farmers and labourers are paid very little, approximately Pula 50 per month, and if stones are not immediately available on their land for use, their salaries make it uneconomic to buy and transport stones from elsewhere. Very few villages in Botswana contain any form of smallholdings or vegetable gardens (Taylor, M. and Scott, 1999, pers com). In Gabane, water standpipes are readily accessible and free water is found less than 100m from any individual house or rondavel (water payment is required if a yard has its own standpipe). The water, however, is not used for gardening and many fences remain in a state of disrepair, allowing goats and donkeys to freely roam the village, eating what vegetation is readily available.

7.4.3 Opportunities for further development

Opportunities are available for the government to support and finance more NGOs in Botswana. At present, 99% of VPR&D's funds are contributed from countries such as Denmark and Germany. Great encouragement is received from representatives of the Ministry of Agriculture during open days, but so far finances have not been forthcoming. Networking between NGOs also opens up opportunities for mutual support and expansion. For example, the Southern Alliance For Indigenous Resources (SAFIRE), based in Harare, is similarly involved in community-based agricultural approaches. A Kenyan NGO called the International Centre for Research in Agroforestry (ICRAF) is involved with indigenous fruit trees in Kenya, Malawi and Tanzania. They have also previously sent some of their employees to Botswana to study some of the country's practices and to ask advice.

The dry winter season in Botswana is used to plan and train farmers but this in itself provides some challenges. It is hard for farmers to see differences the agricultural practices make due to the dormant nature of the trees and the dry land. Training should ideally be carried out during the wet season but it is a busy time for both NGO workers and farmers on their lands. Mutual co-operation is thus required. One suggestion is that advantage be taken of the free time after the ploughing, germination and weeding stages, and just before harvest time, for NGO workers to integrate into the life of a community and provide training. The farmers themselves should also suggest what period is convenient for them (Kobo, 1999, pers com.).

A good future investment opportunity lies in the collection and marketing of indigenous fruits and veld products. The Botswana Development Corporation (BDC) owns and operates various irrigation schemes and commercial companies. These schemes cover a total of 570 ha and are located in the Tuli Block, Mogobane and Kasane (Aquastat, 1995). Farmers in the Tuli Block near Francistown were the first in the country to plant fruit trees commercially, particularly citrus. However, many farmers are conservative in nature and are hesitant to adopt new practices, unless it has already been proven, for example, that growing fruit trees is economic. No markets currently exist in Botswana for indigenous fruits and these must be established before many farmers will be convinced that investment is worthwhile. However, huge potential markets exist in places such as Soweto and Alexandra in South Africa and it is to these that indigenous fruits could be marketed (Taylor, 1999, pers com.). Indigenous fruits are currently being harvested all over Botswana and sold on the informal market but the practice is unprofitable.

7.4.4 Constraints to future expansion

Some farmers have modified the agroforestry approach to suit their own conditions but others have thought that the project might not be feasible in their lands area as a result of only one or two older men or women living there. Many farmers suffer from inertia when faced with the challenge of changing their practices. For example, some prefer to use their own methods such as planting trees for windbreaks but without building catchments for them as their construction is time consuming and demands a high labour input.

Changing agricultural attitudes are having a big impact upon people's changing practices. Maize is favoured over sorghum or millet as the majority of people believe that maize tastes better and more cooking options are available with it (eaten on the cob or as a porridge or meal). It is therefore being grown more frequently in Botswana but many also perceive that maize uses more water than sorghum. Maize needs sufficient rains over a period of six weeks for flowering and grain swelling and if they do not arrive during that duration then the year is officially declared a drought year, even though the rains might be good outside this period. However, maize is not as drought-resistant as, for example, millet of which less is grown (Scott, 1999, pers com.).

Subsistence farmers have shown an unfavourable response to monoculture as it reduces their harvest options. Traditionally, they mix a wide variety of seeds together before scattering these on the ploughed land. During periods with good rains a favourable germination response occurs, and even during poor rains there is usually at least some response from the crops. This way, many farmers can hedge their bets and receive at least a small harvest if the rains are poor.

At GPSS children enjoy agriculture, regarding it as one of their favourite subjects (Scott, 1999, pers com.). However, very little of the information and practical skills they learn, is passed on to their families or to lands areas. The majority of people currently living at the lands are 'elderly'

women who now collect pensions with no consequent interest in practising subsistence farming. Many farms have been abandoned as a result and former lands areas around Gabane have been developed for housing. In Botswana, it is now the social norm for women to have jobs such as secretaries whereas previously they worked at the lands (Scott, 1999, pers com.).

7.4.5 Applying the conceptual framework

Community based agroforestry interventions have the potential to prevent the 'progression of vulnerability' but so far evidence has not been forthcoming. Unsafe conditions could be mitigated through improving communities' food security and consequently encouraging a diversification of the rural economy. Agroforestry does have a role to play in reducing the pressures on at-risk households. However, some members of the community remain sceptical about its success, the labour input that would be required on their part and the distances over which village standpipe water must be transported.

The right enabling environment needs to be established whereby communities receive as much help as they need in order to develop their own drought mitigation agroforestry projects. Currently, each EO has under them between 1000-1500 farmers and this is not conducive to enabling each farmer to develop agricultural rainwater harvesting practices. The access of vulnerable groups to EO or NGO advice and the ALDEP scheme should be promoted and provided more readily. Access, as defined in section 3.1.2, is the ability to use resources that are directly required to secure a livelihood. In rural areas, access to resources and entitlements is low and unevenly spread, particularly amongst women who have less control over their income. With only one EO among 1500 farmers, gaining access to resources has its challenges. When an NGO such as VPR&D arrive in a village, a public meeting is held to explain community based agroforestry and offer it to interested people. In this way, access is more evenly spread.

The low and erratic rainfall is seen as one of the root causes of discouraging lands agriculture and has been responsible for the high levels of rural-urban migration that have occurred since the catastrophic droughts of the early 1980s. The community based agroforestry projects have been slow on the uptake as a result, and therefore the 'progression of vulnerability' in rural areas has remained. Investing in rural areas is questionable given the absence of the young- and middle-aged income-earning bracket of the population. The demography of rural lands and villages is heavily biased towards older men and women and young children. This further inhibits the uptake of agroforestry practices and the reducing of dynamic pressures.

Risk, therefore, remains high and a hazard could easily impact the vulnerable causing a rural drought disaster. However, expected and readily available government intervention and aid, as has already been mentioned, is never far away. This option may appear more attractive than investing in drought mitigation projects in the harsh semi-arid environment.



Plate 7.4: Bauhinia trees in earth-bunded, spherical microcatchments at Gabane Private Secondary School.



Plate 7.5: The vegetable garden at Gabane Private Secondary School maintained by the children and their agricultural teacher.

7.5 Rainwater harvesting - a risk reduction approach for further development

Finally, this section considers rainwater harvesting as a drought mitigation strategy and includes how the technology fares practically in a socio-economic context. It explores the changing context of vulnerability in rural Botswana and the role that rainwater harvesting plays, and could play, to reduce pressures on at-risk households. It specifically questions whether domestic and agricultural rainwater harvesting has a future in a rapidly developing country in which not only the economy is changing but also the demographic social structure as a result of the AIDS pandemic.

The following issues will be considered:

- Botswana Government involvement in water harvesting initiatives
- Social economics of rainwater harvesting in Botswana
- Initiatives for reducing drought vulnerability
- In view of a changing economic climate, is water technology investment worthwhile?
- In view of a changing agricultural environment, is water technology investment worthwhile?
- In view of a changing climate, is water technology investment worthwhile?
- Mitigating the effects of HIV/AIDS

7.5.1 Botswana Government involvement in water harvesting initiatives

Positive aspects of the MoA's involvement in water harvesting

Many farmers are questioning whether they can survive at the lands areas and say that the government is responsible for supplying them with water (Kobo, 1999, pers com.). The MoA is encouraging people to remain at their lands areas and to apply to ALDEP for farming materials and RWCS (Mmutle, 1999, pers com.). Purchasing any RWCS through ALDEP is expensive for individuals, though farmers could syndicate and therefore find it cheaper. ALDEP has very much been the main funding and resources body in the lands areas and has helped to create an enabling environment whereby at-risk households can directly apply for drought mitigating technologies. This in turn has strengthened livelihoods and improved local building infrastructure.

The water quality provided by the ALDEP systems is acceptable by the Ministry of Health, but similarly, another independent, professional opinion is also required (Mmutle, 1999, pers com.). The MoA recognizes that one of the issues requiring attention on the ALDEP system is the absence of a filter that would prevent the washing off of bird dung and dust from the roofs into the water tanks. At the lands, tanks $1 \times 1\text{m}^3$ are dug in the ground to store the cool water, but as a result of the majority of young men living and working in town, many of the older generation find this hard labour difficult. An alternative might be to build tanks from masonry bricks on the ground surface.

The MoA is currently experimenting with collecting runoff from impermeable saltpans in the Kalahari. At the edge of the pan, pits (haffirs) are dug to collect the runoff and the water is then

transported via a pipe into a nearby well. The pits are currently not lined as spreading a bitumen residue or a geotex liner on the base is very expensive (Mmutle, 1999, pers com.). Three such systems have been built already, such as at the village of Tswana in the Kalahari, but they have not received any water yet four months after construction. If the rains continue to fail, the MoA will abandon the project and refocus its initiatives elsewhere.

Negative aspects of the MoA's involvement in water harvesting

In 1994, just before the country's elections, the Minister of Agriculture and the government introduced the Accelerated Rainfed Arable Programme (ARAP) where people were encouraged and paid to clear their lands areas of all their trees. This was promoted throughout the whole country and was intended that the land could subsequently be used for growing crops (Kobo, 1999, pers com.). Farmers were offered subsidies such as cash grants to clear fields and fell trees, which would also rid the crop-growing areas of birds, free seed packages and subsidies on the hire of draught animals. The purpose of this has been to encourage people to remain on their land and cultivate it despite experiencing successive bad harvests (Walker, 1989).

Some NGO workers, however, felt that the scheme was designed to raise popular electorate support through providing quick and easy cash handouts (Kobo, 1999, pers com.). The scheme succeeded, but it may have had an unfavourable effect on the land. Some farmers began to experience land erosion and the birds returned to feed off the crops. The scheme, therefore, contributed to returning the 'progression of vulnerability' to people's livelihoods. Money was also provided if the fields were ploughed, sown and weeded. Poorer members of society and non-earners were particularly attracted to the short-term cash benefit but after the elections, they wanted their fruit trees back again (Kobo, 1999, pers com.). A similar support-raising scheme, such as seed handouts, was planned during the pre-election period in October 1999. However, the ALDEP Co-ordinator, Mr Mmofswa, said,

"It is my feeling that you cannot afford to bear witness to your environment degenerate into a completely barren and unproductive resource. It is therefore Government Policy to discourage farmers from indiscriminate burning of the veld and felling of live trees" (Toto, 1998).

Government involvement in water supply

Sustainable development can only be achieved through the decentralization and privatization of water supply services and the creation of local industries based on local expertise and professional skills development (Rydtun, 1994). The adopted technologies should ideally be simple, durable, with low maintenance and repair demands, and suitable for community management. This approach will encourage the diversification of income generating mechanisms in rural areas by providing the opportunities for the creation of small-scale service industries.

However, obstacles to this development include the fact that many local people have never been prepared, or offered the opportunity, to participate in community water supply provision. The community would also be required to understand that water is an economic product, and should be valued.

At present, the Botswana government are mainly financing all water supply activities, and this will continue until decentralization and privatization programmes are fully established (Rydtun, 1994). In order to reduce government expenditures and water resources, users should be required to pay, or give contributions in kind, for water services. Water supply provision is officially limited to villages that are at least five years old, have a minimum of 100 households or 500 inhabitants, and have been under the control of a continuous recognized traditional authority. However, these conditions are sometimes waived and many smaller villages and settlements through having, or purposefully building, schools and health facilities have become eligible for water supply programmes (Bhebe, 1994).

The private sector in rural communities cannot presently cater for a decentralization of water supplies, either through technology support or knowledge of operation and maintenance (Rydtun, 1994). The current high level of service expectation will limit opportunities in the private sector and their willingness to provide such services, as their investment in water production and technology quality will outweigh their initial skills and abilities (Rydtun, 1994).

Opportunities for future expansion

For two years now, the European Union (EU), through the MoA, has funded agroforestry initiatives. The MoA employs EOs in rural areas and this provides NGOs with the opportunity to work directly with the MoA's grassroots workers. There are many possible options that could be appropriate at the lands areas for farmers to collect water. Dams or boreholes could be constructed if ALDEP's RWCS are not available, or roads could be tapped after rain showers to catch runoff (Mmutle, 1999, pers com.). Farmers need to be involved in all the planning stages and the maintenance of any particular scheme also has its challenges. For instance, the installation processes demands a high time commitment, and while EOs take the lead, the farmers or school participants are also required to invest and commit themselves to the project. Extension officers are called upon for assistance if problems are encountered (Mmutle, 1999, pers com.).

One problem that rainwater harvesting faces is that the advocacy message for domestic rainwater harvesting schemes is not getting through to the population in general (Mmutle, 1999, pers com.). This is one of the root causes of people's vulnerability that limits their access to resources and to the economic systems that provide opportunities to improve living standards. Businesses and housing corporations have not adopted RWCS technology when planning their construction projects. The Botswana Government is also not inclined to focus on providing RWCS when

involved in public construction projects, though RWH does receive widespread encouragement from the appropriate inter-ministerial committees.

Every government building should have rainwater tanks to help provide a supplementary water source for, for example, landscape gardening, and to reduce the burden on a settlement's storm drains (Mmutle, 1999, pers com.). This would help to ensure that the rainwater harvesting advocacy message gets through to the general population. Many government buildings are huge; hospitals, schools, staff housing for doctors and nursing staff, and these are currently not being tapped for their water provision potential. The MoA would encourage the BTC to find ways of catching runoff from every government building so, for example, Gaborone's water costs would be reduced and water for lawns could be supplied from rainwater instead of the public supply.

Rainwater harvesting initiatives for primary and secondary schools in large villages such as Gumare and Etsha 6, which border the Okavango Delta, would reduce the burden on borehole costs (Mmutle, 1999, pers com.). The large roof catchments in these villages are currently not being utilized. Instead, they often rely on a reticulated network with standpipes, an elevated storage reservoir and an engine-powered supply, as Plates 7.6 and 7.7 illustrate.



Plate 7.6: The village water reticulation system in Etsha 6, north-west of Maun on the edge of the Okavango Delta.

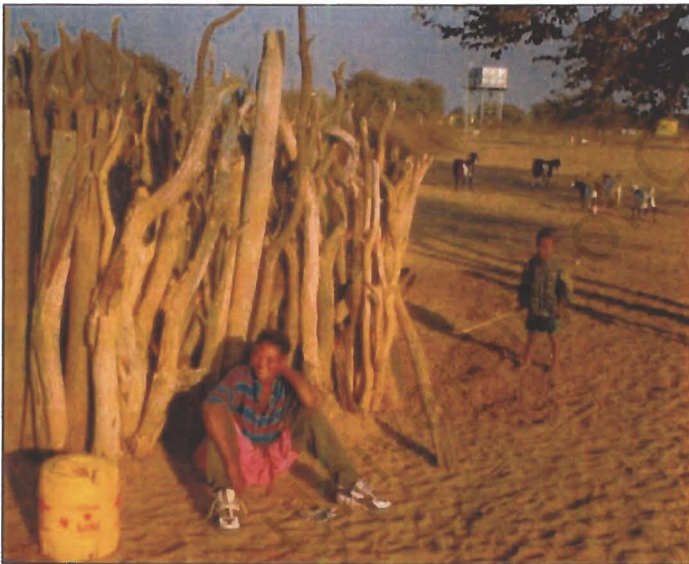


Plate 7.7: Batswana beside a water standpipe, protected from animals by wooden logs, in the village of Kekhenye, to the west of Gaborone. The village water reticulation system looms in the distance.

The MoA would like to encourage co-operation from ALDEP's crop production department, as there is currently no technical know-how on modernizing existing RWCS structures. The formation of farmer syndicates should also be promoted, particularly for constructing large roof collection catchments. People build what they can afford in terms of roofing structures but these initiatives need to be exploited so that they enter under the framework of drought mitigation (Mmutle, 1999, pers com.). Investing in these local syndicate infrastructure improvements will help to reduce the dynamic pressures upon individuals struggling to meet their own RWCS costs and upon the borehole to meet all the local water demand. Education programmes promote the great importance of rainwater harvesting so harvests can be reaped during years with good rains and borehole costs can be minimized. Many semi-arid soils have deep 10cm evaporation zones and deeper ploughing down to 20-30cm might increase the soil reservoir's capacity to hold water for agriculture (Mmutle, 1999, pers com.). The use of manure and composts can also increase the water holding capacity of the soil and reduce the level of transpiration from the soil surface.

7.5.2 Social economics of rainwater harvesting in Botswana

RWCS for households

The degree to which rural households accept RWCS is a reflection of their perceptions concerning their worth, both in monetary and non-monetary terms. Many households are not aware of just how much rainwater could be collected from their roofs, and the benefits of having such a clean source of water in order to help fight disease and ill-health such as gastro-enteritis (Erskine, 1991). It is also important to promote the on-going maintenance and cleanliness of the roofs and gutters, which are the parts that people view and form perceptions about. However, many people would rather deal with a responsible agency than trained, independent entrepreneurs (Erskine, 1991). The promotion of RWCS is heavily dependent upon a collaborative effect between the development agency or NGO, and the community. Where the community takes the decisions and the agency provides a supporting role.

These findings are not unexpected when considered with other southern African countries. For example, in Zimbabwe, only 19% of households practice rainwater harvesting for domestic purposes. In Zvishavane District, in the Midlands Province of Zimbabwe, Intermediate Technology discovered that most people are not aware that any domestic rainwater harvesting technology was suitable for thatch roofs. The belief is that RWCS are only suitable for brick houses with a corrugated iron roofs. The poor, therefore, have never thought of harvesting until such a time that they have this type of house (Rusikie, 2000). Education and exchange visits to farmers who are practising rainwater harvesting initiatives increases capacity building and the 'progression of safety' into local communities.

Installing RWCS on many buildings in Botswana is not considered an option at present. Gutters cannot be installed on thatch roofs because it is very difficult to attach the fixing brackets that also require special manufacture. Moreover, curved gutters for round roofs are not made. Botswana boasts a huge variation in the diameter of the house roofs and gutters could not be economically manufactured for specific buildings. The majority of houses presently being built in Gaborone have corrugated iron-zinc roofs, whereas thatch roofs are limited essentially to isolated, rural communities.

RWCS for schools

Through providing schools with water harvesting technology a wide variety of activities can be encouraged with the supplementary water. Children from at-risk households, who experience water and food shortages at home, can be provided for more readily at school. Safe conditions can be achieved at schools more easily than at many individual households. However, for a school, the financial outlay for a RWCS is enormous, and one example provided is that of Gabane Private Secondary School which is seeking to install one. The school has 12 buildings of size 18 x 8m and one building 40 x 15m that all have ridged roofs with two sloping surfaces 15-20° from horizontal. As well as three other buildings of sizes 20 x 11 m, 14 x 25m and 10 x 10m, each with roofs comprising four surfaces angled as above.

The headmistress at the school sees the development of water harvesting in two phases (Catherine, 1999, pers com.). In phase one, she would like to harvest the surface runoff in the form of sheet and gully wash into ditches and pipes around the perimeter of the school plot. This would flow to the lowest point of the plot in the south-east corner of the school where there would be an underground storage system. Ditches are already in situ but nothing can be done about the storage without funding. The school has approached Environmental Heritage, an organization in Botswana who processes funds from DANCED in Denmark, who if they approve, would grant up to Pula 60,000 for the project. This would then allow the school to contact a local firm to install a fibreglass storage system. The water would then be used for agricultural work such as watering the school's pigs, chickens, vegetables and perhaps toilets, but it would not be used for domestic purposes.

Socially, a RWCS would not be feasible on a community centre because no-one in the community owns it and it would be very difficult to divide the water between all members of the settlement. If, for example, the water was used for a communal vegetable garden then realistic possibilities emerge.

7.5.3 Initiatives for reducing drought vulnerability

Positive influences

Traditional farmers, pastoralists and agropastoralists often live in fragile environments that are ecologically, geographically and economically marginalized. They have, however, often developed coping and adaptive strategies to help reduce their drought vulnerability.

One successful adaptive strategy is the intercropping system where farmers plant more than one crop in the same hole or plant a crop between the rows of a different crop planted previously or simultaneously. This effectively reduces the competition between the crops as they have different water requirements even in the same hole. The crops also exploit different layers of the soil strata for water and nutrients. Farmers can also take advantage of their often-limited field sizes for maximum benefit as well as introducing drought resistant crops, early maturing varieties or eliminating moisture wastage through early intense weeding. These coping mechanisms should be supported by scientific methodologies in order to reduce drought vulnerability and should be accompanied with intervention from both governments and NGOs to help tackle the problem (Elfaig, 1999).

When adopted, strategies such as intercropping help to reduce the dynamic pressures upon households and enable a strengthening of their capacity to withstand shocks such as the failure of one particular crop type. Intercropping provides a range of planting options, such as maize and groundnuts, which help to improve food security and further individual's 'progression of safety'.

Negative influences

There are also some issues that might be raised as obstacles to rainwater harvesting in individual households (Ndege, 2000). For example, the small size of storage containers that result in an inadequate supply of water and the traditional belief that some people hold, that rainwater cannot be stored for any length of time because it develops tadpoles. A lack of ownership for community-built projects, such as tanks at schools or clinics, or even small community dams for watering livestock such as at the Polokwe lands area, may inhibit their successful adoption and maintenance. The lack of ownership of communal projects increases the dynamic pressures upon a community as responsibility for maintenance is left open or up to someone else.

The colour of the rainwater harvested off thatched rondavel roofs may, for some people, make the water unattractive for drinking. People's preferences, therefore, are for collecting rainwater off metal sheets or open ground catchments.

An educational approach

Education can be an effective means of raising people's awareness to drought and water management issues in order to ensure that they know how to respond when a shortage occurs.

Information needs to be targeted at school children, households, communities, small businesses, NGOs and members of government. Somarelang Tikologo (Environmental Watch Botswana) is one organization actively involved in education in Botswana. Their news letters and brochures include reports on how, for example, a particular drought plan is expected to relieve the impacts of drought and what changes people might be expected to make in response to varying degrees of water shortage.

Ideas such as demand control for all non-essential users, not irrigating crops at certain times or strategies for reducing household water wastage are provided. One example of a poster produced by Somarelang Tikologo promoting good water conservation is illustrated in plate 7.8. Members of the public should be kept well informed of the country's current water status and whether 'trigger points' are approaching that necessitates a response such as water restrictions. Those vulnerable to drought also need to know how they can access assistance, thereby reducing their dynamic pressures, instead of being forced to abandon their livelihoods and go in search of relief in the urban environment.

Stakeholder consultation

It is similarly important to involve all of a country's stakeholders in drought planning. These groups need to be included early and for the duration of the consultation to ensure a fair representation for deciding upon effective drought mitigation strategies (Wilhite, 1999). Airing stakeholder concerns early in the collaborative process resolves any conflicts and develops an understanding of where other people have their focus, views and strong points. The power of stakeholders is often underestimated and their influence in policy making may be considerable. They may be involved in local training initiatives, investments, establishing markets for produce and maintaining ethical standards in public life. These factors are constituents in Blaikie's PAR model and contribute towards an advancement of the 'progression of safety'.

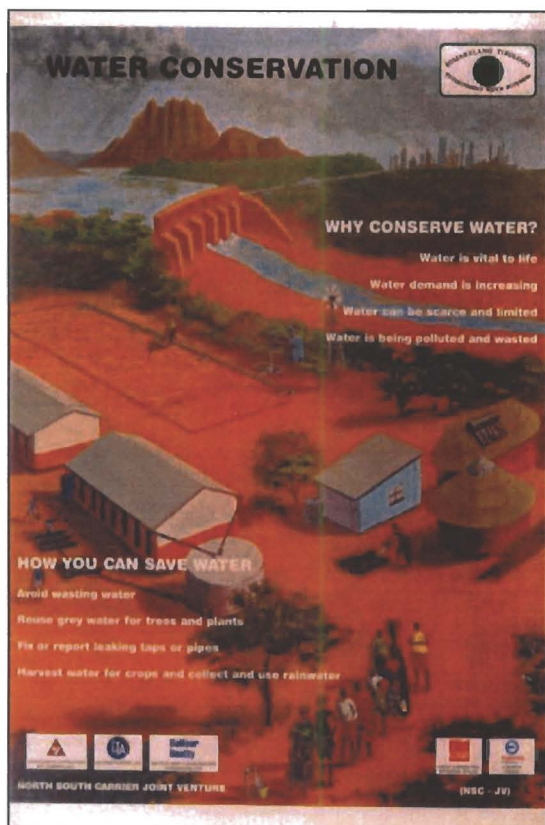


Plate 7.8: Poster produced by Somarelang Tikologo advocating effective water conservation measures in Botswana.

Note the ferrocement tank, galvanised steel tank, irrigation system, wind power generator, solar panel on a rondavel and vegetable watering. The captions read:

Why conserve water?

- Water is vital to life
- Water demand is increasing
- Water can be scarce and limited
- Water is being polluted and wasted

How you can save water:

- Avoid wasting water
- Reuse grey water for trees and plants
- Fix or report leaking taps or pipes
- Harvest water for crops and collect and use rainwater

7.5.5 In view of a changing economic climate, is water technology investment worthwhile?

A pattern of ongoing change in traditional Batswana society has been observed over the last 25 years. Periods of drought and times of reduced rainfall are now characterized by a move into town because, certainly in Gaborone, the streets are literally 'paved with gold' (Taylor, M., 1999, pers com.). The economy is booming, particularly in the construction and motor vehicle industries, vehicle repair and panel beating. The market for mass consumerism is similarly rapidly expanding, for example, in the purchase of cell phones.

Many Sub-Saharan African (SSA) economies are widely perceived as being particularly vulnerable to the effects of drought. This is the result of countries putting an over-reliance on rain-fed agriculture and livestock production to bolster the GDP, having a limited infrastructure, and low levels of capita income (Benson and Clay, 1994). Botswana, however, accepts that food self-sufficiency is neither achievable nor sustainable (Aquastat, 1995). Its objectives are therefore to raise food security at both household and national levels by giving priority to production programmes that are sustainable, resource efficient and environmentally compatible.

Irrigation projects, for example, must prove that they are economically viable and sustainable before their adoption can become widespread. The country faces a substantial shortfall in water supplies as competing uses and high prices make it uneconomical for irrigation. Any large-scale irrigation development is therefore unlikely (Aquastat, 1995). The competition between water users during periods of shortage may result in preference being given to economically large industries and capital ventures, further marginalizing the already vulnerable rural poor. There is, however, some potential for the further spread of molapo farming, the traditional recession irrigation farming found on river and deltaic floodplains.

In the National Water Master Plan, there is provision for the introduction of a sliding subsidy scale. In this context, the government could supply water for irrigation from a baseline of high tariffs and low subsidies that becomes progressively cheaper up to providing water for free. Free water would ensure that Botswana could supply 20% of its national grain requirement by 2020. However, what the government can actually afford over the next two decades will be one factor in determining the scale of irrigation farming actually practised (Aquastat, 1995).

Economic and political systems are two of the primary root causes that can either increase the effects of, or help mitigate, drought. Responsibility for the planning and implementation of irrigation rests with the MoA. The DWA is registrar of the Water Apportionment Board and is responsible for providing the Secretariat and Technical Adviser to the Board. The country's Water Act and Borehole Act, administered by the Board, require that individuals or groups apply for the right to use irrigation water. There are no irrigation water charges at present. The MMR&WA

have indicated that, in the future, the government could provide dams and headworks while irrigation water users would have to cover the distribution costs.

The conservation approach to meeting Botswana's rapidly growing water demand has been to develop new sources of water such as drilling more boreholes and building dams and pipelines. Despite periods of water scarcity, little attempt has been made to seriously curb demand or actively encourage water conservation measures except temporarily during periods of drought (Toteng, 1999). Even in government it is acknowledged that,

"The development of water resources in Botswana has been demand driven, and the conservation (and demand management) measures have not been addressed"
(Government of Botswana, 1997:294, cited in Toteng, 1999).

Cutting water bills as well as achieving good water conservation measures has motivated a few companies in Gaborone. For example, Kgale Quarries and the Grand Palm Hotel have set up their own RWCS to harvest rain. Government policy on urban water stakeholder management systems needs to be clearer so that the knowledge, experience and expertise in these individual companies is not lost (Toteng, 1999).

Water technology investment is a pre-requisite for development and urbanization. An expanding urban population also increases the dynamic pressures upon the water providers to meet this demand. Economic structures that hinder the 'progression of safety' and reduction of vulnerability through all sectors of life in Botswana must be challenged, but particularly where the greatest need lies. In view of the changing economic climate, investment needs to be directed towards those areas such as new settlement housing in large villages and urban centres and job creation projects that demand the greatest levels of water. However, politically, rural Botswana does have a strong voice in government and adequate provision simultaneously needs to be made for at-risk and vulnerable households.

7.5.6 In view of changing agriculture, is water technology investment worthwhile?

In Botswana, unfavourable changes in biomes are predicted with the tree and scrub savanna expected to give way to thorny scrub savanna or desert, under the 'core' and 'dry' scenarios (Hulme, 1996). This is expected to reduce the carrying capacity of the land, favouring small stock and leading to a reduction in the number of livestock. Commercial farmers are expected to fare worst by declining returns in the sector, though communal farmers will probably keep their cattle for longer as the animals are capital assets and are used for many economic and social functions. Table 7. 9 summarizes the possible climate change impact upon human livelihoods in Botswana.

Impact type	'Core' scenario	'Wet' scenario	'Dry' scenario
Sectoral shifts	Desert expansion reduces livestock potential in favour of small stock	Little change; possibly better cultivation opportunities	Desert expansion reduces livestock potential in favour of small stock
Productivity & income by sector	Increase in marginal conditions adversely affects land productivity	Little change, small increase in cultivation	Increase in marginal conditions adversely affects land productivity
Livelihood security/ income distribution	Widespread reduction (extreme events, poorer physical conditions)	Reduced security (extreme events)	Widespread reduction (extreme events, poorer physical conditions)
Development potential/ carrying capacity	Decrease, with some differences between regions	Same or slight increase	Decrease, with some differences between regions

Table 7.9: Summary of possible livelihood impacts from climate change according to the prevailing climate scenario

Source: Hulme, 1996

In communal areas, the low-income group that has the lowest capacity to withstand shocks, and is therefore most at-risk from drought, will experience the most stress from the adverse impacts of climate change (Hulme, 1996). It will be harder to secure access to cattle, water and other resources by traditional methods and the opportunities for hunting and gathering will decline. Access is at its lowest when people do not have the ability to find or use resources that are directly required to secure their livelihoods. This may lead to a marginalization of the rural population if, increasingly, there are restrictions to land and water access and livestock expansion. Low-income groups do have a natural resilience to stresses placed upon them, however, whereas middle- and high-income groups often do not have this inherent resilience. The urban population is in a better position to withstand stress though they may also be less adaptable to changing conditions.

Climate change, together with anthropogenic impacts, will cause changes to the integrity and distribution of the country's flora and fauna. Biomes are expected to shift as a consequence of the increased temperature, leading to a reduction in the faunal biodiversity as only species that can adapt to a wider range of conditions and migrate over large distances will survive (Hulme, 1996). Migration, however, is becoming increasingly restricted with the spread of communal lands, grazing areas and game fences. If the flora and fauna are negatively affected, this can potentially restrict Botswana's agricultural production development opportunities. Vegetation changes that are already exerting dynamic pressures upon Botswana include (Hulme, 1996):

- The expansion of bare soil as concentric circles around settlements or boreholes due to woodland thinning and a depletion of the veld, as a result of increased grazing and soil erosion. This is occurring in northern, central and south-eastern Botswana.
- The development of woody weeds such as *Maytenus*, *Bauhinia*, *Dichrostachys* and *Acacia* species. These species have the competitive advantage with the increases in bare soil cover, higher rainfall events and longer dry periods. It is suggested that increased levels of carbon dioxide favour trees and weeds over grasses, so despite range degradation, carbon uptake (which is usually constrained by nutrient availability, particularly nitrogen and phosphorus) is becoming increasingly effective in the region's rangelands.
- Increases in vegetation fragmentation as land reforms, legislation and new agricultural practices are producing multiple fencing operations.
- The nutrient content of grasses is expected to change as heavier rainfalls remove more soil nutrients, raising the fibre content in relation to protein. This will affect the cattle population in terms of their sustainability.

Increased education in soil science, land husbandry and water conservation, such as through community-based agroforestry initiatives, would enhance the value of water in Botswana. This is particularly important in the country's semi-arid environment where water losses by evaporation and infiltration are large and agricultural practices provide only limited opportunities to recycle water. In this environment agroforestry and ferrocement technology fulfil their potential as they reduce dynamic pressures by making water available for domestic and agricultural uses that would otherwise be lost to the ground. When water has been collected in ground catchments or tanks and saved for the start of the planting season, crops may be planted earlier than the first rains as the water can be used to saturate the soil profile before planting and also added during the plants critical growth stages. The supply of ferrocement tanks to lands areas could, therefore, help to extend the growing season, provided that sufficient tank water was available.

In Botswana, economical methods of raising crops should be researched and experimented with. However, given the current availability of relatively inexpensive food commodities internationally, it is questionable whether large volumes of irreplaceable water should be used on risky commercial, arable agricultural projects. At the same time, however, during periods when the food prices for some commodities are inflated, indigenous food production and agroforestry would make economic as well as strategic sense. Investing in widespread lands agriculture is questionable, however, considering the influence of drought, reduced soil fertilities and rural-to-urban migration. In Botswana there is the danger of rural agricultural expertise being lost as much of the present younger generation grow up in an urban environment. Visiting their families' lands areas would also become less and less frequent than in previous generations. Feelings of insecurity and

experiencing an increasing 'progression of vulnerability' could thus further develop among the remaining members of the farming community who remain at their lands areas.

The concept of a rural Motswana being a self-sufficient, subsistence producer could potentially end, if it has not already done so, as the urban employment sector expands and food provision is left almost entirely in the hands of importers or a few successful commercial enterprises. High spending in the urban sector together with the adoption of large-scale irrigation projects has the effect of limiting an integrated planning approach to agriculture.

Botswana is unable to sustain agricultural growth above population rates and is dependent on food imports. For example, Pula 500 million of milk is annually imported from South Africa (Scott, 1999, pers com.). The droughts of the 1980s have been attributed to for accelerating the exodus from the lands to the towns and the prospect of reliable wages for the household. Botswana is now a prosperous country and in urban areas a wealthy person can expect to earn up to Pula 10,000-12,000 a year, some of which is then extended to other related family members as part of the Batswana culture (Scott, 1999, pers com.). No class system is present within families despite there often being many different levels of income and therefore family members help each other out. However, this can be unhealthy as dependency can build up on working relatives.

Current attempts to revive the commercial Batswana agricultural sector are being carried out by the MoA in co-operation with the Israeli government. Having a similar climatic system to Botswana, the Israelis are helping to evaluate the potential opportunities that the country might have to commercially grow some of its own staple foods such as maize and sorghum (Taylor, 1999, pers com.). The future of agriculture in Botswana is in commercial, arable horticulture, such as that which the Israelis are developing in partial fulfilment of the Agriculture Master Plan (Inger, 1999, pers com.). The Israelis are currently studying maize and sorghum and by their involvement, methods of irrigation farming on all scales from the smallest to the largest are being advocated. The countrywide introduction of modern commercial agricultural practices is very difficult, however, when there is a low level of rural skills, earnings and profitability, combined with the effects that drought and land degradation bring. The agricultural sector is subject to great economic forces generated by the injection of substantial volumes of funds into the urban areas (Allan, 1982).

Any modern agricultural technologies developed, such as irrigation systems, would use larger volumes of water than traditional farming methods, but would increase the stability and security of the country's commercial agricultural base. From an economic perspective, this would benefit commercial farmers when considering Botswana's expanding domestic market. It could be argued that the water technology that ensures the highest rate of return to each cubic metre of water supplied should be pursued. Rendering other factors such as land, capital and labour, less important.

In view of a changing agricultural base, investing in water technology in rural areas could be seen an imperative while at the same time being questionable. The increasing 'progression of vulnerability', particularly in lands areas, means that intervention is essential if the continuing tide of rural-urban migration, drought vulnerability and low food security is to be stemmed. Agroforestry practices do have the potential to reduce dynamic pressures thereby advancing safe conditions, and offer drought mitigating benefits to at-risk households. For example, growing fruit trees and vegetable gardening in household yards using waste water would improve food security. Such activities would provide the 'release' component as a method of helping to reverse disaster 'pressure', and reduce household's vulnerability to hazards.

However, the fragile physical environment coupled with biome changes that have already occurred around settlements, such as the increases in bare soil and woody plants, pose threats to the successful development of new water technologies for agroforestry and for farming in general. The majority of Batswana no longer look to, or rely on, traditional coping mechanisms when the attainment of safe conditions and a higher standard of living can be achieved through moving into town.

7.5.7 In view of a changing climate, is water technology investment worthwhile?

Changing water resources

In the 'core' climatic scenario, as mentioned in section 1.8.3, the anticipated rise in temperature will increase PET rates and, given no change in rainfall, reduce the potential water availability. It is estimated that there will be an increase in PET of between 5-20% across the southern Africa interior upland plateau, as a result of changes in relative humidity, wind speed and radiation. The largest increase of 0.7mm/day, or about 15%, is expected over the interior plateau of Angola, Zambia and Zimbabwe (Hulme, 1996). How important this increase in PET will be for Botswana depends upon associated changes in rainfall.

Rainfall changes envisaged under the 'core' scenario comprise an increase during the peak of the wet season between December and February over much of the sub-continent. However, the length of the wet season is expected to both shorten and become less reliable. The pattern of rainfall change is a mixture of natural variability and greenhouse gas-induced change, but separating the two is very difficult (Hulme, 1996). Rainfall variability is estimated to decrease between 20-30% over much of Botswana, Zambia and Zimbabwe, altering to between 5-15% by the 2050s. The variability could see areas with higher runoff experience a runoff increase, while areas with low runoff see a runoff decrease. The estimated decrease in runoff would, in essence, only amount to a difference from present of a few millimetres.

Under the 'wet' scenario, the majority of the sub-continent (apart from south-west Namibia, western South Africa and the Mozambique coast) would see an increase in rainfall and runoff. Over Botswana and northern Namibia an increase in rainfall would have a low impact upon surface water resources as a result of the high levels of infiltration and low runoff. The 'dry' scenario envisages a higher general decrease in rainfall and runoff than the 'core' scenario, though with little runoff changes from the present climatic situation. From the analysis of model simulations, it also appears that ENSO events do not change significantly in frequency or strength in the 'core' scenario. However, this is still currently an area of on-going climatic research (Hulme, 1996).

Climate change over southern Africa is anticipated. Certainly, as figure 1.14 illustrated, there have been periods of both above and below average percentage departure of normal rainfall over Botswana since 1970. In Botswana, the uptake of rainwater harvesting practices might itself be dependent upon the changing climate. If the country follows a pattern similar to that of the core or dry scenarios, then people themselves will be reluctant to invest in RWCS if they see the land becoming more arid by either/or more PET or less rainfall. Long-term drought strategies must relate agricultural practices and management to periods of unexpected rainfall reduction. Some techniques are effective mitigation practices, such as collecting rainwater during the wet season, but these may not be foolproof enough buffers during periods of heavy and sustained drought.

To effectively combat predicted future periods of reduced rainfall, flexible decision-making is necessary by communities and influential NGOs. Drought resilient strategies can be planned such as employing a greater diversity of cropping patterns and sources of income and food. For people reliant on rain-fed agriculture and rainwater as their sole or supplementary water source, identifying a set of drought mitigating measures is essential as part of any mitigation strategy. This is particularly significant as the rural economy provides a livelihood for at least 55% of Botswana's population (Manamela, 1997).

Despite the uncertainties in southern Africa's future climate, anticipated changes must be taken seriously, mitigated and adapted to. Countries and organizations are going to need support so they will have the necessary resources to plan for the consequences on the land and resources of a changing environment. A range of responses needs to be established that include utilizing indigenous knowledge systems, promoting community-orientated approaches to drought management, and advocating to all levels of society the benefits of water-harvesting, water conservation and storage mechanisms. Four areas of adoption need to be addressed in semi-arid environments (Dalal-Clayton, 1997):

- Policy re-assessments in favour of small stock, wildlife and collecting veld products.
- More research is required on community empowerment and income generating mechanisms from veld resources.
- Drought mitigating measures such as water harvesting and conservation practices, early-warning systems and improving food and resource security.
- Economic diversification practices that focus on creating alternative income and business opportunities outside agriculture and for the purposes of alleviating poverty.

One area for debate is should the promotion of water technologies be in line with presently anticipated climate change? This issue is not unique to Botswana, but is also a current and pressing regional concern. There is a need for the good management of catchment areas with arguably domestic and industrial markets receiving water as a priority rather than irrigation (Dalal-Clayton, 1997). Providing the Botswana with adequate access to water resources is seen as a developmental imperative and the government is currently reaching this goal through building articulated borehole supplies in all large towns and villages. Vulnerability to low rainfall has therefore been decreased and safer conditions achieved in these settlements, which subsequently attract previous lands dwellers who move to within reach of permanent water sources. Many people automatically look to, and depend upon, the government for all their basic infrastructural needs such as water.

In view of the changing climate, drought mitigation should encompass providing water for all sectors of society. Providing that RWCS tanks receive sufficient rainfall, water harvesting does have the potential to sustain lands dwellers for a couple of months during a dry period and provide a supplementary source should village standpipes temporarily fail. A diversification of water sources would also avoid an over-reliance solely upon borehole or reticulated supplies. However, in view also of the changing agricultural base and economic climate, a 'progression of safety' and reduction in livelihood vulnerability may best be achieved through encouraging people to migrate into settlements served by reliable water supplies.

7.5.8 Mitigating the effects of HIV/AIDS

As described earlier Botswana has one of the highest levels of HIV/AIDS infection in Africa. Useful development strategies across all sectors, therefore, should aim to reduce the impact of HIV/AIDS, especially on those most vulnerable, and wherever possible to improve the sustainability of their livelihoods. This is where a positive link could be found between rainwater harvesting and people weakened by AIDS. The development of domestic and agricultural water harvesting practices in Botswana would essentially remove the daily need for many people to walk great distances, particularly in rural settings and lands areas, for water. A close-at-hand RWCS

would provide a very useful supplementary or sole water supply for families, particularly those headed by women who have been weakened through AIDS.

In Botswana, women, most of who are single, head 47% of all households and these households also constitute the majority of all those living in poverty (UNICEF, 1999). Practices such as building agricultural microcatchments, planting fruit trees and conserving soil moisture through the use of mulches increase productivity and, therefore, food security. The benefits that could be reaped for single parents, children and women in particular are potentially huge and would help mitigate poor nutrition and bodies weakened by illness.

Other initiatives could include a reduction in school fees that will help AIDS orphans and children from poor families stay longer in school and so benefit from continued education and health programmes. Mitigating the impact on individual households could be increased with programmes such as home care for HIV/AIDS patients, supporting affected families, offering a foster care option for orphans, child feeding programmes and education (Bollinger and Stover, 1999).

A politically enabling approach to increasing AIDS awareness helps to reduce the stigma and discrimination associated with the illness. This approach also facilitates multi-sectoral involvement by making the fight against AIDS a national priority, and it sends a positive message to national and international donors who help fund important programmes.

The response to the AIDS epidemic in Botswana has not been approached in terms of specific mitigation programmes. What is being done is to essentially mitigate the already disastrous effects of the disease. For example, at Princes Marina Hospital, an emotional support-counselling programme has been established for members of staff who feel overwhelmed by the epidemic (Moffat, 2000 pers com.). One example of what will soon be national mitigation programme is the mother to child transmission (MTCT) prevention programme. Here, pregnant mothers who agree to be tested for HIV and are found to be positive are offered drug therapy for the final six weeks of their pregnancy. These drugs reduce the risk of transmission to the newborn child from about 40% to 10% (Moffat, 2000, pers com.).

In terms of awareness, the government has done everything it can, including using billboards, posters and car-bumper stickers with slogans such as "Don't let casual sex kill Botswana's future" and "Be wise, condomise", but words alone appear unable to stem the rising tide of infections (Barnett, 1999). The problem lies with changing people's behaviour, as the people can no longer say that they are uneducated.

Reducing the impact of HIV/AIDS is one of the most pressing issues, if not the most important, that Botswana is currently facing. Economic and financial gains made in the public and private sectors will be seriously affected if the infection rate does not decrease. HIV/AIDS has the

potential to directly impact much of Batswana life and advance a new 'progression of vulnerability' throughout the country. For example, time that could be spent developing an agroforestry plot or vegetable garden will be taken up attending funerals each week. The rise in the number of funerals will also increase the financial dynamic pressures upon individual households, impacting those livelihoods most at-risk and eroding the local economy. Services such as government primary and home health care, orphanages as well as large families with few or no working-age members have already come under immense pressure. HIV/AIDS could be viewed as a root cause of vulnerability that is going to dramatically increase the dynamic pressures and unsafe conditions within society.

Regional experiences

In Zambia, one of the pre-conditions before economic intervention from the International Monetary Fund (IMF) was the country's implementation of agricultural and poverty-reduction policies and programmes that inhibit the spread of HIV/AIDS (Goma, 1999). In combating the epidemic's effects on rural agricultural production, food security and the labour force, the following recommendations were suggested:

- With the variation in seasonal rainfall contributing to livelihood stress, higher value and more drought resistant crops should be encouraged for low water budget areas.
- Agricultural practices that increase soil moisture conservation increase productivity and therefore food security.
- Communities need to be informed of the level or stage that HIV/AIDS has reached in order to increase their knowledge and realization of the problem at hand.
- To maintain sustainability in AIDS mitigation programmes, farmers must be involved in the planning and implementation of such projects.
- Community participation should be coupled with such interventions.
- HIV/AIDS programmes could include issues of reproductive health but intervention strategies must retain people's dignity and respect while at the same time promoting a balance between their lifestyles and suggested new practices.
- Priority should be given to improving and strengthening the services offered through EOs, such as farmer education and training, in order to combine sustainable rural development in HIV/AIDS affected rural areas (Sharma, *et al.*, 1996).

The above recommendations could be applied to Botswana as well. For example, EOs could encourage those families who have been weakened and made more vulnerable from HIV/AIDS, to adopt water harvesting practices on the roofs of their houses that would reduce the need to walk great distances to fetch water.

7.6 Rainwater harvesting in Botswana today

The research problem that generated this study recognised the recurrence and severity of drought in Botswana and its impact upon people's livelihoods. In this context, reducing the risk of drought and lessening people's vulnerability to drought in rural communities is necessary to promote sustainable development and more robust livelihoods. Rainwater harvesting presents, at least theoretically, an appropriate technology to minimize the impact of drought in at-risk households.

However, there appears to be a mismatch between rainwater harvesting and its place in society today. Rural depopulation has occurred as people migrate into towns, seeking to improve their standard of living. They leave behind the dynamic pressures and unsafe conditions created by low levels of income and work in rural villages. The drought-prone vulnerability in rural areas also questions whether investment in rainwater harvesting is economically viable. The root causes of vulnerability including the semi-arid climate and low, erratic rainfall do not favour the widespread expansion of agricultural activities. Despite the benefits from rainwater harvesting of securing a higher level of food security or obtaining a supplementary water source, uptake of the technology among the Batswana has been poor. The greatest potential area for RWCS adoption lies in rural settlements that are far from, or not served by, reticulated borehole water supplies.

The Botswana government, with one of the best well-developed drought response systems in southern Africa, is very quick to respond to a drought crisis and quickly offers supplementary food handouts. As a result of these subsidies and handouts, there is very little incentive for rural communities to develop drought mitigation schemes in order to reduce risk. This has contributed to the poor uptake of rainwater harvesting initiatives. The drought years of the 1980s in particular were responsible for reducing people's interest in farming, inducing rural depopulation and initiating a diversification of the urban economy. People's vulnerability to these droughts increased their risk to dynamic pressures translating the root causes into unsafe conditions. A higher standard of living can therefore be attained through working in towns than could be received from working in rural villages or on the lands. The present semi-arid environment is also a prohibiting factor to technology adoption, particularly with future predictions of a more arid climate.

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There appears to be a discrepancy between the effective vulnerability-reducing potential of rainwater harvesting and its practical out-working and development in Botswana. Given the changing economic, agricultural and climatic conditions, the practicality of theoretically good, sustainable water harvesting practices needs to be improved. In the final chapter, each objective is revisited to explore possible strategies for lowering vulnerability in rural, drought prone Botswana. The future direction for rainwater harvesting in Botswana as a vulnerability reduction strategy is also considered.

CHAPTER 8

CONCLUSIONS

8.1 Introduction

In the dissertation, the validity of effective rainwater harvesting as a risk reduction strategy against drought and its effect in increasing resilience in developing communities in Botswana has been examined. This has been investigated through evaluating drought mitigation projects that have been initiated in rural villages and lands areas for both domestic and agricultural rainwater harvesting projects. Rainwater harvesting is a potential risk reduction strategy that could contribute to lowering vulnerability in rural communities.

Referring to the aims of the dissertation set out in section 4.1, each initiative could increase the coping capacity against drought in at-risk households and communities.

1. *The installation of ferrocement water tanks has the potential to enhance livelihood resilience in village lands areas and rural communities.*

When water is available from the ferrocement tanks, it has enabled a variety of domestic and agricultural activities to be carried out more easily than collecting water from village standpipes. The tanks have also contributed to reducing the vulnerability and dynamic pressures that people face when their yard or village standpipe breaks down.

While the technology cannot compete with, for example, reliable groundwater or piped resources, it does offer an attractive alternative in areas that experience water problems, temporary shortages, or are too far from piped sources. The RWCS can be established practically anywhere and can provide a high quality source of water, providing the catchment surface and tank is regularly cleaned. Benefits also include the durability of the tanks and the employment that building tanks could create in rural areas if the project expands. Tanks have the potential to temporarily mitigate short periods of both standpipe failure and lack of rainfall during a dry season, providing they are full when the stress is imposed upon at-risk communities.

Technically the RWCS should work perfectly. However, there have been problems in its practical implementation. Hindrances to wider project adoption include a lack of builders willing to be trained in tank construction, poor workmanship and structurally unsound guttering materials. In drought periods, rainwater tanks also yield very little water. Vulnerability therefore returns to

communities and dynamic pressures, such as a lack of skilled men living at the lands, intensify the root causes of vulnerability, such as the poor or unequal allocation of resources and jobs, into increasingly unsafe conditions.

Rural lands areas have, therefore, seen a migration of people into urban centres in order to escape the relatively harsh conditions and low income and work in agriculture. The unreliable and erratic rainfall also questions whether investment in rainwater harvesting is economically viable given the drought-prone climate, a declining interest in agriculture and heavy rural-to-urban migration.

2. Agroforestry and community-based interventions offer resilience against drought-related vulnerability and the opportunity to increase livelihood security.

In the risk reduction framework, risk is the sum of hazard plus vulnerability. In order to help avert or reduce the effects of a disaster, the pressure must be relieved upon a particular people group that will lessen their vulnerability. The rainwater harvesting and water conservation techniques that are demonstrated in the agroforestry and CBAP projects aim to reduce people's vulnerability and increase food security. In this context, rainwater harvesting could be set within the broader context of disaster planning and mitigation as it offers communities the opportunity to create a more sustainable livelihood.

The agroforestry approach integrates indigenous fruit tree production and the intercropping of traditional crops with rainwater harvesting practices. This has potential to succeed as the traditional crops and trees are not only well adapted to the country's environment but they are also familiar and acceptable to subsistence farmers. Sustainable agricultural practices help to mitigate the risks that drought poses to communities. The higher crop and tree yields from using agroforestry techniques would go further to meet household food requirements than traditional arable agriculture that does not utilize such practices.

The community-based agroforestry approach is an example of an anti-poverty and anti-vulnerability programme that aims to increase household security and reduce the chances that a hazard will have a detrimental impact upon a society. The dynamic pressures exerted on people would, therefore, be decreased, and the build-up of unsafe conditions mitigated. Establishing food security is essential in mitigating the risks that drought poses and preventing the abandonment of farming areas when people move into town to find work and a more secure livelihood.

Community-based agriculture has not significantly reduced drought-related vulnerability in the villages of Gabane and Paje. The interventions have so far had only a limited effect and the 'on farm plots' have not been established for long enough to yet influence food insecurity and offset

unsafe conditions. Community-based agriculture does have the potential to impact farmer's livelihoods but the droughts of the 1980s and early 1990s together with the poor, erratic and unreliable rainfall is often cited as one of the principal reasons for the failure of sustainable agriculture projects and the abandonment of the farming lifestyle. The need to transport village standpipe water, at times up to 25km, to sustain lands farming plots also appears to be prohibitive in encouraging the further widespread adoption of this strategy.

3. *Rainwater harvesting and drought-resistant agricultural practices as development strategies in Botswana, as a rapidly urbanizing country.*

The various rainwater harvesting initiatives are technically feasible options for Botswana but it will require time before policy makers can be persuaded to give their full backing to the projects that have already been demonstrated. Many Sub-Saharan African economies are widely perceived as being particularly vulnerable to the effects of drought. This has been influenced by a past over-reliance on rain-fed agriculture and livestock production, the limited infrastructure and the low levels of capita income. Botswana accepts that food self-sufficiency is neither achievable nor sustainable and its objectives are to raise food security at both household and national levels by giving priority to production programmes that are sustainable, resource efficient and environmentally compatible. Identifying a set of mitigating measures to help farmers who are reliant on just rain-fed agriculture is essential as part of any drought mitigation strategy.

Investing in widespread lands agriculture is questionable considering the influence of drought, reduced soil fertilities and rural-to-urban migration. In Libya, agricultural expertise was lost to the country at the very moment when the rural-to-urban migration of Libyans came to a peak between 1970 and 1981 (Allan, *et al.*, 1973). A similar situation might develop in Botswana as a result of much of the present youngest generation growing up in an urban environment and visiting their families lands areas less frequently than previous generations.

The concept of a rural Botswana being a self-sufficient, subsistence producer could potentially end, if it has not already done so, as the urban employment sector expands and food provision is left almost entirely in the hands of importers or a few successful commercial enterprises. High spending in the urban sector together with the adoption of large-scale irrigation projects has the effect of limiting an integrated planning approach to agriculture. The droughts of the 1980s were partly responsible for speeding up the population exodus from the lands to the urban centres, together with the prospect of more reliable wages.

Agroforestry practices that reduce drought vulnerability and risk are feasible options for Botswana and subsistence farmers who want to supplement their food intake and improve their food security.

Providing that the agroforestry techniques are correctly implemented, the crop water requirement is attained and the correct C:CA ratio adopted, the intercropping of fruit trees and vegetables has been shown to be successful in the semi-arid climate. However, in communities, the practices have not contributed to significantly lowering vulnerability and mitigating the build up of unsafe conditions.

The ferrocement tank development project has had problems in its practical construction and implementation and is also highly influenced by the semi-arid climate. In drought periods, rainwater tanks yield very little water. The development project, despite providing benefits to its recipients, does not adequately reduce people's vulnerability to dynamic pressures placed upon them. The supplementary water provided in schools is sufficient to mitigate only temporary village standpipe failures. While in lands areas, providing that a water tank is near full at the start of a dry period, then a family can be sustained for up to 3 months. Thereafter, vulnerability returns to communities and dynamic pressures intensify the root causes of vulnerability into unsafe conditions. People then once again experience the effects of the poor or unequal allocation of resources and jobs.

8.2 Future directions

Vulnerability reduction in the context of recurrent drought requires a multidisciplinary response. While rainwater harvesting affords useful benefits, particularly in isolated arid and semi-arid areas, it is only one of many potential interventions to improve the quality of life of rural Batswana.

While it indeed reduces the impact of dry spells, the technology itself is highly vulnerable to severe drought shocks, thus limiting its role in reducing drought impacts and as vulnerability reduction strategy. In an expanding economy, where rural livelihoods are susceptible to many stresses and shocks, it can be argued that rural-urban migration may be a more viable strategy for reducing exposure to extreme weather conditions, than encouraging agriculture in harsh rural conditions.

Another major constraint to the expansion of rainwater harvesting initiatives is the lack of policy aimed at encouraging communities at all levels to adopt the available technologies. If both domestic and agricultural rainwater harvesting is to make an impact upon reducing the dynamic pressures and risk in society, there must be a strong driving force behind it. Ideally, those organizations already established should be encouraging the government to revise the current Water Master Plan so that it also incorporates rainwater harvesting initiatives. Networking between African and international donors with the practising NGOs and communities could similarly help to raise awareness of the available technology and this may encourage many more people to participate.

Three points need to be addressed that influence the uptake and development of ferrocement, agroforestry and community initiatives in Botswana. The first involves the ongoing question of the viability of rainwater harvesting for rural communities when evidence points to a declining agricultural base and depopulation in rural, drought-prone communities. Rainwater harvesting does not appear to offer to Botswana an opportunity to mitigate the root causes of drought. These are being translated through dynamic pressures into unsafe conditions that result in rural-urban migration and an abandonment of the farming lifestyle for a better livelihood.

Moreover, rainwater harvesting, by nature, is itself vulnerable to recurrent drought and this reduces the uptake of the technology. It must be decided whether the supply of water harvesting tanks and agricultural knowledge is a humanitarian imperative to vulnerable communities, or whether the development is not sustainable.

Finally, communities expect that the Botswana Government will supply them with reticulated water supplies or boreholes and that it is their responsibility to do so. This could also be viewed as a humanitarian delivery imperative. Extremely effective government relief responses tend to discourage responsible mitigation efforts by households or by government departments. Investing in extensive mitigation and vulnerability-reduction is almost not necessary when the government will bale out a 'rare' disaster anyway. During periods of drought, 'disaster management' as a response is very good in Botswana, and with such an emphasis on aid packages and technical engineering projects, there may not be the demand or market for water harvesting technology despite its benefits.

REFERENCES

- Adams, W. M., 1992: *Wasting the rain: rivers, people and planning*, Earthscan, London. In: Dalal-Clayton, B., 1997: Southern Africa beyond the millennium: environmental trends and scenarios to 2015, environmental planning issues no.13, International Institute for Environment and Development, London.
- Ahmed, R., Ragan, K., Oucho, J. and Tselayakgosi, M., 1999: *Country review for Botswana*, paper presented at the Grand Palm Hotel, 30 July – 26 August 1999, United Nations Development Programme, Gaborone.
- Allan, J. A., McLachlan, K. S. and Penrose, E. T., 1973: *Libya: agriculture and economic development*, Frank Cass, London.
- Allan, J. A., 1982: *Libya since independence – economic and political development*, Croom Helm, London.
- Anon, 1996: *Rainwater harvesting project: ferrocement water tank training program: final report July 1996 – December 1996*, Rural Industries Innovation Centre Building Research Unit, Kanye, Botswana.
- Acquah, B. K., 1993: *Economics of rainwater collection*, Rainwater Catchment Systems Application and Technology Workshop, 1st-3rd March 1993, Gaborone/Kanye, 45-49.
- Aquastat, 1995: Botswana: geography, population and water resources, www.fao.org/WAICENT/FAOINFO/AGRICULT/AGL/AGLW/AQU.../botswana.htm
- Anschutz, J. and Nederlof, M. (eds), 1997: Water harvesting and soil moisture retention, Agrodok-series No.13, Agromisa, The Netherlands.
- Austin, M. and Douthwaite, B., 1987: *Select and install your gutters properly*, Appropriate Technology in Botswana, the Botswana Technology Centre, Gaborone.
- Barnett, D., 1999: *AIDS cuts a swathe through Botswana*, Daily Mail & Guardian, 15th October 1999, Johannesburg. Internet address: www.mg.co.z...99oct2/15oct-botswana_aids.h
- Begemann, L., Mulder, P. and Reij, C., 1988: *Water harvesting for plant production*, World Bank Technical Paper 91, Washington D.C.
- Benson, C. and Clay E., 1994: *The impact of drought on Sub-Saharan African economies: a preliminary examination*, Overseas Development Institute, Working Paper 77, London.
- Berkhout, M., 1997: *Agroforestry with rainwater harvesting in Botswana, report of the VPR trial in 1996/97*, Veld Products Research, Gaborone.

- Bhalotra, Y. P. R., 1987: *Climate of Botswana, part II, elements of climate; rainfall*, Department of Meteorological Services, Ministry of Works and Communications, Gaborone.
- Bhebhe, B., 1994: *Changing settlement patterns and their impact on water and other service provision*. In: Gieske, A. and Gould J. E. (eds), 1994: *Proceedings of the Integrated Water Resources Management Workshop*, 17-18th March 1994, Gaborone/Kanye, University of Botswana.
- Blaikie, P., Cannon, T., Davis, I. and Wisner, B., 1994: *At risk –natural hazards, people's vulnerability and disasters*, Routledge, London and New York.
- Bollinger, L. and Stover, J., 1999: *The economic impact of AIDS in Botswana*, The Policy Project, September 1999, The Futures Group International in collaboration with: Research Triangle Institute (RTI) and The Centre for Development and Population Activities (CEDPA). Internet address: www.tfgi.com/ecimaids.asp
- BTC, 1998: *Ferrocement tank review and water quality monitoring, a supplementary to ferrocement tank development project –Phase II, Stage II*, the Botswana Technology Centre, Gaborone.
- Chenje, M. and Johnson, P., 1994: *State of the environment in southern Africa*, report by the Southern African Research & Documentation Centre, the World Conservation Union and the Southern African Development Community, Penrose Press, Johannesburg.
- Chenje, M. and Johnson, P., 1996: *Water in southern Africa*, report by the Southern African Research & Documentation Centre, the World Conservation Union and the Southern African Development Community, Penrose Press, Johannesburg.
- Chishimba, S. N., Davis, G. L. and Naidu, K. G., 1993: *Rainwater catchment: the Botswana Technology Centre experience*, Rainwater Catchment Systems Application and Technology Workshop, 1st-3rd March 1993, Gaborone/Kanye, 35-44.
- Cooke, H.J., 1978: *The problem of Drought in Botswana*, p.7-20. In: Hinchey, M.T. (ed.), 1978: *Proceedings of the symposium on Drought in Botswana*, 5th- 8th June 1978, National Museum, Gaborone, The Botswana Society and Clark University Press.
- Critchley, W., Reij, C. and Sez nec, A., 1992: *Water harvesting for plant production –Volume II: case studies and conclusions for Sub-Saharan Africa*, World Bank Technical Paper 157, Africa Technical Department Series, The World Bank, Washington, D.C.
- Cullis, A. and Pacey, A., 1986: *Rainwater harvesting; the collection of rainfall and runoff in rural areas*, Intermediate Technology, London.

- Dalal-Clayton, B., 1997: *Southern Africa beyond the millennium: environmental trends and scenarios to 2015*, Environmental Planning Issues no.13, International Institute for Environment and Development, London
- Davies, S., 1996: *Adaptable Livelihoods: coping with food insecurity in the Malian Sahel*, Macmillan, London.
- Dreze, J. and Sen, A.K., 1989: *Hunger and public action*, Clarendon Press, Oxford.
- Eldridge, C., 1998: *Effects of drought –executive summary*, Save the Children Fund, Pretoria.
- Elfaig, A. H. I., 1999: *Strategies to reduce drought vulnerability with special emphasis on coping strategies of the poor: Sub-Sahara- semi arid area and western Sudan*, Interdisciplinary conference on integrated drought management: lessons for Sub-Saharan Africa, Pretoria 20th-22nd September 1999, UNESCO International Hydrological Programme.
- Enyatseng, G. R., 1997: *The promotion of rainwater catchment systems in Botswana*, the Botswana Technology Centre, Gaborone.
- Erskine, J., 1991: *Rainwater harvesting systems in southern Africa*. In: Chu, S-C. (ed), 1991: *Rainwater catchment for future generations*, Proceedings of the 5th International Conference on Rain Water Cistern Systems, 4th – 10th August 1991, Keelung, Taiwan, R.O.C., 574-585.
- Finkel, M. and Segerros, M. (eds), 1993: *Water harvesting*, Proceedings of the SADC-ELMS (Environment and Land Management Sector co-ordination unit) Practical Workshop, 10th-28th May 1993, Windhoek and Okakarara, Namibia, Report No. 33.
- Goma, W., 1999: *Avert Impact of drought on some health issues*, International conference on integrated drought management, 20-22 September 1999, Pretoria.
- Gould, J. E., 1984: *The water resources of Botswana: problems, potential and policy*, the Botswana Technology Centre, Gaborone.
- Gould, J. E. and McPherson, H. J., 1987: *Bacteriological quality of rainwater in roof and ground catchment systems in Botswana*, Water International, 12, 3, 135-138.
- Gould, J. E. and Jay, B., 1993: *An overview of rainwater catchment systems in Botswana*, Rainwater Catchment Systems Application and Technology Workshop, 1st-3rd March 1993, Gaborone/Kanye, 3-13.
- Gould, J. E., 1996: *Rainwater utilization in Botswana: problems and possibilities*, Science, Technology & Development, Journal of the Third World Science, Technology & Development Forum, December 1996, 14, 3, 72-87.

- Gould, J. E., 1997: *Catching up – upgrading Botswana's rainwater catchment systems*, Waterlines, 15, 3, January 1997, 13 and 19-20.
- Gould, J. E., 1998: *Review of recent developments in rainwater catchment systems technology in Eastern and Southern Africa*, Science, Technology & Development, 16, 1, April 1998, Frank Cass, London, 44-57.
- Gould, J. E., 1999: *Rainwater harvesting information resources booklet for southern Africa*, The Mvula Trust and Disaster Mitigation for Sustainable Livelihoods Project, University of Cape Town, Cape Town.
- Grenier, L., 1998: *Working with indigenous knowledge: a guide for researchers*, International Development Research Centre, Ottawa, Canada.
- Harrison, P., 1987: *The greening of Africa –breaking through in the battle for land and food*, International Institute for Environment and Development – Earthscan, Paladin Grafton Books, London.
- Hasse, R., 1989: *Rainwater reservoirs: above ground structures for roof catchment; most common rainwater tanks in comparison and construction material*, Deutsches Zentrum für Entwicklungstechnologien –GATE, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Friedr. Vieweg & Sohn, Braunschweig/Wiesbaden.
- Hay, R. W., 1988: *Famine incomes and employment: has Botswana anything to teach Africa?*, World Development, 16, 9, 1113-1125.
- Hay, R. W., 1989: *Food, aid and relief development strategies*, Journal of Social Development in Africa, 4, 2, 7-25.
- Holloway, A., 1999: *Drought –marginal communities –marginal issue: why drought stays in the sidestream of development policy and practice*, International conference on integrated drought management, 20-22 September 1999, Pretoria, Disaster Mitigation for Sustainable Livelihoods Programme, University of Cape Town, Cape Town.
- Holm, J. D. and Morgan, R. G., 1985: *Coping with drought in Botswana: an African success*, Journal of Modern African Studies, 23, 3, 463-482.
- Hulme, M. (ed.), 1996: *Climate change and southern Africa: an exploration of some potential impacts and implications in the SADC region*, World Wildlife Fund International and the Climatic Research Unit, University of East Anglia, Norwich, UK.
- Keve, J., 1997: *Water and sustainability*. In: Aminipouri, B. and Ghoddousi, J. (eds), 1997: *Rainwater catchment for survival*, conference organized by the Ministry of Jihad-E-Sazandegi in co-operation with the International Rainwater Catchment System

Association. Proceedings of the 8th International Conference of Rainwater catchment systems, 25th – 29th April 1997, Tehran, I. R. Iran, 1, 71-77.

Khupe, B. B., 1998: *National Conservation Workshop: June 3rd and 4th 1998*, Department of Water Affairs, Somarelang Tikologo, Water Utilities Corporation, Kalahari Conservation Society, Gaborone.

Manamela, N., 1993: *Botswana: the response to the 1992 drought in the context of long-term development objectives*, Drought management workshops in southern Africa; report of the regional drought management workshop; country assessment papers, 2, 3-24.

Manamela, N., 1997: *Drought preparedness and management in Botswana: issues paper on the assessment of the current state of preparedness*, Drought Policy Seminar, Grand Palm Hotel, Gaborone, 17th-19th November 1997, Ministry of Finance and Development Planning.

Mateke, S., 1997: *Indigenous fruit tree research programme: progress report 1997*, Veld Products Research.

Mateke, S., Mbakile, L. and Opelo, R., 1999: *A review of rainwater harvesting in Botswana*, Veld Products Research & Development, Botswana Technology Centre and Somarelang Tikologo (Environmental Watch Botswana), Gaborone.

Mateke, S. and Taylor, 1999: *A review of rainwater harvesting in Botswana*, unpublished report, Veld Products Research & Development, Gaborone.

Matsinhe, N., 2000: *Rainwater harvesting in Mozambique –assessment report; Buzi, Govuro, Machaze and Vilankulos RWH projects*, CEE –UP/ Universidade Eduardo Mondlane, Maputo. Submitted to Departamento de Agua Rural/DNA and CARE –International, Maputo.

Mbakile, L., 1999: *Water conservation a key for sustainable development*, Somarelang Tikologo (Environmental Watch Botswana). In: Fonsag, 1999: Forum on sustainable agriculture, Vol.2, No.1, Gaborone, 12-13.

Moremi, T., 1987: *Drought planning and response: Botswana experience*. In: Wilhite, D., Easterling, W. and Wood, D. (eds), 1987: *Planning for drought, toward a reduction in societal vulnerability*, Westview Press, Boulder and London.

Mukwaya, J., 1999: *The AIDS emergency*. In: UNICEF, 1999: *The progress of nations 1999*, UNICEF, New York.

Muwira, K., n.d.: *Our community ourselves: a search for food security by Chivi's farmers*, Intermediate Technology, Harare.

- Ncube, P. and Chisvo, M., 1999: *Regional drought management strategy for SADC*, SADC Food Security Technical and Administrative Unit, Harare.
- Ndege, M., 2000: Botswana: country inventory report, the Botswana Technology Centre, Gaborone.
- Nilsson¹, G. I., 1993: *Water harvesting in agriculture and horticulture*, Rainwater Catchment Systems Application and Technology Workshop, 1st-3rd March 1993, Gaborone/Kanye, 54-61.
- Nilsson², G. I., 1993: *Food security a must: food self-sufficiency a great possibility*. In: Brothers, S., Hermans, J. and Nteta, D. (eds.), 1993: Botswana in the 21st Century, Proceeding of a Symposium, Organized by The Botswana Society, 18th – 21st October 1993, Gaborone, 301-305.
- Oldreive, B., 1993: *Conservation farming for communal, small-scale, resettlement and co-operative farmers of Zimbabwe: a farm management handbook*, Prestige Business Services (Pvt) Ltd., Zimbabwe.
- Opelo, J., 1998: *Ferrocement Water Tank Pilot Project Phase II –draft report*, the Botswana Technology Centre, Gaborone.
- Opelo, J., 1999: *Rainwater harvesting programme minutes*, the Botswana Technology Centre, Gaborone.
- Petersen, S. (with additions by Grant, C.), 1993: *Ground based rainwater catchment utilizing salt pans: a supply scheme for domestic use*, Rainwater Catchment Systems Application and Technology Workshop, 1st-3rd March 1993, Gaborone/Kanye, 62-71.
- Preston-Whyte, R. A. and Tyson, P. D., 2000: *The weather and climate of southern Africa*, Oxford University Press, Cape Town.
- RISE, 2000: *Rainwater harvesting – Namibia, country inventory report*, RISE, Windhoek.
- Ross-Larson, B. (ed.), 1999: *Human development report 1999*, United Nations Development Programme, Oxford University Press, Oxford.
- Rusike, E., 2000: *Zimbabwe: country inventory report*, Intermediate Technology Development Group, paper given at the Regional Rainwater Harvesting Workshop, February 2000, Swakopmund, Namibia.
- Rydtun, B., 1994: *Water supply and choice of appropriate technology in Botswana*. In: Gieske, A. and Gould J. E. (eds), 1994: *Proceedings of the Integrated Water Resources Management Workshop*, 17-18th March 1994, Gaborone/Kanye, University of Botswana.

- Scoones, I. (ed), 1996: *Hazards and opportunities; farming livelihoods in dryland Africa; lessons from Zimbabwe*, Zed Books Ltd., London and New Jersey, in association with the International Institute for Environment and Development, London.
- Sen, A. K., 1981: *Poverty and famines: an essay on entitlements and deprivation*, Clarendon Press, Oxford.
- Sharma, N., Damhaug, T., Gilgan-Hunt, E., Grey, D., Okaru, V. and Rothberg, D., 1996: *African water resources; challenges and opportunities for sustainable development*, World Bank Technical Paper 331, Washington, D.C.
- Somarelang Tikologo, 1997: *Water: such a precious resource*, Factsheet 3, Somarelang Tikologo (Environmental Watch Botswana), Gaborone.
- South African Department of Water Affairs and Forestry, 1994. In: Vogel, C., 1998: *EDA/RDSN/Mvula Water Policy Seminar for the Water Policy Book*, 2/10/98.
- Sunstrum, R., 1999: *Veld Products Research and Development –organizational profile*, Veld Products Research & Development, Gaborone.
- Thompson, C., 1993: *Drought management strategies in southern Africa: from relief through rehabilitation to vulnerability reduction*, University of Zimbabwe & the Food Security Unit, Zimbabwe, 21-43.
- Taylor, F. W., 1994: *Community based natural resources management project, project memorandum*, for the AGSP/SAFR/FARMESA programme, Veld Products Research, Gaborone.
- Taylor, F. W., 1997: *A review of rainwater harvesting in Botswana*, Veld Products Research, Gaborone.
- Toteng, E. N., 1999: *The water management problem in Gaborone*, Department of Environmental Science, University of Botswana. In: Dikgang Somarelang Tikologo: newsletter of Environmental Watch Botswana, Winter 1999 issue, 16-17.
- Toto, H. P., 1998: *No environmental protection, no food security*, Agrinews Vol. 29, No. 3, March 1998, 10.
- UNICEF, 1999: *Children orphaned by AIDS –frontline responses from eastern and southern Africa*, New York, 8-11.
- UNDP, 1999: *Human development Report 1999*, United Nations Development Programme, Oxford University Press, New York.

- USAID, 1996: *Performance monitoring and evaluation tips*, USAID centre for development information evaluation, report no's. 1-10. Internet address: www.dec.org/usaids_eval/
- Van Duuren, F. A., n.d.: *Rainwater harvesting –a technical guide*, Water Technology CSIR.
- Van Someren, E., 1997: *Feasibility study for water harvesting*, June 1997, RISE, Windhoek.
- Van Veenhuizen, R., 1999: *Rainwater harvesting, making drylands more productive*, FARMESA / ITDG, Harare.
- Vogel, C., Laing, M. and Monnik, K., 2000: *Drought in South Africa, with special reference to the 1980-94 period*, in Whilite, D.A. (ed), *Drought Volume 1, A global assessment*, Routledge Hazards and Disasters Series, Routledge, London, 348-366.
- Whilite, D. A., 1999: *Drought preparedness in the Sub-Saharan Africa context*, Interdisciplinary conference on integrated drought management: lessons for Sub-Saharan Africa, Pretoria 20th-22nd September 1999, UNESCO International Hydrological Programme.
- World Resources Institute, 1995: *Africa Data Sampler*, in collaboration with the World Conservation Monitoring Centre and Padco.INC, Washington DC.
- Zawaira, F., 1999: *Determinants of the epidemic, WHO annual report*, World Health Organization, Harare.

PERSONAL COMMUNICATION

Name	Organization	Place and date of interview
Catherine (Sister)	Headteacher, Gabane Private Secondary School, Gabane	Gabane Private Secondary School, Gabane, 10 th August 1999
Inger, David	Managing Director, The Botswana Technology Centre	The Botswana Technology Centre, Gaborone, 16 th July 1999.
Kalakawe, Masego	Agricultural Demonstrator, Paje	AD's office, Paje, 17 th August 1999
Keibonge, Dilwana	Farmer and CBAP participant, Paje	Paje village and lands area, 17 th August 1999
Ketshabile, Moses	Community Based Agroforestry Project worker, Veld Products Research & Development	Veld Products Research & Development, Gabane, 15 th July 1999
Kgopiso, Motlotlegi	Farmer, Polokwe Lands Area	Polokwe Lands Area, 1 st August 1999
Kobo, Miriam	Community Based Agroforestry Project worker, Veld Products Research & Development	Veld Products Research & Development, Gabane, 10 th July 1999
Nnwi, Toko	Farmer and CBAP participant, Gabane	Gabane field location, 25 th July 1999.
Ntebogang, Keamogetse	Farmer, Moshupa Lands Area	Kgotla Lands, Moshupa Lands Area, 1 st August 1999
Mateke, Stanley	Researcher and staff member, Veld Products Research & Development	Telephone communication, 20 th October 2000
Mbakile, Leonard	Somarelang Tikologo	Somarelang Tikologo, Gaborone, 28 th July and 15 th August 1999
Mmagohaledi, Mrs	Resident, Gabane	Residence, Gabane, 17 th July 1999
Mmutle, Robert	Hydrogeologist, Ministry of Agriculture	The Ministry of Agriculture, 11 th July 1999
Moffat, Howard (Dr)	FRCP, Superintendent of Princess Marina Hospital, Gaborone and honorary physician to the President of Botswana	Residence, 20 th August 1999 and correspondence 5 th December 2000.
Mpapalela, Lucky	Teacher, Bakoko Primary School, Moshupa.	Bakoko Primary School, Moshupa, 1 st August 1999
Olwedswe, Flora	Farmer and CBAP participant, Paje	Paje village and lands area, 17 th August 1999
Opelo, Jimmy	The Botswana Technology Centre	The Botswana Technology Centre, Gaborone, through July and August 1999.
Osupile, Keikotlhae	Farmer and CBAP participant, Paje	Paje village and lands area, 17 th August 1999
Radithipa, Bareri	Farmer and CBAP participant, Paje	Paje village and lands area, 17 th August 1999
Scott, Diana	Agriculture teacher, Gabane Private Secondary School, Gabane	Gabane Private Secondary School, Gabane, 10 th August 1999
Sekgee, Mr	Farmer and CBAP participant, Gabane	Gabane field location, 26 th July 1999

Sunstrum, Rick	Managing Director, Veld Products Research & Development	Veld Products Research & Development, Gabane, 13 th August 1999
Taylor, Margaret	School teacher (retired), Gabane Private Secondary School, Gabane	Residence, Gabane village, 1 st July 1999
Taylor, Frank W.	Director, Development Consultancies. Managing Director (retired), Veld Products Research & Development	Veld Products Research & Development, Gabane, through July and August 1999
Tsapisa, Johanna	Member of staff, Veld Products Research & Development.	Veld Products Research & Development, 16 th –18 th August 1999

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APPENDIX A

Summaries of the interviews at the ferrocement tank locations are presented below. They are divided into the following sections:

- Introduction and setting of the ferrocement tank location
- Root causes of drought-related vulnerability that increase drought risk
- Lifestyle, situation and dynamic pressures of drought-related vulnerability at the school or rural household
- Drought-mitigating benefits of the rainwater collecting tanks
- Problems encountered and unsafe conditions created by drought-related vulnerability
- Desires for the future of the risk-reducing, tank development programme

BAKOKO PRIMARY SCHOOL, MOSHUPA

Introduction and setting of the ferrocement tank location

The interview was carried out with Ms Lucky Mpapalela, who is a teacher at the primary school. The school has 14 classes with 35 children in each class, giving a total of almost 500 pupils. As part of the pilot project, the 23 m³ ferrocement tank had been built and installed in mid-1996, free of charge to the school by RIIC. In south-eastern Botswana, a 23 m³ tank corresponds to a roof catchment area of less than or equal to 132m² (Opelo, 1998). The tank sits beside one gable end of one of the long school classroom buildings, with two aluminium downpipes leading from the aluminium roof gutters to the tank. The school also has two working above-ground, pre-fabricated galvanized steel rain tanks that were installed when the school was built, see plate 5.1. These remain operational and water is collected from these as well as from the ferrocement tank.

Root causes of drought-related vulnerability that increase drought risk

The school faces water shortages when their standpipe runs dry; either from a mains supply water shortage or a technical failure. Until the tank was built therefore, water had to be collected from Moshupa when the standpipe failed. Many villagers also fetch water from the school when the public supply in Moshupa village is out of order.

Lifestyle, situation and dynamic pressures of drought-related vulnerability at the school

The water collected from the ferrocement tank is used for a whole variety of activities from cooking, washing, drinking and bathing to housework and watering the school vegetable garden. Rainwater is also collected from two old cement tanks that were installed with the building of the school.

The school faces many dynamic pressures if no rainwater is present in the tanks. In order to obtain water people are required to walk to the centre of Moshupa village 1km away, which in the heat of a Botswana dry season is very far. Generally, staff have to walk to the village standpipe twice a month to collect enough water for the school's basic necessities. Even if a sufficient quantity of water is available, some children still have to walk home if food supplies, delivered by the local council, run out. Enough food is supplied for 4 months but supplies are often down to minimal proportions during the last one to two weeks of the term. The school in these situations does not close but the children are instead sent home in the afternoons for food. Generally, the children bring with them to school enough food for the morning but return home in the afternoons if there is no food.

Drought-mitigating benefits of the rainwater collecting tanks

Many of the benefits cited from the rainwater tank include those of improved health for the children. The toilet block is close enough to the tank (a distance of 50m) that the children could go to the tank and collect water from it to wash their hands. The children and staff also regard the harvested rainwater as more palatable than that collected from the standpipe. There is also the opinion that the rainwater is better to wash in. Other benefits include the robustness of the tanks, their non-rust capability and the sun does not affect the water. The rainwater is also used to sustain an agricultural garden in the school, which minimizes the risk of low food security, and helps to reduce people's vulnerability to crop failure during periods of drought or reduced rainfall, see plate 5.3.

Problems encountered and unsafe conditions created by drought-related vulnerability

The school has experienced a number of problems with the design of the guttering for the tank. The aluminium downpipes blew down in gusty winds in April 1999, four months ago, and they had not been mended to date, see plate 5.2. This had caused a crisis in the school because the tank had run dry and it was not being replenished despite the presence of rains. Some of the gutters around the building roofs also leaked during rain. This created unsafe conditions at the school, for during periods when the ferrocement tank was dry and the standpipe was dry; no water was available in the school for any of the daily activities.

No food could be cooked for the children so they went hungry during the day or had to be sent home over lunchtime for their midday meal. This was possible for those children who lived nearby, or had relatives, in Moshupa but many also lived in the lands areas around the village up to 2-3km away and the distances involved were too great. No washing could be carried out after visiting the toilet and the staff houses also had no water in. The tank has also never been cleaned at the start of the rainy season and members of staff are scared to clean out the inside of the tank when it's

dry because of the dark. Upon suggesting that a torch would be useful, it was admitted that this solution had not been thought of.

Desires for the future of the risk-reducing, tank development programme

Ms Mpapalela saw great potential for the rainwater collecting tanks at the school. She saw their role as crucial in reducing the risks of drought and raising the children's food security and livelihood status. As a result, the repair and reinstallation of the gutters is desired in order that the children could once again benefit from the water, improve their well-being and water need not be collected from Moshupa village 1km away. The school would also appreciate the building of even more tanks due to the water shortage problem at the standpipe and in the village.

KGABOPHUTI PRIMARY SCHOOL, MOSHUPA

Introduction and setting of the ferrocement tank location

The interview was carried out with the Head teacher at the 600-pupil primary school. At least 96% of the school children live in the village of Moshupa and the remaining 4% live in the lands areas immediately surrounding the village though can easily attend the school because they only attend midday classes. Two 46 m³ ferrocement tanks were built at the gable ends of two of the long classrooms in 1996, one of which is connected up to a roof via a plastic guttering system, see plate 5.4, and the other one is not connected. Water is collected off only one gable end of the building, at the other end a gutter collects the water but it is left to flow onto the ground surface.

Root causes of drought-related vulnerability that increase drought risk.

In a similar situation to Bakoko Primary School, common shortages at the school and village standpipe prompted Kgabophuti School to apply for and install the rain collecting technology. A couple of small, old cement tanks remain connected to an iron guttering system on some of the other school buildings but the water is not utilized. Corrugated-iron water tanks were installed when the school was built but only the concrete bases remain. Next door to the school is a clinic mission station of which a few of the buildings boast gutters but water tanks have not been installed.

Lifestyle, situation and dynamic pressures of drought-related vulnerability at the school

The water collected from the tank is used for gardening and washing the kitchen's cooking pots. Dynamic pressures are reduced at the school not only through the rain collection system but also from a standpipe that sits within the school grounds and this is connected to the village reticulation water supply that is itself extracted from boreholes in the village.

Drought-mitigating benefits of the rainwater collecting tanks

Since the construction of the ferrocement tanks, gardening has been a continuous activity at the school where vegetables are grown, particularly spinach that is sold to the village community. The money collected from the sales is subsequently used in various school activities and during periods of drought the pupils rely heavily on this water for agriculture. There is no evidence that the health of the pupils had improved or deteriorated since the installation of the tanks. The village supply often experiences breakdown and during such times the mitigating impacts of the tanks are fully experienced when they become the sole source of water even for cooking and drinking until the reticulation supply is re-established. With good rains and when the tanks are full, the water supply can last for up to three months.

Problems encountered and unsafe conditions created by drought-related vulnerability

The ferrocement tanks are deemed too small for the high water demand at the school and the rainfall is often too unreliable in the country with periods of abundant water difficult to predict. Unsafe conditions are thus common and a hazard in life that the school would like security against. Effective construction planning was not extended to the siting of the tank currently in use as water can only be collected from one side of the school building as a result of the asymmetrical roof. One side of the roof lies too low for water to flow by gravity into the tank. In sections along the roof, the plastic guttering has also warped in the heat and any water being transported along it would fall to the ground.

Desires for the future of the risk-reducing, tank development programme

The school would like to see the pilot project expanded and made into an official augmentation scheme on top of the government water supply system. In fact, the school authorities suggest that the project should include provision for all the teachers quarters as well as the main school buildings, further enhancing livelihoods and reducing risks from poor health, food insecurity and drought conditions with very low water availability.

KGOTLA LANDS AREA, MOSHUPA

Introduction and setting of the ferrocement tank location

Mrs Kearmogetse Ntebogang and her family have some lands about 20km outside Moshupa where an 11 m³ ferrocement tank was installed in 1996. The ferrocement tank is fed off a 5 x 8m corrugated iron roof that is supported on a timber frame, see plate 5.5. Under the roof lies a dormant black plastic 'Aquatank' 10m³ water tank that the family used to store water in until the ferrocement tank was built. The plastic tank, installed during the 1990/91 season, was itself non-durable and leaked, so has not been used for the past three years since the construction of the ferrocement tank.

Root causes of drought-related vulnerability that increase drought risk.

The root cause of the Ntebogang family is their great distance from a water source (approximately 5km from a natural spring and 20km from Moshupa) while living amid a drought-stricken land and this was the reason for the construction of a the tank at this location. It is also one of the furthest lands areas from Moshupa that villagers still maintain.

Lifestyle, situation and dynamic pressures of drought-related vulnerability at the lands

Ms Ntebogang only lives at the lands during the ploughing season and was only visiting her rondavels to clean them the day that the interview took place. No crops had been planted in 1999 as a result of the poor rains though normally she would plant beans and maize. This has increased the pressure on the family's food supply and position of food security. Ms Ntebogang used to grow sorghum but the birds, cattle and other wildlife would often eat it so she altered her style of agriculture to grow less appetizing animal foods. During the ploughing season, the whole family moves out to the lands area, 11 in total, comprising her and her husband, six children and three grandchildren. Before the rains the catchment roof will be cleaned and any leaves and debris removed, thus ensuring the highest quality of the rainwater possible. There has been no need or occasion to clean out the tank itself.

Drought-mitigating benefits of the rainwater collecting tank

The roof catchment system with ferrocement tank provides the only source of water at the lands site during the ploughing and rainy seasons. From it the family survive and the livestock, six donkeys, seven cattle and some goats, are watered. The constant use of the tank also provides space for more rain to collect in during the rainy season. The tank has benefited the family enormously and no problems have been encountered with it. The water supply has never run out since it was built in 1996. The drought-mitigating effects of the tank became apparent when neighbours began to regularly visit the family to collect some of the rainwater, as they had no tank themselves.

Problems encountered and unsafe conditions created by drought-related vulnerability

However, the ferrocement tank has never been full of water due to the poor rains. It almost reached its full capacity during the 1996/97 season but not this year. Before the tank was installed, water had to be fetched two hours away by donkey cart from a natural spring 5km from the lands area. If this journey was carried out on foot it would take half a day to collect the water and return with it, after digging a collecting pit in the centre of the surface-dry spring to reach the water table. Other problems associated with living at the lands area are the absence of activities for young people. Children old enough to work will not normally be at the lands but remain in the village to work during the ploughing season. Subsistence agriculture is also becoming, according to Mrs Ntebogang, too insecure and uncertain as a result of the very low and erratic rainfall.

Unsafe conditions through both the erratic, variable rainfall and the lack of labourers at the lands area are therefore created.

Desires for the future of the risk-reducing, tank development programme

The tank has brought wide-ranging benefits to the family and some of their neighbours as well. Survival at the lands would be very difficult without the ferrocement tank, and the family is of the opinion that the pilot project is working well. Female members of the family, says Mrs Ntebogang, will always come to the lands during the ploughing season, particularly the older generation and the young children. There is a great demand for the technology that RIIC and the BTC designed and developed, securing the future of the drought-mitigation project. While being despondent with the sometimes low and erratic rainfall, she would like to see a widespread adoption and use of the ferrocement technology.

POLOKWE LANDS AREA

Introduction and setting of the ferrocement tank location

An 11 m³ ferrocement tank was also installed at the home of Mr Mogorosi Kgopiso in the lands area outside the village of Polokwe. The informant, Mr Motlotlegi Kgopiso, resides on the land all year round with his family of 23, of which 15 are young children. The informant's mother is a reputable farmer in the same area and it was she who made the connection with RIIC and the rainwater harvesting programme from the farmers meetings that she attended. The children attend a primary school in Polokwe while those at secondary school reside in Moshupa. The farm grows sorghum, maize and beans and also hosts five cattle that are watered at a dam built by the district council 4km away. RIIC also installed at this lands area a black plastic 'Aquatan' tank in 1991 but the ferrocement tank superceded this when it was installed in 1996, see plate 5.6.

Root causes of drought-related vulnerability that increase drought risk.

Installation of the tank was an attempt to increase the family's wealth, water provision and reduce the effects of drought. The distant water source was causing many problems at the lands area such as transporting water and the time taken to do it.

Lifestyle, situation and dynamic pressures of drought-related vulnerability at the lands

The collection of rondavels and dwellings depend upon the ferrocement tank, with its 5 x 8m corrugated iron roof catchment for their sole water supply. While visiting the farm, the tank was standing empty and the last rains were in April 1999 but were not of a significant quantity. A public standpipe in Polokwe 4km away provides an alternative source of water when the tank stands empty and members of the family travel by donkey cart into Polokwe three times a week to collect

water. Between three to four 200litre water containers are usually filled and transported back to the lands area.

Drought-mitigating benefits of the rainwater collecting tank

The ferrocement tank has brought tremendous benefits to the family despite the fact that the tank has never previously reached its full capacity. The last good rains in December 1998 provided sufficient water for the following six months and this supply became exhausted one month ago. Mr Kgopiso is of the opinion that his children's health has improved with the water supply from the tank and they no longer suffer from the illnesses that they experienced before the tank was installed. The tank was installed because in 1996 the family's water supply came from a local dam where cattle were also watered and it's quality could not be guaranteed. In 1997, Polokwe village then received its own water supply and even during times of plentiful tank water, the family still supplement their own water store with the village supply. The water stored in the family's tank is much preferred to that from the village standpipe as it is more palatable.

Problems encountered and unsafe conditions created by drought-related vulnerability

No problems were experienced with the black plastic 'Aquatank' tank but the gutters leading from it to the roof catchment were dismantled when the new ferrocement tank was installed. Problems experienced with the new tank include no grate on the gutter intake opening and leaves would enter before a mesh bag was used to block up the hole. The roof catchment is cleaned just prior to the rains but because nearby trees are always shedding their leaves, the water's cleanliness cannot always be guaranteed. This introduces an unsafe condition into the otherwise successful project. When the tank is empty, however, it is usually cleaned out and any debris is removed.

Desires for the future of the risk-reducing, tank development programme

Mr Kgopiso has no plans or intentions to move his family to Polokwe village as his parents and previous generations have always lived at the lands area and he feels compelled to do likewise. The water tank is therefore reducing the risks of unsustainable living at the lands area. Schooling is also not a problem as the primary school is close at hand in Polokwe and the working members of his family use the farm as a base to which they can return any time.

APPENDIX B

This section contains summaries of the group interviews with the community-based agroforestry participants in the village of Paje. The following questions were asked:

- How did you meet VPR&D and when?
- What provides your source of water?
- Has watering become an inconvenience? Has interest in the project been maintained?
- What is your assessment of the work that VPR&D is carrying out? Is more input required?
- Would you like VPR&D to help with the drought-mitigating aspect of the project?
- What do other villagers think of these livelihood risk reduction projects? Are they likewise keen to become involved?
- Have you heard of, or applied for, the ALDEP rainwater collection scheme?
- To the AD: what is the root cause of people's problems and is there a future in lands agriculture?

How did you meet VPR&D and when?

Bareri: VPR&D held a meeting at the Kotla in 1998 where they revealed what they were offering under the CBAP scheme to members of the Paje community. VPR&D offered to interested farmers, the opportunity to build 'on farm plots' on their lands areas where the NGO would provide all the fencing materials for a 50m x 50m plot; including 45 treated poles, five corner poles, two rolls of feltspan wire and one gate. Each would also be given 30 indigenous fruit trees to plant in their plot at a cost of Pula 1 pula, thus handing over ownership of the project to the farmers themselves. Each farmer was provided with the opportunity to plant the trees in the configuration they desired, whether it be randomly, in rows, or as a windbreaker along one side of the plot. After harvesting, farmers prefer to let their animals graze the land, so the fences were necessary to protect the trees.

There was a great deal of initial interest shown to VPR&D by people in Paje, but when it came to the crux of committing themselves to active participation, some people were not keen. The four women interviewed were all very enthusiastic and Flora was impressed that they would be able to keep the fruit trees, in the event of success, after VPR&D had finished their monitoring of the project. Written agreements were drawn up on exactly how the land would be used and all were happy with the conditions and the chance to put in their own work. VPR&D make no claim to the land and it remains firmly in the control of the village farmers. Each individual farmer's responsibility lies in erecting the fence, planting the trees, and managing and maintaining them. If the trees die or the participant loses motivation for the project, then VPR&D have a right to give the materials and trees to another interested party.

What provides your source of water?

Bareri: The water is provided from a village standpipe that is about 15km away from her lands area, but this was not a major inconvenience as she uses a donkey cart to fetch water. During one monitoring visit, VPR&D found one dead tree that had died from a suspected white ant infestation, but they were unable to provide a solution to cure the problem.

Keikotlhae: Her water is similarly provided from a village standpipe that she transports herself to her lands area 10km away. She has also had some problems with white ants, but not as serious as Bareri. However, VPR&D gave her some advice on how to deal with them. A mixture of fine ash and tobacco can be spread on the topsoil around the tree to prevent an infestation from spreading. (Bareri was apparently also aware of this, but it had not worked so well for her).

Dilwana: The trickle bottom system has worked well, but she has been unable to collect all the necessary bottles that are required. Dilwana similarly has to hire a donkey cart and driver to take water out to her plot 25km outside Paje, which, she feels, is a great inconvenience, as she has to spend the night there as a result. This frequently clashes with village social pressures and means that she cannot go her lands area as often as she would like to. Hiring transport, however, is not a problem as it is readily available if required but it is expensive. The tree response to the watering is excellent.

Flora: Water transportation is a major problem, as she has not got her own donkey cart. Therefore, she has to hire a cart that costs Pula 10 for a driver to carry 210litres of water to her lands area about 5km outside Paje. This, Flora felt, is very expensive, especially considering she is not earning any income. Watering is still being carried out, though not as often as she would like to. *Did VPR&D indicate what system is best for watering the trees?* The trickle bottle system was recommended but no bottles were provided for the farmers.

Has watering become an inconvenience? Has interest in the project been maintained?

Dilwana: The large transportation distance is an inconvenience, thus making the project expensive to maintain in terms of watering. This adds pressure to the project and watering becomes essential so the project does not deteriorate. Speaking for all the farmers, Dilwana spoke of an interest and anticipation for the project, and a real love for it. Her worries extend to the casing of grass protection around the trees that often collapses, thus allowing ants to gain access to them.

Keikotlhae: Distance is not a problem as she has own donkey cart and can also walk to her fields if required. *Could her donkey cart be lent out to fellow farmers?* No-body had ever asked her to borrow her donkey cart. *And if they asked her?* No, but she might for a fee. Keikotlhae travels regularly to her plot as it is relatively nearby, filling up the 2litre water bottles in the process.

Bareri: It is of great benefit that the indigenous trees are drought resistant because they do not require as much water as exotic trees. Bareri waters twice a month, as VPR&D recommended, but effort is required, as she has no donkey to help her.

Flora: During the primary stages of the project, the trees were watered twice a month, but since she has now moved back into the village from her lands area, it is not as regular.

What is your assessment of the work that VPR&D is carrying out? Is more input required?

All: Essentially, VPR&D have helped them, and on the whole the experience has been more positive than negative. Great benefit was obtained from a workshop at the NGO's site in Gabane and from an organized field day in Paje itself. VPR&D encouraged the women to maintain the good work that was started and have given them a contact phone number should any problems arise. More field days in the village are planned, which will give more and more people the opportunity to become involved.

Would you like VPR&D to help with the drought-mitigating aspect of the project?

All: An appeal is made for some assistance on the water front as well as techniques that cut down on time, labour and the hiring of donkey carts and drivers. Research wise, if VPR&D overcome the water problems, then there would be more data on the indigenous trees planted, because the farmers believe the trees would grow well in the area. The white ants issue also requires an effective solution.

What do other villagers think of these livelihood risk reduction projects? Are they likewise keen to become involved?

Bareri: Some villagers look on in amusement and are not very convinced of the project's possibilities of success. The project was initiated very well at the Khotla, but once people saw that participatory effort was required, many people turned down the offer of assistance. A further one or two farmers were part of the initial enthusiastic farming group, but after receiving the trees and needing to put in some hard work, they fell away. This is a sign that a person has not 'seen the light at the end of the tunnel.'

Have you heard of, or applied for, the ALDEP rainwater collection system?

Three of the women have applied to ALDEP for fencing materials (main priority), donkey trolleys (second priority) and ploughs, and are currently waiting processing of their forms. All are aware of the RWCS available through ALDEP though none are prepared to apply for it yet as other priorities come first.

To the AD, Masego Kalakane; what is the root cause of people's problems and is there a future in lands agriculture?

Kalakane: Farming is not dying out but the problem is that there is no rain. People are resultantly not interested in farming any longer. For example, many people are broadcasting (scattering seed randomly by hand) rather than planting in rows.

Masego has been the AD in Paje for the last three years. However, she finds her work very difficult with 750 farmers to attend to and no vehicle has been provided for her use.

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APPENDIX C

Appendix C contains the summaries of the results of direct and participant observation of the 'on-farm plots' in the Paje lands area. The farmers were:

- Dilwana Keibonge
- Bareri Radithipa
- Keikotlhae Osupile
- Flora Olwedswe

Dilwana Keibonge

Dilwana currently lives in Paje village itself but travels out to her lands area with her partner, her children all being self-sufficient. Although initially reluctant to reveal her wealthy possessions, the family owns one cow, one calf, two sheep, two lambs, no goats or donkeys, one cock and three chickens. The trees planted on Dilwana's land include Morojwa, Morula, Mogorogorwane, Mmilo and Neem, and they have each been planted with semi-circular earth bunds around them, see plates 5.16 and 5.17. The trickle system has been successful apart from the bottlenecks cracking in the intense UV light, and the water-refilling holes becoming clogged with soil and grass, see plate 5.18.

The trees were last watered in June, two months ago, and are doing well though obviously needed further watering. Food security will be increased markedly when the first fruits are harvested. Upon initiation of the project, many Mopane trees were cut down to clear the ground but these are stubbornly regrowing around the recently planted indigenous trees. VPR&D recommended that the catchment ground between trees be cleared of grass but a lack of time (a dynamic pressure) has thus far prevented any clearing other than a small area 10m². Intercropping between the trees was also planned for this year, but time has similarly been a limiting factor.

Two Mmilo trees were unfortunately discovered dead upon inspection of the trees. Neem, however, is propagating well and was planted as a deterrent to mosquitoes. When its leaves are crushed and sprinkled on other plants, it similarly acts as a deterrent against pests. Mogorogorwane trees in particular, require special care, and thatch and stick shelters are erected around and above the tender young trees to protect them from the harsh winter environment and root causes of severe diurnal temperature extremes.

Bareri Radithipa

Bareri, chairperson of the farmers committee, has the following indigenous trees on her 'on farm plot' in the Tebele area; Morojwa, Morula, Mopudu, Mogorogorwane and Neem. The trees are in excellent condition and benefit from a nutrient-rich black earth and from various forms of winter

protection. Winter mitigating features include white hessian sacks surround Morojwa trees while thatch and stick shelters protect the healthy Mopudu trees just 10cm tall.

The trees, planted as a windbreak in one line to help protect an adjacent field (a risk reduction feature), currently have no microcatchment development around them or water bottles, see plate 5.19. Runoff instead, flows off the adjacent field where maize, sorghum, beans, watermelon, pumpkin and squash are planted during the wet season. January 1999 rains, however, were not enough to warrant any vegetable planting and the last good rains occurred in 1996 when over 50 bags of sorghum were produced from two hectares of land. This has increased the family's vulnerability and could translate the drought-prone land as a root cause into unsafe living conditions for the family. The land is therefore under great pressure to provide for the family's four adults and six children. Bareri's livestock are all kept at the family's cattle post and comprise 15 cows, five calves, six goats, four kid goats, three sheep, three lambs, 10 donkeys and two young donkeys.

Keikotlhae Osupile

This farm plot was discovered overgrown by grass with signs that a small animal had dug underneath the gate and eaten some of the tree's leaves (dynamic pressures). Mogorogorwane trees, currently suffering from drought, appear feeble under their thatch shelters. Moreover, 23 of the trees that VPR&D supplied in late 1998 had not been planted yet and there were signs that disinterest was setting in as the result of a prolonged illness that has meant her children having to maintain the plot. Illnesses can contribute to the dynamic pressures that people face meaning that less energy and motivation is available for normal activities and agriculture. The trees Keikotlhae was supplied with include Morojwa, Neem, Mmilo, Mopudu, Mogorogorwane, Moretlwa and Morutlwa. The adjacent lands area, in comparison, looked well kept and in good fertile condition.

Flora Olwedswe

On her land, Flora has planted Morula, Neem, Mopudu, Moretlwa, Morutlwa, Mogorogorwane and Morojwa. The land has been cleared well of grass though a major problem has been the sandy soil that has prevented the short fencing poles from being firmly hammered into the ground. As a result, cattle have been able to knock the fence down and gain access to the plot, eating most of the trees as a result. These are dynamic pressures that are in need of attention so the project can continue and no unsafe conditions, such as reduced food security, will develop.

Only a few Mogorogorwane remain under their thatch shelters. Consequently, Flora would welcome assistance from VPR&D to help with the fencing problem. Once monthly visits are made to the lands area for watering and maintenance of the plot, though no microcatchments or watering bottles have been installed yet.

APPENDIX D

Appendix D contains summaries of the interviews with the community-based agroforestry participants in Gabane village. Direct and participant observation was also carried out on their 'on-farm plots'. Interviews were carried out with Mr Nnwi and Mr Sekgee and the questions asked were as follows:

- How did you become involved in CBAP?
- What watering regime do you work with?
- What maintenance work is carried out on the plot?
- Do you think the project will succeed and lower vulnerability to drought?
- Where is the water source and is watering an inconvenience?
- Is VPR&D supporting or monitoring you throughout the project?
- What do other community residents think of the drought-resilient enterprise?

MR NNWI

How did you become involved in CBAP?

Toko, a member of the VPR&D building team and a landholder in Gabane, became involved in the project in November 1998 during the ploughing season, see plate 5.20. He carried out all the work himself under VPR&D supervision that comprised advice on some of the projects technical aspects such as how far apart to plant the trees and to what depth. Thirty trees were planted at a cost of Pula 1 each (payment still due), including Morojwa, Mmilo and Mogorogorwane. It was indicated to Toko that if the project were successful, he would receive the trees at the summation of the research period.

VPR&D provided the fencing materials surrounding the plot 30m x 35m in size. Work on the plot has included constructing semi-circular bunds, with upslope-facing openings around the trees, to catch runoff from surrounding higher land and many of the trees have thatch shelters as protection against frostbite and the cold winter wind.

What watering regime do you work with?

Toko waters the trees himself though periods of up to three weeks can pass by without watering. No indication of how often or how much to water the trees, but the indigenous trees are supposed to be drought resistant and hardy, so there's no stringent time frame for watering. Toko waters the trees on the basis of their appearance and whether there are signs of wilting, indicating a thirsty ground.

The trickle bottle system was established for one tree after VPR&D showed him the technique and Toko is expectant of the imminent arrival of more bottles. He could install his own bottles but he was waiting for VPR&D and because they had not arrived yet, he thought there was a reason behind it. The old 2litre milk bottle currently in use is cracked at the top as the result of a 'naked' animal digging it up and testing its edibility. Toko suspects, however, that the bottle was already brittle from exposure to the sun's intense UV rays.

What maintenance work is carried out on the plot?

The microcatchments require weeding and a frequent inspection is carried out of the trees themselves. However, it was observed that the microcatchments opened downslope and so couldn't catch runoff. Toko has also taken the initiative to intercrop the plot with watermelon and sorghum as an extra provision for his family.

Do you think the project will succeed and lower vulnerability to drought?

Toko believes the project has great potential to succeed, but some of his trees are already dead from suspected parasites and ants. During long periods of no rainfall, Toko hopes to maintain the watering of his trees and so reap the benefits from their fruit that will give him increased food security and help mitigate his family during periods of drought.

Where is the water source and is watering an inconvenience?

The water originates from the yard standpipe but Toko also has the option of using a nearby community standpipe as well that he fetches water from using his donkey cart. Watering presents no inconvenience or pressure as it has become a family activity and everyone is aware of the project benefits and therefore wants to lend assistance.

Water rates from Toko's yard standpipe are between Pula 80-100 for four months, or Pula 25 per month, which is considered very expensive but a worthwhile investment. Upon initiation of the project, the community standpipe provided some of the water, that was thus free of charge, but with long queues for water he now resorts to using his own supply.

Is VPR&D supporting or monitoring you throughout the project?

The project is an excellent idea, but there is the question of how long VPR&D would like the project to run for, in case Toko receives a more economically viable or attractive idea for use of the land. He has suggested a period of five years to VPR&D but no binding agreement has been registered. The NGO monitors the project once a month and it was they who suggested using thatch shelters to protect the young trees from the current harsh winter conditions.

Before VPR&D hold workshops or educational tours around the site for schools, exchange farmers or students from the Botswana College of Agriculture (BCA), they ask Toko to clear up his land.

He then removes the weeds and rebuilds any broken microcatchment earth bunds, thus displaying the project to potential participants or analysts.

What do other community residents think of the drought-resilient enterprise?

The community is interested and would like to have this type of project on their land as well, but a few members are also hesitant, thinking that their land will end up in the NGO's hands.

MR SEKGEE

How did you become involved in CBAP?

Moses Ketshabile, VPR&D's CBAP representative in Gabane, approached various farmers in the village and proposed the project to Mr Sekgee in November 1998. Mr Sekgee had already been planning an orchard of exotic fruit trees, so his idea was combined with that of CBAPs to produce a mixed indigenous and exotic orchard containing both orange and Morula trees, see plate 5.21. The farmer attended an open day at the NGO's site in Gabane shortly before establishing the project on his own land. Thirty trees were planted, at a cost of Pula 1 each, of which four have since died from desiccation.

What watering regime do you work with?

Watering is carried out three times a week using a 5litre watering can and each tree receives 15litres of water per week. This, however, will stop after one year when the trees should be well enough established to survive without constant watering. Ten litres a week is actually sufficient, (Ketshabile, 1999, pers com.).

What maintenance work is carried out on the plot?

Mr Sekgee frequently inspects the fruit trees and comments that the indigenous trees grow seemingly very slowly, but will develop over time. The trees planted on the plot include Morula, Morojwa, Mogorogorwane, Mmilo and Neem, Orange, Paw Paw, Banana and White Grape. The White Grape was also bought from VPR&D at a cost of Pula 12.50, and more such cuttings are desired on the land. Intercropped inside or between the semi-circular catchments, are onions, watermelons and sorghum, planted out of initiative by the farmer and his wife.

Do you think the project will succeed and lower vulnerability to drought?

The project has been going very well indeed but the Mogorogorwane trees are taking time to establish themselves and most of them have died if compared to the other indigenous trees. Mogorogorwane are a difficult species to propagate successfully, but once established, they come very well (Ketshabile, 1999, pers com.). The Morula trees are growing particularly well and the family admires the way they have taken to their sandy soil. Mr Sekgee believes the trees will

increase food security if crop failure occurs and so help sustain the family during extended periods of dryness.

Where is the water source and is watering an inconvenience?

Water is collected from a Gabane village standpipe 5km away by donkey cart but the work is strenuous and the donkeys are often not fit enough as a result of the poor grazing. The family's vulnerability is increased through this dynamic pressure. The time taken up collecting and transporting the water constitutes two hours per occasion though the standpipe water is communal and free of charge.

Is VPR&D supporting or monitoring you throughout the project?

Mr Sekgee would like to ask VPR&D if they could visit more regularly as some of the trees die and it is hard to get word to them and ask for help. Monitors previously visited the plot three months ago and Mr Sekgee feels this was too long. However, less maintenance is required during the dry season and during the wet season the visits increase in frequency to once monthly (Ketshabile, 1999, pers com.).

What do other community residents think of the drought-resilient enterprise?

A great deal of interest has been shown in the project other farmers and neighbours in Gabane, and some would be extremely keen to have a similar scheme on their land. They would like the opportunity of reaping some of the benefits such as fruit provision and effective water harvesting techniques, particularly in the dry climate.

APPENDIX E

Map 1 shows the location of Gabane village, 20km west of Gaborone city centre, and the village of Kumakwane 7km west of Gabane.

Map 2 shows the location of Moshupa (written 'Mosopa') and Polokwe, south-west of Moshupa on the road to Kanye.

Map 3 shows the location of Paje, north north-west of Serowe.

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Sheet No. 35, 1:250,000

[illegible]

Sheet No. 23, 1:250,000

This is a detailed topographic map of the Serowe area in Botswana. The map shows the following features:

- Ranches:** BLDC RANCH, SEROWE FARMERS BRIGADE RANCH, and GOVERNMENT RANCH.
- Towns and Villages:** Serowe (the main town, shaded in black), Peka, Molepolole, Maseru, and various smaller settlements like Katsikoma, Molepolole, and Maseru.
- Geographical Features:** The Maseru River, Maseru Dam, and various hills and mountains.
- Topography:** Contour lines and spot heights (e.g., BPS 405, BPS 200, BPS 401, BPS 407, BPS 408, BPS 409, BPS 410, BPS 411, BPS 412, BPS 413, BPS 414, BPS 415, BPS 416, BPS 417, BPS 418, BPS 419, BPS 420, BPS 421, BPS 422, BPS 423, BPS 424, BPS 425, BPS 426, BPS 427, BPS 428, BPS 429, BPS 430, BPS 431, BPS 432, BPS 433, BPS 434, BPS 435, BPS 436, BPS 437, BPS 438, BPS 439, BPS 440, BPS 441, BPS 442, BPS 443, BPS 444, BPS 445, BPS 446, BPS 447, BPS 448, BPS 449, BPS 450, BPS 451, BPS 452, BPS 453, BPS 454, BPS 455, BPS 456, BPS 457, BPS 458, BPS 459, BPS 460, BPS 461, BPS 462, BPS 463, BPS 464, BPS 465, BPS 466, BPS 467, BPS 468, BPS 469, BPS 470, BPS 471, BPS 472, BPS 473, BPS 474, BPS 475, BPS 476, BPS 477, BPS 478, BPS 479, BPS 480, BPS 481, BPS 482, BPS 483, BPS 484, BPS 485, BPS 486, BPS 487, BPS 488, BPS 489, BPS 490, BPS 491, BPS 492, BPS 493, BPS 494, BPS 495, BPS 496, BPS 497, BPS 498, BPS 499, BPS 500).
- Infrastructure:** Roads, railways, and a bridge over the Maseru River.
- Coordinates:** The map is oriented with North at the top and includes a coordinate grid.

