CHAPTER 1
INTRODUCTION

1.1 Background on Zambia

Zambia's population is currently about 10.3 million people (C.P.H, 2001). According to the Census of Population and Housing (C.P.H), it stood at 5.8 million in 1980 which was 40% higher than that recorded in 1969 (CPH, 1981). This indicated an average annual population increase at the rate of 3.1%. By 1990, Zambia's population was 7.8 million and the annual growth rate was about 3.2% (CPH, 1990). At this growth rate, the population in 2001 is estimated to be 10.55 million. This is a rapid population growth rate. About 72.9% of Zambia's population lives in poverty due to insufficient food resources and poor socio-economic conditions. The Government's objective is to reduce this poverty level to 50% by the year 2004. This is quite challenging considering that the country is one of the poorest in the region and is currently undergoing massive economic structural adjustment programmes which entail a lot of suffering particularly for the poorest in society.

"Within the SADC (Southern African Development Community) region, the current population of about 84 million is growing at a rate of approximately 3% per annum. Many people in the region have experienced a decline or stagnation in living standards since 1980. Significant increases in agricultural food productivity will be required to improve food security and quality of life"(World Bank, 1994).

The ever-increasing population of Zambia calls for immediate action towards improving agricultural food production because of the mounting pressure on the food and fibre requirements. The 2.7% annual growth rate of Zambia's agricultural food and fibre production has not matched the population growth rate in recent years (NAP, 1995).

Adverse climatic conditions entailing persistent drought years have had ripple effects on rain fed agriculture which is a mainstay of over eighty percent of the estimated one million Zambian farmers. Due to this phenomenon, there has been a clear shift to utilize Dambos, which remain wet even during severe droughts. Increasing population is escalating the socio-economic pressure to expand the extent to which Dambos are utilized for agriculture.

In Zambia, Dambos have been utilized to bridge the hunger gap when food resources ran out at household level by extending food production into the dry season.

Accordingly, the country faces chronic food deficits in coming years unless positive counter measures are taken to reverse the trends. The decontrol of prices and liberalization of marketing in which the government has withdrawn from direct marketing and became a facilitator has also not been dynamic. The removal of subsidies on agricultural inputs has left small-scale farmers with no capacity to expand cultivation of their land. The system has had poor financing and storage arrangements and flow of marketing information to the extent that arbitrage has emerged. Thus, the marketing system also requires re-orientation.

1.1.1 What is a Dambo?

Daka (1995) describes a Dambo as a wide low lying concave gently sloping treeless grass-covered depression which is seasonally waterlogged by seepage from surrounding high ground assisted by rainfall. It derives its fertility from accumulation of organic matter in this depositional sink of soil nutrients and it exhibits water tables for most part of the year in the upper 50 - 100 cm of the soil profile from which they drain into streams.

This definition seems to accord with hydrological, vegetational and ecological aspects of most Dambos. It is evident that the hydrological aspects of Dambos are the ones that have drawn attention of most farmers, ecotourists, environmentalists and researchers although not much work has been done in this respect. Various definitions for Dambos have been

suggested (Mharapara, 1995; Raussen *et al*, 1996; Ferreira, 1981; Huckaby, 1986; Verboom, 1970) to mention but a few. E.C.Z (1994) quotes the Ramsar Convention to define wetlands of which Dambos are part of as " areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary with water that is static or flowing fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters".

Breen et al. (1997**)** refers to Dambos as shallow, seasonally or permanently waterlogged depressions at or near the head of a drainage network, or alternatively, may occur independently of a drainage system.

1.2 Natural Resources of Zambia

1.2.1 Climate

Variation in altitude, latitude, temperature, relative humidity, radiation distribution and the control of air masses, largely governed by the influence of the Intertropical Convergence Zone (ITCZ), causes differences in rainfall distribution of the country.

The mean annual rainfall ranges from 650 mm in the south to about 1500 mm in the north, falling mainly between October and April. Rainfall totals and intra-seasonal distribution vary greatly from year to year, particularly in the south.

Zambia's rainfall pattern is very undependable especially in agro-ecological Regions I and II where annual totals range from 400 - 800 mm and 800 - 1000 mm respectively with a highly variable distribution in time and space. Conversely, agro-ecological Region III is a high rainfall area with dependable annual total rainfall of 1000 mm - 1500 mm with characteristic perennial rivers and wet Dambos.

Figure 1 shows an agro-ecological map of Zambia.

Temperatures generally vary from 14° C to 30° C. July is the coldest month with average temperatures of 16° C. Night air-frost may be recorded in May, June, July and August particularly in central and western areas of the country. October is the hottest month with mean daily maximum temperatures reaching 30° C. The plateau areas generally experience cooler temperatures because of high altitude. Figure 2 illustrates variations in rainfall and temperature distribution in Senanga district of the western province of Zambia.

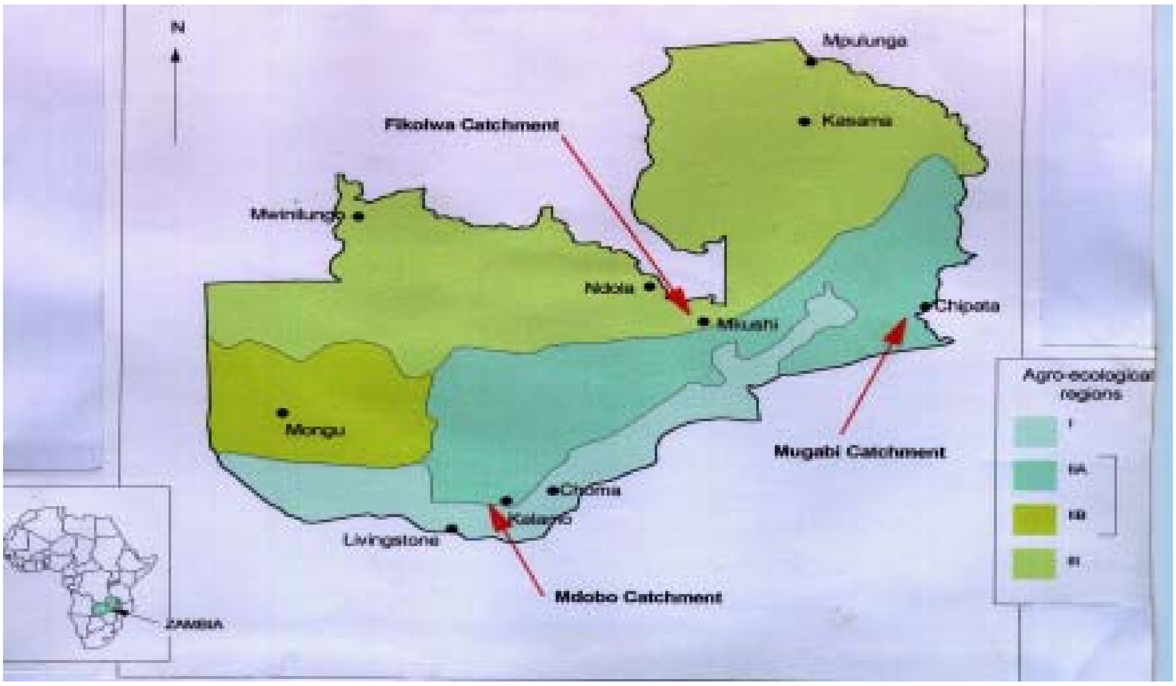


Figure 1: Agro-ecological map of Zambia.

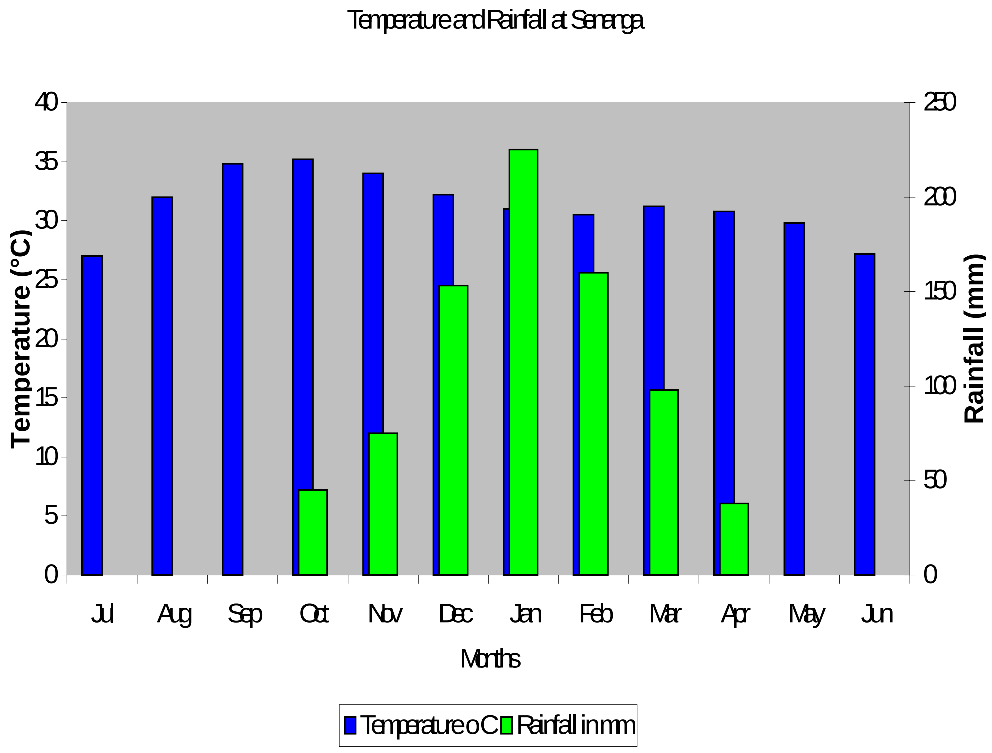


Figure 2: Graphic presentation of the early summer drought hazard (6 years average)

1.2.2 Land Resources

Zambia's main natural resource is land which covers about 75.3 million hectares of which 920,000 hectares are covered by water bodies such as: lakes, swamps, and rivers. NAP(1995) estimates that about 18 million hectares (24% of the country) are arable, of which only about 11% is cultivated annually.

Food and fibre production under irrigation covers about 150,000 hectares of which 100,000 hectares comes from small-scale farmers cultivating vegetables in Dambos/riverines using buckets for irrigation and the remaining 50,000 hectares representing medium to commercial irrigation farmers who use different intermediate to high technology irrigation systems. The major farming activity is essentially from small-scale upland rain fed agriculture which is undependable due to poor rainfall distribution and amounts.

1.2.2.1 Soils

The country's upland soils are essentially of "low inherent fertility". Most of these soils are moderately leached sandveldts, loams and clays. Their texture and structure vary considerably and hence their physical properties. However, the soils occurring in most Dambo areas are characterized by a dark colour in the top 30 cm of the soil profile. In more cases than not the layer is covered by silt loams underlain by silt clay loam with clay developing in deeper layers. Clay appears to have eluviated to lower horizons into water tables. Black colour is chiefly on account of their high organic matter content (humus). Dambo soils have supported crop production on a sustainable basis for several decades without having to apply external inorganic fertilizers on account of their organic matter and high nutrient pool. There is currently an increasing trend to Dambo cultivation due to their wetness and high fertility status for crop production. The variation in soil fertility status of both upland and lowland Dambo soils has to be viewed and approached cautiously with different land management practices applied if production is to be sustainable.

Sustainability in food production would entail continuity of food production given that all limiting factors are mitigated. In agriculture, many factors contribute to proper and increased food production. Such factors include land in its broadest sense (soil, water, climate and vegetation), financial and human resources.

It is understood that given all factors except water are present in abundance, food production is however not possible in the absence of water - one of the components of land resources. Sustainability implies that economic motivation and maintenance of land resources encourages the farmer to produce on a continuing basis and that his work allows him to improve his standard of living.

1.2.2.2 Vegetation

White (1962) documented forest flora for Zambia whilst Burtts (1953 and 1957) derived a field key for the identification of miombo trees. Useful trees for Zambia have been characterized by Fanshawe (1972) and his findings are alluded to by Storrs (1979). Comprehensive accounts of species and vegetation types are given by Fanshawe (1969) while ecological studies have been conducted and described by Lawton (1978). Dambo watershed areas are mainly covered by miombo woodlands which are susceptible to strong bush fires. Miombo woodlands are also called *Brachystegia-Jubernardia* wood (Chidumayo, 1993). Other common species include *Isoberlinia angolensis* and *Marquesia macroura*.

The Dambo margins in most areas are surrounded by *Uapaca* spp which are sources of wild fruits. The ground level vegetation consists of *Hyparrhenia* grasses which are frequent and according to Fanshawe (1969) and Lawton (1978) grass fires occur during the dry season (May - October). In the Dambo proper and the central part of it, many grass species and herbaceous plants are a characteristic. Typical plants are *Loudetia*, *cyperus*, *monocymbium*, *Loxodera* and *Mischantidium* (Ferreira, 1981). Besides grasses and sedges, pink flowered *Dissotis* spp are characteristic. Fanshawe (1969) further describes Dambo vegetation as moderately dense mat of grass, sedges, herbs and shrubs 50-70 cm high with flowering culms. Some streams associated with Dambos are mostly covered by mushitu vegetation (*Syzygium cordatum*) and *Gardenia imperalis* as typical vegetation.

1.2.2.3 Water Resources

A resource is not, it becomes. Until a material becomes relevant to some functional use, it is never a resource. Water is a great resource to our daily lives. It is useful to agriculture, industries, construction works etc. Unfortunately, Zambia has not fully tapped both the water and soil resources for agricultural food production. Zambia is among one of the very few countries in Africa that are blessed with abundant water resources accounting for about

45% of southern Africa's water resources (MAFF, 2000).

There are also large tracts of soils that are suitable for irrigation. Zambia is endowed with 114 billion m^3 of water from both groundwater and surface source. The former constitutes

96 billion m^3 whereas the latter comprises 18 billion m^3 mostly of good quality water for agricultural purposes (Daka, 1986). Small-scale farmers have access to surface water from rivers, Dambos, swamps and dams/shallow wells. Vegetable production is possible throughout the year in Zambia as there are sources of water for irrigation and this provides food for most households. The drainage system for the country is shown in Figure 3.

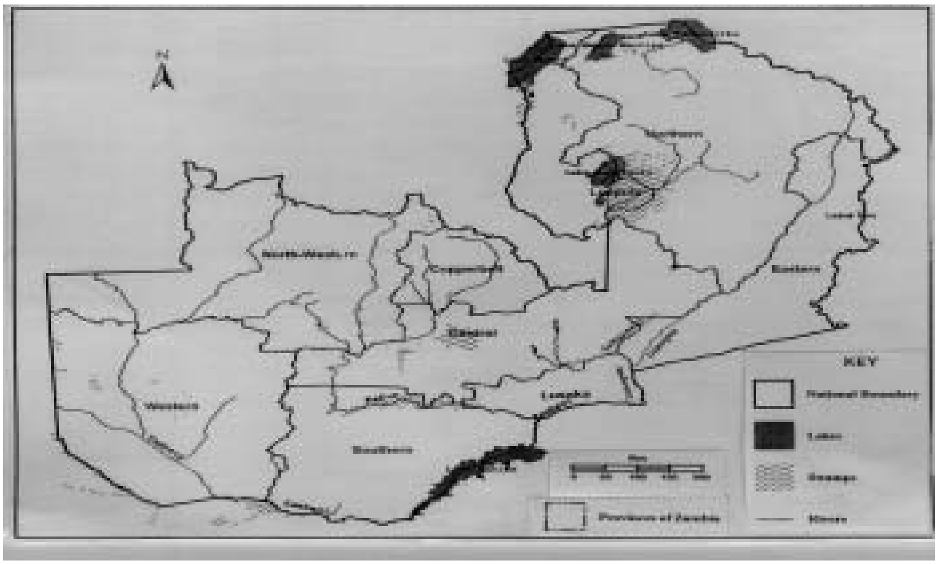


Figure 3: The drainage system for Zambia's water resources.

1.3 Dambo Use and Access for Utilization

Because of increasing populations and decreasing food production in dryland rain fed farming as a result of severe droughts, there has been an increasing trend to use Dambos for crop production in recent years. This is mainly because Dambos are highly fertile and support crop production even in the dry season because of their moisture retention potential.

Dambos are also used for grazing animals in the dry season when upland vegetation is dry with little or no supporting nutrients. In Luapula province, the high population density in the valley areas is a result of people moving from unproductive upland areas to highly fertile and productive Dambos.

Dambos cannot be described today as Dougnac (1999) did indicate that they are “largely unutilized” or very little utilized for agricultural production particularly in Luapula province. This is a misconception considering the increased emphasis on cash and food crop diversification in Mansa, Mwense and Kawambwa districts in the province. Whilst Dambos have been highly utilized for several years in Eastern, Central and Western provinces of Zambia, giving over thirty years of sustainable utilization and indigenous knowledge to cope with flooding in them, there had been a lag-time in wide utilization in Luapula province until early 1990's due to inadequate knowledge to cope with flooding, cultivation of heavy soils and soil acidity which suppressed establishment of most crops. Extreme drought years after this period has forced farmers to adopt practices which counter these associated problems, such as in Eastern province where Dambos are extensively used for agricultural production. Such strategies are discussed in subsequent chapters of this thesis. Another reason accounting to the under-utilization of Dambos in Luapula province during that period, is fishing which is very profitable and is a major occupation of small-scale farmers in the province.

Malnutrition levels being very high in the province and the prevalence of hunger during the dry season, justifies the present adoption of dry season exploitation of Dambos for fishing and vegetable production. Long-term trials by the Adaptive Research Planning Team culminated in the introduction and adaptation of vegetable crops in Dambos of Mabumba in Mansa district, Mubende and Lubunda in Mwense district. However, one factor comes into play when considering Dambo cultivation adoption in Luapula province, i.e. the issuing of free inputs to farmers during trials discouraged continuity without free inputs after trials were concluded. This phase has passed and today there are over one hundred and fifty small-scale farmers using treadle pumps to cultivate upper grassland zones of Dambos to produce vegetables. The FAO has initiated a Luapula Livelihood Food Security Programme and is involved in the promotion of horticultural crop production using the treadle pump technology in Dambos.

Dambos are highly accessible and by virtue of being scattered all over, they play an important role in mitigating problems of food insecurity as the majority of small-scale farmers have access to them without legal processes of acquisition.

Land tenure issues are addressed by chiefs or headmen and land so acquired can be passed to the next of kin. Usually the land rights in Dambos can be described as informal and accommodating particularly because no written contracts are required and other immigrant tribes are allowed access to Dambo land as long as they accept to observe the local customary laws respectfully. No legislation currently exists to restrict exploitation of Dambos in Zambia. However, deliberate efforts for their sustainable use is encouraged through community awareness campaigns on proper land use practices and management of their watersheds.

1.3.1 Potential Uses of Dambos

While forming part of a larger set of wetland habitat, Dambos have certain characteristics which place them apart from environments such as alluvial valleys and justify their study as a separate resource (Adams and Carter, 1987).

Dambos play an important role in the livelihood and food security of most rural people in Zambia. Significant contributions are observed in crop, fish and, to a minor extent animal production (grazing/hunting small animals). This significant role is more prominent in Luapula and Western provinces than other areas. Other livelihood options to the people with access to Dambos are irrigated cropping, supply of water for livestock and domestic purposes, collection of wild foods, soaking of cassava for processing, hunting of small animals, building products such as grass for thatching and reeds for making mats and collection of various coloured soils for moulding of bricks and decorating houses (see Figure 4).

Figure 4: Moulding bricks from Dambo soils for construction purposes.

For several decades farmers in Zambia like those in floodplains of Egypt, Senegal, Niger and along the Zambezi have followed a risk spreading strategy to grow crops in Dambos. Crops planted at different times of the year and at different elevations or zones of a Dambo floodplain eg. Litongo or Sitapa gardens ensure that some escape flooding and others escape drought. A variety of crops ripening at different times cope with differences in annual flooding patterns ensuring a constant food supply.

MAWD/FAO (1986) in proceedings for a National Workshop on Dambos notes that crops grown in Dambos of Zambia have included vegetables grown on ridges and high flat beds, rice, wheat, maize and other cereals while grazing of cattle has been a major activity since 1920's. The report, however, notes that there are different types of Dambos which support various utilization types and thus data and conclusions from one cannot be generalized for all Dambos. It is, however, observed that despite having variable definitions of Dambos, a holistic approach to the classification of Dambos should include technical aspects of hydrology, physiography, climate and soil.

Zambia needs to boost food production through expanded irrigated land area as it possesses a tremendous potential on account of its vast water resources both from rivers and underground.

The expansion programme could be achieved by encouraging small-scale farmers, who comprise about 80% of the Zambian farming community, to practice irrigation and extend the growing season through to the dry season. Such possibilities include a deliberate promotion of Dambo use for irrigation provided associated constraints are uplifted.

A more sustainable solution is to encourage low-cost irrigation technologies for rural applications and explore possibilities for manufacturing such technological equipment locally. Examples of such successes include the use of low lift and low-cost water lifting devices like the treadle pump and the clay pot sub-surface irrigation technologies which have been applied successfully elsewhere in Burkina Faso, Bangladesh, Brazil, India, Iran and Malaysia. Development and transfer of these technologies would promote utilizing the existing potential as a vehicle to increasing the food and fibre production to levels that would match the high food and fibre demands of the population of Zambia.

1.4 The Problem and Approach to the Solution

This thesis highlights crop production constraints in Dambos and the development of a technological package based on farmers' perceived solutions to uplift the major constraints inhibiting increased food production. Fundamentally, the subject deals with understanding the Dambo hydrology and recharge mechanisms in order to derive an appropriate technology for sustainable utilization.

Land utilization in Dambos has been viewed both as a curse and a blessing on account of periodic and sometimes permanent flooding and drying over the growing season. Farmers have over time developed indigenous methods of coping with peculiar difficulties related to flooding and receding of water tables in extreme dry years. Such coping strategies entail the use of a rope and bucket to draw water from receding water tables in hand dug wells and growing crops on raised beds and ridges to avoid flooding. The study aims at using farmers indigenous knowledge to develop a feasible technological package for proper and sustainable land use in Dambos.

1.4.1 Dambos as resource areas

Dambos have been recognized as key-resource areas worth exploiting agriculturally by small-scale farmers for several decades. This has thus attracted attention of many people such as agriculturalists, eco-tourists, hydrologists, ecologists etc. on account of their soil moisture and water potential.

Dambos exist in other parts of Africa and are known by different names such as: Vleis in South Africa and Zimbabwe, Mbugas in East Africa and Fadamas in West Africa. An estimated total of 240 million ha of wetlands exist in tropical Sub-saharan Africa which include: coastal wetlands, river floodplains, inland valleys and Dambos (Andriesse, 1986). The distribution of Dambos in Southern Africa is represented in Figure 5.

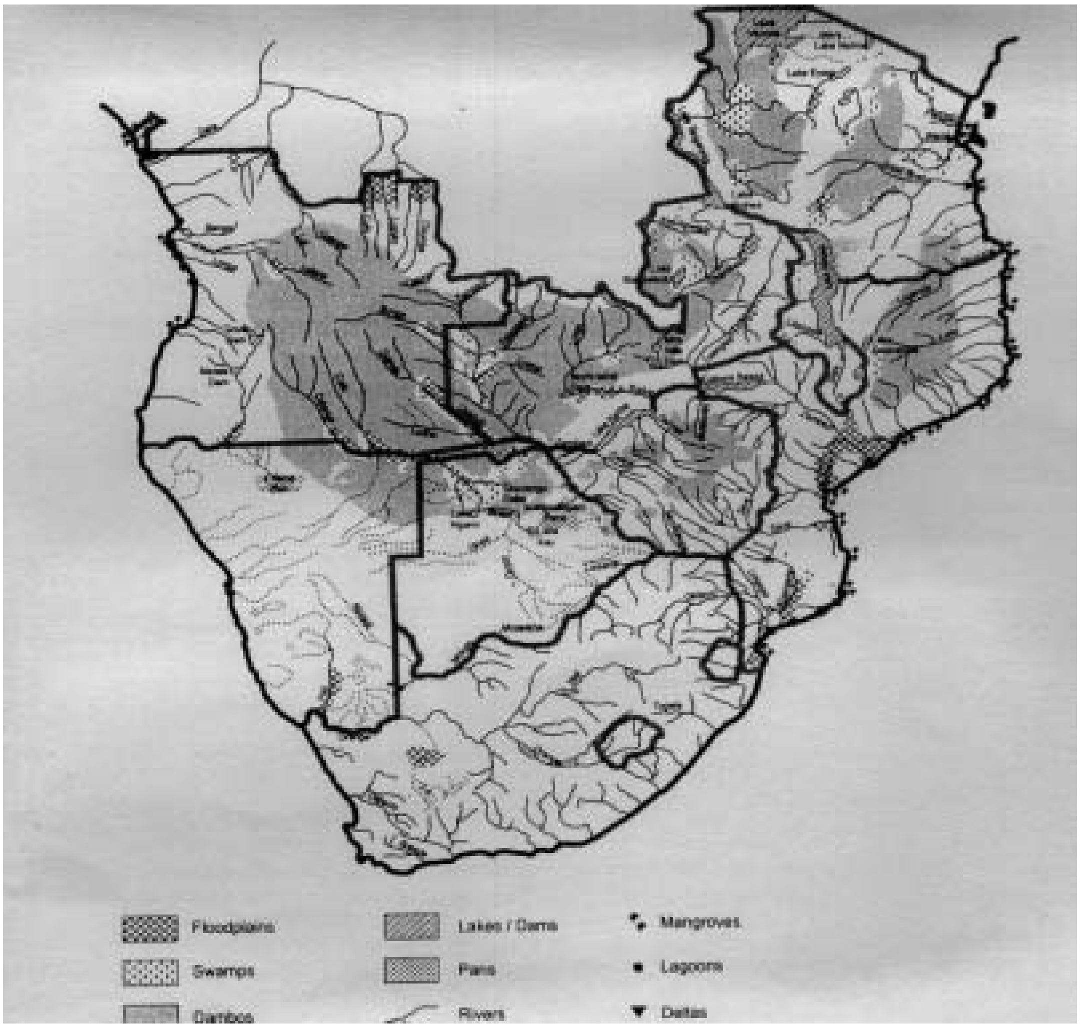


Figure 5: The distribution of Dambos in southern Africa.

Flying in mid dry season over southern parts of Africa, one recognizes what Wien (1995) describes as green islands surrounded by brown sea: moist, green, patchy wetlands, called Dambos, in the dry, brown Savannah (Raussen and Daka, 1999). These Dambos are special ecosystem natural resources as they have been utilized by many rural people to provide for their livelihoods.

The residual moisture of the Dambos is very important in regions with unimodal rainfall (6 - 8 months of dry season) and frequent droughts that reduce or lead to total failure of crop yields from rain fed upland fields. By cropping in Dambos small-scale farmers who usually don't have access to any formal irrigation, can extend the growing season for crops and vegetables in particular, to nearly the whole year. Dambo cropping in the dry season is based on residual moisture and hand irrigation from shallow wells. Irrigated Dambo cropping provides rural communities with cereals, tubers, fruits, vegetables and cash income.

In drought years production from Dambos is a vital safety net (Lovell *et al*., 1995) often providing the only source of food. Dambo cropping has the potential to increase the diversity of foods available and to smoothen out seasonal fluctuations in quantity and quality of foods McEwen (1993).

During most of the dry season upland pastures provide fodder of low quality. The diet of the livestock is significantly enriched by fodder from the Dambos where the herbaceous vegetation continues to grow throughout most of the dry season.

It is however important to understand Dambo use as part of the whole livelihood systems of small-scale farmers. Usually extension of one type of Dambo use competes with other uses. For example cattle grazing may damage vegetable gardens in Dambos.

Considering the importance of water for crop production in drylands, this work gives an overview on hydrology and irrigation aspects of Dambos using a developed water lifting technological device (treadle pump) to enhance crop production for household food security. The thesis recognizes and argues that although degradation of Dambos is not uncommon, with careful and appropriate use, irrigated cropping in Dambos has an enormous potential for sustaining livelihoods of farmers throughout Southern Africa.

This study has characterized natural hydrological phenomena of Dambos in three contrasting agro-ecological regions I, II and III with varying annual rainfall totals. Empirical evidence points to the fact that rainfall is of paramount importance in recharging Dambos. Soil fertility maintainance is discussed. Crop production constraints in different zones of Dambos are elucidated both from the standpoint of farmers and hydrology and vegetation in Dambos.

Use of a developed treadle pump technology and its socio-economic impact on rural small-scale farmers utilizing Dambos is discussed. The clay pot sub-irrigation has been introduced as a water saving technology as is presented in chapter 7.

The study has recognized that Dambos differ from one another and within themselves in terms of soil and chemical composition. The soil and chemical composition in most cases determine the fertility of most Dambo soils. Most farmers utilizing Dambos for crop production perceive Dambo soil to be highly fertile when it attains a black colour. Such soils usually show a presence of high organic matter in the top 30 cm layer.

However, decomposition of crop residues is seen to be poor in saturated zones of Dambos on account of poor aeration. The use of animal manure by virtually all farmers cultivating Dambos is a positive sign of sustaining soil fertility for considerable periods as has been seen in Zambia where no fertility loss beyond threshold levels of meaningful production has been observed for over thirty years of Dambo use.

Dambos are generally classified into different zones as described by Rattray *et al* (1953) and alluded to by Daka (1995) i.e Dambo margin, upper grassland, transition/seepage zone, lower grassland and the central Dambo zone (see Figure 6).

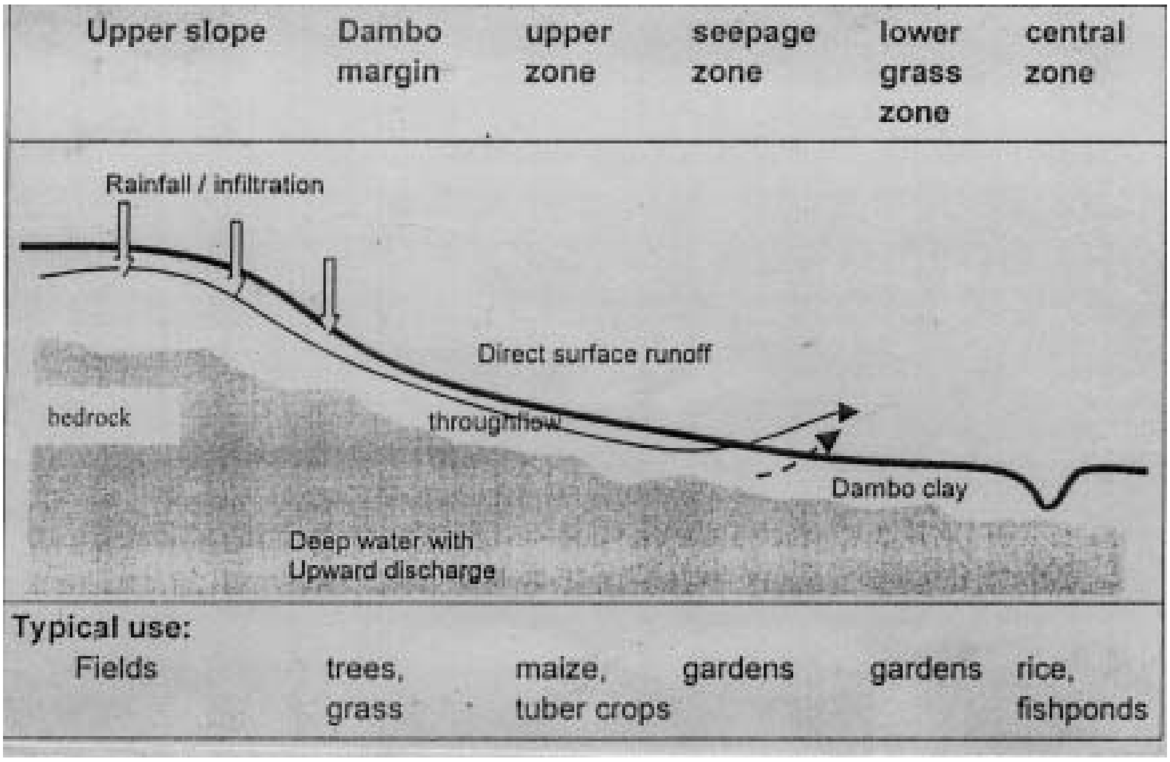


Figure 6: **Delineation of Dambos into soil-moisture zones.**

They are heavily affected by changes in rainfall variability over years. Farmers using Dambos have often confirmed that a good rain season was characterized by generally high water tables throughout the year.

On the other hand, a drought year which is characterized by excessive evapotranspiration has adverse effects of early drying up of Dambos in the dry season resulting in a general lack of water and farmers opting to re-deepen their sources of water (hand dug wells) in order to get water for both vegetable irrigation in Dambos and domestic purposes by using a bucket tied to a rope. The drying of Dambos also has ripple effects on the availability of pasture for grazing livestock.

In most cases Dambos form drainage lines and discharge excess water into streams and rivers which get recharged mainly by rainfall and to a minor extent by Dambos themselves. Some ephemeral streams and rivers continue to flow for some time in the dry season if Dambos have had a good rainfall recharge.

The presence of adequate moisture in the transition/seepage zone long after streams have dried out indicates that water is stored in the upper catchment aquifer of most Dambos. Recharge is promoted if the Dambo is characterized by sandy soils in the upper slopes where infiltration rather than rainfall run-off takes place. Water table variation in sympathy with rainfall input suggests that precipitation is a major contributor of Dambo recharge above all other recharge mechanisms. This study alludes to this fact by empirical evidence and is discussed elsewhere in subsequent chapters of this thesis.

1.4.2 Dambo Genesis

Two hypotheses for the genesis of Dambos have been developed and are summarized below. Different authors have looked at the development of Dambos from various perspectives as described in subsequent sections.

1.4.2.1 Dambos as result of fluviatile excavation, surface flows and sedimentation.

Dambos are the remains of ancient fluviatile valley systems that have filled with smectitic and kaolinitic clays through sedimentary deposition. The deposition led to a progressively weakening of the fluviatile energy to an extent that many Dambos are streamless today.

1.4.2.2 Dambos as result of landsurface incision, subsurface water flows and neoformed clays

Analysis of Dambo configuration in Malawi shows that these Dambos cannot be the result of fluviatile excavation. Dambos occur where differential leaching and landsurface collapses are geologically facilitated. The sizes of the Dambo areas depend on the extent of the incision processes and the groundwater tables. Dambos may therefore be considered a relatively recent incision in ancient landsurface and are under the influence of contemporary groundwater levels and movements (McFarlane, 1995). According to McFarlane (1995) and Bullock (1995) surface water plays a minor role in Dambo hydrology.

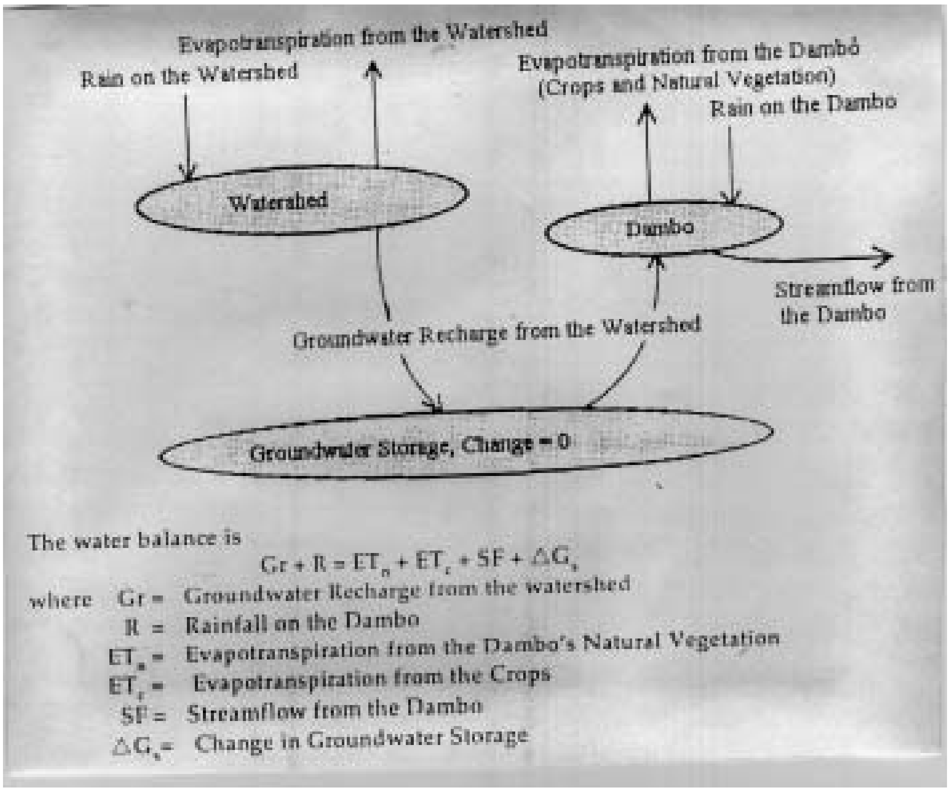
The dominantly smectitic clays in Dambos are unlikely to be sediments since smectite is not found on the catchments. There is some evidence that the smectitic clays in the Dambos are neoformed, as alumino-silicate evaporites from groundwater discharging into Dambos (McFarlane, 1995). This view is supported by Daka (1992) who saw evidence of alumino-silicates as parent material in the Dambos that he investigated in this study.

Due to the limited study area on which the second hypothesis is based, it is not clear whether the first hypothesis has to be reviewed by the more recently developed second one or whether the genesis of Dambos differs over regions and eventually between types of Dambos.

1.4.3 The Dambo watershed water regime

The variations regarding soils and water regimes between Dambos and even within a Dambo are common features (Giesen and Steenhuis, 1995; Lovell *et al.*, 1995; Mharapara, 1995; Bullock, 1995; McFarlane, 1995). However, recent studies agree on some hydrological principles that command the Dambo water regime.

Many studies (Kokwe and Daka, 1996; Raussen *et al*., 1996; Andreini *et al.*, 1995; Bullock, 1995; McFarlane, 1995) stress the importance to examine the hydrology of Dambos in the context of the interrelated components of the watershed Dambo stream flow system as indicated in Figure 7. The figure shows that the Dambo water balance is determined by rainfall, evapotranspiration and subsurface water flows.



The water balance is

$$Gr + R = ET_n + ET_c + SF + \Delta G_s$$

where Gr = Groundwater Recharge from the watershed
R = Rainfall on the Dambo
ET_n = Evapotranspiration from the Dambo's Natural Vegetation
ET_c = Evapotranspiration from the Crops
SF = Streamflow from the Dambo
ΔG_s = Change in Groundwater Storage

Figure 7: Factors involved in determining water balances in a Dambo.

1.4.3.1 The Dambo downstream water regime.

From the lower end of the central Dambo zone, usually a stream emerges into which excess water is discharged. Like in the case of Dambo genesis, the role of Dambos for the stream flow is unclear. The common belief is that Dambo clays overlying sandy layers regulate stream flow in a sponge-like fashion, absorbing water from precipitation by infiltration and slowly discharging it into the stream system. Consequently Dambos would have an important hydrological regulatory function (Dugan, 1994). Other authors (McFarlane, 1995; Bullock, 1995) question the sponge effect that is attributed to Dambos.

Smectitic soils, e.g. Vertisols, which are the most prominent Dambo soils, swell and shrink in response to variation in moisture content in the soil profile. On saturation with water these clays expand and swell tight and so become incapable of slow gravity feed to the stream system. After this, almost all water is lost through surface runoff (overland flow).

Except for the first rains in the season that sink into the cracks of the dry clay and later some retardation of surface flow by the grasses growing in the Dambo, there is no regulatory effect of Dambos on stream flow. This view is supported by recent research from Bullock (1995) who compared water flows from 110 catchments in Zimbabwe, which were still in a natural condition. He found that there is neither a significant influence of Dambo density in the respective catchment on the annual run-off nor on the variability of the annual flow. He concludes that Dambos are a minor factor in determining base flow and dry season flow at national scale in Zimbabwe.

Similar observations are reported by Du Toit (1985) from Zambia. Both authors find that with increasing deforestation of the catchments, both flood and dry season streamflow rise. This is attributed mainly to reduced evapotranspiration (Bullock, 1995) by the shallow rooted crops as compared to the previous perennial forest cover in the catchment.

While there seems to be some good evidence that Dambos play a minor role for downstream water flows, the question requires further hydrological studies over more regions and at various scales before final conclusions can be drawn.
Considering the practical implications of this debate on the sustainability of Dambo use and especially dry season flow of streams and rivers, hydrological research in Dambos needs to be given high priority. This is addressed by this study.

In Zimbabwe a legislation banning the use of Dambos exists for fear of possible dangers of drying these environments. In Zambia, no such legislation exists and farmers have used

Dambos for over thirty years without any seeming dangers of them drying up. What needs to be understood is under what circumstances these Dambos have been used, the problems and strengths of their continued use according to farmers' understanding and the possibilities for making improvements. Daka (1993) reported on variations of wetness intensities in different zones of some Dambos and how these could be used for crop production and elucidated that Dambo hydrology is mainly influenced by climatic conditions (i.e. rainfall, temperature and evapotranspiration), vegetation and soil water storage as affected by different soil types in different Dambo zones. Because of the nature of Dambo shapes which are typified by shallow linear concave depressions on the plateaux, water runs off from higher ground and also infiltrates into the soil and flows laterally in the sub-surface horizons and seeps to the central zone where it drains to the streams. Water typically seeps out onto the surface at so-called "seepage lines" which form at the contact between upper-slope sandier soils and clay soils on lower slopes. This characteristic was observed in all Dambos that he investigated. Dambos thus become seasonally or permanently waterlogged. Farmers have used *Syzygium cordatum* (Musinyika tree) and fig trees as indicators of the presence of water in a particular Dambo zone. In South Africa the "fever" tree (*Acacia xantiphloea*) is the typical indicator of the wet vertic clays in vleis along the Natal coast and in the Lowveld. This tree is also found in Dambos in Zambia and has mainly been used as an indicator of soil fertility.

1.5 Literature Review of Dambo Research

Hydrological and crop production studies for Dambos in Zambia and Africa as a whole are not exacting. From what is documented, many workers on Dambo research have looked at ecological and vegetational issues. Fanshawe (1969) characterized vegetation types in Dambos.

Although no comprehensive surveys have been done, several general accounts of Dambo vegetation exist (Rattray and Fitt, 1977; Rattray, 1957 and 1961; Boughey, 1961; Vincent and Thomas, 1961; Ivy and Bremley, 1972; Ivy, 1981; Mc Garvie, 1977; Kurima, 1981; Whitlow, 1980 and 1985a).

On the other hand Mackel (1974) elucidated the morphodynamics of Dambos in Zambia. Pedogenesis in Dambo soils has been studied in Zimbabwe (Savory, 1965). The process of weathering and dynamics of lateral clay translocation have been examined (Bond, 1963; Purves, 1975 and 1976; Thompson, 1965; Thompson and Purves, 1978; Fullstone, Godwin and Wells, 1981).

In Malawi McFarlane (1995) found that at the margin of Dambos there is often a wedge of clay, which extends upslope below a layer of sand. This clay wedge splits the water which moves laterally towards the Dambo into two distinct components as shallow throughflow moving over the clay wedge and sub-surface deep water passing below the clay wedge. Daka (1998) alludes to this principle and further argues that some of this water which discharges upwards into the Dambo is predominantly at or near the seepage zone (see Figure 8) where the Dambo clay is thinner and can be breached.

Other fractions of the deep water move below the Dambo clay towards the central zone where the clay comprises a tight lid, which prevents upward movement, deflecting the potential discharge downstream below the Dambo floor and may form a stream or river into which excess water is discharged. This principle forms the basis of the definition adopted in this study.

The throughflow and the deep water have distinct chemical characteristics, being rich in bases and silica for the latter and containing aluminum and other elements released in the most advanced stages of weathering for the former (McFarlane, 1995). The presence of nutrient rich springs in the Dambos seepage zone is confirmed by Kokwe (1991 and 1993).

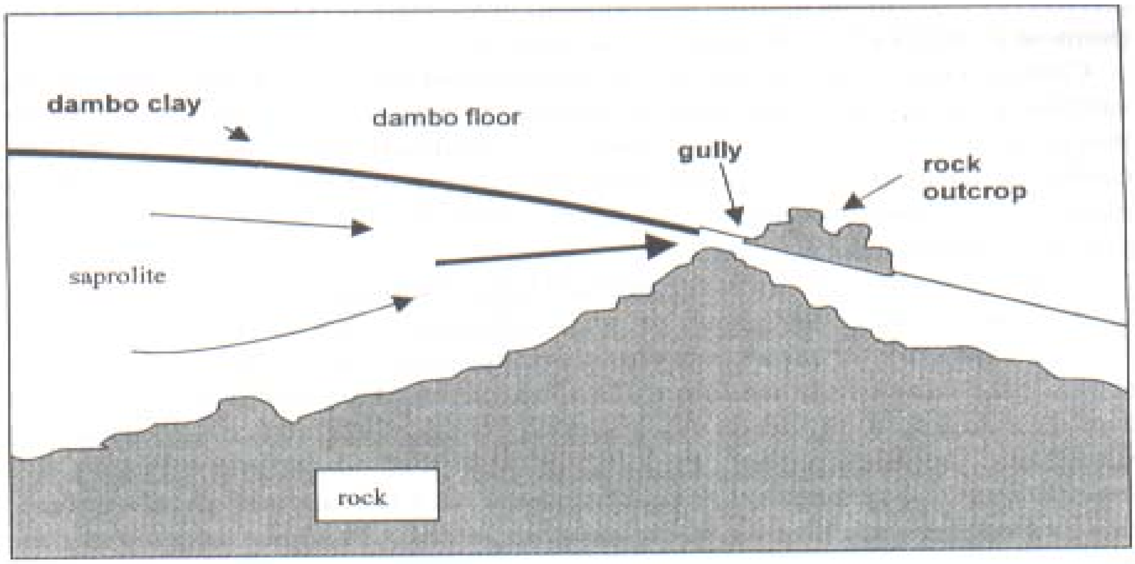


Figure 8: **Water movement and breaching of clay to effect gully erosion in Dambos.**

1.5.1 *Hydrology and Crop Production*

The only documented hydrological studies which dealt with the effects of rainfall in Dambos are those of Balek and Perry (1973) and Muneka and Mwassile (1986). A general study depicting the use of Dambos in Zambia has been initiated (Kokwe, 1991). In Zimbabwe, similar works were done to explain the use of Dambos in rural development (Loughborough University and University of Zimbabwe, 1987). Gosnell (1962) made a review of Vleiland (Dambo) development in west Kenya.

Some researchers have attempted to define Dambos because they are grossly misunderstood due to their complexity in nature. In all these studies, the accounts were rather generalized and using non-farmer participative approaches. The main hydrological processes are: Most rainfall on the watershed infiltrates and flows laterally underground over an impermeable substratum towards the lower lying Dambo areas (McFarlane, 1995; Raussen, Daka and Bangwe, 1996; Mharapara, 1995; Andreini *et al*, 1995; Bullock, 1995). This subsurface water may emerge in the Dambos seepage zone but often remains below ground because the clay soils of most Dambos act as an impermeable lid over the groundwater (Bullock, 1995; McFarlane, 1995). Rainfall directly on the Dambo area adds to the subsurface storage.

According to Daka (1996), most upland Dambos in Zambia show attributes of wetness either on temporal or permanent basis but significantly, all have shallow water tables. For example, some of Luapula and Northern provinces' Dambos are apparently endowed with perennial streams and are themselves usually wet though drying of Dambos due to long-term changes in rainfall patterns is observed. The drying is chiefly because of gradually reduced rainfall over the past ten years which has resulted into serious drought years in the Southern regions of Africa and Zambia in particular. Some coalescent Dambos in Mushota and Mulonga areas of Luapula province are evident and form wide tracts of land available for agricultural use. This observation seems to point to the fact that rainfall is a major contributor to Dambo recharge rather than farmers' land use practices which have been constant and stable over time. It is felt by most Dambo users that in the past much of the rainfall fell over prolonged periods in gentle, even shower intensities so that most of it infiltrated into the ground, whereas in recent years, the bulk of the rain falls in short heavy thunderstorms which mostly runs off to rivers as waste.

Dambos which are usually described as being dry because of their dry surfaces, have their water tables within 2-5 m from the soil surface from which water can be abstracted for irrigation, using buckets or low-lift manually operated suction treadle pumps.

Daka (1992-1997) in hydrological research memoranda alludes to farmers' observation in Luapula province in which rainfall is regarded as the main cause of recharge of Dambos or the lack of it for dryness. Recharge to the Central zone emanates from the seepage zone. Although the Central zone may be having a low water table at the peak of the dry season, it quickly exhibits excess water above the soil surface during the rain season. He further argues that recharge is more pronounced with precipitation than other factors. However, a noteworthy point is the importance of having vegetation in the upper catchment of the Dambo. Since this zone is characterized by sandy soils, infiltration rates are higher here than in the central zone where soils are clayey in nature.

Water in the upper grassland zone moves by both surface flow and sub-surface flow to the transition/seepage zones where it appears above the soil surface and moves as run-off to the central zone. Low infiltration rates in the central Dambo zone often cause inundation of water of which it becomes a permanent feature in high rainfall areas. This phenomenon would probably be the main cause of low pH values in such soils and formation of some peat soils due to incomplete oxidation of organic matter. Because of a thick layer of sand being underlain by clay soil in the seepage and central zones, water is kept in a sponge of sand and released later to contribute to Dambo wetness.

The wetness varies throughout the year according to the evolution of the water table which is a function of some climatic factors such as temperature, rainfall recharge and evapotranspiration, soil physical conditions (texture) and aquifer formation in the catchment area. Dambos in high rainfall areas exhibit more flooding/wetness conditions than in arid and semi-arid areas. A common feature is the fact that water tables will be resident within 1 - 3 m regardless of the extremity of dryness in a drought year as experienced in the year 1992 which was the worst drought ever recorded in the history of tropical Africa (Daka, 1997).

The processes described above result in most central areas of Dambos becoming waterlogged in the rainy season. In dry season groundwater tables may be between 0.1 and 2 meters below ground level. The various zones of the Dambo are associated with different water tables and different levels of recession during the dry season (Daka, 1993; Raussen *et al*, 1996).

In years with low rainfall the groundwater table declines considerably, which at times prevents farmers from irrigating. However, with one season of normal rainfall following, the normal groundwater tables are reached again (Raussen *et al*, 1996; Andreini *et al*, 1995). There appears to be no study suggesting a long-term reduction of groundwater levels in Dambos. McFarlane (1995) found evidence that over longer periods (25000 years) water tables in Dambos of Malawi were considerably lower, e.g. 6 meters. This resulted in a lower piezometric head, which must have prevented discharge of the deep, base rich groundwater into the Dambo.

The role of surface runoff from the watershed seems to vary. Andreini *et al* (1995) and Bullock (1995) argue that it plays a negligible role for the Dambo hydrology. Farmers in Zimbabwe, however, report that without water conservation measures which reduce surface runoff and enhance infiltration at the Dambo margin, the water tables in the Dambo would recess too much for dry season gardening to easily take place (Phiri, 1993).

Evapotranspiration from both the watershed and the Dambo influence the Dambo water balance. McFarlane's (1995) research from Malawi indicates that the widespread deforestation of the watershed to open this land for growing shallow rooted annual crops conserves groundwater through reduced evapotranspiration. Consequently this leads to higher groundwater levels. This raises the piezometric head, prompting increased upward discharge of subsurface water in Dambo zones where the upper clay layer is thin or where constrictions to the subsurface flow, e.g. rock outcrops, occur. This increased point-discharge could be the main factor leading to gully erosion in Dambos.

Daka (1998) agrees with other authors, like Chidumayo (1986), that Dambos are not independent systems but are rather interconnected to the surrounding watershed and the hydrologic cycle. Their sustainable utilization would thus largely depend on proper catchment management and water control.

Past research alluded to above, have clearly indicated that presence or formation of sandy soil layers on adjacent slopes are important for intercepting surface run-off and converting it to base flow which is important for recharging Dambos. To enhance this attribute, the Dambo watersheds and margins should be well vegetated and protected from erosion.

While it is evident that Dambos recharge in the dry season as a result of trees shedding their leaves and reducing evapotranspiration, it does not imply that removal of vegetation in the watershed while not caring for erosion and gully control would promote recharge. On the other hand growing of annual crops which is like vegetation replacement, does not result in water table recession since water loss from these crops is negligible. However, Bullock (1995) and McFarlane (1995) report that the role of possibly reduced infiltration and consequently increased run-off from the deforested catchment areas remain unclear.

Previous studies, e.g. throughout much of the colonial period, hold a different concept, in which surface water flows are of much more importance. While this might be the case in some environments, this perception has to be reviewed in the light of the above recent studies.

During crop cultivation in Dambos, farmers have observed that most of the water drawn from hand dug wells is recycled back to the water table by way of deep percolation. The lost water does not contribute to any meaningful recession of the water table.

1.5.2 Small-scale Informal Irrigation and its influence on the water

Without significant support from agricultural institutions, small-scale farmers have developed irrigated cropping in Dambos for several centuries. They grow cereals and tuber crops during the rain season and vegetables during dry season while perennial crops, fruits in particular, are also grown (Raussen *et al*, 1996). In Zimbabwe paddy rice was grown in the center of the Dambos and is reported to have been the main staple for the population, while vegetable gardens prevailed at the fringes of the Dambo (McFarlane, 1995; Mharapara, 1995).

When European farmers settled in southern Africa they also began using Dambos. Unlike local farmers they used rather massive drainage methods and unsuitable crops, e.g. tobacco, which led to severe gullying and created the perception that Dambos were a fragile environment. This resulted in the introduction of a legislation that made Dambo cultivation illegal.

In spite of the legal restrictions small-scale farmers continued to crop at least at the fringe of Dambos, but rice cultivation reduced drastically and maize grown in the uplands, became the main staple (McFarlane, 1995; Mharapara, 1995). In Zambia and most tropical African countries where Dambos occur, no legislations banning the use of Dambos exist. Traditionally in Zambia, small-scale farmers have utilized Dambos to grow both food and cash crops, some of which include maize, beans, peas, pumpkins, vegetables, rice, potatoes and fruit trees. Cattle grazing has time immemorial been practiced in Dambos where livestock rearing is common. Dambo gardens in Zambia are called **sishango** among the Lozi, **dimba** among the Cewa and **Fisebe** among the Bisa and Lala (Trapnell, 1953; Priestley and Greening, 1956; Trapnell and Clothier, 1957). Kwaw-Mensah (1996) gives a clear outline of the excellent vegetable production by such small-scale farmers in Dambos on the banks of the Zambezi river in the Senanga district in western Zambia. The gardens in which these crops are grown are usually small (0.25 - 1.0 ha) and they have had to cope with constraints such as flooding and drying of Dambos. In order to cope with flooding, traditional technology has involved making of ridges, mounds or banks in between trenches or furrows in order to create drainage in the root zone. These structures vary widely in size depending on the prevailing groundwater levels, soils and crops grown. According to their observation of the Dambo water regimes, farmers make beds at ground level in relatively dry Dambos and raise beds to more than a meter height where waterlogged conditions prevail.

Farmers' choice of suitable crops is usually related to the more general hydrological condition in the respective Dambo zone, whereas the height of beds is used to adapt to small-scale water variations in the Dambo. By doing so farmers respond remarkably well and efficiently to the variations in water levels that exist within a Dambo (Giesen and Steenhuis, 1995). Water quality in Dambos is generally good and salinity is not a problem requiring any drainage efforts (Daka, 1992).

Most of the irrigation systems developed by small-scale farmers are based on a combination of residual moisture, capillary rise and rope-and-bucket irrigation with water lifted from shallow wells (Raussen *et al*, 1996; Murata *et al*, 1995). These methods allow for small to medium size gardens depending on the natural conditions, availability of Dambo land and labour force.

In the southern parts of Zambia and Zimbabwe where relatively low annual rainfall totals are common, farmers may actively irrigate crops in the rainy season, if dry spells occur. This is only required until the roots have reached moist soil layers (Bullock, 1995). In most cases farmers will however, only irrigate dry season crops, mainly vegetables. Some of these vegetables are raised in nurseries at the end of the rainy season and transplanted into the beds in early dry season.

If residual moisture in the topsoil is sufficient, a single irrigation with watering cans may be sufficient for the seedlings to establish. Thereafter their roots will grow downwards to remain in the zone of capillary rise and no further irrigation may be required (Raussen, Kokwe and Daka, 1998).

Similarly, directly sown crops, e.g. beans, may not require irrigation if planted early in the dry season. If groundwater and capillary rise are not within the root zone of crops, especially for those planted later in the season, they require regular watering. In eastern Zambia about 7 mm of water was applied in a 2-day-cycle during the cooler months June-July and double that mount during the hotter part of the dry season from August to October (Raussen *et al*, 1996). During this part of the year irrigation is the most labour intensive activity in the gardens and actually limits the extent of the area under crops unless use of labour saving technologies, such as the treadle pump for water lifting and clay pots for sub-surface drip irrigation, are employed.

According to studies in Zimbabwe by Andreini *et al* (1995) the irrigation water applied in dry seasons amounted to less than 25% of the evapotranspiration from the vegetable plots. The remaining water is provided from subsurface water. Although irrigation is generally critical to the production of dry season crops, it represents a small proportion of the water consumed. Hence, although farmers' delivery methods are usually very labour intensive, they may be considered efficient because only a fraction of the crops' water requirements have to be actually applied by farmers (Andreini *et al*, 1995). Using traditional irrigation technologies, the relative increase in evapotranspiration compared to Dambos in their natural state is not very high.

Faulkner and Lambert (1991) found in Zimbabwe that when 10% of the Dambo area is cultivated, evaporation increases by 60% compared to that of an undisturbed Dambo. This resulted in a depletion of the aquifer by 17%, which the authors consider as having little effect on the moisture regime.

The authors conclude that an extension of Dambo cultivation will not have significant effects on the moisture regime of the Dambo if the cultivated area is less than 10% of the Dambo area or 30% of the total catchment area, whichever is smaller. Farmers who usually do not see the water tables in their gardens affected by their neighbours' irrigation activities (Faulkner and Lambert, 1991) confirm this rather conservative estimation. In Zambia it is observed that often much more than 10% of the Dambo area is irrigated without farmers realizing any effects on the groundwater table.

A further increase of the area under irrigation in Dambos may be possible without threatening its water regime through irrigation methods (such as clay pot and drip irrigation and application of mulch) that reduce evapotranspiration. Murata *et al* (1995) compared these efficient irrigation methods in southern Zimbabwe. The introduction of mechanized pumps (whether manual, draught or engine powered) may pose a serious risk for the Dambo water regime if irrigation water quantities are not limited to safe levels, however.

Considering the heterogeneity of Dambo hydrology, a detailed characterization of the respective Dambo water regimes is required before the introduction of water lifting devices. However, farmers are very interested in such labour saving equipment. The treadle pump development as a technology for irrigation in Dambos is one such equipment which can be used harmoniously in Dambo systems as its discharge is modest (1.5 l/s) and most of the water applied on the Dambo soil either percolates back to the shallow water table or is taken up by the crop.

Irrigation of areas outside the Dambo with water from the Dambo may pose a serious threat of groundwater depletion and should only be considered after hydrological studies have proven the sustainability of such methods for a particular area (Andreini *et al*, 1995). Experiences with such approaches have left parts of the wetland either too dry or too wet (Giesen and Steenhuis, 1995).

There are fears that over-drainage of Dambo soils may cause irreversible drying, leading to acidification and loss of organic matter and associated fertility (Kokwe and Daka, 1996; Giesen and Steenhuis, 1995). In most of the southern parts of the region, drainage systems beyond individual gardens are not an issue. In the northern areas with higher rainfall, some form of Dambo drainage beyond individual gardens might be required. The variability of the water regimes within a Dambo is a major obstacle for uniform drainage to take place. Trafficability is not an issue for small-scale farmers and they usually consider management of high water tables easier than to cope with too low water levels. Giesen and Steenhuis (1995) therefore suggest a restrained engineering approach to Dambo drainage. Such an approach should not attempt to prevent every possible drainage problem but acknowledge the technical capacity which exists at farm level. Any drainage effort should therefore allow flexibility at the farm level.

1.5.3 Sustainability issues

The wide belief that cropping in Dambos is the main cause for their degradation is not supported by most studies. Raussen *et al* (1996) found no serious degradation in Dambos in eastern Zambia where they have been used for decades to intensively cultivate vegetables and other crops in gardens. Sustainable use of Dambos is not dependent on technical factors only. Other important factors for the sustainable use of Dambos are of socio-economic nature, e.g. legislation, tenure, and extension. These are discussed in Section 1.8.

1.5.3.1 Soil erosion in Dambos

Erosion was evident in Dambos (or parts of Dambos) used for grazing livestock. Bullock (1995) reports similar findings from Zimbabwe, where contrary to common expectation the most extensively cultivated Dambos are associated with lower incidence of gullying. He observed more gullying in Dambos used for grazing. Raussen *et al* (1996) confirm these findings by the evidence of acid Dambos remaining undisturbed as they are neither used for grazing nor gardening. Overgrazing with subsequent increased insolation and desiccation as well as trampling by cattle is likely to compound gully initiation. But the main cause for gullying in Dambos appears to be deforestation of the catchment areas (McFarlane, 1995; Bullock, 1995). From agricultural practice there is some evidence that surface run-off from the catchment is often not the main agent of gullying. This is supported by observations where gullies advance even when protected by physical soil and water conservation structures.

Further observations from Zimbabwe (McFarlane, 1995) indicate that gullies in the Dambo occur frequently where the clay layers are shallow or where rock outcrops occur. The rock outcrops as well as thin clay layers encourage the point discharge of subsurface water which then causes gullying (see Figure 8). Often these gullies are self-healing. They move in a caterpillar-like fashion upslope: cutting headwards and heal at the downward end (McFarlane, 1995).

Considering this concept of gully formation in Dambos, their control would be possible by reducing point discharge of subsurface water, through:

- Avoidance of groundwater table rise in the watersheds.
- Replacement of natural forests by annual crops needs to be kept to safe limits in order to avoid reduced evapotranspiration in the watershed.
- Increased evapotranspiration from the Dambo within safe hydrological limits.
- Cultivation in Dambos enhances evapotranspiration and thereby increases subsurface
- Recharge of the Dambo groundwater table by subsurface flows from the catchment. This leads to a lower piezometric head and consequently to reduced water discharge at the fringe of Dambos (McFarlane, 1995).

Daka (1998) believes that conservation efforts for Dambos should therefore concentrate on the management of the whole catchment rather than focussing on Dambos alone. The hydrology and erosion processes of Dambos can only be understood and substantially influenced if the whole Dambo catchment system is considered as a unit. Conservation of the catchment is however a difficult task, since it requires a joint effort by all those farming in the watershed. Lack of social cohesion poses a serious obstacle to success. Furthermore, not all farmers cultivating within the catchment might have access to the Dambo and therefore will be less interested to participate in catchment conservation unless they derive other benefits from the catchment management, e.g. sustainable fuelwood supply. Projects for watershed management require full involvement of the communities concerned and have to share with them responsibilities from problem identification through planning and implementation of conservation effort.

Erosion of the levees along rivers because of their mismanagement may have serious negative impacts on Dambo hydrology. Mr. Jacob Zikhali, a farmer along the Pongola river in the Maputoland area of South Africa explained that chiefs have always been very reluctant to allow people to plant on levees alongside the river. If these are cleared of vegetation, they become vulnerable to erosion by the flood waters. If the levees are washed away, the river will scour one big water way and the floodplain will disappear (Victor, 1993). This notion also points to the fact that drainage of water from a Dambo at its outside boundaries, may cause drying up.

1.5.3.2 Disruption and destruction of Dambo systems by engineering structures

Injudicious construction of structures either at Dambo outlets or upstream in the catchments can lead to serious disruption and even permament destruction of Dambo systems.

Damming a Dambo outlet may cause permanent inundation in all its different zones. In the 1970's one of the biggest vegetable producing areas in central New York state, USA, was put out of production because of waterlogging/inundation caused when an interstate highway was constructed across the outlet of the area, which had characteristics similar to those of Dambos. This should serve as a warning of what could happen to a Dambo area upon such development.

In commercial farming areas in South Africa the outlet of a vlei area is often closed off with an earthern wall to create a storage pond for water supply, e.g. stock watering. These ponds are very vulnerable to destruction by floods during heavy rains, such as brought about by tropical cyclones, for example. The result is severe gully erosion, leading to excessive drainage of the Dambo system afterwards, causing it to dry up.

Building of big storage reservoirs in upper cathments can eliminate flooding and thus cause Dambo areas to dry up, with disastrous consequencies for small farmers who are dependent on cropping in the Dambos. A classical example is the Jozini dam in the Pongola river in South Africa. The dam eliminated flooding of the Dambos downstream in which local communities grow their crops, as well as of the pans in which they do fishing. After realizing the impact of this, artificial flooding by opening the sluices of the dam wide, to let out large volumes of water to simulate floods, was done. The initial attempts created big problems, because the natural flooding systems were not properly understood.

A farmer Mr. Petrus Kanini recalls the disruption brought about by the construction of the Jozini dam to the age old farming system: "Before the dam, you knew what to expect. The flood lasted three days, but afterwards when the dam was constructed, the sluices were opened for seven to ten days and the crop rotted." Another farmer Mr. Jacob Zikhali describes how the system used to work; " We started planting at the end of August after the first rains. Most of the crops take 3-4 months to grow i.e maize, pumpkins and water melons. We also planted madumbes and sweet potatoes which grow in flood water like rice. If the flood takes away the mealies (maize), the sweet potatoes and madumbes are still there."

1.5.3.3 The Effect of Dambo Use on Fertility Sustainance

Apart from alterations of Dambo hydrology and erosion processes, depletion of soil nutrients is a potential threat for the sustainable use of Dambos. Most Dambos are rich in organic matter and being depressions surrounded by high ground, act as nutrient depositional areas. This makes them very fertile lands for crop cultivation. Observations indicate that farmers usually maintain soil fertility of their Dambos through regular application of manure, organic debris and fertilizer (Raussen *et al*, 1996). This practice has proven sustainable and no acidification problems have been reported so far. However, micronutrient deficiencies have been reported (Kokwe, 1991). Seasonal fallows with suitable legumes, e.g. Crotalaria spp. are suggested for replenishing nitrogen and organic matter levels (Kokwe, 1991).

Some farmers burn vegetation in Dambos during cultivation (especially on virgin land). In Dambos used for grazing as well, this practice would promote regeneration of new herbaceous plants and grass which are palatable for livestock to graze. On sour or acid Dambos which are deficient in basic nutrient elements, burning would further lead to loss of nitrogen taken up and stored in plant biomass such that if nutrients are not replaced, the Dambo would lose its fertility and become unproductive in the long-run. A major problem which exacerbate fertility loss in Dambos is erosion due to overgrazing which leads to loss of top soil and its nutrient reserves and lowers its soil moisture retention capacity (Daka, 1998).

1.5.3.4 Pollution due to Pesticide Use in Dambos

So far no documented evidence of Dambo pollution due to pesticide use in Zambia exists after more than thirty years of crop production in Dambos. Most Dambo users traditionally use botanical pesticides such as tephrosia, ground hot chili or wood ash dissolved in water and sprayed on vegetables to control pests such as aphids, red ants and red-spidermite. Increasing use of such methods is currently noticeable. Some farmers use agro-chemicals to some extent, but with good knowledge of handling both the chemical and the equipment used for spraying.

These farmers do not use the same well for both domestic and irrigation purposes. Wells used for drawing domestic water are most often located in Dambo margins whereas those for irrigation are located in the seepage and lower grassland zone.

Studies elsewhere in Europe (Hallberg, 1987) have indicated a widespread opinion that pesticides usually do not leach through soils to surface and groundwater. This hypothesis may explain why even users of agro-chemicals in Dambos have not alluded to any form of pollution in Dambos.

Contamination of wells and streams has occurred (Erne, 1970) but was mainly the result of incorrect handling of application equipment (sprayers) and pesticide residues and spray drift. Some pesticides may find their way to water sources through surface run-off to streams or wells in Dambos. Accidents with pesticide use in Dambo gardens have only been apparent through theft and consumption of sprayed vegetables before the pre-harvest period.

1.5.3.5 Degradation and Sustainability: A Question of Skepticism or Reality?

In as much as Dambos have been reported to have been used stably and in a sustainable way by small-scale farmers, it is important that an environmentally friendly approach is adopted in their utilization. Creation of high ridges for free drainage in the root zone and formation of high flat beds without loss of water downstream or outside the Dambo, is a very sustainable way of utilizing Dambos.

Commercialized crop production which entails use of mechanized farm machinery like tractors to make drainage channels leading to outside Dambos, should not be allowed as this would alter the water movement and its fate in which recycling would no longer be the case.

Over-grazing by cattle in Dambos used for crop production as well is reported to be the major cause of erosion and this should be discouraged at all costs. Use of village headmen and chiefs in bringing about awareness among village communities has proven very useful particularly in Eastern province.

Deforestation in the catchment area is another big problem requiring control as this causes erosion and affects the water regime in Dambos since run-off rather than infiltration is promoted. Afforestation should be encouraged in Dambo fringes and their catchment areas in which planting of fuel woodlots would help re-afforestation.

1.5.4 Legal and Socio-economic Issues Related to Dambo Usage

1.5.4.1 Legislation and policy issues

Particularly in Zimbabwe pronounced calls for amendment and moderation of restrictive legislation on Dambo utilization through the Water Act (from 1927, amended 1976) and the 1952 Natural Resources Act have been voiced (Mharapara, 1995; Maseko and Bussink, 1995; Bullock, 1995; McFarlane, 1995). This legislation and similar laws in some neighbouring countries are based on incorrect perceptions of Dambo hydrology and degradation processes.

It is also argued (Maseko and Bussink, 1995) that the legislation was introduced during early colonial periods because through their use of Dambos small-scale farmers competed very well with the new settlers, especially on the rice and wheat markets. These crops performed even better in Dambos than on upland soils because of high fertility levels. Dambos are not a particularly fragile environment but they are highly influenced by the condition of the catchment.

Some critics feel that use of Dambos would reduce downstream water flow and eventually dry out these streams. Although still a matter of debate, Dambos may have much lower influence on streamflow than previously thought.

Notwithstanding the above concerns, the existing legislation is currently rarely enforced considering the importance of Dambo farming for small-scale farmers' livelihoods. Common knowledge points to the fact that current restrictive legislation should be changed and accept that well practiced cultivation in Dambos is sustainable. However, this needs to be accompanied by criteria defining safe limits of Dambo utilization and could furthermore be linked to certain conditions regarding catchment management, e.g. a minimum tree cover. However, laws alone will be insufficient if not accompanied by good extension based on process and adaptive research. Local knowledge of Dambo use is advanced in areas where Dambos have been used traditionally (Kokwe and Daka,

1996) and this knowledge should be made use of. Where Dambo farming is a relatively new venture greater emphasis has to be placed on extension work and education of communities.

1.5.4.2 Land Tenure

Many African countries have a dual law system, especially as with regard to land tenure. This is a relic of the colonial past. Customary laws usually apply in trust, reserve or communal lands while the state land is governed by statutory law (Kokwe, 1991). In the former the allocation of Dambo land to farmers is through chiefs or village headmen. The right of use is guaranteed with the allocation but can usually not be sold or mortgaged. Absentee land ownership is common and artificially increases Dambo land shortage in some areas (Kokwe and Daka, 1996). Equity concerns regarding access to Dambos need to be addressed (McEwen, 1993). Some land tenure issues have also been delt with in Section 1.3.

1.6 Future Scope of Dambo Utilization

Considering the extent and importance of Dambo farming, the question is not whether Dambos should be used but how Dambos can be used in an ecologically and economically sustainable manner. Frequent droughts, widespread soil fertility decline on the upland fields, population growth and an increasing demand for vegetables by the urban markets leave farmers with little choice but to use Dambos which are a fairly robust environment and more productive than upland fields. While labour invested per unit Dambo area is often double that invested on upland fields the average production from them is often threefold to fourfold (Scoones, 1993).

Although Dambos are far less fragile than often thought, there is a need to define conditions for sustainable, extended Dambo use and to set the agenda for comprehensive research and extension work. Many studies have been reductionistic, addressing only one or a few components of a larger system. By doing so the results of the research do not address the complex and dynamic interactions between farmers' activities and the catchment Dambo stream flow system.

As reviewed in this chapter, the hydrology of Dambos is still a matter of many debates and hydrology of Dambos may differ between Dambo types and areas. Kokwe (1993) in a review of technical research on Dambos concludes on the whole that hydrological research in Dambos remains an area of contradictions of findings and perhaps forms one of the greatest challenges to researchers in understanding the Dambo and the resources it avails to life supporting systems.

1.7 Extent, Distribution and Economic Importance of Dambos

In Zambia, there are about 3.6 million hectares of Dambos (Perera, 1980) representing 8.3% of the total arable land. Proper and successful land use of Dambos requires an understanding of water movement, recharge and storage mechanisms and its fate. This information is lacking and to a great extent very little has been documented primarily due to lack of interest by researchers and policy makers in the field of wetland development for decades until only in recent years.

The last thirty years have seen small-scale farmers exploit Dambos for food production whilst at policy level Dambos have been classified as marginal lands for crop production and only suitable for grazing cattle. This is particularly because Dambos remain partially or permanently flooded for most part of the year and would almost always be endowed with fresh grass and some herbaceous plants palatable for cattle. Notwithstanding the above merits, farmers have had to cope with inherent problems such as excessive flooding, soil acidity, heavy soil texture difficult to cultivate and lifting water using buckets to irrigate relatively dry portions where crop production is feasible to mention but a few problems. In the past ten years, Zambia has experienced frequent droughts with the 1992 drought being the worst ever in human history on the continent of Africa. This drought was disastrous as farmers lost livestock and upland crop production was unsuccessful, with widespread food insecurity resulting.

During this period and subsequent years, there has been an increasing demand for use of Dambos to grow crops and graze cattle in them, owing to the moisture potential which prevails for most part of the year and can be exploited for dry season cropping and grazing.

This study has shown that soil moisture potential in upland and lowland Dambos is adequate enough to produce crops even in dry years as seen in the severe drought of the 1991/1992 agricultural season since water tables remain resident within 1-5 m below soil surface. Digging of shallow wells to 8 m levels allowed farmers access to water to grow vegetables for household consumption and sale of surplus for income generation at household level for an extended period in the dry season.

Need for water lifting technologies was however underlined when water was to be drawn from 3-5 m below the ground level using the traditional laborious method of a rope and bucket as this would cut down on the labour investment into Dambo cultivation. This phenomenon shows how Dambos could play a major role in achieving sustainable household food production in the light of frequent droughts which are characteristic of tropical and sub-tropical Africa. Most importantly is the need to derive sustainable ways of utilizing Dambos which are considered as environmentally vulnerable ecosystems yet very resourceful ecologies for sustaining human livelihoods. With regard to this, the study has addressed the following fundamental objectives.

1.8 Objectives of the Study

The initiated study seeks to fulfill the following specific objectives:

1. To develop a technological package that would entail increased food production through sustainable use of Dambos based on sound knowledge of farmers and scientific backing.
2. To identify crop production constraints in Dambos using a participatory rural appraisal approach.

3. To identify farmers' solutions to some constraints and the rationale used in arriving at them with a view to backing this knowledge with empirical scientific evidence from the study observations.
4. To investigate some mechanisms that recharge Dambos to become wetlands in dry lands through monitoring, quantifying and characterizing rainfall and water-table variations.
5. To establish the effects of water-table variations on the moisture storage and soil profile chemical development of Dambos with relevance to crop production.
6. To characterize farming or cropping patterns in Dambos and establish a cropping calendar according to agro-ecological zones in which the Dambos occur.