CHAPTER 4
UNDERSTANDING DAMBOS: A FARMER PERSPECTIVE TOWARDS SUSTAINABLE CROP PRODUCTION

4.1 Background

The preceding chapter demonstrated the importance of Dambos as key environmental resource areas that act as socio-economic safety-nets for bridging the hunger gap and providing food at household level. On account of this, they need to be exploited in a sustainable manner. Dambo study reviews have established these environments as being complex in nature and requiring multidisciplinary research to understand them better. This chapter analyzes farmers'experience and synthesizes them with empirical findings of this study in order to make the understanding from a single qualitative perspective. Dambo land use, folklore and myths are discussed from a scientific standpoint.

Variations of water table depths in the upper grassland, seepage, transition, lower grassland and central Dambo zones, were monitored as described in Section 2.4. The water movement, storage and fate in the various Dambo zones was understood by analyzing the collected data which was treated against the prevailing precipitation and evapotranspiration as collected from the weather station to produce Figure 10.

A socio-economic survey was conducted using a Participatory Rural Appraisal (PRA) involving a sample of some farmers cultivating Dambos for crop production (see Section 2.2). Using the hydrological results, coupled with farmer practices and constraint analysis, crop calendars were developed and recommendations made for best practices.

4.2 Results and Discussion

4.2.1 Precipitation and Dambo Hydrology

From farmers' perspectives of long-term use of Dambos, they have well understood Dambo hydrology. Years of droughts and good rainfall have affected Dambos by drying and recharging respectively. However the drying is understandably superfluous in that water is usually available within 1-3 m depth from the soil surface. This study has monitored water table variations resulting from rainfall input and evaporation. The observations so far suggest that precipitation is a major contributor of Dambo recharges. Folklore and myths suggest that vegetation removal reduces rainfall but farmers found that despite widespread vegetation removal for fuelwood and replacement with annual crops such as maize and vegetables in Dambos and their catchments, rainfall did not change and in fact Dambos recharged.

These observations were confirmed by farmers from the Eastern and Northern Provinces of Zambia where tree cutting is rampant. In the Northern Province, the system of upland cultivation involves tree branch cutting, grass slashing and burning. This type of cultivation is called the **"Chitemene"** farming system. Dambo recharge has remained relatively unaffected despite vegetation removal. It would appear that the inducement of Dambo recharge after vegetation removal is chiefly due to reduced evapotranspiration from annual plants as opposed to tree crops which are often deep rooted. Evidence of water tables rising shortly after trees have shed their leaves is not uncommon. It is thus inferred that although not a panacea, forest vegetation removal and replacement by annual crops does help to recharge Dambos. Rainfall events however promote recharge in Dambos as seen in Figure 10.

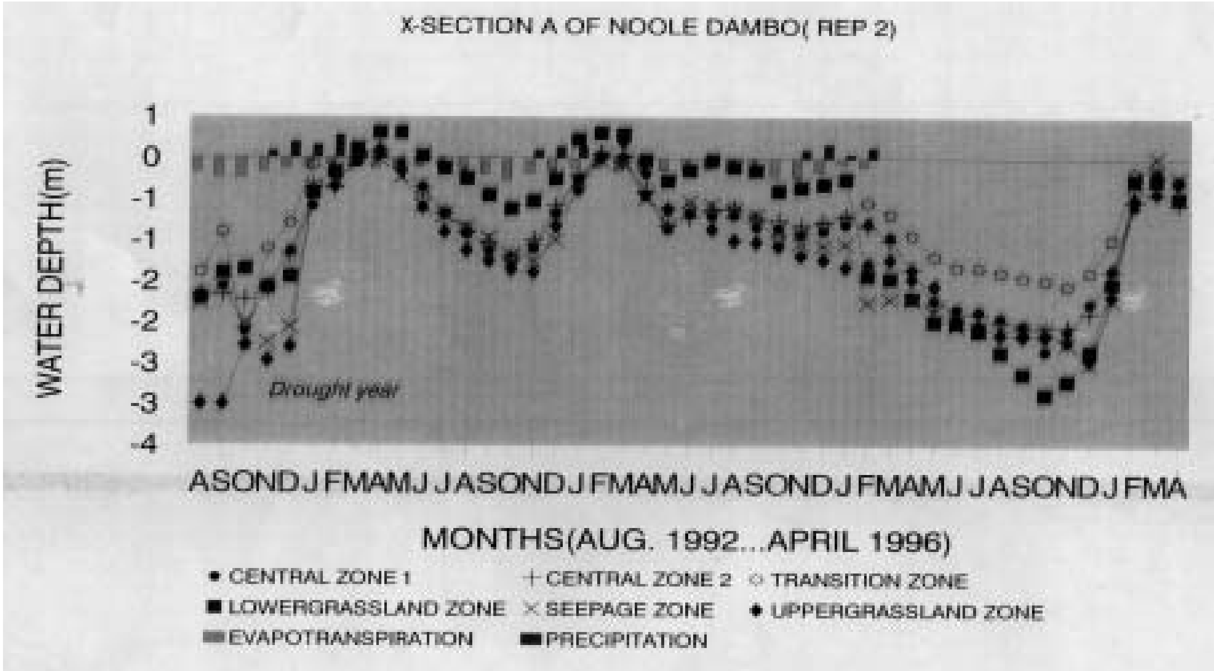

Figure 10: Variation of water table depths in Noole Dambo.

From Figure 10 it is evident that a quick response of water table recharge with respect to rainfall events exists. Depending on soil type in the Dambo, as well as sub-surface inflow from the interfluve, a time lag of one month may be experienced. However excessive evapotranspiration (direct evaporation and transpiration from vegetation) has an effect of lowering water table levels. Dambo interfluves that are largely covered by tree vegetation effect water table recession in the main Dambo system because of increased evapotranspiration.

Farmers' perception over several decades of Dambo use is that wetness is heavily affected by changes in rainfall intensity and distribution in space and time. They confirm that a good rain season is followed by a general rise in water tables in Dambos throughout the rain period. On the other hand, a drought year with excessive evapotranspiration causes early drying of Dambos. Farmers often have to dig their wells deeper to access the water

for irrigation and

livestock from the receding water tables. A normal rain season following a drought year recharges Dambos with water almost immediately. Farmers respond with increased cropping in Dambo gardens rather than abandoned gardens with disused fences which ensue and characterize a drought year.

Pereira (1989) suggests that forests are not generators of rainfall, yet this "Myth" like many others in forest hydrology may contain a modicum of truth that prevents it from totally being laid off to rest. Evidence from the present study suggests that there is no direct relationship between removed forest cover and decreased rainfall (see Section 1.5.1). Pereira (1989) concludes that much of this folklore is seen to be either exaggerated or untenable. Whereas there may be some limited increase in rainfall due to the presence of forest trees, this is almost always offset by increased transpiration, which leads to an overall reduction in water resources. Hence there is an observed reduction in groundwater levels in Dambos surrounded by trees. Meteorological theory indicates small increases in rainfall due to the orographic effect of tall trees that intercept some of this rain which is later re-evaporated and returns as rain but it never amounts to significant increases in rainfall.

The distribution of forest vegetation is a consequence of climate and soil conditions and not ***vice-versa*.** However a hydrologic relationship exists, with Dambos recharging after forest vegetation has been removed. Daka (1995) delineated Dambos into zones and agrees with Rattray's classification **(Rattray, 1953)** but characterizes these zones on the basis of field and empirical observations as shown in Table 11.

Table 11: Dambo characterization in terms of slope, water table and crop production limitations.

Zone	Characterization of water table	Slope	Specific limitations
Upper grassland	Water table is usually between 20 – 70 cm in the rain season and1 - 2 m in the dry season.	0-1%	The dry season may promote water shortages and salt accumulation in root zone. Some difficulties to lift water using bucket when water table is quite deep. Use of manual lift devices is advised.
Transition/ Seepage	Water table usually at surface level and above in the rain season. Lies at between 40cm above the surface in the rain season and 50 cm below the surface in the dry season.	1 -1.5%	Excess water becomes runoff downstream. Capillary rise water often meets crop water requirements in the dry season and in the rain season, when flooding is common, special crop adaptation is required for proper growth.
Lower Grassland	Has intermediate attributes of the Upper grassland and Transition zones	0.5-1%	Root zone often saturated, but with natural outflow to the Central zone. Planting on raised beds is recommended for good crop growth.
Central	Water table usually is between 10-50 cm above the surface in the rain season and 50 cm below the surface in the dry season.	0-1%	Excess water impairs crop growth. Crops grown on raised beds, which provide good drainage and aeration.

Water tables rise sharply following an event of rainfall but also begin to recede at the cessation of the rain season when trees are still at a vegetative stage. The Seepage zone supports widespread growing of vegetables for most part of the dry season due to high water tables that effect capillary rise. Farmers'gardens are usually concentrated in this zone as not much effort or skill is needed to control or manage water to irrigate crops.

During the rain season, flood injury to crops may occur, so farmers shift their gardens to the upper grassland zones which are well drained as a result of deeper water tables. Shallow wells are dug to a depth of 2-3 m to access the water for irrigation. Lifting such water may require use of a water-lifting device as opposed to the present use of a rope and a bucket, which is tedious. Figure 11 shows how farmers cope with variations of water tables and difficulties of water application in Dambo gardens. In the rain season and also in very wet Dambos during the dry season, farmers grow crops on raised flat ridges and beds in order to restitute a normal root zone with good drainage and aeration for proper crop growth. Farmers also impound water in between the beds and use this to scoop the water for supplementary irrigation. In the event of using a water-lifting device, these buffer ponds from impounded water act as sources of water (Figure 12).

Figure 11: Scooping water from furrows between flat beds and watering crops with a bucket

Normal rooting depth for vegetables is 30-60 cm. Thus it follows that the flood level in any Dambo zone will determine the height of the ridge. The beds are raised to a height of 50-100 cm so as to effect capillary rise from the height of water that collects in furrows between the ridges and beds. If capillary rise is inadequate and/or the plant roots are too shallow to access water from the wetting front, farmers scoop the water with buckets and apply it on the crop simulating rainfall to supplement the crop with water.

Ridge heights of 50-100 cm are common in the rain season but are destroyed in the dry season to ensure planting is done on flat ground following the receding water table and taking advantage of capillary rise. During the rain season most parts of Dambo gardens are used to grow an early maize crop (planted at the end of the dry season between August and October) of which much is harvested and sold as green cobs. With the exception of a few farmers, vegetable production is restricted to the dry season by most farmers. This is due to the risk of flooding and occurrence of pests and diseases during the wet season.

Figure 12: Raised beds with impoundment water ponds for irrigation.

4.2.1.1 Precipitation versus run-off in Dambos

Because of their wet conditions for most part of the year, Dambos produce more run-off from rainfall and less evapotranspiration than surrounding high ground throughout the rain season (Daka, 1993). It was found that the woodland catchment had infiltration rates ranging from 30-50 mm/hr at Noole Dambo as compared to 3-5 mm/hr in the Dambo central parts where clay soils were dominant. The catchment of a Dambo and its margins had more vegetation cover and was covered with light sandy soils with a larger aquifer than the Dambo itself. In this way more groundwater was stored in the woodland catchment area. This is responsible for late season stream flow when vegetation is

removed and replaced with annual crops. The inference here is that the Dambo generates more surface run-off while the woodland contributes more ground water component during the rain season. Robinson, Moore and Blackie (1997) indicate that drainage activities associated with forests increase dry season flows. Evidence from South Africa point to the fact increased dry season transpiration reduces both dry season and annual stream flows (Bosch, 1997).

From a theoretical standpoint, it would appear that increased transpiration and increased dry season tranpiration will increase soil moisture deficits and thus reduce dry season flows. Increased infiltration that occurs in vegetated upper margins of Dambos, will lead to higher soil water recharge and increased dry season flows. This view seems to support the myth that **"Forests Reduce Erosion".** This common wisdom appears to hold water on account of the following factors;

1. The high infiltration rates in natural woodlands of Dambo catchments reduces the incidence of surface run-off and thus reduce erosion. Farmers do note that the existence of sandy soils in Dambo margins promotes infiltration and sub-surface flow of water rather than run-off, and that this reduces erosion.
2. The reduced rainfall impact and run-off and the binding effect of tree roots enhance slope stability, which tends to reduce erosion.
3. On steep slopes, forestry or agroforestry may be a sustainable solution where conventional soil conservation techniques and bunding may be insufficient to contain mass movement of soil.
4. Land use practices such as cultivation, drainage, road construction, road use and felling trees increase erosion.

4.2.2 Dambo Attributes and Characteristics

Dambos as resource areas possess different attributes and characteristics worth exploiting agriculturally. Scoones (1992) observed a number of common features of Dambos. The present study, following a participatory rural appraisal of Dambo environments, found that the farmers are aware of these features. The following attributes and characteristics of Dambos are noteworthy;

1. Areas that act as drainage pathways or sinks for the surrounding dryland catchment.
2. Areas with higher levels of soil moisture than the surrounding upland during the dry season and in drought periods.
3. Depositional areas where organic matter and soil nutrients accumulate, making the soil richer than the surrounding top land.
4. Areas that are generally small in relation to overall available area but have the potential for extended seasonal use and provide opportunity for diverse usage.
5. Areas that are often key components in sustaining rural livelihoods, both in agricultural and pastoral systems as complement to upland dry land use.

On account of these observed attributes and characteristics, farmers have identified Dambo soils to be inherently rich in plant nutrients and thus do not require much additional fertilizer whenever needed. Most farmers have observed a good crop response without any additional inputs to grow them. They generally describe Dambo soils to be highly fertile.

Soil fertility may be defined as the ability of the soil to provide physical conditions favourable to root growth and to supply enough water and nutrients to enable a crop to make the most of other environmental features of a site.

4.3 Dambo Chemistry

The study has identified a number of Dambos with similar attributes but sometimes different from one another in terms of chemical and hydrological conditions. Observations and soil analyses are compatible with those of Verboom (1970). On the basis of these findings, Dambos have been classified into three categories as follows;

(i) ***Sweet Dambos***
(ii) ***Intermediate Dambos*** *and*
(iii) ***Sour Dambos****.*

The classification is primarily based on soil pH and vegetation. The respective Dambo types are described as follows;

4.3.1 Sweet Dambos

Sweet Dambos are found on soils developed from basic rocks and have a pH higher than 6.5. Vegetation and soils characterize these environments well. Most farmers are utilizing these Dambos for grazing and crop production. Sweet Dambos are the most exploited by the small-scale farmers in Zambia. A number of crops do well in such Dambos as they are adapted to the neutral to alkaline pH levels that prevail. Because of optimal pH levels, a number of shrub and grass species that flourish here are palatable and highly nutritious for grazing livestock. Farmers grow vegetable crops and graze their cattle in these Dambos. To do both activities at once, the vegetable gardens are fenced off for protection from cattle or the cattle are looked after during grazing by a care taker. Farmers perceive Dambos that are less grazed by cattle as being sour or acidic and thus avoid them for crop production.

4.3.2 Intermediate Dambos

Intermediate Dambos have soils developed from mixed sediments with a pH between 5.5 and 6.5 and have a wide range of vegetation species with mixes of palatable and some unpalatable species for cattle grazing. Such Dambos are prevalent on the Zambian plateaux and are moderately used for crop production and animal grazing. Farmers use only selected parts with good soils and water for vegetable gardening while areas with little or no water and with poor soils/pasture are used for grazing. Farmers perceive Dambo areas with Fig trees and Msinyika tree (Syzygium cordatum) as areas with very good water sources at shallow depths from the ground surface.

4.3.3 Sour Dambos

Sour Dambos are common in the high rainfall northern half of Zambia which experiences excessive leaching of soils. Soil pH in these Dambos is below 5.5 and so they are strongly acidic in nature. Such Dambos are not good for cattle grazing as most grass species found here are unpalatable and have low nutritional value. Crop production requires special management practices such as selecting acid tolerant crop species or judicious liming. Small-scale farmers know through experience what crops are better suited to different types of Dambos. Soil pH in a Dambo may vary with seasons, becoming more acidic in dry seasons (pH=4.5) than during rain seasons (pH=6.0). Raussen *et al.* (1994) reported that farmers usually burn grass in sour Dambos to allow regeneration of fresh grass of which some are palatable for cattle grazing. To some extent plant ash also acts as a liming agent. Through experience farmers have come to know crops which like growing in burnt spots within a sour Dambo. These include pumpkins, beans, cucumber and irish potatoes.

4.4 Dambo Cropping

Dambos manifest different levels of soil fertility and thus differences in crop responses to soil acidity are observed. Table 11 for example outlines the types of crops that do well in different types of Dambos as identified by farmers in the field. Their identification of crop suitability was matched with soil pH prevailing in those soils. Using this indigenous knowledge and matching it with technical know-how (i.e considering nutrients, soil pH and flooding hazard) recommendations for crop adaptability in Dambos have been derived, such as growing crops on high ridges to avoid flood damage, providing aeration in root zones will allow proper decomposition of organic matter, raise pH and thus making most soil nutrients available to crops. Burning of vegetation whilest being beneficial through having a liming effect and acting as fertilizer, should be timed early in the dry season. Acid Dambos should not be burnt later than the month of May to avoid severe fires that will lead to loss of nitrogen in the plant biomass. If these are accidentally burnt by people who hunt small animals for food, then kraal manure should be added before planting a crop.

Common wisdom and indigenous knowledge points to the fact that very sandy Dambo soils are weakly buffered and tend to be strongly acid in nature due to excessive leaching and thereby posing a range of fertility constraints.

Table 12: Low pH tolerance of various vegetables

Slightly tolerant (pH 6.0- 6.8)	**Moderately tolerant (pH 5.5-6.8)**	**Very tolerant (pH 5.0-5.5)**
Cabbage	Tomato	Irish Potato
Spinach	Bean	Sweet Potato
Rape	Carrot	Rhubarb
Broccoli	Pumpkin	Shallot
Cauliflower	Squash	Water Melon
Chinese Cabbage	Cucumber	
Lettuce	Eggplant	
Okra	Garlic	
Onion	Mustard	
	Pea	
	Green Pepper	
	Radish	

(source: Raussen, Daka and Bangwe, 1996).

Crop failure, which some farmers have attributed to soil wetness in Dambos, could in some cases be caused by soil acidity or a combination of the two. Noole Dambo soil analysis shows some differences of soil pH in different zones and at various soil depths in the same zones as indicated in Table 13. Effects of anaerobic soil conditions due to waterlogging are manifested through yellowing of plants due to a nitrogen deficiency. Sometimes losses of applied inorganic nitrogen occur by denitrification, particularly if the soils are saturated immediately after fertilization. Attention to good drainage (use of high ridges or cropping in upper grassland zones) and aeration often results in net positive effects of applied nitrogen. Purple colour in crops has also been observed under waterlogged conditions. This is due to a phosphorus deficiency (Figure 13).

Figure 13: Plant phosphorus deficiency in cabbage grown at Indaba Dambo (Chipata).

Plant nutrient balance and supply is generally more favourable in soils with a moderately high clay content (Gleysols, Vertisols) and a high level of well decomposed organic matter, both of which provide colloidal exchange sites for the major plant nutrients. However, when under continuously wet conditions, Dambo soils frequently accumulate poorly decomposed organic matter (peats and mucks) and are strongly leached with low pH (high acidity). Under strongly acid conditions there may be deficiencies in plant available nitrogen, phosphorus and/or molybdenum and/or toxic levels of aluminium and/or manganese. This study observed that the organic matter content of Dambo soils was usually several times higher than that of upland soils, but often not as well decomposed (see section 3.1.2.2).

Table 13: Soil pH in different zones and soil depth for Noole Dambo

Soil depth (cm)	Upper Grassland zone pH ($CaCl_2$)	Transition zone pH ($CaCl_2$)	Seepage zone pH ($CaCl_2$)	Central zone pH ($CaCl_2$)
0-20	5.57	4.75	5.89	6.56
20-40	5.63	4.73	5.85	6.54
40-60	5.66	4.54	5.76	7.08
60-80	5.53	4.81	6.58	7.12
80-100	5.72	4.90	6.44	7.15

The data in Table 13 indicate that the lower lying zones have more nutrient reserves and higher pH values than the upper grassland/transition zones. This is due to lateral subsurface transport of dissolved bases and other nutrients from higher lying zones and their accumulation in these sink zones where the water collects. This is an often underestimated phenomenon of major proportions in many tropical and sub-tropical toposequences. At high pH values a wide range of crops grow well. It confirms the well-known relationship between soil pH and soil fertility. Kandela (1993), for example, mentioned the well-known relationship between low pH (pH = 4.5 - 5.0) and low base saturation percentage as well as low cation exchange capacity. On the other hand, at a high pH such as 6.5 and above, a base saturation percentage of 100% and a cation exchange capacity of 33 $cmol_{(+)}$/kg are not uncommon.

Given the pH levels at Noole Dambo and taking into account farmers' experiences, the following vegetable types can be grown in its different zones as presented in Table 14.

Table 14: Suggested vegetable types to be grown in various zones of Noole Dambo

Dambo zone	**Recommended vegetable types to be grown**
Upper grassland zone	Tomatoes, Beans, Eggplant, Green pepper, Pumpkin, Carrot, Cucumber.
Transition zone	Water melons, Maize, Irish potatoes, Shallots.
Seepage/central zone	Cabbage, Rape, Cauliflower, Okra, Onion, Lettuce, Maize, Spinach, Chinese cabbage.

4.4.1 Flood Injury to Crops in Dambos

Flood damage can be in the form of direct physical damage to crops by the fast flowing water. It can also be in the form of crops being covered by transported soil which settles out when the flood subsides. "Indirect" flood damage, associated with reduced plant growth, chlorosis (yellowing of leaves), senescence and death, is common in flooded agricultural lands. When free oxygen in the soil is exhausted during waterlogging, microbes resort to other substances in the rhizosphere as electron donors in place of oxygen and as a consequence the rhizosphere becomes more anaerobic (lacks oxygen). Phytotoxic products such as nitrites, ferrous ion, sulphides, and manganous ions are produced due to reduction processes of nitrates, ferric ions, sulphates and manganic ions respectively. In some cases plant roots themselves produce toxic substances, like cyanides, under waterlogged conditions.

Flooding is often aggravated, both in terms of intensity and frequency, by land mismanagement in catchments. Reduction of the vegetative cover in a catchment, due to overgrazing or over-exploitation of the vegetation for firewood or construction can, for example, greatly enhance runoff and aggravate flooding.

From farmers' standpoint, floods can be both a blessing and a curse. A blessing in that as they try to cope with them by digging trenches in the upper slopes of the Dambo margin/transition to arrest any possible surface run-off, they harvest this water which proves useful for dry season cropping as it recharges the Dambo itself.

Another strategy is where farmers plant on high ridges to avoid flood injury. For some crops, like maize, farmers will plant early at the end of the dry season in August so that the crop is well established at the onset of the rain season. In this way the crop would be well above the flood level not be sub-merge. The flood recession has also been utilized by farmers. In some areas farmers plant crops like maize behind a receding flood at the end of the flood season to exploit the water stored in the soil. They refer to this system which utilizes residual moisture without any supplementary application of water as **"Zilili"**.

At the University of Fort Hare in South Africa Prof. J.N. Marais simulated this by filling a soil to field capacity with a flood irrigation before planting and comparing it with normal dryland cropping. He gave no further irrigations during the season. The normal dryland maize died from drought before Christmas. The maize planted on a full profile and which after that had to survive on the same rain, did not only survive, but yielded 8.5 tonnes per hectare (Laker, 2001; personal communication).

4.4.2 Crop Calendars Developed by Farmers

The Participatory Rural Appraisal (PRA) survey revealed that while crops grown in different Dambo areas were similar, they were planted at different times of the year. Reasons for different timings vary from flood injury escape, disease avoidance to marketing of Dambo produce. For example maize planted in August does not only escape drought at the onset of the rains during November/December but is harvested and sold as fresh at high prices since it comes as an off-season crop. At this time there is an easy market since it coincides with high demand in the month of December. Similarly tomatoes are planted on upper zones of the Dambo and on ridges around in August to coincide with high prices in December through to March. However, this window period is the most difficult time to grow tomatoes because of associated diseases. Tables 15, 16 and 17 show cropping calendars, intensities and cultural practices for their management as developed by farmers at various Dambo sites.

Table 15: Cropping calendar at Chipala Dambo in Agro-ecological zone III

CROPS	J	F	M	A	M	J	J	A	S	O	N	D
1. Cabbage	*	*	*	*	*	*	*	*	*	*	*	*
2. Maize								*	*	*	*	*
3. Rape	*	*	*	*	*	*	*	*	*	*	*	*
4. Tomatoes				*	*	*	*			*	*	*
5. Water melons	*	*	*	*	*	*	*	*				
6. Bulb onion				*	*	*	*	*	*	*		
7. Okra				*	*	*	*			*	*	*
8. Beetroot			*	*	*			*	*	*	*	*
9. Carrot				*	*	*	*	*	*			
10.Irish potatoes				*	*	*	*	*			*	*
11. Beans				*	*	*	*	*			*	*

Table 16: Cropping calendar at Siachitema Dambo in Agro-ecological zone II

CROPS	J	F	M	A	M	J	J	A	S	O	N	D
1. Cabbage	*	*	*	*	*	*	*	*	*	*	*	*
2. Maize	*	*	*	*	*			*	*	*	*	*
3. Giant Rape	*	*	*	*	*	*	*	*	*	*	*	*
4. Tomatoes				*	*	*	*			*	*	*
5. Cauliflower	*	*	*	*	*	*	*	*				
6. Spring onion				*	*	*	*	*	*	*	*	*
7. Paprika	*	*	*	*	*	*	*	*	*	*	*	*
8. Green pepper			*	*	*	*	*	*	*	*	*	*

Table 17: Cropping calendar at Musofu Dambo in Agro-ecological zone I/II

CROPS	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
1. Cabbage	*	*	*	*	*	*	*	*	*	*	*	*
2. Maize							*	*	*	*	*	*
3. Giant Rape	*	*	*	*	*	*	*	*	*	*	*	*
4. Tomatoes	*	*	*	*	*	*	*	*	*	*	*	*
5. Cauliflower				*	*	*	*	*				
6. Spring onion				*	*	*	*	*	*	*	*	*
7. Paprika	*	*	*	*	*	*	*	*	*	*	*	*
8. Eggplant	*	*	*	*	*	*	*	*	*	*	*	*
9. Peas	*			*	*	*	*			*	*	*
10.Impwa	*	*	*	*	*	*	*	*	*	*	*	*
11.Irish potato	*	*	*	*	*	*	*	*	*	*	*	*
12. Green pepper		*	*	*	*	*	*	*	*	*	*	*

4.4.1.1 Land preparation

In nearly all the Dambo areas, land preparation begins at the end of the rain season during April. Hand hoes are used in most cases, except in Southern province at Siachitema Dambo where ox-drawn ploughs are commonly used. Both these methods are appropriate as they do not require draining of the Dambo. Depending on the water level, ridges and raised flat beds are prepared. When planted on the flat ground (without ridges or raised

beds), small channels for simple drainage within the Dambo are made. Crops like tomatoes and cabbages are planted in nurseries and transplanted later around May/June. Other crops are directly planted in the field and thinned to the required spacing. During land preparation, grasses or rice stover from previous crops are worked in and allowed to decompose for fertility enhancement of the soil.

4.4.2.2 Diversity of crops, timing of planting and marketing

The data in the previous tables indicate that Dambos support a wide range of crops. At Musofu and Chipala a larger variety of crops are grown than at Siachitema. Some crops grown include; cabbage, rape, tomatoes, peas, eggplants and watermelons, to mention but a few. The wide range of varieties is particularly because of the high demand for vegetables from the Copperbelt province. At Musofu in particular, tomatoes, green pepper, impwa and irish potatoes are grown throughout the year, indicating the economic importance in the livelihoods of the farmers and the community. In Luapula Province, particularly in Mwense, Kawambwa and Nchelenge districts, farmers have started growing indigenous vegetables in Dambos. Such local vegetables are only common during the rain season but command a high demand during the dry season when they are off-season. Certainly Dambos have accorded small-scale farmers to grow them during the dry season in Dambo gardens.

Most gardens are located in the seepage zones where soil moisture is in abundance. During the rain season, drainage within a Dambo becomes important. The local market mostly influences the timing of crops at the time of harvesting. However, glut occurs when all farmers plant the same crop at the same time and thus forcing low prices for their produce because of abundant supply.

Growing of crops during the rain season is difficult due to diseases. Control of such diseases is usually untenable by most farmers because they lack finance to purchase the chemicals. It is during this time that vegetables are scarce and that premium prices on the produce is characteristic. It was observed that the indigenous vegetables are quite resistant to most diseases and thus offers great potential for popularizing in Dambo cropping.

4.5 Potentials and Limitations of Dambos for Crop Production

4.5.1 Potentials

- Extended use of Dambos for crop production is possible even in the dry season and drought periods owing to their shallow water tables that make them remain wet/moist.
- Minimum inorganic fertilizer inputs need to be used in Dambos since they possess inherent high fertility as they are depositional areas or sinks of organic matter from surrounding high ground. Farmers understand this important aspect and apply it well to their advantage by not unduly applying fertilizer to their crop.
- Dambos usually absorb water from rainfall and this is stored in deeper sandy layers which are overlain by clay soils and thus acting as sponges that release water slowly even into the dry season for later use in crop production.
- Small- scale irrigation is possible in Dambos due to the prevailing hydrological conditions that allow for crop production in the dry season with capillary rise water and water drawn from shallow water tables for irrigation.
- Dambos are so widely and scatteredly distributed in space that they become accessible to the majority of small-scale farmers who are the main contributors to national food production.
- The relative abundance of water in Dambos does not call for great management efforts to distribute it.

- Excess water applied by way of irrigation returns to shallow water tables as recharge for later use.
- Most of the water required by plants is directly taken up from the capillary zone above the shallow water table. At other places, where water tables are too deep, pumping becomes critical in order to irrigate the crops.
- Dambos are also a source of wild fruits such as orchids and a good environment for indigenous vegetables that grow wild and become a source of relish.
- Dambos are used for hunting small animals and as grazing land for cattle.

4.5.2 Limitations

- Dambos may become flooded during the rain season or throughout the year, thus limiting their use for crop production unless special management practices are employed as coping strategies.
- Some Dambos become acidic in nature due to prolonged dry and wet cycles and thus special knowledge of crop suitability is essential.
- Heavy clay soils usually occur in the central zone due to clay translocation from the upper Dambo catchment and iluviation in the lower zones. These are difficult to cultivate and they limit the extent to which Dambos may be utilized with simple hand hoes as tools.
- Infiltration rates from the upper catchment may be impaired if deforestation occurs, coupled with overgrazing which might cause excessive erosion from run-off water.
- Dambos do not compromise their use between cropping and grazing unless the former is preceded by fencing the gardens.

4.6 Farmers' Views on Constraints of Crop Production in Dambos

4.6.1 Constraints to Dambo Utilization

1. Flooding of Dambos during the rain season limits growing of crops in them only in the dry season except for a few farmers who plant on high ridges, which they consider laborious to make.
2. Dambo soils are usually difficult to cultivate, particularly when wet or when too dry.
3. Hand hoes, axes and slashers are commonly used for land preparation at present.
4. Because of wet conditions, only certain adapted grass species prosper in Dambos. Such grasses form dense mats which are deep rooted up to 50 cm of the soil profile and thus make it difficult for farmers to cultivate the land.
5. Pests and diseases limit vegetable yields as farmers cannot easily control them due to lack of availability of chemicals in their areas, coupled with incapacity for them to afford these expensive pesticides when available. Sometimes chemicals become available very late when damage has already occurred.
6. Implements such as slashers, pangas, rakes, spades, hoes, cans and sprayers are not locally available for farmers to purchase in rural areas.
7. Credit institutions are not willing to give support to farmers on small vegetable gardens in Dambos as they favor upland fields with crops like maize. On the contrary farmers note that they find small Dambo gardens more lucrative than upland fields.
8. Unavailability of vegetable seeds and fertilizers (when required) hampers correct timing of planting. Sometimes cropping is completely abandoned. There is no flexibility to choose a correct cropping pattern.
9. Farmers have to deepen wells when water tables recede. In many cases a rope and bucket is used to draw water for watering vegetables. This is laborious and time consuming.
10. In fragile sandy soils, wells collapse easily.

11. Some Dambos are acidic in nature and thus require special knowledge on soil management or crop adaptability.
12. Excessive drainage may cause lowering of the water table.
13 Market for produce is not readily available in some cases and prices may vary greatly with time, sometimes disadvantaging the farmer.
14. Use of heavy machinery will dry the Dambo and destroy it permanently, especially where dam construction impedes downstream flow of water and change the water regimes.

4.6.2 Lack of Appropriate Technologies for Dambo Development

One of the primary constraints, given high priority by the farmers, is that of lifting water from shallow wells. The use of a rope and a bucket has been classified as a laborious and time consuming activity.

This study identified and helped to develop, in conjunction with the International Development Enterprises and FAO, a device known as a treadle pump for water lifting. This is a device which has reduced the time spent to irrigate gardens. The device has been demonstrated and many farmers have acquired the pumps. The pump is sustainable and appropriate as it does not require use of diesel, kerosene, petrol or electricity. Many farmers who have adopted this technology, have been able to increase the sizes of their gardens by two and a half fold from 0.10 ha to about 0.25 ha.

Another technology that has found a niche in Dambos, is the clay pot irrigation. This technology saves irrigation water and labour. It is appropriate for use in areas where water is scarce as is common in most parts of Africa. Chapters 5, 6 and 7 deal with the development, implementation and impact of these technologies.

4.7 Conclusions And Recommendations

1. Dambos have been recognized as resource areas in many countries and are exploited for various purposes such as eco-tourism, pastoralism and crop production. They have thus been called different names in order to distinguish them as special resources requiring special attention in technological research to contribute to national food security.
2. Dambos are not independent systems but are rather interconnected to the surrounding watershed and the hydrological cycle. Their sustainable utilization would thus largely depend on proper catchment management and water control in them.
3. 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 and market opportunities.
4. Damming a Dambo outlet may cause permanent inundation in all potential crop production zones.
5. 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 although their nutrient pool may be negatively affected by soils becoming acid in nature.
6. Farmers have sustainably kept their Dambo lands fertile by supplementing with compost, livestock manure and to some lesser extent inorganic fertilizers. This practice has proven sustainable and no acidification problems have been reported so far.

6\. Some farmers burn vegetation in Dambos during cultivation (especially on virgin land). In Dambos which are also used for grazing, this practice would promote regeneration of new herbaceous plants and grasses which are palatable for livestock to graze.

7. 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. It is recommended to use manure after burning has taken place.
9. 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. It is recommended not to overgraze on Dambo land and to keep appropriate livestock numbers for the Dambo carrying capacity. Unrestricted burning and grazing, it is believed, lead to gullying and drying up and this problem is likely to become more widespread and acute if there are increases in livestock numbers.
10. In as much as Dambos 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.
11. Commercialized crop production which entail use of mechanized farm machinery like tractors to make drainage channels leading 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.
12. 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.
13. Grazing of cattle in Dambos used also for crop production is reported to be the major cause of erosion and this should be discouraged at all costs.
14. Use of village headmen and chiefs in bringing about awareness among village communities has proven very useful particularly in Eastern province.

15 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.