

**EFFECTS OF HUMAN ACTIVITIES ON THE HYDROLOGY AND
ECOLOGY OF CHASSA DAMBO IN SINDA AREA, EASTERN PROVINCE,
ZAMBIA**

by

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**A dissertation submitted to the University of Zambia in partial fulfilment of the
requirements of the degree of Master of Science in Geography**

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DECLARATION

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APPROVAL

ABSTRACT

Dambos are depressions that are waterlogged and grass covered and these are surrounded by savanna woodland. In Zambia, there is no clear legislation on the protection, conservation and management of wetlands including *dambos*. Therefore, the aim of this study was to examine the physical characteristics of Chassa *dambo* in Sinda, Eastern Province of Zambia and assess how these characteristics have been affected by human activities for the purpose of finding a lasting solution.

The objectives were to: (i) describe the physical characteristics of Chassa *dambo* in terms of geomorphology, morphology, soils, hydrology, ecology and vegetation cover; (ii) determine the uses of Chassa *dambo* and the agricultural activities in the area; (iii) assess the effects of human activities on the geomorphology, morphology, soils, hydrology, ecology and vegetation cover of Chassa *dambo*; and (iv) to assess ways for sustainable use of Chassa *dambo*.

On methodology, primary data was collected through direct observation through section sampling in one metre depth pits for analysis of physical and chemical characteristics in order to determine fertility and sedimentation areas. Structured and Semi-structured interviews were administered to different stakeholders and local community members. A total of 80 heads of households (8.8%) out of 905 households were sampled. Secondary sources of data included maps and use of Google Satellite imagery for assessment of physical features of the *dambo*.

Analysis of data revealed that Chassa *dambo* catchment had been cleared to pave way for commercial farming, subsistence farming and settlements. The *dambo* had been dammed for storage of water for irrigation and canalised for the purpose of diverting water to the dams and draining the middle and central parts of the *dambo*. Heavy machinery was used in commercial farming leading to soil compaction.

Overall, the field evidence showed that physical characteristics of Chassa *dambo* have been adversely affected by human activities. Hydrologically, the *dambo* has deteriorated due to reduced soil moisture and increased overland flow attributed to tree and grass clearing and burning of vegetation. The ecology of the *dambo* revealed adverse effects of these activities which have affected the natural *dambo* ecosystem. The chemical analysis of the *dambo* soils showed an accumulation of nutrients in the lower *dambo* and the organic carbon being below the critical value thus, indicating degradation of the soil properties.

It is concluded that human activities have affected the morphology, ecology and hydrology of Chassa *dambo* which suggest the need for legislation for the protection and sustainable use of *dambos* for the benefit of local communities.

DEDICATION

To my children; Tukuza, Tackson Emmanuel, Mphaso, Chikondi and Daliso
Chisomo

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ABBREVIATIONS AND ACRONYMS

CPRs	Common Property Resources
CSO	Central Statistics Office
DWA	Department of Water Affairs
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organisation of the United Nations
FNPP	FAO Netherlands Partnership Program
IEE	Initial Environmental Examination
NPE	National Policy on Environment
NWP	National Water Policy
MACO	Ministry of Agriculture and Co-operatives
MEWD	Ministry of Energy and Water Development
MTENR	Ministry of Tourism, Environment and Natural Resources
NGOs	Non Governmental Organisations
PAM	Programme Against Malnutrition
ZAWA	Zambia Wildlife Authority
ZEMA	Zambia Environmental Management Agency

CHAPTER ONE: INTRODUCTION

1.1 Introduction

Dambo wetlands do not only determine the pattern of settlements but also support livelihood in most parts of Africa. Dambos are major sources of water for people and animals. However, dambos like other types of wetlands are degraded or lost through human activities such as construction, agriculture, damming, canalisation, grazing, deforestation, irrigation, siltation and pollution. Therefore, the research focuses on determining the physical characteristics of Chassa dambo and to assess how these characteristics have been affected by human activities for the purpose of finding intervention measures.

1.2 Theoretical Basis of the Study

There is a school of thought that believes in using resources for basic sustenance. One gets from nature what is needed and also allows nature to replenish itself. Thus, there is little disturbance to the natural environment. However, there is another school of thought that believes in overexploiting the environment in order to attain economic development which would translate into acceptable living standards for the people. The realisation that there was need for sustainable use of resources if the human race is to continue existing led to the emergence of the environmentalism movement.

Mayhew (2015) states that environmentalism, was a concern for the environment especially with the bond between humans and their environment. In contrast,

O’Riordan (1989) states that Greenness, a subset of environmentalism applies to demands for fundamental reform in specific policy areas such as wilderness and wildlife protection, pollution control, conservation of resources, and appropriate management so as to replenish renewable resources.

Environmentalists have thus promoted sustainable development. It should be noted that the efforts of environmentalists have not been in vain as governments both in developed and developing countries are now putting much emphasis on sustainable utilisation of resources and this is evident in the current policies and legislation. For instance, the vision of the National Policy on Environment for Zambia is to ensure that natural resources are managed on a sustainable basis and retain their integrity to support the needs of the current and future generation (MTENR, 2007: 9).

Serious consideration of the need to preserve wetlands was evident by the holding of an international conference called the Ramsar Convention of 1971 in Iran. The focus of the Convention was on the use of wetlands. According to PAM (2007:85), the major obligation under the Convention was the implementation of the principles of "wise use" which were defined as the "sustainable utilisation for the benefit of humankind in a way compatible with maintenance of the natural properties of the ecosystems". PAM (2007) further states that sustainable utilisation was defined as “Human use of a wetland so that it may yield the greatest continuous benefits to the present generation while maintaining its potential to meet the needs and aspirations of future generations”. It is on this theoretical basis that this study focused on the sustainable utilisation of Chassa dambo, a wetland in Sinda area, Eastern Zambia.

1.3 Statement of the Research Problem

Though wetlands are being degraded, threatened or lost through human activities, not enough has been done in Zambia to ensure that wetlands are managed for the benefit of the present and future generations. Water use is covered by policies and legislation under different Government departments and institutions such as the Department of Fisheries, Department of Water Affairs, Department of Natural Resources and Environmental Protection, Department of Forestry, the Zambia Environmental Management Agency (ZEMA) and the Zambia Wildlife Authority (ZAWA). According to PAM (2007), the duty to co-ordinate wetland initiatives was given to ZEMA in 1992. Consultative processes took place to develop a Policy for wetlands conservation and management in Zambia but progress has been slow. As at January 2013, the Policy had not yet been finalised by ZAWA.

PAM (2007) states that conflicts have tended to arise among the mentioned departments when it comes to the overall management of the natural ecosystems of the wetlands as each department wants to carry out only its mandate in the wetlands. In addition, the Environmental Management Act No. 12 of 2011 administered by ZEMA does not have specific provisions for wetlands and there is no specific legislation that relates to the protection of wetlands.

Therefore, lack of legislation on wetland management has left wetlands vulnerable to degradation as a result of human activities. Chassa dambo is situated in an area where the majority of the people may not see the need for the sustainable use of the wetland. It is being degraded and threatened by the cultivation and deforestation that is taking place in the upland areas. The dambo is further threatened by canalisation,

damming and commercial farming. The use of herbicides and pesticides though not the focus of the study are also posing a threat to the ecology of the dambo. Therefore, the problem of the study was that it was not known to what extent human activities such as cultivation, irrigation and grazing had affected the morphology, ecology and hydrology of Chassa dambo. As such, the study sought to investigate changes in the physical characteristics and to assess the extent to which human activities had influenced the recent changes observed in Chassa dambo.

1.4 Aim of the Study

The aim of the study was to examine the physical characteristics of Chassa dambo and assess how these characteristics have been affected by human activities for the purpose of finding intervention measures.

1.5 Research Objectives

Arising from the aim highlighted above, the following were the research objectives:

- i. To describe the physical characteristics of Chassa dambo in terms of geomorphology, morphology, soils, hydrology, ecology and vegetation cover;
- ii. To determine the uses of Chassa dambo and the agricultural activities in the area;
- iii. To assess the effects of human activities on the geomorphology, morphology, soils, hydrology, ecology and vegetation cover of Chassa dambo; and
- iv. To assess ways for sustainable use of Chassa dambo.

In order to attain the above objectives, research questions were used to guide the conduct of the study.

1.6 Research Questions

The research questions were as follows;

- i. What are the physical characteristics of Chassa dambo in terms of geomorphology, morphology, soils, hydrology, ecology and vegetation cover?
- ii. How does the community use Chassa dambo?
- iii. What types of agricultural activities take place in the study area?
- iv. How do human activities affect Chassa dambo in terms of geomorphology, morphology, soils, hydrology, ecology and vegetation cover?
- v. In what ways can Chassa dambo be used in a sustainable manner?

1.7 Significance of the Study

Settlements especially in the rural areas have been influenced by the location of the dambos because these wetlands have been sources of water for domestic use, agriculture, grazing and fishing.

This study can assist the Zambian government and other stakeholders in policy and legislation formulation on the use of dambos. Government Ministries that would make use of the findings of the study include; Ministry of Agriculture and Livestock formerly known as Ministry of Agriculture and Co-operatives (MACO), Ministry of Tourism and Art, Ministry of Lands, Natural Resources and Environmental

Protection and Ministry of Energy and Water Development. MACO (2004) identified irrigation as a way of attaining food security in order to alleviate poverty and in turn contribute to economic growth. The policy identified dambos as excellent locations for irrigated agriculture, particularly of short season high value crops but stressed the need for a study on sustainable dambo utilisation.

Consequently, the significance of the study is that by highlighting the importance and uses of dambos, the possible threats would be brought to the fore and the need for sustainable management of dambos could be proposed and supported by appropriate legislation on their use.

1.8 Organisation of the Dissertation

The dissertation contains seven chapters beginning with the introduction which gives an overview of the subject. Chapter One contains the introduction and covers the theoretical basis, statement of the research problem, aim of the study, research objectives, research questions and the significance of the study. Chapter Two deals with the Literature Review and covers the distribution and classification of dambos, hydrological and ecological characteristics of dambos, socio-economical uses of the dambos, degradation of dambos and the current legislation in Zambia. Chapter Three provides an overview of the Study Area in terms of the location, climate, physical characteristics and socio- economic status of the population. Chapter Four outlines the Methodology used in the study. Chapter Five highlights the Findings of the research while Chapter Six discusses the literature review and the findings. Chapter Seven provides the Summary, Conclusion and the Recommendations of the study.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Literature on dambos has shown that the uncontrolled use of these wetlands both for pasture and cultivation can lead to their degradation. The literature review of dambos covers definitions of dambos; their distribution on earth; their classification based on certain physical characteristics; their use; and human activities that lead to their degradation.

2.2 Defining Wetlands and Dambos

Wetlands and dambos have several definitions depending on their geographical location and physical characteristics.

2.2.1 Definition of Wetlands

The Ramsar Convention defined wetlands as 'areas of marsh, fen, peat land 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'(Ramsar Convention Secretariat, 2013:7).

Matiza (1994) states that in addition to the above definition, wetlands have been classified according to their geographical location and these are: marine, estuarine, riverine, lacustrine and palustrine systems. According to Breen et al. (1997), the palustrine systems include all non-tidal wetlands dominated by trees, shrubs and emergents and also refer to ponds, springs or headwaters. They state that an important palustrine wetland is a dambo which is widely distributed and utilized in

many parts of Africa as a source of water for domestic purposes, grazing and for dry season agriculture.

2.2.2 Definitions of Dambos

Mackel (1986) defines dambos as shallow linear depressions in the head ward zone of rivers without a marked stream channel. They are water-logged and grass covered, bearing the true woodland vegetation, the surrounding woodland, or woodland savanna generally stopping abruptly at the dambo margin.

Matiza (1992) states that dambo definitions have been so diverse that since its introduction in scientific research, the term dambo has been defined in different ways depending on the individual's perception and field research.

Huckabay (1986) explains that there seems to be no appropriate English word for these shallow treeless troughs in which water collects during the rains, so wherever they are encountered in Africa, a local descriptive term for them has been incorporated into English. In Zambia and Malawi, these features have been named dambo which is a vernacular word in Ci- cewa. In other parts of Africa, the features are called "Mbunga in Swahili, Vlei in Africaans, Matoro or Bane in Shona, Fadama in Hausa, Northern Nigeria and Bolis in Sierra Leone" (Shimada, 1992: 59).

2.3 Distribution of Dambos in Zambia

Breen et al. (1997) states that dambos in Zambia are generally distributed on the plateau area and their variations are attributed to rainfall, topographical setting and substratum. They state that the dambos of the high rainfall belt of the country bear swamp characteristics whereas those occurring in the drier parts of the country have plant associations.

2.4 Classification of Dambos

Scholars have come up with the following major classifications of dambos in Zambia:

a. Geomorphology

Shimada (1992) states that several attempts have been made to classify dambos from the geomorphological point of view and that Mackel (1986) showed that there are alternative sets of dambos, namely: (1) interior plateau dambo and scarp dambo; (2) degradation dambo which occur usually in the flat to gently inclined plateau regions and aggradation dambo that occur in the lower marginal plateau or in the transitional zone towards the escarpment with hilly interfluvies; (3) linear depressions and broad dambo plains; and (4) clay dambo with vertisols and schist and sand dambo with hydromorphic soils (Shimada, 1992:60).

b. Landscape

Shimada (1992) further states that Acres et al. (1985) identified four types of dambos according to their position in the landscape and these are: (1) headwater dambos - most widespread and occur in the headward zone of valleys, channelless, broad and sometimes coalescing; (2) slope dambos - extended

headwards or laterally up valley sides and have steeper slopes than headwater dambos; (3) hanging dambos (or scarp dambos) - perched above escarpments on plateau margins; and (4) river dambos - downward extension of headwater dambos on either side of river channels or floodplains.

c. Rainfall

Rainfall is another characteristic that has been used in the classification of dambos. Mackel (1985) points out that well developed dambos occur in the Northern plateau regions of Zambia with an average annual rainfall of more than 1,300mm and in the Southern plateau region with less than 800 mm. Ferreira (1981) identified five types of dambos in the high rainfall areas of the Northern plateau of Zambia and these were: (1) upland dambos – are swampy, shallow valleys with a stream in the centre and have a distinct seepage zone and a relatively constant water level of the central swamp; (2) valley dambos - are one sided as they lead down to the swampy margins of a river lagoon or lake; (3) hanging dambos – are formed by springs that arise on high ground near the outer edge of a basin; (4) flush dambos- are sandy types that are found on the basal slopes of hills while the clay types are as a result of clay being flushed during the rainy season in the form of flash floods; and (5) sand dune dambos- are formed behind the shores of a lake or between the dunes and they are acidic and have high levels of phosphorous.

The above classification was done in order to determine the chemical composition of the dambos and their suitability for rice cultivation and other economic activities.

d. Morphology

Shimada (1992) states that Whitlow (1984) classified dambos based on the geographical shape or morphology and the nature of the bedrocks. He explains that Whitlow first divided dambos into two; lobate type and linear dambos. The lobate type is further divided into two that is, the dambos with irregular shapes and those with a dendritic pattern. He explains further that the lobate type of dambos occur on granitic rocks while the linear type which have deep peat deposits develop on the Kalahari sands.

For headwater dambos, Shimada (1992:61) points out that Acres et al. (1985) came up with eight leaf shaped descriptors and these included: Obovate, Linear, Lanceolate, Bifurcate and Truncate. They also argued that dambo morphology was principally controlled by the gradient of the water table in the seepage zone at the edge of the dambo relative to the longitudinal gradient of the dambo and the geological structure. The classification of dambos using morphology gives one an idea of the nature of the underlying rocks as well as the gradient of the water table.

e. Soil

The chemical composition of the soil can also be used in the classification of dambos. Shimada (1992) points out three categories of dambos using the soil pH and these are: sweet dambo; intermediate dambo; and sour dambo.

He further states that 'sweet dambos are found in soils developed from lime-rich rocks with a pH higher than 6.5 and intermediate dambo is found on soils with a pH between 5.5 and 6.5 and those with a pH below 5.5 are defined as sour dambo' (Shimada, 1992).

Breen et al., (1997:14) explain that sour dambos occur in high rainfall areas and are dominated by plant species and a large number of sedge species whereas, sweet dambos occur in low rainfall areas and are predominantly covered by plant species. The mixture of vegetation between the sour and sweet dambo is found in the intermediate dambo.

Shimada (1992) points out that the classification based on soil types is relevant for agricultural land use of dambos. Sweet dambos are said to be more suitable for crop cultivation and grazing.

f. Hydrology

Under the hydrological criterion, Veldkamp (1986:11) states that two types of dambos in Zambia were identified and these are: hydromorphic or phreatic dambos which receive water mainly from precipitation and groundwater and fluvial dambos which receive water from streams, runoff and surface water.

Having explained the classification of dambos in Zambia using the different physical characteristics, Bell and Roberts (1991:303) state that in Zimbabwe, the main types

of dambos are: headwater dambos (channelless, broad and sometimes coalescing); stream dambos (adjacent to second and third order stream channels); and residual dambos (narrow and linear, typically along first order side streams).

2.5 Dambo Geomorphology

The geomorphology of areas evolves over time. Goudie (2013) states that dambos are best developed on ancient planation surfaces and occur on a wide range of rock types, from unconsolidated kalahari sand through to shales, quartzites, schists, gneisses and granite.

Heyden (2004) states that the favourable conditions for the formation of dambos in Central Southern Africa are plateau surfaces with gentle relief resulting in low energy surface runoff that enables water infiltration. He further states that the dambo forms where the regolith can no longer contain the water with the subsurface flow paths and the stream forming as a result of geological, hydrological or morphological changes in the dambo area, resulting in regolith incision.

2.6 Dambo Morphology

The morphology or shape of individual landforms is primarily controlled by the inherent geological characteristics of the region or by surficial processes of weathering and erosion acting on a landscape, or by a combination of both (Holmes 2012:26). Heyden (2004) states that the lithological changes in the dambo, are key determinants in dambo shape and size and that its formation follows folds and fractures, structural weaknesses and bedrock transitions in the underlying lithology.

There have been arguments on how dambos are formed. Goudie (2013) states that there are two schools of thought and the fluvial school envisages dambos as simple extensions of the channelled drainage network and that sheet-wash processes under seasonal rainfall regimes may be especially important in their formation. He states that the other school of thought advocates differential chemical and biochemical corrosion or sapping rather than mechanical erosion as the main process and that dambos tend to have a low gradient of 2 degrees.

2.7 Dambo Soils

Matiza (1992) states that dambo soils represent the bottom of the tropical catenary sequence because of their location in the landscape. Roberts (1988:141) states that in-situ decomposition of grass and sedge dominated vegetation cover lead to a build up of organic matter and the creation of a hydromorphic or sometimes peaty, upper soil horizons. Chidumayo (1992) adds on to say that dambo soils vary and range from sandy loam to clay and that both are often overlain by an organic top layer. He further says that wet dambos may peat layer of up to 50cm overlaying the soil.

Heyden (2004) states that the increased agricultural fertility of dambo soils, demonstrates that the soils possess higher concentrations of potassium, phosphate and organic matter, and greater cation exchange capacities compared with soils of the interfluve. He further states that the dambo soil characteristics reflect the greater biomass production, lower decomposition rate and the inwash of ions from upslope.

2.8 Hydrology of Dambos

Hydrological characteristics refer to the water regime of the dambo system which is influenced by climate, vegetation, soil type and relief of the land. Matiza (1992:93) states that Rattray et.al (1953) listed four fundamental pre-requisites for dambo formation and these are: the existence of a surface soil with a high infiltration and a low field capacity; a subsoil which becomes progressively more clayey until an almost impermeable layer of clay or rock is reached; a shallow depth of permeable soil; and topography which is generally broad, gentle sloping and undulating. He further states that hydrology and vegetation were also considered to be important parameters in the formation and maintenance of dambos.

There has been debate on the role of the dambo in the hydrology of an area. Bell and Roberts (1991) state that some authors (Balek and Perry 1973; Hough 1986) have argued that dambo catchments act as hydrological reservoirs, storing water in the rainy season and releasing it for evapotranspiration on the dambo surface and for dry season base-flow. Heyden and New (2003) state that there is a school of thought which says that dambos act like sponges that soak up the wet season rain which they release slowly into rivers during the dry season. They further state that the view is opposed by another school of thought which argues that in the middle to late dry season, the water is actually released from aquifers into dambos.

However, Mazvimari (1994) states that the sponge model of the dambo is incorrect in Zimbabwe and that these wetlands have no effect on catchment yields or characteristics of both dry season flows and storm flows. He further argues that high

transpiration losses within the seepage zone suggest that dambos are important in returning water to the atmosphere rather than contributing to river flows.

Dixon (2003) points out that the process behind the eco-hydrological functioning and degradation of dambos remain ambiguous despite the attention that they have received. He argues that though research has suggested that dambos contribute to downstream water flows as a result of their water storage properties, evidence suggest that dambos cause a reduction in stream flow as a result of high evapotranspiration rates from their surface and catchment.

Heyden and New (2003:339) state that the issues at heart of the debate are the role of the dambos in: the catchment evapotranspiration (ET) budget; augmentation (increase) of dry season flow; flood flow attenuation (reduction) and retardation; and determining the dominant source of water to the dambo and the hydrogeological model.

As studies on dambo hydrology were being reviewed, it was concluded that the nature and significance of the dambo in the hydrological cycle is likely to be complex and contradictory within, and between, regions for three reasons: (1) dambos occur in association with a variety of geological, climatological and vegetational assemblages; (2) dambos themselves vary with respect to morphology, soil, vegetation and channel characteristics, leading to variability in the dambo hydrological response, even where catchment characteristics are similar; and (3)

dambo hydrological response is dynamic as a result of variability among hydrological inputs and dambo soil moisture regimes. Heyden (2004:556)

It is evident that scholars have over the years had divergent views on the issues. Nevertheless, it is argued that the effect of dambos on catchment evapotranspiration rate loss depends primarily on the vegetative characteristics of the interfluves and to some extent the soil characteristics. Heyden and New (2003) point out that augmentation of dry season flow is primarily a function of groundwater discharge. They further state that stormflow is attenuated during the early wet season through soil infiltration and dambo filling while later in the wet season, the dambo has little influence on storm flow due to marked soil wetting and decreased infiltration.

2.9 Ecology of Dambos

Ecological characteristics of dambos refer to the interaction between organisms and the dambo environment and FAO (1998) describes dambos as complex ecosystems which play a role in the biodiversity of regions. Chidumayo (1992) states that the major resources of dambo environments are; soils, water, vegetation and their associated fauna.

Human beings have over the centuries depended on dambos primarily as sources of water and food. Dambos are very important as they support various organisms such as fish, birds and animals. Roberts (1988) states that dambos retain moisture during the dry season and support a vigorous growth of grasses when the other forms of grazing are in short supply.

2.10 Vegetation Cover in Dambos

Vegetation in the dambos varies and Chidumayo (1992) states that most dry dambos are covered with grass, with or without scattered trees whereas in their undisturbed state, wet dambos are covered with extensive evergreen forests called *mushitu* in Zambia.

Heyden (2004) states that three broad vegetation zones were identified and these are: (1) the dambo margin adjacent to the interfluve, (2) a central transition zone and (3) a zone bordering the channel. Mapaure and McCartney (2001) states that the diversity of species composition within catchments containing dambos is widely attributed to hydrological conditions. Heyden (2004) states that the grasses dominate the dambo margin and the transition zone, and that the zone bordering the channel is predominantly vegetated by sedges. The upland ideally is covered by woodland.

2.11 Socio-economic Uses of Dambos

Dambos have been used widely by peasant farmers. For instance, Nyati (2007) states that dambo cultivation among peasant farmers was reported nearly a century ago and that remnant of ancient ridges and furrows occur in many dambos in the wetter parts of Zimbabwe and may date back some 250 and 300 years. Matiza (1992) pointed out that prior to white settlement in Zimbabwe, dambos were used for shifting cultivation and grazing but the coming of white settlers led to an extensive cultivation of dambos due to their fertility and moisture.

Dambo gardens provide a good regular supply of crops for home consumption as well as for sale in urban centres. For instance, Shimada (1992:65) states that in

northern Nigeria, over 89 percent of the dambo lands are cultivated and that in the Hanang district of Tanzania, the dambo is the essential land for grazing.

Shimada (1995) states that since independence in 1964, the dambo land in Zambia did not attract people but dambos that are near urban centres and towns are now being extensively cultivated due to a growing demand for vegetables and other agricultural products such as water melons. He further stated that dambo cultivation played an important role not only to increase but also stabilise the incomes of farmers though farmers are not serious about the sustainable use of the dambos.

In addition, the FAO Netherlands Partnership Program (FNPP) (2004) states that Chipala dambo, located in Masaiti district and bordered by Luanshya district on the northern side, Kapiri Mposhi district on the southern part and Ndola district on the eastern side, is a sweet-dambo with intensive crop production. The report points out that the people utilizing Chipala-Ibenga dambo had depended heavily on the wetland for their livelihoods due to factors such as; the closure of the mines on the Copperbelt which pushed retired employees into horticultural production and the migrations from drought prone areas where upland farming was a virtual failure. Furthermore, Daka (2007) explains that dambos are suitable environments for treadle pump technology which enables peasants to grow more food for consumption and for sale. He states that the use of the pump increased household incomes.

According to FAO (1998) dambo uses include: a dry season water source; grass used for thatching and fencing material; clay is used for building, brick-making and earthen ware; growing vegetables; soaking bitter cassava in dug ponds; fishing; fish ponds; rice cultivation; wood for construction, soil for plastering houses and medicinal plants.

2.12 Degradation of Dambos

Mayhew (2015) has defined land degradation as the long term loss of ecosystem function and productivity caused by disturbances from which the land cannot recover unaided. Similarly, dambo degradation occurs when there is an extensive use of the of the dambo environments mainly by humans. Mackel (1986) points out that the impact of humans is mainly through cattle grazing, cultivation, fire and tree felling. He explains that when the miombo woodland close to the dambo is cleared for cultivation, it leaves the surface unprotected thus, resulting in accelerated sheet erosion and a gradual lowering of the surface which then becomes frequently waterlogged or even flooded in the rainy season.

Roberts (1988) states that dambo ecosystems are fertile but also fragile where their utilisation is intense and in drier dambos where mean annual rainfall is below 1000mm. He further argues that much as late dry season burning in dambos is used to encourage regrowth of new and palatable grass, burning is said to lower the water tables and has a deleterious effect on soil nutrient budgets and if over frequent, kill valuable plant species. Shimada (1992) argues that burning of trees in the miombo woodland surrounding dambos increases sheet wash of fine material from marginal

miombo woodland into the centre of the dambo, thus changing the ecological conditions of the dambo. This results in the lowering of the surface of marginal areas of the dambo and accelerated sedimentation in the central parts of the dambo.

Matiza (1992) explains that from the 1920s legislation was introduced in Zimbabwe because the extensive cultivation of dambos was leading to gullying and desiccation. Shimada (1992) states that prolonged cultivation of wheat and other commercial crops, ploughing across the central part of the dambo itself and the excavation of ditches along the central axes of the wetland for draining, all led to the deterioration of the dambo environment in Zimbabwe.

However, Owen (1994:109) adds on to say that in Zimbabwe, the Natural Resource Act of 1951 was enacted, in part to protect dambos from the gullying and erosion which had resulted from the mechanised ploughing of whole dambos on commercial farms. He further states that gullying was seen both as a mechanism of soil loss, with concurrent downstream siltation, and a cause of dambo desiccation by accelerated drainage. Nevertheless, Owen (1994:110) argues that the unfortunate effect of the legislation had been to increase grazing on the dambos and increase cultivation on the interfluves (upland) thereby causing deforestation and resulting in the these effects: (1) livestock tracks provided channels for concentration of surface runoff and promoted gullying; (2) removal of interfluves woodland increased interfluves water levels, thus increasing hydrostatic pressure below the dambo and promoting breaching of the clay and gullying; (3) replacement of cultivated crops with grazing on the dambos had reduced evapotranspiration from the dambo resulting in higher

subsurface water pressure and promoting breaching of the dambo clay and gullying; and (4) reliance on rain fed agriculture alone had reduced land productivity, yields and food security and had led to extended cultivation and deforestation.

As regards the impact of human activities on the hydrology of the dambo, Shimada (1992:68) states that increased sheet wash inside a dambo leads to increased sedimentation of sandy soil in the centre, which in turn causes change in the composition and coverage of its vegetation. He explains that the change in vegetation cover in catchment areas of dambos causes another degradation process because it induces change in evapotranspiration rates.

Shimada (1992) further argues that high transpiration rates in catchment areas lowers the water table of a wetland which then reduces the level of downstream water-flows thus, leading to the drying of the wetland. Owen (1994) adds on to say that evapotranspiration loss is the most significant factor influencing water balance in dambo catchments. He states that changes in the vegetation in the uplands, particularly the removal of trees, may have a more important influence on evapotranspiration losses than cultivation on dambos. He further argues that the hydrological process is so intermingled that the change in vegetation cover brings about change in the hydrological characteristics of a wetland which in turn influences the vegetation.

FNPP (2004) states that at Chipala Ibenga, downstream households (30% of respondents) reported reduced stream flow after cessation of rains in April and

streambed drying in August and this was attributed to increased water abstraction. PAM (2007) points out that at least 30 percent of dambos in Southern, Lusaka, Central and Eastern Provinces of Zambia are degraded through inappropriate agricultural practices, siltation, overgrazing due to overstocking and human settlements. Chidumayo (1992) points out that the desertification of dambos marks the end of the productive, economic and ecological life of dambo ecosystems.

2.13 Use of Pesticides on Dambo Wetlands

Both small scale farmers and commercial farmers use fertilizers, pesticides and herbicides in order to increase yields both in the upland and dambo areas. Chenje and Johnson (1996) state that pesticides or their degraded products are carried by rain water and reach the aquatic environment by runoff. They further state that the pesticides are generally not biodegradable and they persist for a long time in the environment and are absorbed into living organisms and accumulate along the food chain and that pesticides can kill fish, birds and small animals and can also affect their reproductive system. They also point out that high levels of nitrates in drinking water can cause miscarriages and blood poisoning in young children. Shimada (1995) points out that in Chinena village, fertilizers and insecticides had been used in order to raise income from dambo cultivation. He states that though no severe contamination problems were found, the accumulation of nitrates in some water holes was observed.

2.14 Wetland Conservation and Sustainable Management

According to Dixon (2003), wetland conservation is the only management option where the wetland is so rich that any alternative management strategy has a detrimental impact. He adds on to say that the word 'richness' is a subjective term in that from an economic perspective, it can refer to the diversity of wetland functions which contributes significantly to the local or national economy whereas 'richness' from a biodiversity perspective would mean that any reduction in the gene pool can be regarded as degradation. Owen (1994) suggests that conservation of dambos would require these measures: (1) dambo catchments being managed as integrated systems and each catchment requiring a specific utilization plan; (2) dambo cultivation being allowed provided, systems of a patchwork of ridges, furrows and basins, separated by grassed strips, are used to reduce runoff and soil loss; (3) dambo grazing being severely reduced or prohibited; (4) dambo burning being prohibited; (5) interfluvial areas to be managed as these provide most of the water for the dambo system; (6) water pumping or lifting for irrigation being limited, based on the rainfall and individual dambo hydrology; and water levels and gully development being monitored (Owen, 1994:110-111).

2.15 Policy Framework in Zambia

Zambia has different policy guidelines and pieces of legislation that govern natural resources. Though there is a policy on the environment and water, there is no specific policy on wetlands. The policy on the environment aims to create a framework for effective natural resource utilisation and environmental conservation which would be sensitive to the demands of sustainable development (MTENR, 2007:1). Whereas, the aim of the National Water Policy is to provide a management framework for the

country's water resources so as to ensure that they are managed on a sustainable basis and retain their integrity to support the needs of the current and future generations.

However, some of the concerns raised in the two policies include: (1) lack of attention to an integrated water resource management policy; (2) inadequate management of water resources and catchments; (3) land degradation through inappropriate use of chemical agents and improper agricultural practices; and lack of monitoring and evaluation of programmes and projects relating to water.

CHAPTER THREE: STUDY AREA

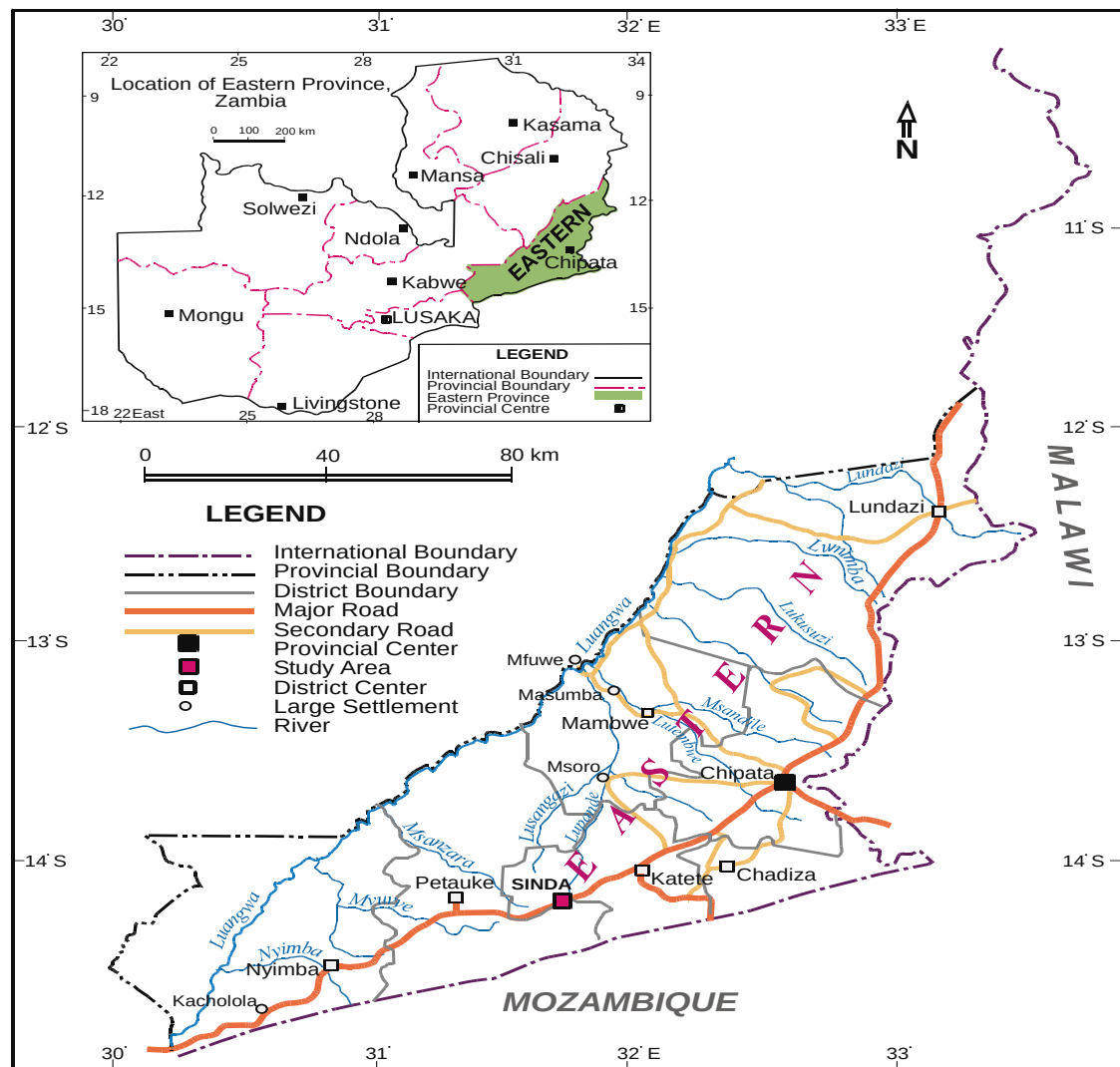
3.1 Introduction

This Chapter provides the general description of the study area in terms of the location, climate, physical characteristics and socio-economic characteristics. The physical characteristics include; the description of the geomorphology of the area, the morphology of the dambo, soils, hydrology, ecology and vegetation cover of the area. The chapter also describes the socio-economic characteristics of the area including the population and income levels.

3.2 Location

Sinda is located between latitudes 14°12' S and 14°18'S and longitudes 31°42'E and 31°48'E in Sinda District, Eastern Province of Zambia. Sinda town is found along the Great East Road (Figure 1). The area of concern is the palustrine wetland (locally known as dambo) found in Sinda. The palustrine wetland, which has been given the name Chassa dambo lies south of the Great East Road. It has Chassa Mission and Chassa Secondary School in the East and several villages dotted within the dambo vicinity.

The total area under consideration on the topographic maps was approximately 119,089 km². This included details of the flow of the five streams namely; Kafunde, Kasansa, Kapoche, Chassa and Nthongole that merge to form Chassa dambo. The outlet that flows out of Chassa dambo is known as Kapoche stream. The 1974 topographic map shows that the dambo covered an area of about 15 km².



Source: Ministry of Local Government, Housing, Early Education and Environmental Protection, 2011

Figure 1: Map showing the location of the study area in Eastern Zambia.

3.3 Physical Characteristics of the Study Area

The physical characteristics of the area include; climate, the description of the geomorphology of the area, the morphology, soils, hydrology, ecology and vegetation cover of Chassa dambo.

3.3.1 Climate

Sinda falls under the second Agro-ecological zone (Region IIa) which is characterised by annual rainfall ranging from 900mm to 1000mm (Figure 2). There are three (3) distinct seasons in Zambia.

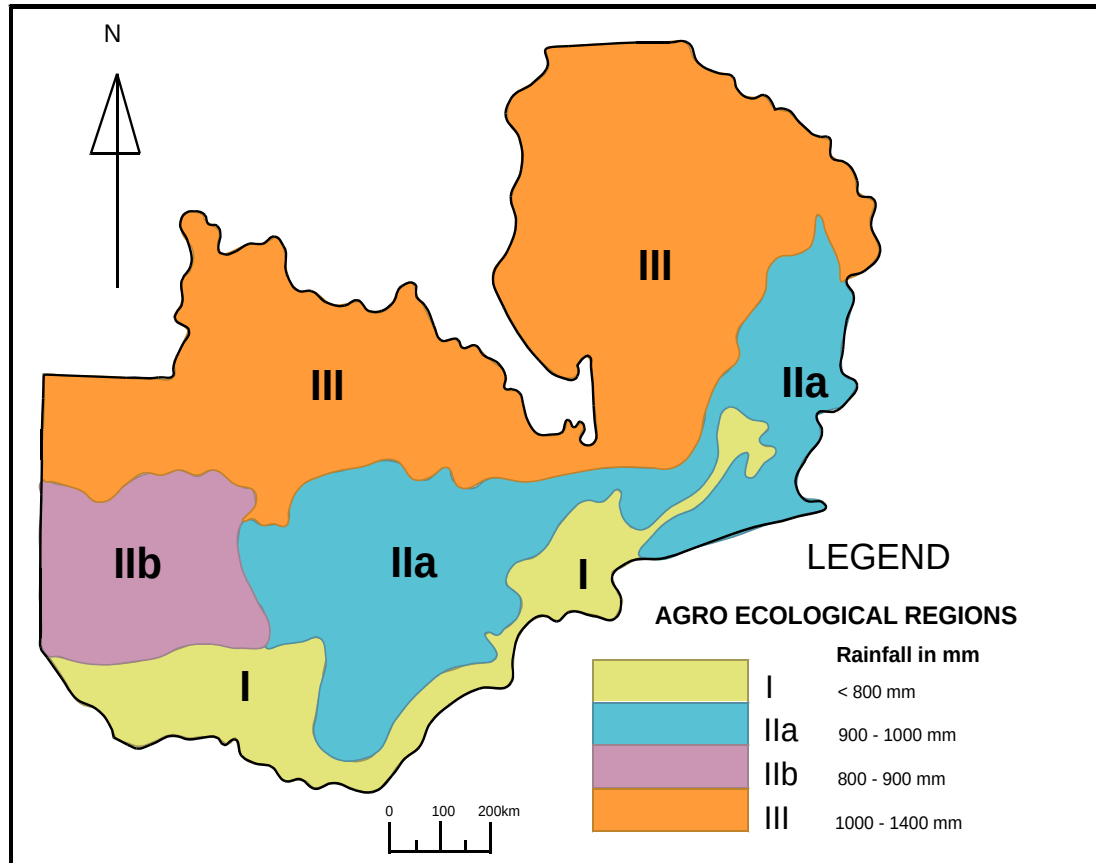


Figure 2: Map showing Agro-Ecological Zones of Zambia. Source: Ministry of Environment and Natural Resources, Lusaka, 1994.

Chipungu and Kunda (1994) explain that the wet seasons stretches from November to April, the cool (cold) season stretches from May to July and the hot season stretches from August to October. The temperatures range from 10°C in the cold season to about 35°C in the hot season.

3.3.2 Geomorphology

The streams that form Chassa dambo start from a watershed with the height that ranges from 1120m to 1180m above sea level. The watershed has several streams that flow out in all directions. The landscape is generally sloping northwards with the lowest elevation being 1060m above sea level. In the North-eastern direction, the land surface decreases down to a height of 1120m. The land is generally flat with a relief of 120m between the highest and lowest levels.

3.3.3 Morphology

The morphology or shape of Chassa dambo has principally been influenced by the gradient of the land and the streams that flow from the watershed. The dambos begin to form along the streams and begin to broaden where the streams converge. The broad and wettest parts of the dambo occur where the five streams converge.

3.3.4 Soils

According to Mackel (1971), the study area is under the Southern ferrallitic soils. The soils vary from sandy loams to loamy sands. The soil colour changes from yellowish-red to yellowish –brown in areas which are well drained to grayish–brown in poorly drained areas such as dambos.

3.3.5 Hydrology

Hydrology refers to the water regime of an area and this includes both surface and underground water. Four streams flow into Chassa dambo, namely Kafunde, Kasansa, Kapoche and Chassa. The lowest area at 1060m can be said to be a permanent seepage dambo as it is waterlogged (marsh) throughout the year. The

portion of the dambo in Nthongole is seasonal in that surface water dries up during the dry season. During the rainy season, water flows from Nthongole at an altitude of 1120m to the larger dambo lying at an altitude of 1060m.

3.3.6 Ecology

The size and availability of water makes Chassa dambo a major source of water for humans and other organisms. The dambo also supports the growth of grass making it a source of fodder for both domestic and wild animals. The trees found in the dambo are also ideal nesting areas for birds. It is also a source of fish for human consumption and birds.

3.3.7 Vegetation

The study area lies within the miombo woodland characterised by *Brachystegia*, *Jubelnardia* and *Isobertia* species (Mackel, 1971). The area had thick forests and open bush tree grasslands. Chassa dambo was predominantly surrounded by thick forests and tree bush tree grasslands.

Chassa dambo was covered by the *hyparrhenia* grass and sedge in waterlogged portions. Figure 3 shows the physical features of study area in 1974.

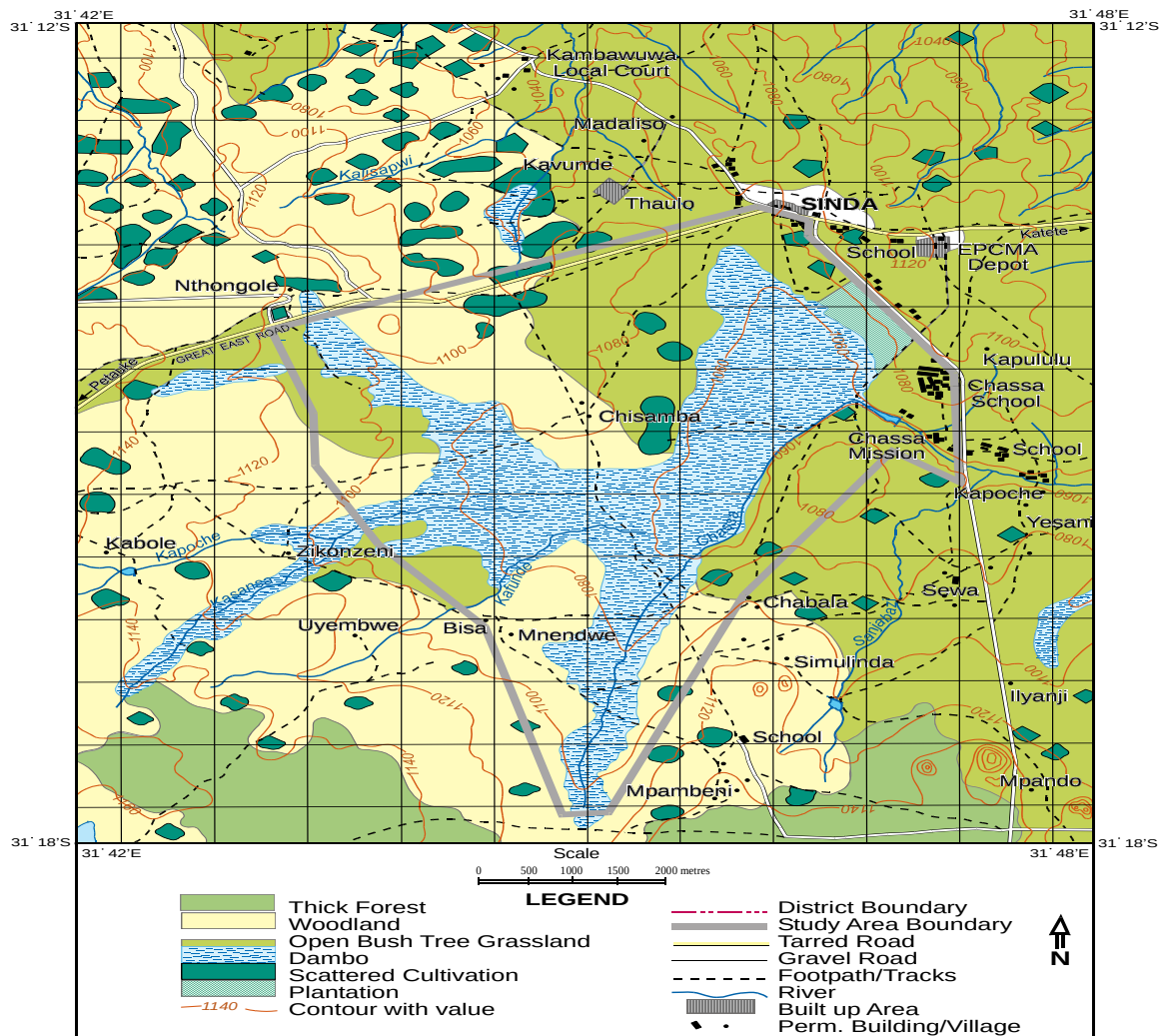


Figure 3: Map showing the vegetation cover of the study area in 1974. Source: Topographic maps 1431B1, 1431B2, 1431B3 and 1431B4

3.4 Socio-economic Characteristics

Generally, Sinda is an area which is expanding in terms of settlements and economic activities. The population is also increasing mainly due to migration of people from various places including the villages beyond the study area. The area has a number of public institutions such as: primary schools; secondary schools; post office; police station; and a health centre. More Government departments have been created as the area has been designated as a district. Private establishments include: shops, motel,

cotton ginnery and a transport company. However, the area has many villages and the majority of the people are small scale farmers.

3.4.1 Population

According to Central Statistical Office (CSO, 2011), Sinda had in the year 2010 a total of 2,699 households. The area had a total population of 13,457 people of which 6,550 were males and 6,907 were females. This population is widely distributed in the study area and comprises mainly of the Chewa and Nsenga speaking people.

3.4.2 Incomes and Livelihood

The people in Sinda are engaged in different economic activities. The public service employees earn income from Government. Other employees earn their salaries from individual employers.

There traders earn income through the sale of goods locally and beyond the District. Some traders run shops which are concentrated along the main road that is the Great East Road, while others buy agricultural produce for resale in other provinces including the capital city, Lusaka. The long established trader and transport company is Sable transport, whose business started in the 1950s. However, in the 1990s, they embarked on growing of maize and wheat on a large scale in the upland areas and middle dambo.

The company, Continental Ginnery, involved in the purchase of cotton from the local farmers provides employment to local people. The wheat and maize cultivation in the

dambo also provides seasonal employment for local people while others are employed on full time basis.

Chassa Mission and Secondary School have always made use of the water from the dambo. A small dam was built across the dambo outlet. The water from the dam is used at the mission and the school. Apart from domestic use of water, some of it is used for livestock and irrigation of gardens hence, making the institutions self reliant in terms of food.

People in villages that are dotted in the dambo vicinity depend mainly on subsistence agriculture. Apart from maize, crops such as groundnuts, beans, pumpkins and cotton are grown. However, a few people that have access to dambo land also grow vegetables and sugarcane for sale. Those with cattle use the animals for farming and they are also a source of milk. Goats, pigs and chickens are reared for food and also for sale. Some people are engaged in fishing but the majority catch fish during the rainy season when the rain water fills up all the dambo areas.

A smaller number of the people in the area has access to cleaner water provided by the local municipality. The dambo remains a major source of water for domestic use and for livestock. Though some villages have bore holes with hand pumps, the people still get water from shallow wells. When the hand pumps break down, replacing or indeed repairing of the pumps usually takes longer thus making dambos more reliable sources of water. The area has very few protected wells. Dambos provide grass for animals especially during the dry season.

CHAPTER FOUR: METHODOLOGY

4.1 Introduction

This chapter describes the tools and methods used to gather information. The tools used include: topographic map (1:50,000), a Global Positioning System (GPS), Google imagery of study area and questionnaires. The chapter also outlines the methods used in the collection of field data and samples as well as analytical techniques used.

4.2 Data Collection

Data collection involved the gathering of both secondary and primary data. The topographic map of the study area was used when identifying the settlements. Though it was proposed that questionnaires would be administered in Zikonzeni and Bisa villages, the two villages no longer existed. The name 'Mthongole' on the original topographic map was corrected to read Nthongole while 'Chansamba' was changed to read Chisamba. Both the topographic map and the Google maps of the study area were used to identify areas where soil samples could be obtained. The Google map showed the land use of the dambo such as cultivation and damming. The Global Positioning System (GPS) was used to get coordinates and elevation for the soil pits.

4.2.1 Secondary Data

Secondary data was obtained from written literature that is; books, journals, Government policy documents, reports and legislation, topographic maps (1:50, 000: 1431B1, 1431B2, 1431B3 and 1431B4) of the study area.

4.2.2 Primary Data

Primary data was collected from the field through questionnaires, interviews, photographic and general observations. The data collected included responses to the questions in the questionnaire and responses to interviews. Photographs, soil samples and notes on the general observations of the study area were also taken.

4.2.3 Questionnaires

Structured interviews were conducted in the villages. Questionnaires (Appendix A) were administered in Nthongole, Chisamba, Mnendwe and Sinda town (Tiyeseke, Nyakundu and Mnyamazi compounds). When administering questionnaires, the local languages (Nsenga and Chewa) were used because most respondents had not attained higher levels of formal education. The method helped to overcome misunderstandings and misinterpretation of some words or terms. However, respondents at Chassa Secondary School and Chassa Mission answered the questionnaires on their own as most of them had gone through tertiary education and they were able to read and write. A Semi-structured interview was conducted with the commercial farmer.

4.2.4 Sampling Procedure and Sample Size

The household of a chairperson of each compound in Sinda town and the household of each headman of a village at whatever location in a settlement became the starting point in administering questionnaires. The technique where the starting of administering questionnaires at the chairperson or headman's household was located in a settlement can be termed as the Interval or Systematic sampling. Bless and Achola (1988) state that this technique is based on the selection of elements at equal

intervals starting with a randomly selected element on the population list. In this case, the chairperson or the headman was purposively selected because tradition demands that when visiting a settlement or village, the chairperson or headman must be seen first. As such, they became the first respondents on the visit. A total of 80 respondents from 80 households out of 905 households were interviewed. The number represented 8.8% of the total number of households.

4.2.5 Soil Samples

Soil samples were collected from various points, targeting different zones of Chassa dambo, that is; the upland area, the dambo margin, lower dambo and the base of the dams (Figure 4).

Though it was suggested that soil samples should be collected along transects, this could not be done because the natural processes of soil erosion had been disturbed by canalisation and extensive/intensive cultivation of the dambo soils. The machinery (tractors and combine harvesters) that was used also compacted the soil.

Pits were dug up to a maximum of 100 cm depth in various points. The pits in the upland area (Pit 2 and 4) were dug to ascertain the type of soils and to determine soil erosion to the lower dambo. Therefore, if upland soils are found in the lower dambo, which would mean that there is sedimentation as the lower dambo is expected to be overlain with clay soils. A tape measure was used to measure the depths of the pits and the profiles. Soil profiles were described in detail using Peter Woode's (1987) Technical Guide.

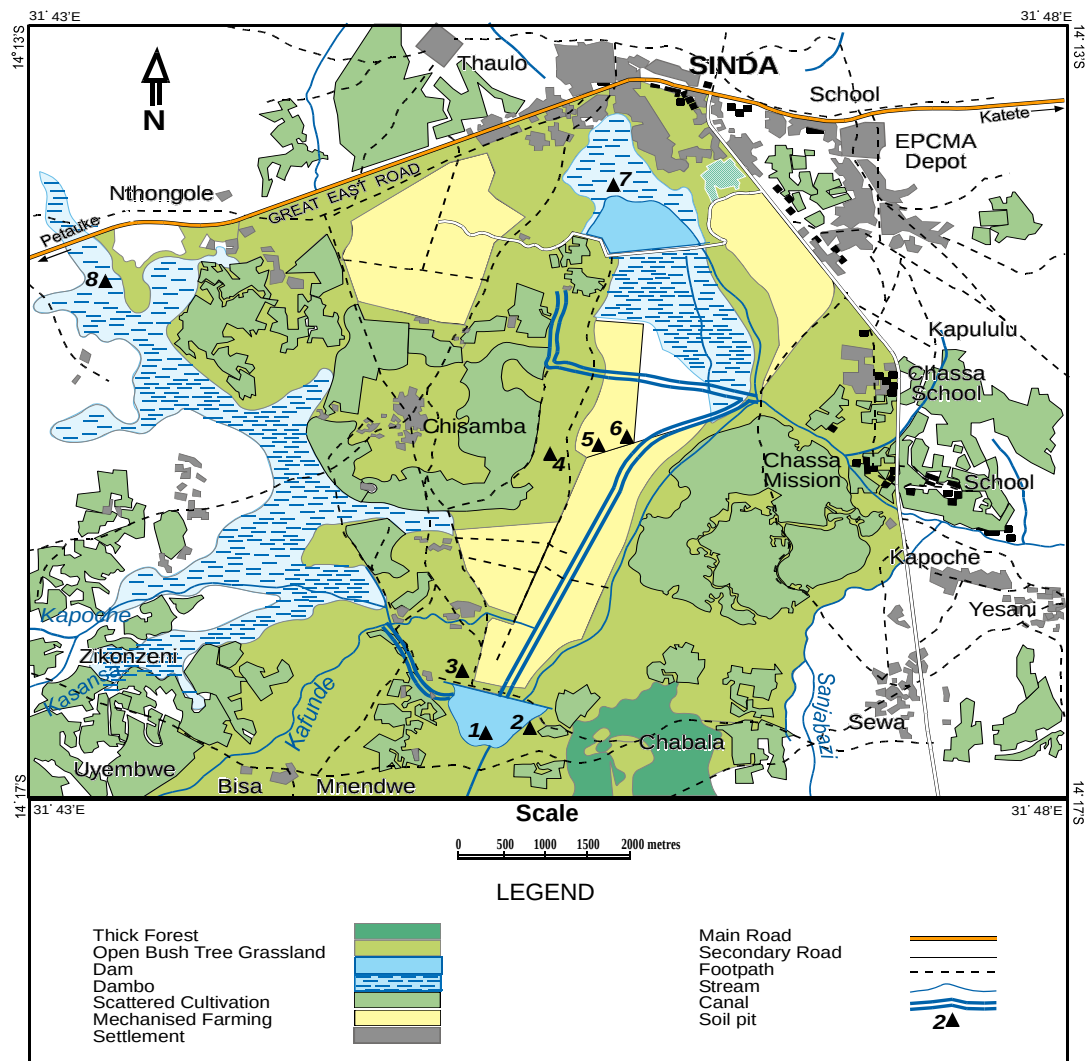


Figure 4: Map showing the location of soil pits, vegetation cover and land use. Source: Extract from the Google imagery (2006) and topographic maps.

The use of bottled water was essential in identifying the changes in the soil colour and texture when dry, moist or wet. A knife was used when collecting soil from sections of each profile to ensure precision when collecting the soil samples. The soil samples were placed in well labelled plastic bags and taken to Mount Makulu Research Station for physical and chemical analysis.

4.3 Data Processing

Data processing involves the transformation of raw data from the field into information that is easy to understand and interpret. Data processing involved cleaning of questionnaires, data coding and analysis.

4.3.1 Cleaning of Questionnaires

The questionnaires were first cleaned to ensure that they were properly completed. The additional information given by respondents and the village Headmen was also written down.

4.3.2 Data Coding

The questionnaires were numbered from 1 to 80. The questions were then changed into statements and given a variable number. The answers were given numerical values e.g. Yes = 1, No = 2. Multiple options were also changed into statements and the answers were given numerical values. For open ended questions, all answers from respondents were recorded. Similar answers were grouped together and given a numerical value while unique or infrequent answers were labelled “other” and given a numerical value.

After coding the data, it was entered into the SPSS (Statistical Package for the Social Sciences-17.0) programme. From 18 questions in the questionnaire, 42 variables were identified and coded accordingly.

4.4 Data Analysis

Data analysis was done once data processing and data coding was completed. Statistical analysis was performed in order to infer some properties of the population from the sample results. This covers both quantitative and qualitative data. Qualitative analysis was used where quantification was difficult.

4.4.1 Quantitative Analysis

Tables, graphs and pie charts were used to summarise the quantitative, data that had been coded using the SPSS software.

4.4.2 Qualitative Analysis

This analysis applies to information that cannot be quantified hence; physical features were merely described. The analysis included the description of the geomorphology, morphology, soils, hydrology, ecology and vegetation of study area.

4.4.3 Soil Analysis

The soil samples were taken to Mount Makulu Research Station, Soil Survey Unit for physical descriptions and chemical analysis including soil pH. This was done in two stages, namely; analysis and classification of physical properties and determination of chemical characteristics of dambo soil.

For chemical analysis, the soil samples were air dried at room temperature before any chemical analysis was done. The soils were then ground and sieved through a 2mm sieve. The samples were analysed for pH, organic carbon, phosphorus, potassium, calcium, magnesium, nitrogen and cation exchange capacity (CEC).

Organic carbon was determined by Walkley Black Method. Available phosphorus was measured using the Bray 1 Method. Soil pH was done in CaCl_2 0.01M using a soil to salt solution ratio of 1:2 on volume basis. CEC was determined by using the Ammonium Acetate method. Total nitrogen was determined by the Kjeldahl method. Exchangeable bases (Ca^{++} , Mg^{++} and K^+) were extracted by leaching the samples with 1N ammonium acetate buffered at pH 7. Ca^{++} and Mg^{++} were measured by atomic absorption spectrophotometry and K^+ by flame photometry.

CHAPTER FIVE: ANALYSIS AND FINDINGS

5.1 Introduction

This chapter reports results from physical observation to the information obtained from respondents supplemented by photographic illustrations of human activities such as agriculture, damming, canalisation, grazing, settlements and deforestation. In addition, the chapter presents results of analysis in form of quantitative data, graphs, tables and pie charts. The results are presented under different themes covered by the study.

5.2 Characteristics of Respondents

The study had to ascertain the characteristics of respondents in terms of gender, occupation and education levels.

5.2.1 Sex of Respondents

The majority of the respondents were females. The men had either gone for work or attending to other business away from the villages or homes. Nevertheless, the headmen or chairpersons of all the settlements in Sinda were interviewed in order to get additional information. Questionnaires were administered to 80 respondents of whom, 45 percent were males and 55 percent were females.

5.2.2 Occupation of Respondents

The majority of the people in the study area were peasant farmers. Some were traders while others were professionals such as teachers. Out of the 80 respondents, 57.5 percent were peasant farmers, 5 percent were traders mostly from Sinda town itself, 11.3 percent were teachers from Chassa Secondary School while 8.8 percent were housewives in Sinda town (Table 1). The other 17.5 percent of respondents included drivers, carpenters and security guards.

Table 1: Occupation of respondents in Sinda area

Occupation	Frequency (No.)	Relative Frequency (%)
Farmer	46	57.5
Trader	4	5.0
Teacher	9	11.3
Housewife	7	8.8
Others	14	17.5
Total	80	100

Source: Field data.

5.2.3 Education Levels of Respondents

The majority of the respondents had not attained higher levels of education except for those found at Chassa Mission and Secondary School. A total of 75 percent of the respondents had not attained basic education (Grade 1 to 9) despite the area having primary schools and a secondary school. Of the 75 percent, 24 percent had no formal

education and 51 percent had merely attained primary education. The situation could be attributed to long distances to the nearest schools and the general laxity of the people in attaining higher levels of education. The 14 percent of respondents who had attained tertiary education were found at Chassa Mission and the Secondary school. Figure 5 shows the education levels attained by respondents by 2009.

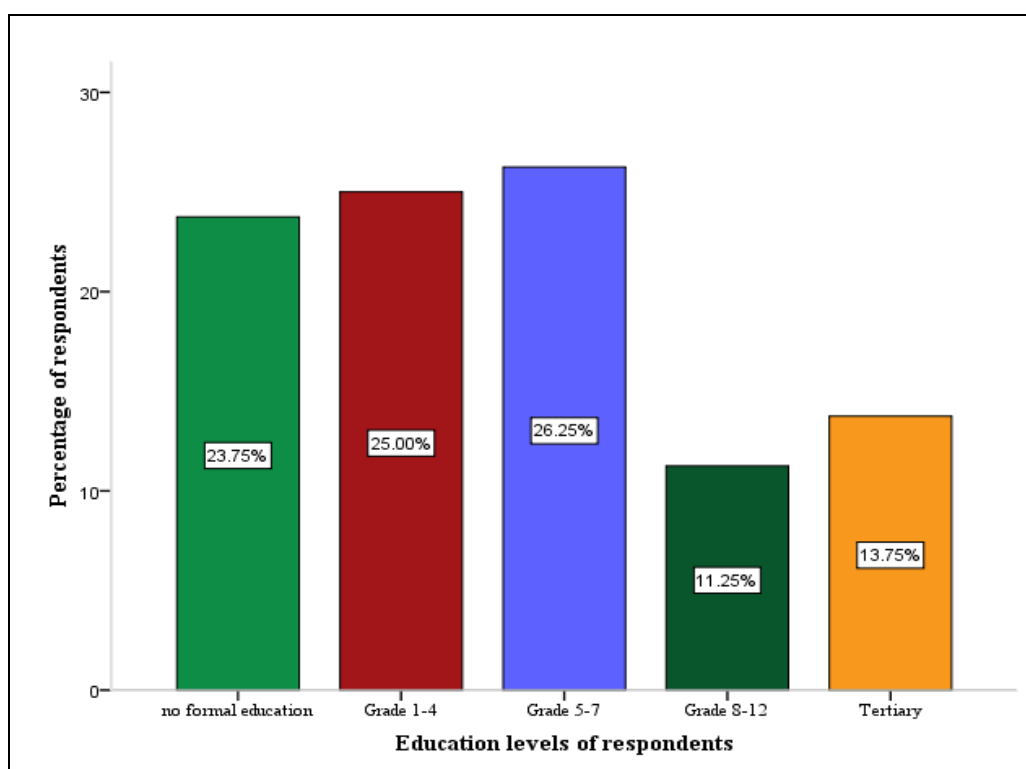


Figure 5: Graph showing education levels attained by respondents by 2009.
Source: Field data

5.3 Physical Characteristics of Chassa Dambo and Effects of Human Activities

5.3.1 Geomorphology of Chassa Dambo

The formation and sustenance of the dambo geomorphology requires gentle relief to promote water infiltration and excess water flows out through an outlet. The deep regolith incision forms the dambo outlet (stream) called Kapoche. However, the

typical geomorphology of the dambo has been altered mainly by the two dam walls that were built across the dambo (Figures 6a). The dam walls altered the general elevation in the lower dambo. In addition, the geomorphology has been altered by the excavation of the upland areas of the dambo (Figure 6b).

(a)



(b)



Figure 6: Photographs showing (a) excavated ditches in the upland areas of Chassa dambo and (b) the northern dam wall in Chassa dambo, October 2009. Source: Field data.

5.3.2 Morphology of Chassa Dambo

The morphology of Chassa dambo was altered mainly due to canalisation and draining of the middle dambo. A canal was dug to drains water from Nthongole, Kapoche, Kansansa and Kafunde streams to the Southern dam. Pipes were also used to drain water from the lower dambo to the Northern dam (Figure 7). Therefore, the

draining of the middle and the lower dambo for cultivation has distorted the original shape of the dambo.



Figure 7: Photograph showing a pipe used for pumping water from the lower dambo into the Northern dam, October 2009. Source: Field data.

5.3.3 Soil Characteristics of Chassa Dambo

Soil samples from different points of the dambo were obtained in order to assess their physical and chemical characteristics.

5.3.3.1 Physical Properties of Chassa Dambo Soils

The majority of the soils in Chassa dambo were poorly drained, deep very dark gray to dark grayish brown and gray sandy clay loam to sandy loam and clay soils. In some places sandy soils were observed in the subsurface horizon.

5.3.3.2 Characteristics of the Soil Samples

Soil samples were obtained from the dambo margin, the middle and the lower dambo in order to ascertain the physical and chemical characteristics. Pits 002, 003 and 004 were dug at the dambo margin principally to ascertain the soil types and possible erosion. Pits 001 and 007 were dug in the drier portions of the dam to ascertain sedimentation while Pit 008 was dug to compare the levels of erosion and sedimentation with Pits 001 and 007. Pit 008 was dug in the lower dambo where soil disturbance due to human activities was minimal.

5.3.3.3 Location and Brief Description of Soil Pits

A brief description of eight surveyed soil pits is provided below:

a. Pit 001 (031°44.762' E) and (14°16.157'S)

The pit was dug at the base of the Southern dam. The top layer contained sandy clay loam instead of clay soil. The second contained sandy clay loam and the third layer contained sandy clay. The fourth layers contained coarse clay (Figure 8).



Figure 8: Photograph showing the soil profile at Pit 001, October 2009. Source: Field data.

b. Pit 002 ((031°44.987' E) and (14°16.075'S)

Pit 002 was dug on the eastern side of the southern dam that is the dambo margin. The colour of the soil was bleached or white sand. The top layer contained silty loam whereas the second, third, and fourth layers contained sandy loam, sandy loam and sand respectively (Figure 9). The soils were moderately well drained and no appreciable water erosion was observed. The soils were generally weak, loose and non sticky.



Figure 9: Photograph showing the soil profile at Pit 002, October 2009. Source: Field data.

c. Pit 003 ($31^{\circ}44.477'E$) and ($14^{\circ}15.869'S$)

The pit was dug at the dambo margin where the land had been cleared for cultivation (Not illustrated). The soils were well drained and no appreciable erosion was observed. The first, second, third and fourth layers contained sandy clay loam, sandy clay loam, sandy loam and sand respectively.

d. Pits 004, ($31^{\circ}44.906'E$) and ($14^{\circ}14.721'S$)

Pit 004 was dug at the dambo margin (Figure 10). The soils at Pit 004 were well drained. The first, second and third layers of the pit contained sandy clay

loam, sandy clay loam and sandy clay respectively. The soils from the upper layers broke into weak and fine sub angular blocky.



Figure 10: Photograph showing soil profile at Pit 004, October 2009. Source: Field data.

- e. **Pit 005**, ($31^{\circ}45.054'E$) and ($14^{\circ}14.758'S$) - Pit 005 had poorly drained soils with slow permeability (Not illustrated). The pit was dug in the middle dambo and the first, second, third and fourth layers contained silty clay, silty clay loam, sand and sandy clay respectively.
- f. **Pit 006**; ($31^{\circ}45.109'E$) and ($14^{\circ}14.757'S$) - Pit 006 was dug in the lower dambo and had poorly drained soils with very slow permeability (Figure 11). The first, second and third layers contained silty clay, clay and clay

respectively. The soils in all the three layers were moist. The soils were compacted due to the use of heavy machinery when cultivating or harvesting crops.



Figure 11: Photograph showing soil profile at Pit 006, October 2009. Source: Field data.

- g. Pit 007; (031°41.255'E) and (14°13.624'S)** - The soils in Pit 007 were poorly drained. The pit was dug at the base of the northern dam. The first, second, third and fourth layers of the soil contained silty clay, sand, clay and clay respectively (Figure 12). It was observed that the second layer contained

deposited sand. The soils in the second layer broke into weak and coarse crumbs.



Figure 12: Photograph showing the soil profile at Pit 007, October 2009. Source: Field data.

- h. Pit 008 (031°42.842'E) and (14°13.882'S)** – Pit 008 was dug at the headward dambo in Nthongole area where there was also burning, grazing and clearing of land for cultivation. The soils were poorly drained and floods were common (Figure 13). The first, second, third and fourth layers contained silty clay, sandy loam, sandy clay.



Figure 13: Photograph showing soil profile at Pit 008, October 2009. Source: Field data.

5.3.3.4 Physical Characteristics of Chassa Dambo Soil Profiles

The physiography of the soil is that of the degraded Central African Plateau. The soils in the dambo margin were moderately well drained and that was observed in Pits 002, 003 and 004. The soils obtained in the middle and lower dambo were poorly drained with permeability being slow to very slow. Though soils from the dam bottom (Pits 001 and 007) were poorly drained and permeability was slow, the

soil contained sand washed from the upland areas and the canals. The detailed physical characteristics of Pit 001 to Pit 008 are shown in Appendix B.

5.3.3.5 Chemical Characteristic of Studied Soil Pit Profiles

The detailed Chemical Characteristics of Soil profiles of Pits 001 to 008 are shown in Appendix C. The summary of results of the actual chemical content of the studied soil profiles are shown in Appendix D while the results for interpretation of the chemical characteristics of soils are in Appendix E.

5.3.3.6 General Descriptions of the Chemical Characteristics of Profiles of Pit 001 to Pit 008

The chemical analysis of the soils indicates the elements namely; calcium, magnesium, potassium, phosphates nitrates and organic carbon. These elements were either below or much higher than the critical levels. The critical levels for calcium, magnesium, potassium, phosphates are 200, 50, 40 and 15 mg/kg, respectively. The critical levels for nitrates and organic carbon are 0.10% and 1.58%, respectively.

The soils obtained from Pit 001 dug at the base of the southern dam contained very high levels of nutrients especially in the profile 18-60 cm. The profile contained calcium, magnesium, magnesium and potassium at 1,600, 310, 90mg/kg, respectively. The carbon content was below the critical value and the soils were found to be slightly acidic.

The soils in Pit 002 dug at the dambo margin had soils that were medium to slightly acidic. The elements were generally below the critical values except for the calcium level in the first profile which was above the critical value. The organic carbon was less than 0.01 percent.

The soils in Pit 003 dug at the dambo margin were medium to slightly acidic. The quantities of the elements in the soil were less than the critical values though a general reduction in the nutrients was observed as you go down the profile. The organic carbon was less than 0.01 percent.

The soils in Pit 004 dug slightly after the dambo margin had soils that were medium acidic. The elements were fluctuating with some being higher than the critical values and others being much lower than the critical values. However, higher levels of nutrients were observed in the top and bottom horizons.

The soils in Pit 005 were obtained where the dambo had been drained, cultivated and lime applied before planting of maize. The results show that the soils were medium to slightly acidic. Generally, the difference in the nutrient levels in the top two horizons was minimal. However, it was observed that the bottom horizon had an accumulation of calcium, magnesium and potassium.

The soils obtained in Pit 006 dug in the lower dambo had very high concentration of nutrients. The highest levels were found in the second horizon with calcium being at 1450mg/kg and magnesium and potassium levels being 369 and 160mg/kg, respectively. Soil compaction was also observed as digging of the pit became difficult.

The soils obtained from Pit 007 dug at the base of the northern dam were medium acidic. The soils contained a high concentration of nutrients. The calcium and magnesium levels were 910 and 290mg/kg, respectively. The potassium level was 1338mg/kg in the third horizon.

The soils in Pit 008 were obtained in an area where there is subsistence use of the dambo though burning was observed. Though the soils were not disturbed by subsistence farming, the nutrient levels were fluctuating. It was observed that the bottom horizon had much higher levels of nutrients with calcium, magnesium and potassium being at 940, 270 and 140mg/kg. The soils were extremely acidic.

5.3.4 Hydrology of Chassa Dambo

The hydrology of Chassa dambo had changed due to canalisation, damming and draining of the lower dambo. Though the main dambo received water from four streams (Kafunde, Kasansa, Kapoche and Chassa), one outlet continued to flow out as Kapoche stream.

During the early 1990s when commercial farming started in the dambo area, dams were created in order to store water for irrigation. Chassa stream was blocked by a high wall hence stopping the free flow of water through the dambo. This resulted in some areas of the dambo becoming drier. Such drier parts of the dambo were used to grow crops such as maize. At the time of the research, lime was being applied in the middle dambo in readiness for planting. On the western side of the dambo, a long canal was dug in order to divert water from Nthongole area, Kapoche and Kafunde streams to the southern dam. Nevertheless, the northern part of the dambo was water logged during the driest month of the year (Figure 14).



Figure 14: Photograph showing a portion of the waterlogged dambo, October 2009. Source: Field data.

It was observed that the pumping of water from the lower dambo was being done to control water levels so that the cultivated middle dambo was not flooded. The source of water in the northern dam was the underground aquifer as the dam had abundant water (Figure15)



Figure 15: Photographs showing water in the Northern dam at the end of the dry season, October 2009. Source: Field data.

Much of the water stored in the dam is used to irrigate the wheat and maize fields in the upland areas (Figure 16).



Figure 16: Photograph showing an irrigated wheat field in the upland area of Chassa dambo, October 2009. Source: Field data.

Regarding the negative effects of canals and dams, Figure 17 shows that 26.3% of the respondents said that canals and dams had no effect. Such answers came from respondents interviewed in Nyakundu, Tiyeseko and Mnyamazi compounds in Sinda town and Nthongole.

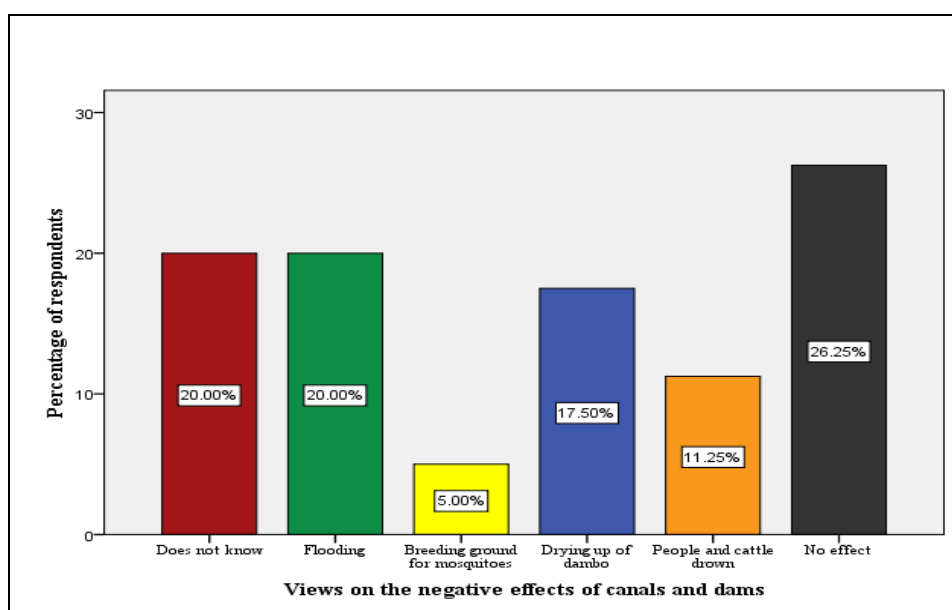


Figure 17: Graph showing the views of respondents on the negative effects of canals and dams. Source: Field data

Some respondents especially those from Mnendwe village (20%) complained that there was flooding. They said that the road to Chisamba and Sinda became impassable in the rainy season due to flooding when the canal overflowed. Hence, the community had problems accessing health care at the clinic as well as accessing basic goods and services from the town. Respondents (17.5%) especially from Chassa Mission complained that their area had dried up and that they were not able to grow vegetables and other crops in their gardens. They attributed the situation to the fact that there was no free flow of water in the dambo due to damming. The small

dam built on the dambo outlet had little water. Additionally, some respondents (5%) complained that the dams were breeding grounds for mosquitoes while (11%) complained that two people and cattle had drowned in the southern dam and the canal, respectively.

5.3.5 Vegetation in the Study Area

The study area lies in the midst of miombo woodland which is characterised by area with a partly closed canopy of trees five to 20 metres high, a few shrubs beneath and often sparse but continuous layer of grasses and other ground cover. Some tree species found around Chassa dambo included: *Ficus Sycomorous* (Mkuyu), *Strychos Spinosa* (Mzimbili), *Piliostigma Thonningai* (Msekese), *Brachystegia boehmii* (Mfendanzinzi), *Julbernardia Paniculata* (Mtondo), *Stiganotaenia Araliacea* (Chifyopole) and *Uapaca Kirkiana* (Masuku). However, the acacia albida (Mtubetube) is an obvious tree species in dambos. The grass species are *Hyperhania* sp. The scientific names of some tree species in the study area were obtained from Storrs (1979).

It was observed that large portions of the original miombo woodland had been cleared for agriculture and settlements. Land had also been cleared to pave way for houses in settlements such as Nyakundu, Mnyamazi and Tiyeseke. Secondary vegetation was observed in some places where trees had been cut for small scale farming. Areas along the streams and those very close to villages had some original vegetation. The North Eastern part of the dambo had a few trees along a stretch that was waterlogged. Burning of grass was also observed in the dambo.

Figures 18(a) shows that vegetation around the dambo had been extensively cleared, mainly for commercial farming and settlements that were expanding towards the northern part of the dam. Figure 18(b) shows burning in the dambo and this was also observed in Nthongole area.

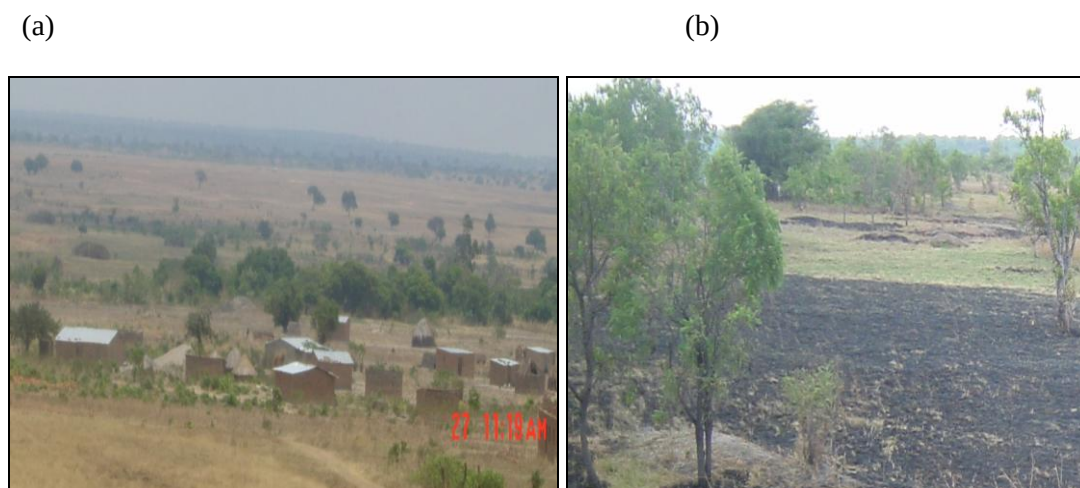


Figure 18: Photographs showing (a) vegetation cleared for settlements and farming and (b) a burnt portion of Chassa dambo, October 2009. Source: Field data.

5.3.5.1 Analysis of Satellite Images and Data on Land Cover by Extent (1990 and 2009)

The analyses of satellite images on land cover for 1990 and 2009 showed significant changes in the land cover (Figure 19 and 20). The notable changes in land cover from the data in Table 2 and 3, in terms of percentages include: (a) dense vegetation reducing from 0.33% to 0.31%; (b) sparse vegetation reducing from 47% to 4.30%; (c) shrub land increasing from 2.17% to 4.61%; (d) bare ground increasing from 6.47% to 21.29%; water increasing from 0.05% to 0.39%; (f) grassland increasing from 0.4% to 1.04%; (g) crop fields increasing from 25.14% to 50.85%; and (h) wetland reducing from 0.97% to 0.27%.

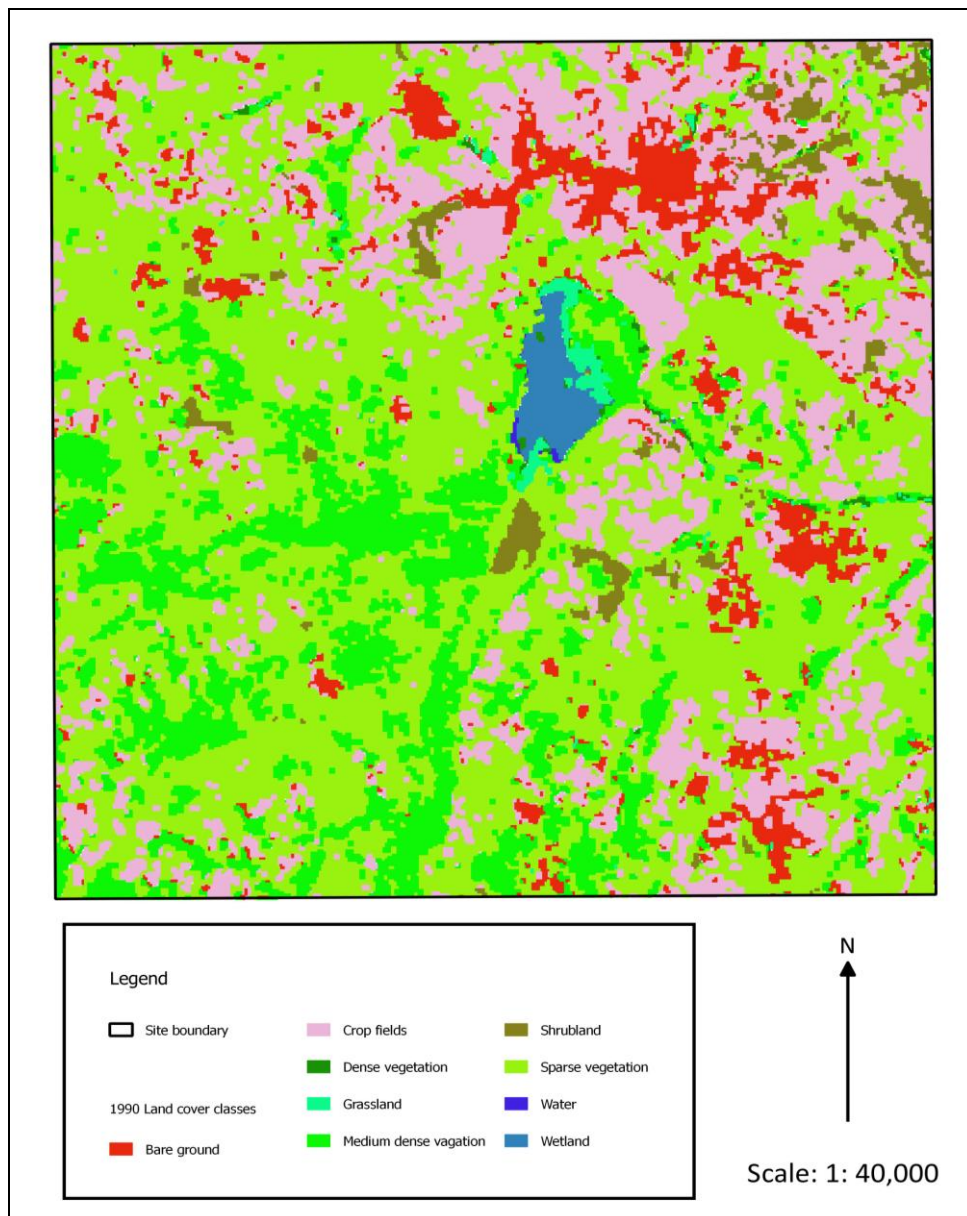


Figure 19: Landsat image showing land cover of the study area in 1990.

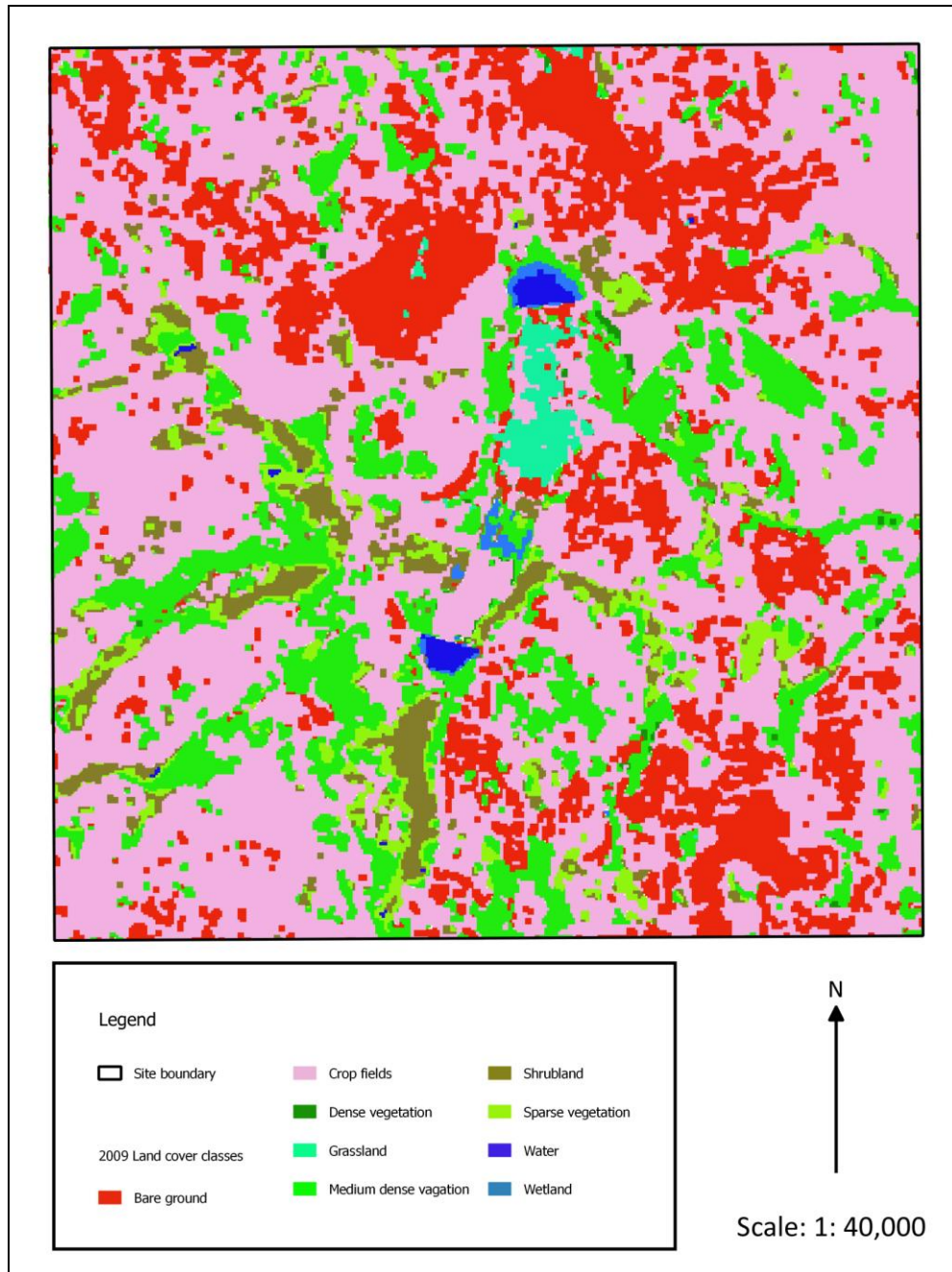


Figure 20: Landsat image showing land cover of the study area in 2009.

5.3.5.2 Land Cover in Chassa Dambo Area (1990 and 2009)

Table 2 and 3 presents, the land cover changes by extent for the period 1990 and 2009 in the study area.

Table 2: Land cover by extent of the study area in percentages by 1990

Land cover classes	Area (m ²)	Area (Ha)	Percentage by cover
Dense vegetation	393,129.00	39.31	0.331
medium dense Vegetation	20,152,734.75	2,015.273	16.960
Sparse vegetation	56,281,614.75	5,628.161	47.366
Shrub land	2,575,644.75	257.564	2.168
Bare ground	7,684,697.25	768.470	6.467
Water	60,918.75	6.092	0.051
Grassland	641,677.5	64.168	0.540
Crop fields	29,873,742.75	2,987.374	25.142
Wetland	1,158,268.50	115.827	0.975
Total	118,822,428.00	11,882.243	100.00

Table 3: Land cover by extent of the study area in percentages by 2009

Land cover classes	Area (m ²)	Area (Ha)	Percentage by cover
Dense vegetation	369,900.00	36.99	0.311
medium dense Vegetation	19,412,100	1,941.21	16.300
Sparse vegetation	5,125,500	512.55	4.304
Shrub land	5,485,500	548.55	4.606
Bare ground	26,109,000	2,610.9	21.924
Water	468,900	46.89	0.394
Grassland	1,233,900	123.39	1.036
Crop fields	60,563,700	6,056.37	50.855
Wetland	321,300	32.13	0.270
Total	119089800	11908.98	100.00

5.3.5.3 Changes in Land Cover Classes in Chassa Dambo Area from 1990 and 2009

Between 1990 and 2009, land cover changes occurred into different land cover classes. The percentage changes are given in various cells of Table 4. The intersection of the column and rows gives the amount of land cover change for a

given land cover type between 1990 and 2009. For example, the sparse forest land cover changed to crop fields by 56.57% in 2009. In order to know how much of the original land cover type e.g. sparse forest remained, , one has to look at the intersection of the column and rows for the same land cover type. In this case, ‘sparse forest’ (column) intersection with ‘sparse forest’ row shows that the remaining land cover is only 4.72 percent.

Table 4: Changes in land cover classes in percentages (1990 and 2009).

Land cover Status in 1990(%)									Land cover status in 2009 (%)
dense vegeta tion	mediu m dense vegeta tion	water	Bare grou nd	Sparse forests	Gras s land	Crop fields	Wet land	Shrub Land	
0	0.33	0	0.12	0.28	1.39	0.17	0.49	0.16	
6.82	0.85	0	0.08	0.20	2.66	0.05	0.07	0.63	
40.70	36.99	1.33	5.84	17.66	13.54	2.96	2.31	7.32	
0.21	9.44	0	0.82	4.72	1.52	1.36	0	5.46	
0.21	9.55	0	0.52	5.04	2.78	1.48	0	6.97	
3.31	5.78	4	52.90	14.61	16.08	39.56	5.26	20.28	
0.62	0.61	0	0.45	0.46	8.48	0.02	0	0	
13.22	0.28	68	0.02	0.21	9.49	0.12	73.42	1.10	
34.71	35.71	26.67	38.98	56.57	42.91	54.22	18.44	56.48	
0.21	0.43	0	0.26	0.25	1.14	0.06	0	1.608	
0	0.02	0	0	0.01	0	0.01	0	0	
100	100	100	100	100	100	100	100	100	
93.18	63.01	100	47.11	95.28	90.51	45.78	100	93.03	
6.61	3.94	686.7	240.2	90.77	94.43	103.2	72.51	111.8	

A brief explanation based on Table 4 is as follows:

- a) Of the dense vegetation that was in the study area in 1990, 40.7% changed to medium dense vegetation, 0.21% changed to sparse vegetation, 0.62% to water, 3.31% to bare ground, 13.22% to grassland, 34.71% to crop field, and 0.21% to wetland by 2009.

Therefore, of the dense vegetation in 1990, 38.64% had changed to bare ground, crop fields and water collectively. Only 6.82% of the dense vegetation present in 1990 existed in 2009 and that 93.18 % of the initial dense vegetation had changed form to other land cover types.

- b) Of the amount of water in the study area, 1.33% changed to medium dense vegetation, 68% changed to grassland, and 26.67% changed to crop fields.
- c) Of the sparse vegetation that was there in 1990, 0.2% changed to dense vegetation, 17.66% changed to medium dense vegetation, 5.04% changed to shrub land, 14.61% changed to bare ground, 6.46% changed to water, 0.21% changed to grassland, 56.57% changed to crop land, and 0.25% changed to wetland by 2009. Only 4.72% of the sparse vegetation present in 1990 existed in 2009 and that 95.28 % of the initial sparse vegetation had changed form to other land cover types or lost altogether. This shows that 71.63% of sparse forests had been lost to bare soil, crop fields and water collectively. This alternatively implies that 23.64% was retained

forest cover despite the many forms it had changed into. Therefore, 71.63% will be considered as loss of forest cover in this land cover class.

- d) Of the grassland that was available in 1990, 13.54% changed to medium dense vegetation, 16.08% changed to bare ground, 8.48% changed to water, and 42.91% changed to crop fields. Therefore, 57.47% of the grassland was lost to bare ground, water and crop fields collectively. Only 9.49% of the grasslands present in 1990 existed in 2009 and that 90.51% of the initial grassland had changed form to other land cover types.
- e) Of the wetland that was there in 1990, 2.3% changed to medium dense vegetation, 5.26% changed to bare ground, 73.42% changed to grassland, 18.44% changed to crop field. Table 4 shows that 0% of the wetland remained and that it had been lost to other forms of land cover classes by 100%.

5.3.6 Ecology of Chassa Dambo

Chassa dambo is an ecosystem that involves the interaction of organisms both on land and in water. In essence, animals and aquatic organisms such as fish depend on the dambo for food and water and other resources. Human beings were also heavily dependent on the dambo as a source of water and food (fish, birds, mice and growing of vegetables). The animal life that was seen in Chassa dambo included; birds, cattle, goats, insects, mice and fish. Chassa dambo was a source of food for domesticated

animals especially cattle and goats as these wetlands are rich in grass. Figures 21(a) and (b) show that the dambo is an ideal grazing ground for cattle. Grazing in the main dambo was allowed only when it was not under cultivation.



Figure 21: Photographs (a) and (b) showing cattle grazing in Chassa dambo, October 2009. Source: Field data.

Figure 22 shows that trees in the dambo are an ideal habitat for birds. The *acacia albida* locally known as *Mtubetube*, is a tree that is ideal for bird nests.



Figure 22: Photograph showing bird life in Chassa dambo, October 2009. Source: Field data.

Some respondents said that animals such as waterbucks, impalas and rabbits that once frequented the dambo were not seen because they were killed for consumption and also due to deforestation. Some respondents said that in the past, the area had a high population of birds but numbers had reduced due to high mortality which they attributed to pesticides sprayed on the wheat. Respondents from Chisamba and Mnendwe villages said that the birds that died as a result of pesticides were consumed by children.

The respondents from Chisamba village said that the dambo had a lot of fish and that they depended heavily on this resource for consumption and for sale. Some respondents said that in the past, they were able to exchange fish with maize as a way of sustaining themselves. However, 70% of the respondents said that the fish numbers in the dambo had reduced. The fish that were once a lifeline for the local people were now confined to the waterlogged portions of the dambo in small numbers. Fishing from the dambo was also restricted by the commercial farmer as he had acquired the land from chieftainess Nyanje.

The ecology of Chassa dambo was also being affected by the change in the composition of the soil in the middle and lower dambo. Sedimentation or deposition of sand at the bases of the two dams was observed (Figure 23) and the second horizon at Pit 007 contained loose sand.



Figure 23: Photograph showing sand deposited at the base of the southern dam, October 2009. Source: Field data.

5.4 Uses of Chassa Dambo

The information obtained from the respondents show that some respondents had multiple uses of the dambo. The uses of the dambo included cultivation of crops, growing of vegetables, fishing, source of water for drinking and irrigation, obtaining grass for thatching and grazing of domesticated animals. The findings show that 58.8% used it as a source of vegetables and fish and 36.3% of the respondents used it to catch fish for sale and consumption. The respondents who used the dambo for the cultivation of crops were at 25% and those who used it to grow vegetables for sale were at 28.8%. However, 75% of the respondents used the dambo as a source of water (Figure 24).



Figure 24: Photograph showing a shallow well in Nthongole area, October 2009. Source: Field data.

5.5 Agriculture in the Study Area

Subsistence farming is predominant in the study area. Larger areas have been cleared to pave way for farming. Figure 4, shows areas where mechanised farming had taken place and scattered cultivation was widespread. Tables 2 and 3, show that crop fields increased from 25.14% in 1990 to 50.85% in 2009. Commercial farming in the upland areas and the dambo itself started in the early 1990s.

In terms of economic benefits, about 100 people were employed during the planting, weeding and harvesting periods. Herbicides, fertilizers and pesticides were used. The harvested wheat and maize were sold in Lusaka and US \$ 300,000 turnover per year was realised from the sales.

CHAPTER SIX: DISCUSSION

6.1 Introduction

In this chapter, findings are discussed in relation to available literature. The focus was to ascertain whether the human activities taking place in Chassa dambo and the upland areas have had a negative effect on the physical characteristics of the dambo with respect to the geomorphology, morphology, soils, hydrology, ecology and vegetation cover in the study area.

6.2 Classification of Chassa Dambo

Chassa dambo has characteristics of both a stream dambo and a hydromorphic or phreatic dambo. Stream dambos occur adjacent to streams (Bell and Roberts, 1991). Chassa dambo occurs adjacent to Kapoche, Kasansa, Kafunde and Chassa streams. The dambo is also Hydromorphic or phreatic as the sources of water are both from precipitation and underground water. The portion of the dambo from Nthongole area is as a result of an underground stream that flows from a height of 1120 metres. The water from the streams meets along the lowest part of the area at 1060 metres above sea level creating a marsh with abundant water throughout the year. The dambo is an intermediate type because the vegetation is a mixture of plant and sedge species (Shimada, 1992).

Furthermore, the pH levels in the majority of Chassa dambo soils sampled are in the range 4.2-5.5 and a few in the 5.5-6.5 pH range. This shows that Chassa dambo is a mixture of sour and intermediate types based on pH classification.

6.3 Physical Characteristics of Chassa Dambo and Effects of Human Activities

6.3.1 Geomorphology

Heyden (2004) stated that the favourable conditions for the formation of dambos are plateau surfaces with gentle relief that results in low energy surface runoff that enables water infiltration. These conditions can be said to be correct in the case of Chassa dambo. However, the geomorphology of the main dambo has been altered by the erection of dam walls across the dambo which have led to the change in the relief of the dambo.

6.3.2 Morphology of Chassa Dambo

The morphology of dambos is influenced by physical characteristics such as topography, geological structure and the availability of either surface or underground water. Shimada (1992) points out that Acres et al. (1985) stated that dambo morphology was principally controlled by the gradient of the water table in the seepage zone at the edge of the dambo relative to the longitudinal gradient of the dambo and the geological structure. The morphology of Chassa dambo is mainly controlled by topography and the gradient of the water table (Figure 3). The figure shows that both surface and underground water flowed from areas of higher altitude of 1120 m to the area with the lowest altitude of 1060m. However, Figure 4 shows that the morphology of Chassa dambo was not only controlled by physical characteristics but also by human activities.

The creation of dams, dam walls and the draining of the middle dambo had distorted the morphology of the main dambo. The original shape of the dambo had changed as some of its portions had dried up while others had been flooded due to damming. Dambo characteristics remained in areas where the impact of human activities has been minimal.

6.3.3 Chassa Dambo Soils

Bell and Roberts (1991) state that dambo soils represent the lower segment of tropical catenary sequence and that in situ decomposition of grass and sedge vegetation under seasonally oxygen deficient conditions lead to a build up of organic matter and the creation of hydromorphic, sometimes peaty conditions.

The results of soil analysis showed that the presence of silty clay was found in Pits 005,006, 007 and 008. Therefore, the presence of silty clay is an indication that there is in situ decomposition of grass and sedge in the dambo. The main physical properties observed included sandy clay loam and sandy clay to clay subsurface soils.

Though one would have expected the dambo to have soil pH between 5.5 and 6.5 as it was located in a medium rainfall region as classified by Shimada 1992, the pH values showed that the soils were extremely acidic to slightly acidic with the pH values ranging from 4.0 to 6.6. The acidity of the soils could be attributed to: (i) the removal of vegetation; (ii) harvest and export of biomass thereby removing the bases

stored in the vegetation; (iii) the use of Ammonium containing fertilizers such as Urea; and (iv) the annual burning of the dambos.

The detailed chemical analysis of Chassa dambo soils showed signs of fertility having declined in some pits while certain profiles had an accumulation of nutrients which could be attributed to chemical fertilisers and lime. Notable, were the high levels of nutrients in Pit 001, 005, 006, 007 and 008.

The high levels of nutrients in the lower horizons were attributed to the failure by crops to take up nutrients and sedimentation. This phenomenon is plausible as maize and wheat which are shallow rooted crops were grown in the middle dambo.

The content of the organic carbon in all the soil profiles was below the critical value of 1.58% and in some cases, less than 0.01%. The phenomenon is an indication of soil fertility decline which entails that there is deterioration of physical, chemical and biological properties. The lowering of soil organic matter in the soil leads to degradation of physical properties including; reduced water holding capacity, reduced nutrient retention capacity (Cation Exchange Capacity) and base saturation. Organic carbon is associated with the formation of stable complexes with metals such as copper, iron, manganese and zinc and it is in this form that the nutrients are made available to the plants.

Nitrogen essentially stimulates microbiological activity. The results in Appendix D show that Chassa dambo soils had nitrate content that was less than the critical level

of 0.10% and in some cases the content was below 0.01%. However, only the soils from the top layers of Pits 006 and 008 contained 0.12% of nitrates. The source of the high content of nitrates was chemical fertiliser used in maize farming and washed down to the lower dambo during the rain season.

Degradation of soils due to its acidity results in a complex change in the soil such as the increase in toxic levels of Aluminium and Manganese, inhibition of microbial processes, reduction of the cation exchange capacity, reduced availability of soil phosphorus reserves and diminished solubility of Molybdenum and boron. The findings showed that the levels of Manganese in some pits were as high as 403mg/kg and the critical value is 50mg/kg. The phosphorous level whose critical value is 15mg/kg was as low as 7mg/kg.

The concern therefore would be that the toxic levels of manganese as was the case in Pit 007 dug at the base of the northern dam could have adverse effects on the ecosystem comprising birds, animals, fish and other organisms.

6.3.4 Hydrology of Chassa Dambo

The literature review showed that scholars have had divergent views on the role of dambos in the hydrology of an area. Some scholars argued that dambos act like ‘sponges’ that soak up rain water during the rainy season and slowly releasing it during the dry season (Heyden and New, 2003) while others have argued that dambo wetlands have no effect on catchment yields or characteristics of both dry season

flows and storm flows (Mazvimari, 1994). Thus, Dixon (2003) points out that the process behind the ecohydrological functioning of dambos remains ambiguous.

Essentially, the functions of Chassa dambo would be likened to what has been stated by Bell and Roberts (1991) that the dambo catchment acts as a hydrological reservoir, storing water in the rainy season and releasing it through evapotranspiration and as base-flow in the dry season. Heyden and New (2003) point out that augmentation (increase) of dry season flow is primarily a function of groundwater recharge. They further state that stormflow is attenuated (reduced) during the early wet season through soil infiltration and dambo filling while later in the wet season, the dambo has little influence on storm flow due to marked soil wetting and decreased infiltration.

The hydrological functioning of Chassa dambo can include: (i) the dambo acting as a reservoir or indeed a “sponge” as it received water from surface run off, streams and underground sources and the water was stored in the lower dambo (marsh); (ii) at the beginning of the rainy season, infiltration of water into the soil was highest as the soils were dry; (iii) infiltration of water recharged the aquifer; (iv) during the middle rainy season, the baseflow and the surface runoff contributed to the dambo outflow as the aquifer would have been recharged; (v) in the dry season, the underground aquifer discharged water as dambo outflow through the outlet; and the water released through the outlet becomes the source of Kapoche stream.

However, the hydrological function of Chassa dambo has changed due to: (i) the construction of the dams and the dam walls; (ii) water diversion from the main middle dambo; (iii) draining or pumping of water from the lower dambo; (iv) compaction of soil in the middle and lower dambo ; and clearing of vegetation.

These changes can have the following effects:

- i. At the beginning of the rainy season, surface runoff accelerated due to lack of vegetation and soil infiltration was slower;
- ii. Soil infiltration in the middle and lower dambo reduced due to soil compaction;
- iii. In the dry season the water discharged from the dambo was mainly from the underground aquifers;
- iv. The dambo outflow greatly reduced due to damming, diversion; and
- v. Transpiration levels remained relatively lower during the dry season as a result of scanty vegetation but evaporation was higher on the dam surfaces and irrigated fields.

Therefore, exposure of bare land to intense heat, damming of water and irrigation are believed to have led to high evaporation thus, lowering the water table and reduction of downstream water flow.

6.3.5 Ecological Status of Chassa Dambo

Chassa dambo ideally provides conditions for organisms to thrive. The miombo woodland in the upland area, the grass in the middle and lower dambo and the

availability of water and moisture are ideal conditions for organisms to grow, feed, develop and reproduce. As reported by respondents, the dambo had in the past attracted small animals such as rabbits, waterbucks and impalas. The dambo also had an abundant bird life and fish. It was an ideal grazing ground for domesticated animals especially during the dry season and during the years of drought. The communities being part of the ecosystem benefited from the dambo as they were able to catch animals, fish and birds for consumption. They were also able to grow crops and harvest wild fruits such as *masuku* and as such, the communities benefited significantly from the dambo.

However, clearing of trees mainly for cultivation led to the destruction of animal habitat. As the local population grew, there was more demand for land thus clearing of vegetation in the upland areas of the dambo. Clearing of not only the upland areas but also the middle dambo occurred when commercial farming in the main dambo commenced in the early 1990s. The indiscriminate cutting down of trees also led to the destruction of trees that produced edible fruits for humans, birds and other wildlife.

In addition, exposure of bare land to elements (rain wind and heat) led to the loss of moisture in the soil consequently destroying certain organisms. Draining of the dambo and irrigation led to reduced water levels which resulted in reduced numbers of fish. Reduced outflow from the dambo also has adverse effects on aquatic organisms downstream and the availability of water for both humans and domesticated animals is also affected.

Respondents from Chisamba and Mnendwe villages said that the use of herbicides and pesticides in the wheat and maize fields led to the death of birds and other organisms with possible health effects on people who consumed the birds. As most pesticides are not biodegradable, Chenje and Johnson (1996) state that pesticides persist for a long time in the environment and are absorbed into living organisms and accumulate along the food chain. They state that pesticides do not only kill fish, birds and small animals but also affect their reproductive system. Pesticides and fertilizers washed down to the lower dambo through rain water have certainly had negative effects on organisms.

Chenje and Johnson (1996) also point out that the high levels of nitrates in drinking water can cause miscarriages and blood poisoning in young children. Though the soil samples generally had nitrate levels that were below the critical level, there is a possibility of increased levels of nitrates with the continued use of chemical fertilisers. The fish in Chassa dambo can have high levels of pesticides which in turn would affect organisms including people.

6.3.6 Changes in Vegetation and Land Cover Classes (1990 and 2009)

The results of a comparison of the satellite imagery of the study area (Figure 19 and 20) between 1990 and 2009; and the results in Table 2 and 3 show significant changes in the land cover by extent. The changes are mainly attributed to human activities such as tree felling, burning, farming, damming and draining of water through canals.

Table 4 shows that there were major changes in the land cover classes. Notable were: (i) dense vegetation remaining at 6.82% in 2009 and 93.18% having changed to other land cover classes of which 38.64% changed to bare ground, crop fields and water collectively; (ii) the water that was available in the area 1990 having changed to other land cover classes by 100% in 2009; (iii) only 4.72% of the sparse vegetation remaining in 2009 and 95.28% having changed to other land cover classes of which 71.63% was lost to bare ground, crop field and water; (iv) of the grassland in 1990, 9.49% remained in 2009 and 90.51% had changed to other land cover classes of which 42.91% was changed to crop field; and (v) the wetland having changed to other land cover classes of which 73.42% changed to grassland and 18.44% changed to crop fields.

What has been outlined above indicates that the vegetation in the study area has been altered mainly due to human activities. The change in land cover class of the wetland by 100% also shows that the dambo wetland characteristics and functions are being lost. The loss in the wetland can be attributed to both subsistence and commercial farming in the dambo. The diversion of water and draining of the main dambo is the major reason for the 73.42% of the wetland changing to grassland.

6.4 Degradation of Chassa Dambo

Generally, Chassa dambo has been degraded in that its environment has deteriorated through depletion of resources such as vegetation, soil and water. Mayhew (2015) defined land degradation as the long term loss of ecosystem function and productivity caused by disturbances from which the land cannot recover unaided.

Mackel (1986) points out that the impact of humans on dambos is mainly through cattle grazing, cultivation, fire and tree felling. Subsistent farming taking in the upland areas contributes to sheet wash in to the dambo areas. Commercial farming of wheat and maize that was taking place in the main dambo led to irrigation, damming, ploughing and draining of the dambo. In this regard, Shimada (1992) pointed out that intense land use of the dambo wetlands by commercial farmers in Zimbabwe led to gully erosion and desiccation. He explained that prolonged cultivation of wheat and other commercial crops, ploughing across the central part of the dambo itself and the excavation of ditches along the central axes of the dambo wetland for draining, all led to the deterioration of the dambo environment. Dixon (2003:26) observed that dambo degradation as a result of either overgrazing or intensive cultivation is characterised by: (i) a lowering of the water table; (ii) a reduction of surface vegetation leading to exposure of bare soil; (iii) increased evapotranspiration; (iv) erosion and gully formation; (v) the reduction of organic matter and loss of fertility; and (vi) the desiccation of soils.

These observations in the literature are consistent with the findings of this study. The observations include; (i) the respondents at Chassa Secondary School complaining of reduced flow of water through the dambo outlet making their gardens drier; (ii) the dambo soils were exposed to elements as a result of clearing and burning of the dambo; (iii) there was an increase in evapotranspiration on the dam surfaces and the irrigated fields; and (iv) the soils had reduced organic matter and had lost fertility as indicated by the chemical analytical results obtained.

Sedimentation was observed at the bases of the dams (Pit 001 and Pit 007) and the second and third soil profiles of Pit 008. The sandy soil was weak in Pit 007, an indication that the sand had been deposited at the base of the dam. The fact that the other layers contained clay also shows that the sand was brought to the dam through erosion from the upland areas that had been cleared mainly for cultivation.

The second and third profiles of Pit 008 contained sandy loam and sandy clay loam, respectively. This phenomenon could be attributed to sedimentation as most of the upland areas had been cleared for cultivation. The change in the composition of the soil could lead to changes in vegetation. This is supported by Shimada (1992) who observed that increased sheet wash inside a dambo leads to increased sedimentation of sandy soil in the centre, which in turn causes change in the composition and coverage of its vegetation.

The continued utilisation of the dambo without regard for conservation can lead irreversible degradation and desiccation. Roberts (1988) states that dambo ecosystems are fertile but also fragile where their utilisation is intense. He further argues that much as late dry season burning in dambos is used to encourage regrowth of new and palatable grass, burning is said to lower the water tables and has a deleterious effect on soil nutrient budgets and if over frequent, kill valuable plant species. Chidumayo (1992) adds to state that the desertification of dambos mark the end of the productive, economic and ecological life of dambo ecosystems.

6.5 Sustainable Use of Chassa Dambo

The Department of Water Development through the Water Board has powers to control the use of water in public streams even when such a stream passes through private property. There is need to ascertain the usage of the dambo and possibly reverse the effects of human activities in the area. This can be done by relevant Government Departments who can work closely with local leaders. Therefore, the dambo can be used in a sustainable manner by adopting measures such as: (i) prohibiting damming and draining of dambos; (ii) prohibiting the indiscriminate cutting of trees in the dambo catchment; (iii) restoring the vegetation and the natural flow of water in the dambo; (iv) promoting agro-forestry and other land conservation methods in the upland areas of the dambo system in order to reduce surface runoff and erosion; (v) minimising the use of chemical fertilisers and encourage the use of compost manure in farming; (vi) encouraging dambo cultivation that involves minimum tillage; (vii) prohibiting burning of dambos and the upland areas; and (viii) limiting irrigation to the use of treadle pumps and buckets.

CHAPTER SEVEN: SUMMARY, CONCLUSION AND RECOMMENDATIONS

7.1 Summary

Chassa dambo as an ecosystem supported organisms including communities around it. Small animals, fish, birds and other organisms thrived and the communities used it as a source of water, fish, fruits and grazing for domesticated animals. However, population growth and demand for arable land led to the degradation of the dambo. The situation was exacerbated by the introduction of commercial farming in the upland areas and the middle dambo. Commercial farming led to; clearing of upland areas, canalisation, draining of the middle and lower dambo and damming.

The human activities have thus degraded the dambo. The soil was found to be acidic and had lost its fertility with very low levels of organic carbon. An accumulation of minerals such as manganese and calcium was observed as a result of the application of fertilisers and lime in the maize and wheat fields. The accumulation of minerals could have adverse effects on the biodiversity of the area. The herbicides and pesticides also posed a danger to biodiversity including human beings. These activities in the dambo have resulted in reduced quantities of water thus, negatively affecting biodiversity in the dambo and downstream areas.

The analysis of the satellite imagery for 1990 and 2009 shows that the entire wetland had changed to other land cover classes thus the dambo is losing its wetland characteristics and functions.

7.2 Conclusion

Based on the study findings, it is concluded that the physical characteristics of Chassa dambo have been adversely affected by human activities. The dambo geomorphology and morphology has also been distorted due to the creation of dams, dam walls and artificial drainage lines. Hydrologically, Chassa dambo has deteriorated due to reduced soil moisture and increased surface runoff. The ecology of the dambo has been degraded due to vegetation clearing and draining of the water from the lower dambo. A larger percentage of the land cover classes had been changed to crop land. The soil fertility greatly reduced due to its acidity with the pH values ranging from 4.0 to 6.6. The results of the chemical analysis of the soils exhibited characteristics of declining soil fertility. Some soil samples showed that there was an accumulation of nutrients due to the use of chemical fertilisers and lime. The carbon content in all the soil profiles was below the critical value, a sign of degradation of the soils. The soil acidity and the toxic levels of some elements pose a danger to the ecosystem comprising of birds, animals, fish and human beings.

Overall, the findings revealed that human activities have led to the degradation of Chassa dambo. The soil characteristics and the data on land cover classes provided, will act as baseline for future studies on the dynamics of Chassa dambo. The observed changes on Chassa dambo suggest the need for legislation for the protection and sustainable use of dambos for the benefit of local communities.

7.3 Recommendations

It is necessary that relevant Government institutions such as Ministry of Lands and Environmental Protection and the Ministry of Energy and Water Development should consider the development of policy and legislation to protect wetlands as a priority. The following recommendations have been made in the interest of sustainable utilisation of Chassa dambo in particular:

1. The dambo be made accessible to the community for their use;
2. Farming near the central parts of the dambo be prohibited as the hydrological and ecological damage can be irreversible;
3. Damming of the dambo should be prohibited as this leads to dambo desiccation and destruction of the fragile ecosystems;
4. Cutting of trees in the upland areas of the dambo be prohibited in order to protect the catchment;
5. Conservation techniques in the use of the dambo be mandatory;
6. Dambo cultivation be allowed provided ridges and furrows separated by grass strips are used to reduce runoff and soil erosion;
7. Irrigation by use of buckets or treadle pumps should be allowed and monitored;
8. Government should finalise the wetland policy and formulate Legislation on the use of wetlands including dambos; and
9. Environmental audits of all major economic activities in dambo areas be conducted to assess the environmental impacts.

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APPENDIX

APPENDIX A: QUESTIONNAIRE

Age Sex:
Name of Village: Ethnic Group:
Marital Status: Occupation:
Family Size: Education Level:

1. How do you view the Chassa dambo?

(a) An important resource ☐

(b) A valueless resource ☐

(c) I don't know ☐

2. Do you benefit from the dambo?

Yes ☐ No ☐

3. If yes, how (tick as many as possible)

(a) Cultivation of crops ☐

(b) Growing vegetables for sale ☐

(c) Fishing ☐

(d) Grazing ☐

(e) Grass for thatching ☐

(f) Clay for brick making, building & earthenware ☐

(g) Source of water ☐

(h) Buy vegetables and fish from the dambo. ☐

4. What changes have taken place at the dambo margins?

- (a) Clearing land for cultivation ☐
- (b) Excessive burning ☐
- (c) Clearing of land for settlements ☐
- (d) I don't know ☐

5. In what ways has commercial farming in the dambo negatively affected the communities?

- (a) Loss of settlements ☐
- (b) Loss of arable land due to flooding ☐
- (c) Loss of gardens because the land has dried up ☐
- (d) Submerging of the historical place (grave yard) ☐
- (e) Loss of grazing land ☐
- (f) Wells easily dry up in the dry season ☐
- (g) Any other (specify) ☐

6. Have you been negatively affected by the canalling of the dambo as an individual?

Yes ☐ No ☐

7. If yes, how? (Tick as many as possible)

- (a) Loss of my home due to flooding ☐
- (b) Loss of my field due to flooding ☐
- (c) Drying up of my garden ☐
- (d) Loss of grazing land ☐

8. Has access to dambo resources been restricted as a result of part privatization of the dambo?

Yes ☐ No ☐

If yes, how?

9. Have the numbers of fish reduced as a result of commercial farming?

Yes ☐ No ☐

10. Have you benefited from the commercial farming taking place in the dambo areas?

Yes ☐ No ☐

11. If yes, how?

- (a) Employed ☐
- (b) My business has improved because more people have money in their pockets ☐
- (c) It is a cheaper source of food ☐

12. Have you ever heard of sustainable use of natural resources?

Yes ☐

No ☐

13. If yes, from where? (Tick as many as possible)

(a) Radio ☐

(b) Television ☐

(c) At school ☐

(d) Newspaper ☐

(e) Any other (specify)

.....

.....

14. What does sustainable use of resources mean to you?

.....

.....

15. Do you think that the dambo needs to be protected in order to avoid degradation?

Yes ☐

No ☐

I don't Know ☐

16. If yes to question 15, how?

.....

.....

17. Has there been any one from government or NGOs who has come to the area to talk about:

- | | | | | | |
|-----|-------------------------|-----|--------------------------|----|--------------------------|
| (a) | Conservation of soils | Yes | ☐ | No | ☐ |
| (b) | Conservation of forests | Yes | ☐ | No | ☐ |
| (c) | Better farming methods | Yes | ☐ | No | ☐ |
| (d) | Protection of dambo | Yes | ☐ | No | ☐ |

18. Do you have any suggestions on how the Dambo should be conserved?

.....
.....
.....

Thank You

End of questionnaire

APPENDIX B: OBSERVED PHYSICAL CHARACTERISTICS OF CHASSA DAMBO SOILS

Soil Pit No. 1; Profile No. EP/09/001

Location: Chassa Dambo – Sinda District; Eastings: 031°44.762'; Southings: 14°16.157'; Elevation: 3519Ft. **Classification:** Physiography: Degraded central African Plateau; Slope: 2% (simple lower slope); Drainage: Poorly drained; Permeability: Very slow; Vegetation: Grassland dambo; Parent Material: Alluvial; Soil depth: Deep soils; Agro-ecological Zone: II; Moisture condition: dry, moist; Water erosion on site: No appreciable erosion.

Soil profile description of Pit 001

Horizon	Depth(cm)	Description
Ah	0 - 7	Very dark gray (2.5YR3/0) moist and Gray (5YR4/1) dry, fine, sandy clay loam; Moderate, medium, sub-angular blocky and breaking into moderate, medium, sub- angular blocky; Soft dry, friable moist, slightly sticky, slightly plastic; Unspecified, moderately weakly cemented, discontinuous over 1m; Many fine, random, few, medium, vertical roots; highly porous, many, very fine, interstitial, common, fine, inped, vesicular, common medium expd tubular pores; 30% fine gritty fragments; Clear smooth boundary.
BA	7 - 18	Very dark gray (5YR 3/1) moist and gray (5YR 5/1) dry, fine, sandy clay loam; Weak, medium, sub-angular blocky breaking into weak, coarse, crumb; Loose dry, loose moist, non sticky wet, non plastic; Unspecified, weakly cemented, discontinuous over 1m; Common, medium, unfilled, krotovinas, partly filled soil material, irregular other animal holes, in local concentrations; Many, fine random, few, medium vertical roots; highly porous, many, very fine, inped, common, fine inped, vesicular, many, medium, expd, tubular pores; 80% coarse gritty fragments; Diffuse, wavy boundary.
Btvs	18- 60	Gray (5YR 5/1) moist and dark gray (5YR4/1) dry, coarse, sandy clay; Many, coarse, prominent, clear reddish yellow (7.5 YR 6/8) mottles, rusty root channels, both interior/exterior of peds; Strong, medium, prismatic, breaking into strong, coarse, sub-angular blocky; Very hard dry, friable moist, sticky wet, plastic; Unspecified, cemented, discontinuous over 1m; Many, prominent, thick, dark gray (5YR 4/1) clay skins, in root channels, both horizontal and vertical ped faces; Many, coarse, irregular clay sheets, throughout horizon; Many, fine random, common, medium, oblique roots; Slightly porous, many, very fine, inped, interstitial, common, fine, inped, vesicular pores; 50% fine gritty fragments; Smooth boundary.
Btv	60 -100	Dark gray (2.5YR 4/0) moist and gray (2.5 YR 5/0) dry, coarse clay; Strong, medium, sub-angular blocky breaking into moderate, coarse, sub-angular blocky; Very hard dry, very firm moist, very sticky wet, plastic; Unspecified, cemented, discontinuous over 1m; Many, distinct, thick, gray (2.5YR 5/0) clay skins, both horizontal and vertical ped faces, many, coarse, irregular, clay sheets throughout horizon; Many, fine, random roots; slightly porous, many, very fine, inped, interstitial, common, fine, inped, vesicular pores; 60% coarse gritty fragments; abrupt, smooth boundary.

Described by: M.J. Malambo and Khadija Mvula; Date sampled: November, 2009.

Soil Pit No. 2; Profile No. EP/09002

Location: Chassa Dambo – Sinda District; Eastings: 031°44.987'; Southings: 14°16.075'; Elevation: 3544Ft.

Classification: Physiography: Degraded Central African Plateau; Slope: 2% (simple – lower slope); Drainage: Moderately well drained; Permeability: medium; Parent material: Alluvial; Vegetation: Grassland dambo; Soil depth: deep soils; Agro-ecological zone: II; Water soil erosion on site: No appreciable erosion.

Soil profile description of Pit 002

Horizon	Depth(cm)	Description
Ah	0 -13	Very dark gray (7.5YR3/0) moist and dark Gray (7.5YR4/0) dry, very fine, silt loam; Moderate, fine, sub-angular blocky breaking into moderate, medium, sub-angular blocky; Moderate, hard dry, friable moist, slightly sticky, slightly plastic; Few, fine, lined, irregular termite holes, in local concentrations; Many, medium, unfilled, partly filled soil material, irregular other insect holes, in local concentration; Many, fine, random, common, medium, both vertical and horizontal roots; Highly porous, many, fine, inped, interstitial, common, medium, inped, interstitial pores; Clear, smooth boundary.
BAh	13–29	Pale brown (10YR 6/3) moist and light gray (10YR 7/2) dry, fine, sandy loam; Weak, fine, sub-angular blocky breaking into moderate, medium, angular blocky; Slightly hard dry, very friable moist, non sticky wet, non plastic; Few, fine, lined, irregular other insect holes, in local concentrations; Many, fine, random, common, medium, oblique roots; Highly porous, many, fine, inped, interstitial, many, medium, exped, interstitial, common, coarse, exped, tubular roots; Clear, smooth boundary.
Bi	29–64	Very pale brown (10YR 8/3) moist and white (10YR 8/2) dry, fine, sandy loam; Weak, fine, sub-angular blocky breaking into weak, medium, crumb; Soft dry, very friable moist, non sticky wet, non plastic; many, fine, random, few, medium, vertical roots; Highly porous, many, fine, inped, interstitial, many, medium, exped, interstitial pores; 30% fine gravelly fragments; clear, smooth boundary.
Biz	64–100	Very pale brown (10YR7/4) moist and very pale brown (10YR8/3) dry, fine, sand; Weak, fine sub-angular blocky breaking into weak, medium, crumb; Loose dry, loose moist, non sticky wet, non plastic; Sesquioxides (Fe, Al, Mn), cemented, local discontinuous, common, coarse, irregular, strong brown (7.5YR5/8) iron-manganese concretions, in local concentrations; Few, medium, unfilled, irregular other insect holes, in local concentrations; Common, fine, random roots; Highly porous, many, fine, inped, interstitial, many, medium, exped, interstitial pores; 50% fine gravelly fragments; clear, smooth boundary.

Described by: M.J. Malambo and Khadija Mvula; Date sampled: November, 2009

Soil Pit No. 3, Profile No. EP/09/003

Location: Chassa Dambo – Sinda District, Eastings: 031°44.477', Southings: 14°15.869', Elevation: 3523 Ft.

Classification: Physiography: Degraded Central African Plateau, Slope: 1.5% (simple – middle slope); Drainage: well drained; Permeability: Rapid; Vegetation: Grassland dambo; Parent material: undifferentiated; Soil depth: deep soils; Moisture condition: Dry; Water soil erosion on site: No appreciable erosion.

Soil profile description of Pit 003

Horizon	Depth(cm)	Description
Ah	0 – 17	Very dark gray (7.5YR3/0) dry and gray (5YR 5/1) moist, fine, sandy clay loam; Moderate, fine, sub-angular blocky breaking into moderate, medium, sub-angular blocky; Moderately hard dry, friable moist, slightly Sticky wet, non plastic; Many, fine, random, common, medium, both horizontal and vertical roots; Highly porous, many, fine, inped, interstitial pores; Clear, smooth boundary.
Bah	17–30	Dark gray (10YR4/1) dry and gray (10YR5/1) moist, fine, sandy clay; Moderate, fine, sub-angular blocky breaking into moderate, medium, sub-angular blocky; Slightly hard dry, Very friable moist, slightly sticky wet, non Plastic; Common, medium, partly filled soil material, termite holes in local concentration, irregular other insect holes, unfilled, partly filled soil material, common, medium, in local concentrations, irregular; Many, fine, random, common, medium, random roots; Highly porous, many, fine, inped, interstitial, common, medium, exped, interstitial; Clear, smooth boundary.
Bi	30–69	Light gray (10YR7/2) dry and light brownish gray (10YR6/2) moist, coarse, sandy loam; Moderate, fine, angular blocky breaking into weak, medium, granular; Soft dry, loose moist, non sticky wet, non plastic; Strongly cemented sesquioxides (Fe, Al, Mn), local discontinuous; Reddish yellow (7.5YR6/8) iron-manganese , concretions, medium, local concentrations irregular; Few, medium other insect holes, unfilled, partly filled soil material, in local concentrations, irregular, ellipsoidal; many, fine, random, few, medium, random, both vertical and horizontal; Highly porous, many, fine, inped, interstitial, few, medium, exped, interstitial pores; Clear, smooth boundary.
Bc	69-100	White (5YR8/1) dry and light gray (10YR7/2) moist, coarse, sand; Weak, fine, angular blocky breaking into weak, medium, granular; Loose dry, loose moist, non sticky wet, non plastic; Common, fine, random roots; Highly porous, many, fine, inped, interstitial pores; Clear, smooth boundary.

Described by: M.J. Malambo and Khadija Mvula; Date sampled: November, 2009

Soil Pit No. 4, Profile No. EP/09/004

Location: Chassa dambo – Sinda District, Eastings: 031°44.906', Southings: 14°14.721', Elevation: 3521Feet.

Classification: Physiography: Degraded Central African Plateau; Slope: 2% (simple – middle slope); Drainage: Well drained; Permeability: rapid; Vegetation: Grassland – Dambo; Parent Material: Undifferentiated; Soil depth: deep soils; Moisture condition: Dry; Water soil erosion on site: No appreciable erosion.

Soil profile description of Pit 004

Horizon	Depth(cm)	Description
Ah	0 – 15	Dark grayish brown (10YR4/2) moist and grayish brown (10YR5/2) dry, very fine, sandy clay loam; Moderate, medium, sub-angular blocky breaking into weak, very fine, sub-angular blocky; Slightly hard dry, friable moist, slightly sticky wet, slightly plastic; Common, medium, unfilled, partly filled soil material, irregular other insect holes, in local concentrations; Many, fine, random, few, medium, random roots; Highly porous, many, fine, inped, interstitial, common, medium, exped, interstitial, common, medium, exped, interstitial pores; 20% fine gritty fragments; Clear, smooth boundary.
BA	15 – 44	Reddish brown (5YR4/3) moist and brown (10YR5/3) dry, dry, very fine, sandy clay loam; Moderate, medium, sub-angular blocky breaking into weak, very fine, sub-angular blocky; Slightly hard dry, friable moist, slightly sticky wet, slightly plastic; Common, medium, unfilled, partly filled, soil material, irregular other insect holes in local concentrations, few, coarse, partly filled soil, material, irregular other animal holes in local concentrations; Many, fine, random, few, medium, vertical roots; Highly porous, many, fine, inped, interstitial, many, medium, exped, tubular pores; 30% fine gritty fragments; clear, wavy boundary
Bc	44 – 100	Light olive brown (2.5Y5/6) moist and Olive yellow (2.5Y6/6) dry, dry, very fine, sandy clay; Moderate medium, sub-angular blocky breaking into weak, very fine, sub-angular blocky; Slightly hard dry, friable moist, sticky wet, plastic; Sesquioxides (Fe, Al, Mn), cemented, local discontinuous; many, coarse, strong brown (7.5YR5/8) irregular iron-Manganese concretion, throughout horizon; Many Medium, unfilled, partly filled soil material, Krotovinas, irregular other animal holes, in local concentrations; Many, fine, random, few, medium oblique roots; Highly porous, many, fine, inped, Interstitial, many, medium, exped, tubular pores; 40% coarse gritty fragments; Clear, smooth boundary.

Described by: M.J. Malambo and Khadija Mvula; Date sampled: November, 2009

Soil Pit No. 5, Profile No. EP/09/005

Location: Chassa dambo – Sinda District, Eastings: 031°45.054', Southings: 14°14.758', Elevation: 3524Ft.

Classification: Physiography: Degraded Central African Plateau; Slope: 1.5% (simple – lower slope); Drainage: Poorly drained; Permeability: slow; Vegetation: grassland – dambo; Parent material: Alluvial; Soil depth: moderately deep; Moisture condition: dry, moist; Water soil erosion on site: No appreciable erosion.

Soil profile description of Pit 005

Horizon	Depth(cm)	Description
Ahp	0 – 9	Dark gray (10YR4/1) moist and gray (5YR5/1) dry, Very fine, silty clay; Moderate, medium, sub-angular blocky breaking into moderate, fine, sub-angular blocky; Slightly hard dry, friable moist, slightly sticky wet, slightly plastic; Common, medium, partly filled soil material, irregular termite holes, in local concentrations, common, medium, unfilled, irregular other insect holes, in local concentration; Many, fine, random, few, medium, random roots; Moderately porous, many, fine, inped, interstitial pores; Clear Smooth boundary.
ABh	9 – 24	Dark gray (10YR4/1) moist and gray (5YR6/1) dry, fine, silty clay loam; Common, medium, clear, strong brown (7.5YR5/8) mottles, rusty root channels; Moderate, medium, sub-angular blocky breaking into weak, medium, angular blocky; Slightly hard dry, friable moist, slightly sticky wet, Slightly plastic; Common, medium, partly filled soil material, irregular termite holes, in local concentrations; Common, medium, spherical other insect holes, in local concentrations; Many, fine, random, few, medium, both horizontal and vertical roots; Moderately porous, many, fine, inped, interstitial, common, medium, exped, tubular pores; 10% fine gritty fragments; clear, Smooth boundary.
Bc	24–46	Light brownish gray (10YR6/2) moist and white (10YR8/1) dry, coarse, sand; many, medium, clear reddish yellow (7.5YR6/8) mottles, both interior exterior of peds; Weak, medium, sub-angular blocky breaking into weak, medium, angular blocky; Loose dry, loose moist, non sticky, non sticky, non plastic; Few, medium, unfilled, irregular other insect holes, in local concentrations; Many, fine, random roots; Moderately porous, many, fine, inped, interstitial; Many, medium, exped, tubular pores; 50% coarse gritty fragments; Clear, irregular boundary.
Bmc	46–100	Grayish brown (10YR5/2) moist, fine, sandy clay; Many, medium, sharp, strong brown (7.5YR5/6) mottles, both interior/exterior of peds; Strong, coarse, sub-angular blocky breaking into strong, medium, sub-angular blocky; Extremely hard dry, firm moist, very sticky wet, plastic; Unspecified strongly cemented, continuous over 1m; Many, coarse, unspecified accumulations, iron-manganese, throughout horizon; common fine, random, very few, medium, vertical roots; Slightly porous, many, fine, inped, interstitial pores; 40% coarse gritty fragments; Diffuse, abrupt boundary.

Described by: M.J. Malambo and Khadija Mvula; Date sampled: November, 2009

Soil Pit No. 6; Profile No. EP/09/006

Location: Chassa dambo – Sinda District, Eastings: 031°45.109', Southings: 14°14.757', Elevation: 3507Ft.

Classification: Physiography: Degraded Central African Plateau; Slope: 1.5% (simple-lower slope); Drainage: poorly drained; Permeability: very slow; Vegetation: grassland – dambo; Parent material: Alluvial; Soil depth: deep soils; Moisture condition: Moist; Water soil erosion on site: No appreciable erosion.

Soil profile description of Pit 006

Horizon	Depth(cm)	Description
Ah	0 – 14	Very dark gray (10YR3/1) moist, very fine, silty clay; Common, fine, distinct, clear yellowish Brown (10YR5/6) mottles, rusty root Channels; Moderate, medium, sub-angular blocky; Friable moist, slightly sticky wet, slightly sticky wet, slightly plastic; Few, fine, unfilled, spherical other insect holes in local concentrations; Many, fine, random, common, medium, random roots; Slightly porous, many, very fine, inped, interstitial common, fine, inped, interstitial pores; Clear, smooth boundary.
Bat	14 – 41	Gray (10YR5/1) moist, very fine, clay; Common, prominent, sharp strong brown (7.5YR5/8) mottles, both interior/exterior of peds; moderate, medium, sub-angular blocky; Friable moist, sticky wet, plastic; Common, distinct, moderately thick gray (10YR5/1) clay skins, both horizontal and vertical ped faces; Many, fine, vertical roots; Slightly porous, many, very fine, inped, interstitial pores; 30% fine gritty fragments; Gradual, wavy boundary.
Bt	41 – 95	Gray (10YR5/1) moist, fine, clay; Moderate medium sub-angular blocky; Friable moist, very sticky wet, plastic; many, prominent, thick gray (10YR5/1) clay skins, both Horizontal and vertical ped faces; Very few, distinct, thick white (5YR8/1) carbonate coats, both horizontal and vertical ped faces; Many, fine, vertical roots; Slightly porous, many, very fine, inped, interstitial pores; 40% coarse gritty fragments; Clear, smooth boundary.

Described by: M.J. Malambo and Khadija Mvula; Date sampled: November, 2009

Soils Pit No. 7, Profile No. EP/09/007

Location: Chassa Dambo – Sinda District, Eastings: 031°41.255', Southings: 14°13.624', Elevation: 3512Ft

Classification: Physiography; Degraded Central African Plateau; Slope: 2% (simple – lower slope); Drainage: Poorly drained; Permeability: slow; Vegetation: Grassland dambo; Parent Material: Alluvial; Soil depth: deep soils; Moisture condition: Dry, moist; Water soil erosion on site: No appreciable erosion

Soil profile description of Pit 007

Horizon	Depth (cm)	Description
Ah	0 – 23	Very dark gray (7.5YR3/0) moist and gray (10YR5/1) dry, very fine, silty clay; Few, medium, reddish yellow (7.5YR6/8) clear mottles, rusty root channels, moderate, medium, sub-angular blocky breaking into moderate, coarse, sub-angular blocky, slightly hard dry, friable moist, slightly sticky wet, non plastic; many, fine, unfilled, partly filled soil material; spherical, irregular other insect holes, throughout horizon; Many, fine, random, few, medium, random roots; moderately porous, many, fine, inped, interstitial common, medium, exped tubular pores; Clear, smooth boundary.
BAc	23 – 39	Dark grayish brown (7.5YR4/2) moist and grayish brown (10YR5/2) dry, coarse, sand; Weak, medium, crumb breaking into weak, coarse, crumb; Loose dry, loose moist, non sticky wet, non plastic; Many, fine, random, few, medium, vertical roots; Highly porous, many, fine, inped, interstitial common, medium, exped, interstitial pores; 80% coarse gritty fragments; Clear, wavy Boundary.
Bt1	39 – 67	Grayish brown (10YR5/2) moist and dry, fine, clay; Many, coarse, prominent, sharp, reddish yellow (7.5YR6/8) mottles, both interior/exterior of peds; Strong, medium, prismatic breaking into strong, coarse, columnar; Very hard dry, firm moist, sticky wet, plastic; Many, prominent, moderately thick clay skins, both horizontal and of ped faces; Many, coarse, irregular clay sheets, throughout horizon; Many, fine, random roots; Slightly porous, many, fine inped, interstitial pores; 30% coarse gritty fragments; Gradual, irregular boundary.
Bt2	67 – 100	Gray (5YR5/1) moist, fine, clay; many, coarse, prominent, sharp red (2.5YR4/8) mottles, both interior/exterior of peds; Strong, medium, sub-angular blocky breaking into moderate, Coarse, sub-angular blocky; Hard dry, friable moist, very sticky wet, plastic; Many, prominent moderately thick clay skins, both horizontal vertical ped faces; Many, coarse, irregular clay sheets, throughout horizon; Common, fine, random roots; Slightly porous, many fine, inped, interstitial pores; 30% coarse gritty fragments; Clear, smooth boundary.

Described by: M.J. Malambo and Khadija Mvula; Date sampled: November, 2009

Soil Pit No.8, Profile No. EP/09/008

Location: Chassa Dambo – Sinda District; Eastings: 031°42.842'; Southings: 14°13.882'; Elevation: 3639Ft.

Classification: Physiography: Degraded Central African Plateau; Slope: 2% (simple – middle slope); Drainage: Poorly drained (floods common); Permeability: medium; Vegetation: grassland – dambo; Parent material: Alluvial; Soil depth: Deep soils; Moisture condition: Dry, moist; Water soil erosion on site: No appreciable erosion.

Soil profile description of Pit 008

Horizon	Depth(cm)	Description
Ah	0 -12	Very dark gray (10YR3/1) moist and gray (10YR5/1) dry, very fine, silty clay; Moderate, medium, sub-angular blocky breaking into very fine, moderate, sub-angular blocky; slightly hard dry, friable moist, slightly sticky wet, non plastic; Many, fine, spherical, unfilled, partly filled soil material other insect holes, throughout horizon; Few, medium, distinct, clear yellowish brown (10YR5/8) mottles, rusty root channels; Many, fine random, common, both vertical and horizontal medium roots; Slightly porous, many, fine, inped, interstitial, common, medium, inped, interstitial pores; Clear, smooth boundary.
BAc	12 – 30	Dark gray (10YR4/1) moist and dry coarse, sandy loam; Weak, medium, sub-angular blocky breaking into weak, very fine, granular; Slightly hard dry, very friable moist, slightly sticky wet, non plastic; Common, fine, unfilled, spherical other insect holes, in local concentrations; Common, medium, unfilled, irregular other Insect holes, in local concentrations; Many, fine, random, common, medium, both vertical and horizontal, oblique pores, moderately porous, many, fine, inped, Interstitial, many, medium, inped, interstitial pores; Clear, wavy boundary.
Bcg	30 – 51	Grayish brown (10YR5/2) moist and dark grayish brown (10YR4/2) dry, coarse, sandy clay loam; Common, medium, distinct, clear strong brown (7.5YR5/8) mottles, rusty root channels; Weak, medium angular blocky breaking into weak, very fine, granular; slightly hard dry, very friable moist, slightly sticky wet, non plastic; few, medium, lined, spherical other insect holes, in local concentrations; Many, fine, both vertical and horizontal roots; Moderately porous, many, fine, inped, interstitial, common, medium, inped, interstitial pores; 50% coarse gritty fragments; Clear, smooth boundary.
Bgt	51 – 100	(10YR5/4) moist, fine, clay; Many, coarse, prominent, both Interior/exterior of peds, clear sharp Red (2.5YR4/8) mottles; moderate, medium Sub-angular blocky breaking into moderate Fine, sub-angular blocky; friable moist, Sticky wet, plastic; many, coarse, irregular, Clay sheets, throughout horizon; few, Medium, lined, spherical other insect holes, in local concentrations; many, fine, both Vertical and horizontal roots; slightly porous Many, fine, inped, interstitial pores; 10% Coarse gritty fragments; clear, smooth Boundary.

Described by: M.J. Malambo and Khadija Mvula; Date sampled: November, 2009

APPENDIX C: OBSERVED CHEMICAL CHARACTERISTICS OF CHASSA DAMBO SOILS

Soil Pit 001

Depth: 0-7cm

The top soil of the profile was medium acid and the pH value was 4.5. This was not good for crop growth and liming would be required to reduce the pH to a level suitable for crop growth. Plant nutritional disorders can develop at this pH value. The layer had 43mg/ kg and it was above the critical level of 15mg/kg. Calcium, magnesium and potassium were above the critical levels of 200, 50, and 40mg/kg respectively. This horizon had 418mg/kg of Calcium, 50mg/kg of magnesium and 124.8mg/kg of potassium. The Organic carbon levels were at 0.28 percent and this was below the critical level of 1.58 percent.

Depth: 7-18cm

The pH for this horizon was 4.3 and it was 1.25 times more acidic than the top horizon. The subsoil pH was not good for deep rooted crops. Deep lime application was necessary if one was contemplating on growing tree crops. The organic carbon levels were at 0.39 percent and higher than those in the previous horizon but 11mg/kg, lower than the levels in the previous horizon. Calcium, magnesium and potassium levels in this horizon were 211, 31 and 9.7 mg/kg respectively. The levels were lower than those in the previous horizon.

Depth: 18-60cm

In this horizon the pH was 5.7 indicating that the conditions were slightly acid. The calcium, magnesium and potassium levels were higher as compared to the first two horizons. The level of calcium was 1600mg/kg, the magnesium level was 310mg/kg and the potassium level was 90mg/kg. The organic carbon levels were 1.01 percent. Phosphorus levels were 9mg/kg and these were less compared to those in previous horizons.

Depth: 60-100cm

The pH was 6.0 and this horizon was slightly acidic. The levels of Phosphorous were 14.4 mg/kg and these levels were higher when compared to the two immediate horizons. The organic carbon levels were 0.36 percent. In the profile the subsoil was more acidic than the rest of the horizons.

Soil Pit 002

Depth: 0-13 cm

The top soil pH was 4.6 and could be classified as medium acidic. Liming would be required for any crop production because plant nutrition problems often develop at this pH value. The level of Phosphorous was 16 mg/kg and this was slightly above the critical level of 15 mg/kg. Phosphorus fertilizers are necessary to amend the low levels. The organic carbon and nitrate levels were 0.99 and 0.07 percent respectively. The levels of calcium, Magnesium and potassium were 466, 23 and 125.8mg/kg respectively. The level of Magnesium was below the critical level of 50 mg/kg as compared to calcium and potassium which was above the critical levels.

Depth: 13-29 cm

The sub-soil was slightly acidic with a pH value of 5.2. Such a value could not cause a problem. The magnesium levels were very low at 11mg/kg. The values of Calcium and Potassium were 118 and 83.9 mg/kg respectively. The levels of organic Carbon and Nitrogen were below 0.01. The Phosphorous level was 10 mg/kg.

Depth: 29-64 cm

The soil pH was 5.7. The calcium, Magnesium and Potassium levels were 60, 7 and 81.1 mg/kg respectively. Organic carbon was less than 0.01 percent. The phosphorus concentration was 7 mg/kg.

Depth: 64-100 cm

The pH was 5.8. The calcium, Magnesium and Potassium concentrations were 43, 13 and 82 mg/kg respectively. The phosphorus concentration was 9 mg/kg. The Organic carbon and Sodium were less than 0.01 percent. In the profile, the pH decreased to high values as you went deep into the profile. The concentration of Calcium also decreased as you went deep down the profile. For phosphorus, the levels decreased downwards until the last layer where there was a slight increase. The other notable feature was the low level of Carbon deep down the profile.

Soil Pit 003

Depth: 0-17 cm

The top soil had pH of 5.6 and this was favourable for crop growth and liming was not required. You do not expect the nutrient problems in this range. The levels of Calcium and Magnesium in the profile decreased as you went down the profile. The levels of Phosphorous were almost constant and the change was insignificant. The levels of Organic carbon in the first two layers were almost the same but with a slight difference. The last two layers had Organic carbon less than 0.01 percent. The levels of Potassium were fluctuating.

The Phosphorus level in the top soil was 9 mg/kg which was below the critical level of 15 mg/kg. This was inadequate for crop production. The level of Organic carbon in the top soil was 0.31 percent and below the critical level of 1.58 percent. Magnesium level was 49 mg/kg and was slightly below the critical level of 50 mg/kg. Calcium and Magnesium levels were 296 and 97.7 mg/kg which was higher than the critical levels (200 and 40 mg/kg, respectively).

Depth: 17-30 cm

The pH was 4.4, which is classified as medium acidic. This was of major concern for deep rooted crops and would therefore require remedial measures (i.e. liming). The level of calcium, Magnesium and Potassium were 245, 34 and 104 mg/kg. The level of Organic carbon was 0.49 percent. The level of Phosphorous was 8 mg/kg.

Depth: 30-69 cm

The soil pH was 4.9. The levels of Calcium, Magnesium and Potassium were 72, 19 and 93.6 mg/kg. These levels were far much less than those of the immediate top horizon. The phosphorus levels were 9 mg/kg and slightly more than those in the immediate top horizon. The Organic carbon was less than 0.01 percent which is far below the levels in the immediate top horizon.

Depth: 69-100 cm

The pH in this horizon was 5.6 which was less acidic than that of the previous horizon. The levels of Calcium, Magnesium and Potassium were 53, 7 and 93.6 mg/kg respectively and were at lower levels compared to the previous horizon. The level of Organic carbon was less than 0.01 % which was comparable to the immediate top horizon.

Soil Pit 004

Depth: 0-15 cm

The top soil had a pH of 4.8 and was classified as medium acidic. There was need to lime the soil if it was to support crop growth. Failure to lime would lead to nutrient unavailability. The calcium, Magnesium and Potassium levels were 134, 29 and 123 mg/kg, respectively. The calcium and Magnesium levels were below the critical levels. The level of Organic carbon was 0.37 percent which was below the critical level of 1.58 percent. The phosphorus level was 16 mg/kg which was 1 unit more than the critical level.

Depth: 15-44 cm

The pH of the horizon was 4.7. The level of Calcium, Magnesium and Potassium were 45, 16 and 103 mg/kg, respectively. The levels were far below those in the immediate top horizon. The Organic carbon levels were less than 0.01 percent. The phosphorus levels were 10 mg/kg and were less than those in the immediate top layer.

Depth: 44-88 cm

The pH in this horizon was 5.2 and the levels of Calcium, Magnesium and Potassium were 93, 57 and 128.2 mg/kg, respectively. The pH was slightly higher than in the previous horizons. The levels of Calcium, Magnesium and Potassium were higher than the immediate top horizon. The level of Organic carbon was 0.29 percent, which was higher than that of the previous top horizon. The phosphorus levels were 8 mg/kg and were lower than those of the previous top horizon.

NOTE: It was generally observed that the top and bottom horizons had higher nutrient levels relative to the middle layers.

Soil Pit 005

Depth: 0-9 cm

The top soil had a soil Ph of 4.9 and is classified as medium acidic. The levels of Calcium, Magnesium and Potassium were 257, 39 and 126.7 mg/kg, respectively. Calcium and Potassium levels were above the critical levels. Magnesium was however, far below the critical level. Phosphorus levels were 22 mg/kg, which was above the critical level required for crop growth. The Organic carbon level was 1.05 percent and was below the critical level.

Depth: 9-24 cm

The pH in the horizon was 4.7. Calcium, Magnesium and Potassium levels were 279, 51 and 98.8 mg/kg, respectively. The levels of Calcium and Magnesium were higher than those in the immediate top horizon (top soil). The Organic carbon levels were 0.36 percent which was slightly less than that in the previous horizon. The phosphorus levels were 9 mg/kg and were less than those in the immediate top horizon.

Depth: 24-46 cm

The pH was 4.9. Calcium, Magnesium and Potassium levels were 52, 25 and 86.9 mg/kg, respectively and were lower than those in the immediate top horizon. Organic carbon levels were 0.01 percent and the Phosphorous levels were 8 mg/kg.

Depth: 46-100 cm

The soil pH was 5.5. Calcium, Magnesium and Potassium levels were 522, 130 and 106.4 mg/kg. When compared to the above horizon, these levels were far much higher and it could be because of continued sedimentation or inability of the roots to take up these nutrients. The levels of Organic carbon were 0.61 percent and this was also higher compared to the previous horizon. The levels of Phosphorous on the other hand were the same (8 mg/kg) as in the above horizon.

Soil Pit 006

Depth: 0-14 cm

The pH of the top soil was 4.8 and would require liming to raise the pH to levels suitable for crop production. The levels of Calcium, Magnesium and Potassium were 850, 123 and 139.6 mg/kg, respectively and were above the critical levels. However at such low pH levels, the nutrients may not be available for crop uptake as they may form complexes with other compounds. The levels of Phosphorous were 20 mg/kg and were above the critical levels. Organic carbon was 1.51percent which was slightly less than the critical level of 1.58 percent.

Depth: 14-41 cm

The soil pH was 5.8. The Calcium, Magnesium and Potassium levels were 1450, 369 and 160 mg/kg. These levels were relatively higher to those in the top soil. This could be attributed to crop uptake which could result from the area having vegetation with shallow roots. A sharp decline was however recorded (from 1.51 to 0.01 percent) relative to the top soil. The levels of Phosphorous were 11 mg/kg.

Depth: 41-95 cm

The pH in the horizon was 6.6. The Calcium, Magnesium and Potassium levels were 1200mg/kg, 324 and 138.9mg/kg. These were slightly lower than those in the previous horizon. The Organic matter levels were 0.51whilst the Phosphorous levels were 12mg/kg almost at the same level with the previous horizon.

In this profile the pH values increased with depth of the profile. Calcium, Magnesium and Potassium levels were high in the subsoil as compared to other horizons.

Soil Pit 007

Depth: 0-23cm

The pH was 4.9 and is classified as a medium acidic. In terms of crop production, liming would be required. Nutritional disorders may occur at this pH level. The levels of Calcium, Magnesium and Potassium are 254, 58 and 106.7 mg/kg respectively. These levels were above the critical levels. Phosphorus concentration in the horizon was 10mg/kg and this was below the critical level of 15mg/kg in crop production. Organic carbon levels were 0.65 percent and also below the critical level of 1.58 percent

Depth: 23-39cm

The pH of this horizon was 4.5. Calcium, Magnesium and Potassium levels were 143, 39 and 97.7 mg/kg respectively and these were lower when compared to the top horizon. Organic carbon levels were 0.47 percent and Phosphorous concentration in this horizon was 15mg/kg. This was higher than in the previous horizon.

Depth: 39-67cm

The pH of this horizon is 4.6. Calcium, Magnesium and Potassium levels were 514,223 and 1338 mg/kg respectively and were higher than those in the previous top horizon. The Organic carbon levels were 0.61percent and Phosphorous levels were 13mg/kg. The Organic carbon was at a higher concentration as compared to the levels in the previous horizon.

Depth: 67-100cm

The pH in this horizon was 4.2. Calcium, Magnesium and Potassium levels were 910,290 and 30 mg/kg respectively. Organic carbon level was 0.36 percent. That was slightly less compared to levels in the previous horizon. In the profile, Calcium and Magnesium levels were more in the last two horizons. Potassium levels were high in the third horizon whilst Phosphorous levels were high in the subsoil.

Soil Pit 008

Depth: 0-12 cm

The top soil had a soil pH of 4.4 and was classified as medium acidic. Liming was required to reduce the pH to levels suitable for crop growth. The levels of Ca, Mg and K were 311, 83 and 173.2 mg/kg, respectively. Calcium, Magnesium and K levels were above the critical levels. Phosphorus levels were 7 mg/kg, which was below the critical level required for crop growth. The organic carbon level was 1.15 percent and was below the critical level.

Depth: 12-30 cm

The pH in the horizon was 4.0. The subsoil was acidic and this would be of major concern in crop production. Calcium, Magnesium and Potassium levels were 74, 23 and 100.6 mg/kg, respectively. The levels of Calcium, Magnesium and Potassium were less than those in the immediate top horizon (top soil). The Organic carbon levels were 0.47 percent which was slightly less than that of the previous horizon. The phosphorus levels were 11 mg/kg and were more than those in the immediate top horizon.

Depth: 30-51 cm

The pH was 4.8. Calcium, Magnesium and Potassium levels were 220, 90 and 50 mg/kg, respectively. Calcium and Magnesium were more than those in the immediate top horizon. Organic carbon levels were 0.36 percent and Phosphorous levels were 18 mg/kg. Phosphorous levels are higher than those in previous horizon.

Depth: 51-100cm

The soil pH was 4.2. Calcium, Magnesium and Potassium levels were 940, 270 and 140 mg/kg. When compared to the above horizon, these levels were far much higher possibly because of continued sedimentation or inability of the roots to take up these nutrients. The levels of Organic carbon were less than 0.01 percent. The levels of Phosphorous on the other hand were almost the same (17mg/kg) as the above horizon.

APPENDIX D: ANALYTICAL RESULTS OF CHASSA DAMBO SOIL PROFILES

Sample ID Chassa	pH CaCl ₂	Ca	Mg	K	Na	Org. C	N	P	CEC
	0.01 M CaCl ₂	Mg/kg or mg kg ⁻¹				%	%	mg kg ⁻¹	cmol _c kg ⁻¹
ch001 0-7	4.5	418	50	124.8		0.28	0.01	43	20
ch001 7-18	4.3	211	31	9.7		0.39	0.03	11	9.4
ch001 18-60	5.7	1600	310	90		1.01	0.08	9	30.1
ch001 60-100	6.0	226	403	191.3		0.36	0.02	14.4	29.0
ch002 0-13	4.6	466	23	125.8		0.99	0.07	16	16.8
ch002 13-29	5.2	118	11	83.9		< 0.01	< 0.01	10	6.1
ch002 29-64	5.7	60	7	81.1		< 0.01	< 0.01	7	4.3
ch002 64-100	5.8	43	13	82		< 0.01	< 0.01	9	5.8
ch003 0-17	5.6	296	49	97.7		0.31	0.02	9	58.9
ch003 17-30	4.4	245	34	104		0.49	0.04	8	14.4
ch003 30-69	4.9	72	19	93.6		< 0.01	< 0.01	9	11.9
ch003 69-100	5.6	53	7	83.6		< 0.01	< 0.01	8	8.7
ch004 15-44	4.7	45	16	103		< 0.01	< 0.01	10	6.3
ch004 44-100	5.2	93	57	128.2		0.29	0.01	8	12.5
ch005 0-9	4.9	257	39	126.7		1.05	0.08	22	9.9
ch005 24-46	4.9	52	25	86.9		0.01	0.01	8	4
ch005 46-100	5.5	522	130	106.4		0.61	0.05	8	15.4
ch006 0-14	4.8	850	123	139.6		1.51	0.12	20	14.9
ch006 14-41	5.8	1450	369	160		< 0.01	< 0.01	11	13.2
ch006 41-95	6.6	1200	324	138.9		0.51	0.03	12	30
ch007 0-23	4.9	254	58	106.7		0.65	0.05	10	6
ch007 23-39	4.5	143	39	97.7		0.47	0.04	15	6.5
ch007 39-67	4.6	514	223	133.8		0.61	0.04	13	16.3
ch007 67-100	4.2	910	290	30		0.36	0.02	8	22.3

Sample ID Chassa	pH CaCl ₂	Ca	Mg	K	Na	Org. C	N	P	CEC
	0.01 M CaCl ₂	Mg/kg or mg kg ⁻¹				%	%	mg kg ⁻¹	cmol _c kg ⁻¹
ch008 0-12	4.4	311	83	173.2		1.15	0.12	7	15
ch008 12-30	4.0	74	23	100.6		0.47	0.03	11	4.6
ch008 30-51	4.8	220	90	50		0.36	0.03	18	9.4
ch008 51-100	4.2	940	270	140		< 0.01	< 0.01	17	19.6

APPENDIX E: KEY FOR INTERPRETATION OF SOILS

Sample ID	pH	Ca	Mg	K	Na	Org. C	N	P	CEC
	CaCl ₂								
	0.01 M CaCl ₂	Mg/kg or mg kg ⁻¹				%	%	mg kg ⁻¹	cmol _c kg ⁻¹
High	5.5-6.5	>3000	>300	>250		4.00	>0.30	>60	
Low	<4.5-5.0	200	50	40	-	1.58	0.10	15	-

Explanatory notes for pH- CaCl₂

Below 4.0 Extremely Acidic

4.5-4.9.....Medium Acid

5.0-6.3.....Slightly acid

6.8-7.2.....Neutral

Above >7.2 Alkaline