INVESTIGATION OF GARDENING, CULTIVATION AND GRAZING ON THE INTUNJAMBILI WETLAND

By

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Abstract

The research was carried out to assess the effects of the management practices on the Intunjambili wetland during the 2005-2006 rainy season. After assessing the effects interventions were supposed to be created that enable sustainable development of the wetland to occur. Changes in the water regime were also to be investigated so as to determine the characteristic fluctuations and effects of the fluctuations. The hypothesis was that current management practices and methods were harmful and environmentally damaging since the farmers were using unimproved traditional methods of management. Baseline and exploratory surveys were first carried out to visually observe the practices in use on the wetland. This was then followed by informal, then formal interviews to obtain relevant data on the practiced methods. Water table elevations over the period of investigation were obtained from observation wells situated on the wetland and implemented for long term observation of the wetland. Cultivation was mainly carried out on the fields using conventional tillage and some of the farmers used ridges and furrows. The maize crop was somewhat stunted at the end of the season due to waterlogging. Broad belts broad furrows were mainly used on the gardens by most of the farmers though some simply used furrows for vegetable production. Some of the wetland vegetables showed signs of lack of nutrients due to leaching and some had stunted growth due to excessive weeds on the gardens, another sign of excess water (the excess water discouraged weeding). A lack of aeration due to waterlogging also possibly caused some of the above effects. The pastoral areas for grazing rather flourished during the period of investigation with no ill effects noted. Water table elevations over the period of investigation were obtained from observation wells situated on the wetland and implemented for long term observation of the wetland.
The water table levels for the period of study showed some fluctuations mostly due to rainfall recharge and discharge due to well abstraction by the farmers. The water table readings were not taken for a substantially long period to make any major conclusions about the water regime since just one season was used for observations. At around March 30, 2006 the water table had started to fall. Immediate effects of waterlogging and rainfall recharge were however evident by the end of the cropping period on the planted crop. Statistical analysis of the water table fluctuations showed a similarity between the behaviours of wells. From the ANOVA analysis at the 5% level of significance there was no significant difference between the fluctuations of well 1 and well 2 though for well 2 and well 3 there was a significant difference. There was a significant difference between the fluctuations of well 3 and well 4 at the 5% level of significance. There was a high correlation between the fluctuations of well 1 and wells 2, 3 and 4 as can be shown from the values of the Pearson correlation values and there was a low correlation between the values of well 2 and well 4. It is suggested that the wetland farmers practice their tillage activities using ridges and broad belts broad furrows, which maintain a high water table. The wetland farmers should also practice most of their tillage activities at the upland also to maintain a high water table.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

1.1.1 Overview

The most predominantly used type of wetland ecosystem in Zimbabwe are dambos which are low lying seasonally waterlogged treeless areas in the headwater regions of river systems. There is approximately 1.28 million hectares of dambo in Zimbabwe of which 2, 5 % are found in communal areas. Dambo gardens are especially important during drought years when dryland crops are poor, but wet conditions in dambos are still adequate to yield reasonable harvests (Mazambani, 1982). According to Mharapara (1995) nearly 20000 hectares of dambos were under informal tillage and were at a capacity to be increased due to that farmer initiated tillage practices were and are cheaper to develop than state supported schemes. Dambo catchments were thought to act as hydrological reservoirs, storing water in the rainy season and releasing it through evapotranspiration from the dambo surface and dry season stream flow and this was used as a basis for legislative protection of wetland but has not been supported by more recent hydrological investigations (Owen et al., 1995). Discouraged by colonial legislation dambos have been developed entirely through local initiatives. There has been a preoccupation with the hazards of soil erosion and drying out of dambos in Zimbabwe (Jennings, 1923; Rattray et al; 1953) such that legal restrictions have prevented realization of the potential of these seasonally waterlogged lands through various prohibitive measures enshrined in the legislature. These laws were instituted in order to protect dry season river flows and to reduce erosion and siltation. Current legislation, the Zimbabwe Environmental Management Act (EMA) 2002 allows utilization of wetlands only if authority has been granted by the Ministry of Environment and Tourism including

the Ministry of Water Resources. According to Mharapara (1995) farmers have however developed a variety of land utilization systems and tillage practices according to their needs. Cormack (1972) has argued that the dambo water should be put to more productive use in growing crops or improved pastures within dambos, providing there is no damage to soils or stream flow.

1.1.2 Justification

According to Mharapara (1995) the degradation of dambos, particularly in the communal areas, continues unabated as the system is subjected to a variety of pressures and uses. Wetland ecosystems are generally fragile and sensitive to use and any activities carried out have to be sustainable hence there is a need to study the effects of different activities such as gardening, grazing and cultivation so as to create appropriate interventions. In recent years, dambos have been threatened by an extension of agriculture and overgrazing, caused by a range of socio-economic pressures often linked to government policies. In many areas, this has resulted in a lowering of the water table which has resulted in soil erosion, a loss in organic matter and a reduction in local and downstream water supplies. Those local communities who derive their livelihoods from dambos and those downstream who rely on a constant supply of freshwater, have suffered as a consequence. According to Mharapara (1995) dambos derive their potential from the high moisture and organic content of the soil. The high moisture affects the wetland organic content hence water balance on dambos needs to be adequately investigated together with the practices. Care must be taken so as to avoid excess drainage and unhealthy practices which can have a detrimental effect to the dambo ecosystem. Dambos can be a good alternative to irrigation in that they are cheaper and require no special infrastructure or complicated machinery and in addition dambo cultivation can be successfully integrated with dryland farming hereby helping in hunger alleviation in communal areas. Since water resources are more limited than land in Zimbabwe, proper water management strategies are necessary to be part of a sustainable agricultural production system. Legislation for the control and protection of dambos has proved to be a failure as dambos in communal areas have been utilized and degraded due to population pressures and overgrazing.

1.2 OBJECTIVES

Main objective

To observe the effects of present management practices on the wetland and to create interventions which are soil and water conserving

Minor objectives

1. To identify the land use activities and management practices in use in the wet season.
2. To determine changes in water table over time due to the current practices.
3. To develop interventions that aim at sustainable development on the wetland.

1.3 HYPOTHESES

The hypothesis is that current management practices and methods are harmful and environmentally damaging and that changes occur on the water table that reflect management practices.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

Dambos referred to as seasonally waterlogged, predominantly grass covered shallow depressions in the headwater zone of rivers. Dambos occur on the plains of eastern and southern Africa. Because of the availability of soil moisture in dambos during dry periods, these areas are important to local communities who use them for crop cultivation and cattle grazing. In the dry season small-scale agriculture in dambos is practiced in the form of maize and vegetable garden cultivation, based on indigenous water management techniques. During the rainy season when most of the dambo remains flooded, rice can also be grown. Each year, the decomposition of the grass and sedge dominated vegetation leads to the build up of organic matter in the dambo soil - a valuable agricultural resource.

Among the uses developed by traditional communities are as water sources for domestic use and livestock grazing, cultivation of cereals or root crops in the wet season, cultivation of vegetables in the dry season, gathering of wild fruits and medicines or a combination of these (Mharapara ,1995). In communal areas gardens have been instituted on dambos by communal farmers. Research carried out by Mharapara (1995) has shown that dambos are adequately fertile such as to offer high output and returns should they be utilised to the full.

2.2 DAMBO UTILISATION HISTORY

Dambos have long been utilized in Zimbabwe since the early times. There have been rapid developments however occurring in the last 100 years concerning dambo utilization. These changes have involved population increases and widespread degradation of dambos including the passing of legislation.

2.2.1 Pre-colonial era

According to Mharapara (1995) widespread cultivation of dambos took place in Zimbabwe before the arrival of the Europeans and this is evidenced by folk stories and visible remains of cultivation practices. Ridges and furrows provide ample evidence of cultivation on the dambos by the black settlers and this practice has continued into the present day. The

traditional system of cultivation dominated in this pre-colonial era. Rice was for long a staple food for the Mashona on the dambos on the swampy areas in eastern Zimbabwe and was the main cereal crop though it was later abandoned in favour of the recently introduced maize crop (E.R. Sawyer, 1909).

2.2.2 Colonial era

This era was characterised by the adoption of different agricultural technologies. According to Mharapara (1995) when the European settlers arrived in Zimbabwe dambos had by then been long utilized by the traditional farmers. On settling they immediately discouraged the traditional farmers from farming since they perceived them as competition and had the traditional farmers send to the reserves or Tribal Trust Lands. Environmental degradation however occurred due to population pressures on these reserves from people and livestock. On the other hand commercial farmers, on seeing the potential of dambos instituted fields on these dambos for growing crops such as maize, wheat and tobacco. Since the crops do not grow well under waterlogged conditions drainage ditches were dug to remove the excess water. This then resulted in degradation in the form of gullying, silting and lowering of water table. The then government then enacted prohibitive legislation on dambo utilisation namely the Water act of 1927 and the Natural Resources act of 1941 (revised in 1952). These two acts prohibited any cultivation along stream banks, in dambos and around the stream source area.

2.2.3 Post colonial era to present day

The post colonial era has been characterised by land pressure on the former reserves as well as the need to redress socio-economic imbalances created by the previous administrators. During this era dambos had mainly been maintained as non arable land. Two different scenarios have occurred during the post-colonial era. According to Mharapara (1995) commercial farmers mainly maintained the dambos by engaging in controlled grazing on the dambos. On these commercial farms there was little or no cultivation and there were dams on these lands which maintained the water table. On the communal areas however, there was heavy human and livestock pressures due to the shortage of land. Poor conservation measures abounded and this led to degradation of the dambos. There was, as a result of this some overgrazing, erosion and trampling as a

result. This then in part led to the enactment of new legislation (EMA) in 2002. There is still, however, an extensive lack of understanding and appreciation of wetland values, functions and products by planners and decision-makers and this has largely led to irreversible damage to the wetland systems of Zimbabwe. A number of the threats and issues stem from national problems of poverty, population pressure and uncoordinated sectoral developments. More recently, the conservation and wise use of wetlands as ecosystems has received increasing attention countrywide.

2.3 HYDROLOGIC FUNCTION OF WETLANDS

Wetland hydrologic functions are the roles that wetlands play in modifying or controlling the quantity of water moving through a wetland. Some of the major hydrologic functions of wetlands are as flood storage and stormflow modification, ground-water recharge and discharge and alterations of precipitation and evaporation. An understanding of wetland functions and the underlying chemical, physical, and biological processes supporting these functions facilitates the management and protection of wetlands. The hydrologic and water-quality functions of wetlands are controlled by landscape position, climate, topographic location, presence or absence of vegetation, type of vegetation, type of soil and water inflow and outflow from the wetland. Natural functions of wetlands can be altered or impaired by human activity and management practices. Although slow incremental changes in the natural landscape can lead to small changes in wetlands, the accumulation of these small changes can permanently alter the wetland function (Brinson, 1988).

2.3.1 Wetland groundwater

The hydrologic and hydraulic characteristics of a wetland influence all wetland functions and affect its use. The processes by which water is introduced, temporarily stored, and removed from a wetland are commonly known as the water budget. Water is introduced to a wetland through direct precipitation, overland flow (or runoff), channel and overbank flow and groundwater discharge. Temporary storage includes channel, overbank, basin, and groundwater storage. Water is removed from the wetland through evaporation, plant transpiration, channel and overland flow and groundwater recharge. To evaluate whether groundwater is influenced by wetland functions, it is important to understand ground

water processes.

2.3.2 Factors affecting groundwater flow

Groundwater flow is influenced by a number of factors, including hydraulic gradients, hydraulic conductivity, porosity, and storage coefficients.

Hydraulic Gradients	The hydraulic gradient is the difference in piezometric head between two locations divided by the distance between them. Generally, this is measured by installing several wells, bore holes, or piezometers, and measuring the head in each. For groundwater flows to or from the surface water, the elevation of the surface water is the upper piezometric head.
Hydraulic Conductivity	This is the ability of the soil to conduct water under hydraulic gradients. The hydraulic conductivity or permeability depends on soil characteristics such as type, size, shape, and packing. Hydraulic conductivity can be estimated in a number of ways (Xiscoll 1986, Lamb and Whitman 1969). Local values of hydraulic conductivity can be measured by performing a slug test in a well location. Field-wide measurements can be determined from an aquifer performance test, in which one well is pumped and the variation of the piezometric head in nearby wells is observed over time (SCS 1992).

Porosity	Porosity is the fraction of a soil volume occupied by voids, and represents the potential area through which water can flow. It is usually measured in the laboratory from a soil sample, although knowledge of the soil type can give a fair estimate of porosity. Together with the flow rate calculated from Darcy's Law (Freeze and Cherry 1979), the soil porosity can be used to estimate groundwater travel times.
Storage Coefficient	The storage coefficient is a measure of the amount of water stored in an aquifer for a unit rise in the elevation of the piezometric head. For an unconfined aquifer, the storage coefficient (or specific yield) determines the rate of change in elevation of the water table. Values of this parameter can be estimated, crudely, from knowledge of the soil material.

2.4 HYDROLOGIC AND HYDRAULIC PROCESSES

Some of the major hydrologic functions of wetlands are as flood storage and storm flow modification, ground-water recharge and discharge and alterations of precipitation and evaporation. Natural functions of wetlands can be altered or impaired by human activity. Although slow incremental changes in the natural landscape can lead to small changes in wetlands, the accumulation of these small changes can permanently alter the wetland function (Brinson, 1988).

2.5 HYDROLOGIC AND HYDRAULIC PROCESSES

The primary hydrologic and hydraulic processes that influence wetland groundwater interaction are precipitation, infiltration, groundwater discharge or recharge, shallow and deep groundwater flow, groundwater pumping, and evaporation and transpiration.

2.5.1 Precipitation

Groundwater processes associated with wetlands result from local and regional precipitation patterns. Precipitation can influence a wetland water budget directly through rain within the wetland, or indirectly through inflows from upstream watersheds.

2.5.2 Groundwater Discharge and Recharge

Groundwater discharge occurs where the elevation of the water table exceeds that of the surface water and recharge results when the opposite occurs. Estimates of the rate of groundwater discharge or recharge can be obtained by applying Darcy's Law. Wetlands have been observed to change seasonally from discharge to recharge or flow-through systems. As a result, it is important to examine the variability of wetland groundwater characteristics.

2.5.3 Shallow and Deep Groundwater Flow

The interaction between the shallow groundwater zone and the underlying regional groundwater system can influence the rate of shallow groundwater transport, and thus the interaction with surface waters and wetlands. In some systems a confining layer exists that decouples the shallow and deep groundwater zones. In these cases it is important that local shallow-water well piezometric heads are used to assess wetland groundwater function. The potential influence of the deep groundwater zone can be examined by inspecting available information for evidence of confining material or other significant changes in formation composition. This process can be further examined utilizing measurements of head from shallow piezometers and deep wells to develop piezometric contours of the system.

2.6 EFFECT SHALLOW WATER TABLE ON CROPPING

Plants have several requirements which need to be met if they are to be productive. The hydrologic behaviour of the water table affects the plant characteristics in turn. Generally water in the ground rises by capillary action and when it reaches o 1500mm below the surface of the land the land is said to be waterlogged. When this happens the soil pores within the root zone are filled with subsoil water. The air circulation within the root zone is then totally stopped and the plants suffer as a result.

According to Basack (2003) the effects of waterlogging are:

1. Salinisation - when dissolved salts come to the surface by capillary action and when they are deposited there, salinisation has occurred. The soil then becomes alkaline and the alkalinity inhibits plant growth.

2. Lack of aeration - When this occurs, the anaerobic conditions cause bacteria and micro-organisms to undergo minimum breakdown. Complex compounds are then not broken down into simpler compounds which can then be uptaken by plants.
3. Temperature reduction - Low temperatures inhibit micro-organism effects and behaviour.
4. Prevalence of disease – There is a multiplication of diseases when there are excess water conditions.
5. Restricted root growth – excess water causes the prevalence of restricted root growth.

CHAPTER THREE

METHODOLOGY

3.1 Site description

The Intunjambili wetland lies at about 42 kilometres from Bulawayo. This wetland area is along Tuli, a tributary to the Limpopo River and covers an area of approximately 30hectares. Soils are sandy, with some black clay and the slope is gentle. The wetland is located at 20º27ºS, 28º41ºE and is at 1500m above sea level. The area lies in region 4 which has low annual rainfall (400 to 600mm per annum). There are several farmers situated on the Intunjambili wetland who carry out various management practices. Several families are settled on the wetland and these carry out grazing, cultivation and gardening on the wetland. Maize cropping and vegetable gardening is carried out on some sections of the land and gardens are the predominant activity on the wetland. The Intunjambili wetlands climate is characterised by a very long and hot dry season.

3.2 Methodological steps

The methodological steps were as follows

3.2.1 Baseline and exploratory surveys

This involved initial inspection of the methods and practices being employed by the farmers. It involved going throughout the wetland and observing what was being undertaken by the

wetland inhabitants and their daily activities especially before the current cropping season. This data will serve as a benchmark for monitoring and evaluation.

3.2.2 Informal interviews

Interviews were carried out on the ordinary individual farmers on their practices, methods of management and scope and intensity of their activities and the cropping habits. The interviews mainly aimed at assessing the production practices including the specific crops which are cultivated on the wetland. Some key participants were interviewed and differences and similarities in their methods noted.

3.2.3 Formal interviews

This was done with the aid of two local males who accompanied the research party throughout the wetland and helped in questioning the wetland inhabitants about their methods. These males helped in translating the farmers' responses during interviews helping to overcome the language barrier by helping to communicate the questions to the wetland inhabitants.

3.2.4 Evaluation

This involved evaluation during and after the cropping season to note the management practices carried out by the farmers and the state of the crops at the end of the cropping season.

3.2.5 Technical Measurements

3.2.5.1 Water table observation wells

Four wells were used and their water table levels continuously from around 23 December to 31 March. Regular monitoring of the water table level from the surface was carried out weekly and a tape measure was used to measure from the surface to the water table depth. These wells were chosen because they were located on areas where the activities of gardening, grazing and cultivation were being carried out in close proximity so as to measure the water table at positions whereby the effects of the three activities were greater more acute and more representative.

3.2.5.2 Well structure

Small diameter pipes were used which were vertically inserted into the ground. These were used to determine the depth of the water table from the ground level. Since the water table is close to the surface shallow observation wells were used.

The wells in use are composed of a PVC casing, a locking well plug, a curb box and a PVC pipe. A locking well plug casing was set in around the above grade portion of a well with a locking cap. A Curb box or manhole and cover flush with the pavement surface were used to protect the well. A locking well plug or other appropriate seal was used to insure that wells installed at ground level were watertight. A PVC pipe was used that reached to about 1.5 to 2.5 meters below the ground.

3.2.5.3 Analysis of data

Data from questionnaires was analysed using the SPSS statistical package and data from the wells was also analysed using the SPSS statistical package. An Analysis of Variance (ANOVA) was carried out to determine if there were any significant differences between the different water table elevations. A p value was then used to interpret the results at a 95% confidence interval. The Pearson's correlation was used to determine the correlation between the values of the water table fluctuations. The short questionnaire was analysed using the SPSS statistical package.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Wetland use activities

These were gardening, cultivation and grazing for the 2005-2006 cropping season.

4.1.1 Cultivation

The crop mainly grown on the plots was maize during the summer season. Each of the plots was subdivided into maize fields and gardening. On each plot, shallow irrigation wells were dug whereby the farmers access their water for irrigating their fields. A cultivated field is shown in fig1.

Fig 1 Cultivated Fields

Maize cultivation took place on the dambos from around October 2005 to March 2006. The wetland inhabitants left some of the land fallow for the duration of the cropping season. There was no intercropping practiced. Most of the dryland dambo farmers practiced conventional tillage for maize cropping. Only a small amount of the cultivated land has ridges on contours or has any ridges at all. Some of the farmers had ridges and furrows trending down the slope to facilitate drainage of excess water from the wetland.

4.1.2 Gardening

The farmers relied on the common water resources such as streams and shallow wells. Gardens were situated on land that is either seasonally flooded or holds water from the rainy season long into the dry season. Shallow wells have been dug on the gardens to provide water for irrigation especially during the dry season as shown in fig 2. Water is abstracted from these shallow wells throughout the year. No abstraction occurred during the rainy season because the gardens were wet though by March 30, when the water level was going down abstraction occurred for gardening purposes.

Fig 2 Shallow Well On Gardens

Broad belt broad furrows were generally used on some of the gardens as can be seen from the fig 3. These were used by most of the farmers especially those on the lowland part of the wetland.

Fig 3 Broad Belts Broad Furrows On Dambo

4.1.3 Grazing

Grazing occurred throughout the wetland with the entire uncultivated dambo being used as grazing lands. Grazing occurred alongside cultivation and gardening and even on the marshy land. No rotational grazing took place on the dambos and there appeared to be no fodder production done by the dambo farmers. No ill effects or overgrazing was observed on the grazing pastures. Fig 4 shows some of the pastures.

Fig 4 Grazing Area As At 30 March

4.2 ADVANTAGES AND CONSTRAINTS

4.2.1 Gardening

Some of the farmers seemed to maintain broad furrows and ridges, which are a recognized conservation practice that maintains a high water table, though there are some minor signs of nutrient loss. The wetland however experienced an excess of water as can be seen by the state of the choumolier at around 30 March as shown in fig 5. The vegetable has some purple leaves, a possible sign of potassium deficiency caused by excess water. The vegetables also experienced stunted growth and the prevalence of tiny leaves which may also have been caused by a lack of aeration in addition to nutrient loss. The gardens show some neglect as evidenced by the presence of the grass and weeds on the gardens. This is because of the excess water that made weeding impossible.

4.2.2 Cultivation

Most of the farmers had ridges and furrows on their fields. In addition some of the farmers had left some of their land fallow which are both good practices for conserving soil and nutrients.

There was however excess water on the fields as can be seen from the state of the maize crop. The maize crop appears to have experienced excess water as evidenced by stunted characteristics of the maize, evidence of insufficient uptake of nutrients and a lack of aeration, which may have been caused by excess water.

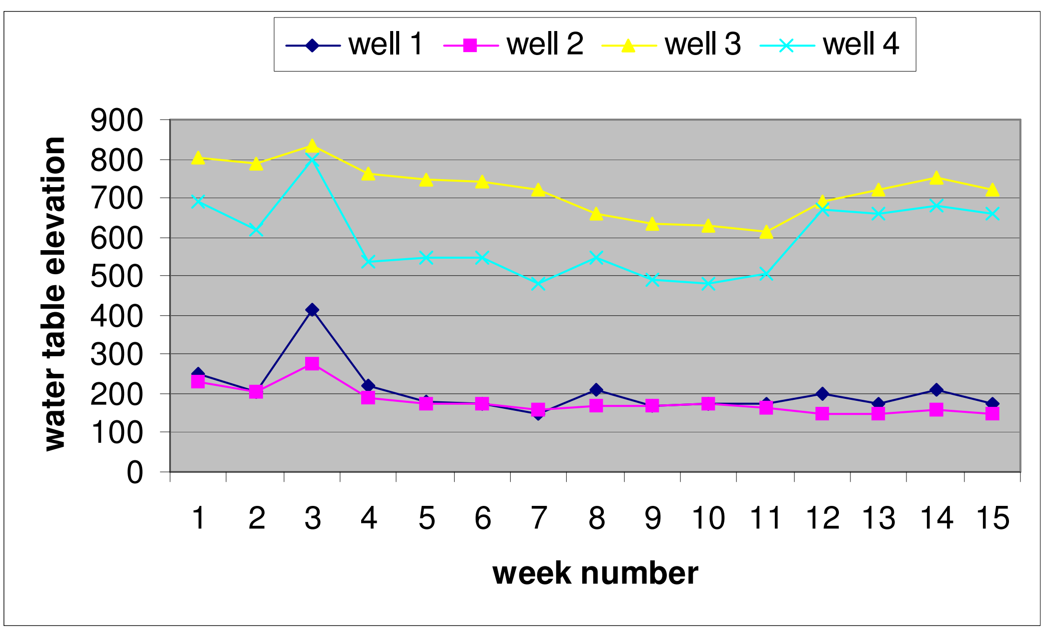
4.2.3 Grazing

There were no recognizable ill effects on the grazing pastures

Fig 5 State of Choumolier As At 30 March

Fig 6 Cultivated Fields As On 30 March

4.3 WATER TABLE READINGS



The wells 1 and 2 were on elevation A on the lowland and the wells 3 and 4 were on

elevation B on the upland. Since the above levels were measured from the surface of the ground to the surface of the water, peaks relate to a decline in the water table levels whilst drops relate to a rise in the water table levels. Wells A and B were almost similar in their variations over the cropping season as can be shown by the statistical analysis. During the period of data collection for well 1 the water table value remained lower than 400mm for the whole period of data collection with the exception of week 3 where the depth was 415m though the water table level did not go lower than 100mm. The water table depth for well 2 did not go lower than 100mm nor did it go higher than 300mm for well 2 for the whole period of data collection. For elevation B the variations are rather different with well 3 experiencing higher water table levels than well 4 throughout the entire period of data collection showing that the water table was lower. The trend however is that of a continuous decrease in the value of the level of well 3 until about week 11 showing that the water table level was increasing. From then on there is an increase then a slight decrease in the values on the final week (week 15). The water table elevations did not go lower than 600mm or higher than 805mm for the whole period of data collection. Roughly the same variations are observed on the well 4 though some spikes do occur on weeks 3, 6, 8, 12 and 14. The upward spikes and rises were due to discharge due to rainfall. On week three there was a sudden peak possibly caused by abstraction of water from the wells for gardening and also due to wetland discharge. It can be observed that the rainfall intensity before the readings were taken (before week 1) was much lower since the trends of the wells show a gradual decline meaning that there was a gradual recharge of the water table. The low points on the graph were due to rainfall recharge.

4.4 STATISTICAL ANALYSIS

Analysis of the data was done by the SPSS statistical package. One way ANOVA was used and also Pearson's correlation. Four water table observations were analysed for their water table fluctuations over a period of 15 weeks.

From the ANOVA tables there was no significant difference between the means of the fluctuations of well 1 and well 2, well1 and well 3 and well 1 and well 4 since $p>0.05$. There was no significant difference between the means of well 2 and well 3 and well 2

and well 4 since also $p>0.05$. There was no significant difference between the means of well 3 and well 4 since $p>0.05$.

There was a high correlation between the fluctuations of well 1 and wells 2, 3 and 4 as can be shown from the values of the Pearson correlation values of 0.882, 0.630 and 0.720. There was a lower correlation between the values of well 2 and well 4 where the Pearson value was 0.495.

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 CULTIVATION, GARDENING AND GRAZING

The crops on the different gardening activities on the wetland showed an acute response to variations in the wetland water table and also to the different activities being carried out on the wetland. The cultivated fields where maize cropping was predominant generally experienced low yields due to that most if not all of the plants experienced stunted growth or premature maturation. The plants obviously suffered from an excess of water during the rainy season due to their tillage practices namely conventional tillage with minimal ridging. The waterlogged conditions on most of the fields caused adverse effects to be experienced on the fields namely the leaching of nutrients and a lack of aeration. The gardens experience the same problems whereby there was excess water with an obvious adverse effect on the vegetables on the gardens and again leaching of nutrients. Waterlogging especially on the non broad based gardens causes various negative results on most of the plants (purplish leaves and stunted growth), drying up of leaves and also the promotion of pests and diseases which led to drying out of leaves. The excess water also discouraged weeding which caused the grass to flourish on the gardens, again leading to stunted growth due to nutrient uptake by the grasses. The grazing areas did not experience any noticeable adverse effects and they actually flourish during the rainy season. From the water abstraction well on fig 2 it is evident that the water table level had gone down considerably by 30 March. From the statistical analysis tables there was no significant difference between the means of the fluctuations of well 1 and well 2, well1 and well 3 and well 1 and well 4 since $p>0.05$. There was no significant difference between the means of well 2 and well 3 and well 2 and well 4 since also $p>0.05$. There was no significant difference between the means of well 3 and well 4 since $p>0.05$. There was a high correlation between the fluctuations of well 1 and wells 2, 3 and 4. This showed that the behaviour of the wells were similar on both the upland and the lowland where recharge and discharge were concerned and the similarity on correlation show how close the behaviour of the fluctuations were.

5.2 WATER TABLE READINGS

As can be seen from the abstraction water wells on fig 2 there was a lowering of the water table at around March whereby recharge from the rains had ceased. The fluctuations of the water table had a direct effect on the conditions on the wetland surface, from water logging to dryness. The practices carried out by the farmers such as conventional tillage, maize cropping non-ridged gardening were inadequate to cope with the excess water which is experienced on the wetland. The water table levels for the lowlands do not experience great variation from week 4 to week 15 though some spikes due to rainfall discharge were evident.

5.3 CONCLUSIONS

The current dambo farming practices on the wetland require some improvement since it is evident that the excess water experienced during the rainy season is affecting the yields. There is however no noticeable adverse effects on the water table on the wetland except for some normal fluctuations due to rain recharge. At around March 30, 2006 the water table had started to fall. The effects of the rain were very marked on the water table as can be seen from the graphs. The practices in place do little to help improve the output in a sustaining manner. Tillage activities, which are in use, require improvement to increase yields and to make the area more sustainable. Lack of adequate drainage has resulted in waterlogging on the tillage fields and this has resulted in wasted effort by the farmers. The same thing has occurred on the gardens where broad furrows were not being used. Dambo farming on the wetland seems to require some changes and interventions so as to enhance the output hence the adoption rate for the changes and interventions is of great importance. The adoption rate for the technologies can however take some time since the interventions may require some machinery and other expensive inputs. The suggested interventions are in no way exhaustive since there may be more requirements for wetland improvement, which have not currently been looked into.

CHAPTER SIX

6.0 RECOMMENDATIONS AND INTERVENTIONS

6.1 Gardening

Some of the farmers were using broad belts broad furrows on their gardens as shown below.

Fig 7 Broad Belts Broad Furrows After Construction

Not all the farmers seem to be using broad belts in their gardens and this has led to a gradual lowering of the water table hence the first suggested intervention is the adoption of broad belts broad furrows on all the gardens which help to raise the level of the water table. The excess water on the gardens as observed by the state of the vegetable leaves necessitates the creation of drainage ditches to drain the excess water from the gardens especially on the lowland parts of the wetland where excess water is a problem. There is also evidence of fungi and pests as a result of the excess water.

6.2 Cultivation

Some conservation tillage practices such as contouring and the use of drainage ditches

will reduce the amount of excess water on the field at the same time reducing ponding, which seems to be a problem where conventional tillage is practiced. The use of broad belt broad furrows is a safe practice that has been confined to gardening though it can also be used for cultivation so as to raise the water table in the wetland. It is advised that cultivation be confined to the upper part of the dambo where water logging is not a problem instead of the lowland. The institution of the rice crop on the wetland seems a feasible option since rice does well on the excess water. Rice can be intercropped on the wetland together with maize crop especially in the drainage ditches if drainage ditches are instituted.

6.3 Grazing

Rotational grazing is advised since this may relieve pressure that may in the future occur on the dambo pastures. Fodder production is also advised though there are no noticeable adverse effects of the presence of pastures on the wetland.

6.4 SUMMARY OF WETLAND MANAGEMENT REQUIREMENTS

1. It is suggested that the wetland farmers practice their tillage activities using ridges and broad belts broad furrows, which maintain a high water table. Subsurface drainage is also advised to drain away excess water during the rainy season.
2. The wetland farmers should also practice their tillage activities at the upland.
3. Planting dates should be shifted so that the farmers plant earlier than their current dates to avoid waterlogging.
4. To make maximum use of the fields or any drainage channels instituted, intercropping with rice can prove to be beneficial within the channels or rice cropping with no intercropping can be used.
5. The pastoral lands should be left untouched since they have always been used without any adverse effects.

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APPENDICES

APPENDIX 4

QUESTIONNAIRES

1. What are the numbers of households using dambos?
2. When did you start growing crops on dambos?

   1. 1 year ago 2. More than 1 year ago
3. How have you been watering your crops?

   1. Using shallow wells 2. Not using shallow wells
4. What is the size of your garden?
5. How have the people used dambos?

   1. as gardens and fields 2. As pastures
6. When was it used for crop production?

   1. 1 year ago 2. More than 1 year ago
7. What are the problems faced?

   1. Pests 2. Water logging 3. Lack of water
8. What technology is used?

9. At what time is the dambo used most and why?

1. Throughout the year 2. During the rainy season

10. When do you carry out various operations in the dambos?

1. Throughout the year 2. During the rainy season

11. How do you overcome waterlogging problems in gardens?

1. Tolerate them 2. No solutions 3. Furrows and ridges

12 How do you overcome waterlogging problems in fields?

1. Tolerate them 2. No solutions 3. Furrows and ridges

13. What are the existing cultural practices in terms of land preparation

1. No tillage 2. Cultivation then ridging 3. Cultivation then planting

14. What are the existing cultural practices in terms of planting?

15 What are the existing cultural practices in terms of irrigating?

1. Throughout year using shallow wells 2. No irrigating 3. Streams

16 What are the existing cultural practices in terms of weeding?

1. No weeding 2. Weed throughout year 3. Weed only when necessary

17 What are the existing cultural practices in terms of fertilizing?

1. No fertilizing 2. Fertilizing with manure 3. Adequate fertilizing

18 What are the existing cultural practices in terms of harvesting?

1. Hand harvesting 2. Harvesting with beasts

19 What are the existing cultural practices in terms of crop rotation?

1. No crop rotation 2. Adequate crop rotation

13. What methods are used to improve soil fertility?

1. None 2. Manure 3. Fertilizing. 4. Crop rotation

14. What are the problems associated with each crop?

1. Water logging 2. Pests 3. Inadequate nutrient

15. What animals are used for grazing?

1. Cattle 2. Goats

16. How are the dambos managed for fodder production?

1. No fodder 2. Fodder produced

17. How are the dambos managed for rotational grazing?

1. No rotational grazing 2. Rotational grazing

APPENDIX 1

ANALYSIS OF VARIANCE FOR WELL FLUCTUATIONS

ANOVA 1

		Sum of Squares	df	Mean Square	F	Sig.
WELL2	Between Groups	15473.733	9	1719.304	12.642	.006
	Within Groups	680.000	5	136.000		
	Total	16153.733	14			
WELL3	Between Groups	41593.333	9	4621.481	1.324	.397
	Within Groups	17450.000	5	3490.000		
	Total	59043.333	14			
WELL4	Between Groups	91414.433	9	10157.159	1.327	.396
	Within Groups	38262.500	5	7652.500		
	Total	129676.933	14			

ANOVA 2

		Sum of Squares	df	Mean Square	F	Sig.
WELL1	Between Groups	52760.000	8	6595.000	13.045	.003
	Within Groups	3033.333	6	505.556		
	Total	55793.333	14			
WELL3	Between Groups	49230.833	8	6153.854	3.763	.062
	Within Groups	9812.500	6	1635.417		
	Total	59043.333	14			
WELL4	Between Groups	105281.100	8	13160.138	3.237	.085
	Within Groups	24395.833	6	4065.972		
	Total	129676.933	14			

ANOVA 3

		Sum of Squares	df	Mean Square	F	Sig.
WELL1	Between Groups	55376.667	12	4614.722	22.151	.044
	Within Groups	416.667	2	208.333		
	Total	55793.333	14			
WELL2	Between Groups	16087.067	12	1340.589	40.218	.025
	Within Groups	66.667	2	33.333		
	Total	16153.733	14			
WELL4	Between Groups	108076.933	12	9006.411	.834	.665

	Within Groups	21600.000	2	10800.000
	Total	129676.933	14	

ANOVA 4

		Sum of Squares	df	Mean Square	F	Sig.
WELL1	Between Groups	54764.167	10	5476.417	21.285	.005
	Within Groups	1029.167	4	257.292		
	Total	55793.333	14			
WELL2	Between Groups	16024.567	10	1602.457	49.624	.001
	Within Groups	129.167	4	32.292		
	Total	16153.733	14			
WELL3	Between Groups	50443.333	10	5044.333	2.346	.213
	Within Groups	8600.000	4	2150.000		
	Total	59043.333	14			

APPENDIX 2

4.4 Correlations

		WELL1	WELL2	WELL3	WELL4
WELL 1	Pearson Correlation	1.000	.882	.630	.720
	Sig. (2-tailed)		.000	.012	.002
	N	15	15	15	15
WELL 2	Pearson Correlation	.882	1.000	.668	.495
	Sig. (2-tailed)	.000		.007	.061
	N	15	15	15	15
WELL 3	Pearson Correlation	.630	.668	1.000	.694
	Sig. (2-tailed)	.012	.007		.004
	N	15	15	15	15
WELL 4	Pearson Correlation	.720	.495	.694	1.000
	Sig. (2-tailed)	.002	.061	.004	
	N	15	15	15	15

Correlation is significant at the 0.01 level (2-tailed).

Correlation is significant at the 0.05 level (2-tailed).

APPENDIX 3

FREQUENCY DISTRIBUTION FOR QUESTIONNAIRES

WHENCROP

	Frequency	Percent	Valid Percent	Cumulative Percent

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	more than i year ago	10	100.0	100.0	100.0

HOWWATER

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	using shallow wells	10	100.0	100.0	100.0

USEDAMBO

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	gardens and fields	8	80.0	80.0	80.0
	pastures	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

WHENPROD

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 year ago	3	30.0	30.0	30.0
	more than 1 year ago	7	70.0	70.0	100.0
	Total	10	100.0	100.0	

PROBFAC

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	pests	1	10.0	10.0	10.0
	waterlogging	9	90.0	90.0	100.0
	Total	10	100.0	100.0	

TIMEUSE

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	throughout year	6	60.0	60.0	60.0
	rainy season	4	40.0	40.0	100.0
	Total	10	100.0	100.0	

HOWATERL

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	tolerate	9	90.0	90.0	90.0
	11.00	1	10.0	10.0	100.0
	Total	10	100.0	100.0	

CULLAND

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	cultivation then ridging	3	30.0	30.0	30.0
	cultivation then planting	7	70.0	70.0	100.0
	Total	10	100.0	100.0	

CULIRR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	shallow wells	6	60.0	60.0	60.0
	streams	4	40.0	40.0	100.0

		Frequency	Percent	Valid Percent	Cumulative Percent
	Total	10	100.0	100.0	

CULWEED

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	throughout year	8	80.0	80.0	80.0
	when necessary	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

CULFERT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no fertilizing	2	20.0	20.0	20.0
	manure fertilizing	8	80.0	80.0	100.0
	Total	10	100.0	100.0	

CULHARV

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	hand	8	80.0	80.0	80.0
	beasts	2	20.0	20.0	100.0
	Total	10	100.0	100.0	

CULCROP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no crop rotation	7	70.0	70.0	70.0
	adequate crop rotation	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

SOILLFER

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	manure	5	50.0	50.0	50.0
	fertilizing	5	50.0	50.0	100.0
	Total	10	100.0	100.0	

PROBCRO

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	waterlogging	7	70.0	70.0	70.0
	pests	3	30.0	30.0	100.0
	Total	10	100.0	100.0	

GRAZANI

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	cattle	10	100.0	100.0	100.0

FODDPR

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no fodder	10	100.0	100.0	100.0

ROTATG

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no	10	100.0	100.0	100.0

rotational
grazing