EFFECTS OF WETLAND UTILIZATION ON THE WATER TABLE FOR
INTUNJAMBILI WETLAND, MATOPO.

An Undergraduate Research Project Submitted in Partial Fulfillment of the
Requirements of the Degree of Bachelor of Science Honours in Agricultural
Engineering.

BY

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ABSTRACT

Intunjambili wetland was used for this research. The wetland was used by farmers for gardening and as pastures for livestock among other uses. Livestock trampling and compaction reduce infiltration whereas furrows used by farmers lower the water table. The wetland was divided into three zones according to land use. Ten observation wells were drilled in the wetland and water table monitoring was done for sixty-six days. Rainfall was also measured during the period of data collection. Response to rainfall recharge varied across the wetland. Zone A only responded to rainfall greater than 20 mm. This was attributed to low infiltration rates caused by livestock trampling and compaction. Water abstraction by phreatophytes also led to a rapid depletion of groundwater in zone A. Wells located in zone B showed that the water table responded immediately to rainfall. Zone B is the area where cultivation was the main activity and it enhanced infiltration. The rise of the water table more the rainfall received was noticed and this was explained by runoff inflow to the wetland from the surrounding rocks. Zone B had the highest water table because farmers irrigated their gardens. In zone C, the water table depleted rapidly soon after each rainfall event but steadied after reaching 400 mm depth. Zone A had an average water table depth of 508 mm compared to 400 mm for zone B and 854 mm for zone A. Human activities had a negative effect on the water regime of the wetland. Gum-tree plantations are not recommended in wetlands. Water table lowering methods such as use of furrows and broad beds should run across the slope.
DEDICATED TO

……..to my Parents………..

….and the Mamanes……

….you are far too kind !

I owe you so much.

love Sipho.
ACKNOWLEDGEMENTS

I would like to express my appreciation to my major advisor, Mr K.E. Mosti, for his support and guidance. My appreciation also goes to Mr L. Nyagwambo of I.W.S.D. I would like to acknowledge the contribution of my colleagues at the University of Zimbabwe, farmers and village heads in Intunjambili. I thank the Department of Soil Science and Agricultural Engineering stuff at the University of Zimbabwe and all those who made this project a success. A word of appreciation also goes to IWMI for providing financial resources. Above all, I praise God for showing me the way.

Forever.
CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

1.1.1 Overview

Water resources in the Southern Africa region are subject to extreme variability. Zimbabwe has not been spared; droughts are frequent occurrences, the 1992 being the most severe drought in the last twenty years. The droughts have resulted in declined food security and living standards particularly in the communal areas. Measures to improve the socio-economic situation by increasing agricultural production need to be taken. Adequate arable land is available but water is not sufficient to meet crop water requirements. Wetlands resources have a high potential of increasing agricultural production since they have shallow water table and fertile soils. Irrigation on wetlands can be easily developed without installing expensive sophisticated technology. Wetlands are one of the most economical valuable resources in communal areas and their utilization should be such that they are available for future generations. Both people and wildlife converge on wetlands for water and food during droughts. According to IUCN fact-sheet on wetland in disaster mitigation (2004) it is stated that, during the 1969-70 drought that affected Zimbabwe, 84% of the farmers with wetland fields were able to support their families. However, considering current wetland management practices such statistics would be impossible to record in the near future. Lack of land use planning and poor agronomic practices can lead to excessive abstraction of water from the wetland. Wetlands are opened without detailed land use planning for example, planting phreatophytic plants. Use of improper water management methods further compounds the problem. Farmers resort to drainage that they can hardly control as the only alternative to lower the water table, yet there are other options such as shifting planting time. Technically sound wetland management plans need to be developed and implemented.
1.1.1 Types of wetlands

Under the Ramsar Convention (1971) wetlands are defined as “areas of marsh, fen, peat-land, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh or brackish or salt, including areas of marine water the depth of which at low tide does not exceed six meters.” This definition covers all the types of natural and man-made wetlands found in Zimbabwe (Chenje et al, 1996).

There are various types of wetlands but the main wetlands in Zimbabwe comprise dambos, pans, floodplains, riverine systems and artificial impoundments. Flood plains are found in the mid-Zambezi valley and around the Save Runde confluence in South-eastern Zimbabwe. In the Zambezi, the major permanent pools are the Mana Pools surrounded by swampy land and a series of varying sized pools lying in the depressions of the former river channel.

Riverine wetlands are usually characterized by riparian vegetation such as Acacia tetracantha, Cordyla africana, Croton megalobotrys, Anibourtia conjugate, Pteleopsis myrtilolia, Salvadoria angustifolia, Xanthocercis zambeziana and Terminalia gazensis (Hughes and Hughes, 1992). Riverine wetlands are found in the Save-Runde catchments, Manyame, Gwayi, Shangani, Mazowe and Sanyathi basins.

The dambo, a palustrine wetland is widely distributed in Zimbabwe. With an estimated area of 1.28 million hectares, dambos are an important wetland resource in Zimbabwe (Matiza, 1994). Informal irrigation is popular in dambo wetland areas. Water supply to dambos is a combination of residual moisture and shallow lift ground water. Pans are not widely spread in Zimbabwe. They occur mainly in Tsholotsho communal land and Hwange National Park in the western districts. In the southern districts pans are found in Gonarezhou National Park and some parts of Mwenezi districts. Due to its position on the plateau of Southern Africa, Zimbabwe does not possess significant areas of swamps. Notable swamps include Tsamsta and Kwazulu swamps, both located in the low rainfall areas. Artificial impoundments include lake Kariba, Mitirikwi, Chivero, Manyame, and Mazvikadei dams, among others.
1.1.3 Intunjambili Wetland

Tuli, a tributary of the Limpopo River, has several wetlands in its catchment. The wetlands cover 416 km$^2$ and they are all riverine systems (Breen et al, 1997). Intunjambili wetland is located approximately 42 km from Bulawayo along Old Gwanda road. The wetland covers approximately thirty hectares with gentle slopes and is drained by one main stream. Black clay soils rich in organic matter are found in the area making it suitable for crop cultivation. Apart from collecting water for domestic use, the wetland is used as pastures for livestock and for cultivation of different crops. Different water management practices are used for cultivation. The ridge furrow system is dominant and different size combinations are used depending on the crop. Ridges allow for water drainage along the furrow while crops grow on non-saturated ridges. There are also gum-tree plantations in the wetland. The local people have been using the wetland, since their settlement in the early 1940s, after the Rhodesian government displaced them.

All the above activities have different effects on water table. Alteration of the natural ecosystem and change of land use have changed the natural water regime of the wetland besides changes occurring in the catchment. It is therefore imperative to investigate water fluctuations for different land uses so that activities that may lead to excessive abstraction of water from wetlands can be identified and necessary corrective recommendations made. Necessary steps taken also need to be taken to reduce the effect of activities that inhibit recharge of the wetland. The question is not about sustainability only but it also concerns development of an optimal wetland utilization system. The wetland has to remain wet and the livelihoods of the community have to improve.
1.2 OBJECTIVES
The main objective is to investigate the fluctuations of the water table level across the wetland. The specific objectives are:
1. to investigate the wetland response to rainfall.
2. to investigate the effects of different land use and water management practices on the water table.
3. to provide technical guidelines for planning and development of water management practices that prevent excessive drainage.

1.3 JUSTIFICATION
Wetlands are socially and economically important natural resources in communal areas of Zimbabwe. Irrigation development on wetlands is cheaper when compared to irrigation development on arable land. The costs of irrigation development are summarized in table 1 below:

<table>
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<th>Type of Irrigation</th>
<th>Cost ZW$/ha</th>
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<tr>
<td>Drip</td>
<td>36 M</td>
</tr>
<tr>
<td>Sprinkler</td>
<td>25-30 M</td>
</tr>
<tr>
<td>Surface</td>
<td>25-30 M</td>
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<tr>
<td>Wetland</td>
<td>&lt; 1 M</td>
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Wetlands combine ground water storage and surface storage unlike boreholes where drilling is required or dams where dam walls have to be built. Farmers use wetlands throughout the year and earn their income from crops grown on wetlands. However, due to poor water management practices such as use of random drains, which may drain at more than anticipated rates leading to desiccation, the continued use of these resources is not feasible. Soil degradation and nutrient loss are also likely to occur in uncontrolled drainage of wetlands. Ridges and raised beds used also have a tendency of over draining the wetland thereby necessitating frequent irrigation.
The study seeks to investigate the response of the wetland water table to rainfall and farming practices. Changes in land use lead to differences in the way the wetland responds to rainfall. There is a need to promote rainfall recharge of the wetland so that water can be available for crop cultivation throughout the year. The response of the wetland to rainfall measures the rise of the water table to rainfall received. Depletion of ground water on cultivated areas and grazing land, relative to virgin parts of the wetland is also going to be investigated. The intention is to ascertain whether cultivation of the wetland causes significant water table level depressions within the wetland. The behavior of the water table will be explained considering different land uses and methods of water management. Measures of reducing the excessive drop in water level are then going to be formulated. The essence is to insure that the wetland resource is used such that it is available for future generations.

Variability of wetland resources in terms of rainfall, activities occurring and individual wetland hydrology necessitates a utilization plan for each wetland. Therefore, methods of wetland management that are used in Western countries cannot be prescribed for Zimbabwe. It is imperative that research is carried out on local wetlands so that management plans that suit Zimbabwean conditions are developed. Local farmer knowledge needs to be integrated with technical aspects to come out with sound wetland management plans.

The current legislation still prevents utilization of wetlands for agricultural purposes despite research findings on wetlands that have been obtained up to date. Environmental Management Act 2002 protects wetlands and does not recognize the socio-economic importance of wetlands to rural communities. Other stakeholders have not managed to convince the government that wetlands can be properly utilized mainly for cultivation without any degradation. In this research, the behavior of water table is used to investigate effects of different activities, so that proper wetland management systems can be developed. In addition, the responsible government authorities have limited institutional capacity to enforce environmental legislation they have drawn up. As a result, communal people are continuously using wetlands without any laid down wetland
management structure and plan thereby subjecting wetlands to overuse which inevitably leads to their desiccation (Marapara et al, 1997).
CHAPTER TWO
LITERATURE REVIEW

2.1 HISTORY OF WETLANDS UTILIZATION

Utilization of wetlands dates back to the early civilization in Egypt where settlements were in flood plains along river Nile. Egyptians cultivated crops they traded with in return of other goods. Wetlands were therefore an economically important resource in early Egypt settlement and their utilization expanded across Africa since then. However, in other parts of Africa, the tropics in particular, utilization of and settlement on wetlands exposed man to life threatening diseases such as malaria. This led to the belief that wetlands needed to be drained so that diseases would be controlled. Attempts to enhance agricultural productivity of wetlands in sensitive tropical areas also led to degradation of the wetland resources. Consequently, past legislation had a tendency of preventing utilization of wetlands (Matiza and Crafter, 1994).

In Zimbabwe wetlands were cultivated long before the arrival of Europeans. Mharapara (1995) notes that remain of ridges and furrows in many wetland areas throughout Zimbabwe provide evidence of cultivation, a practice currently used by communal farmers. When land was taken over by Europeans in the 1890s, traditional farmers were forcibly relocated to Communal Areas. Commercial farmers opened wetland fields using drainage ditches for water management. In communal areas wetlands were subjected to both human and animal pressure. Drying up and degradation of wetlands was observed. Poor conservation measures in both commercial and communal areas also contributed to degradation of wetlands (Scoones and Cousins, 1991 and Mharapara et al, 1995).

In response the Rhodesian government passed prohibitive legislation: the Water Act of 1927 and Natural Resources Act of 1941, which was later revised in 1952. The two legislative acts prohibited stream bank cultivation, declaring both commercial and communal wetlands non-arable. Even today, the legal framework in use does not encourage utilization of wetlands. Zimbabwe Environmental Management Act (EMA) 2002 allows utilization of wetlands only if authorization has bee granted by the Ministry
of Environment and Tourism in consultation with the Ministry of Water Resources. However, cultivation on wetlands still continues and it is in this respect that environmentally sound wetland utilization plans need to be developed. The wetlands should remain wet and the livelihoods of communal people need to be uplifted.

2.2 HYDROLOGY OF WETLANDS

2.2.1 Hydrological characteristics

Rainwater infiltrates into the soils of the catchment, percolates downwards to supplement ground water reserves and seeps towards low lying wetlands over the sloping horizon, which may be dense clay or bedrock. The wetland is formed where the seepage from the upper catchment accumulates and the water table lies at the ground level.

In summarizing hydrology characteristics of wetlands Brooks et al (1997) said that wetlands have a shallow water table and flat topography. As a result they are areas that lose large quantities of water via evapotranspiration and produce low levels of discharge to streams. The depth of water governs evapotranspiration and stream flow discharge from wetlands. Annual evapotranspiration far exceeds annual discharge for most wetlands. Wetlands tend to be ground water discharge areas more often than ground water recharge areas and they function much like simple reservoirs; they attenuate flood peaks by temporarily storing or detaining water. Wetlands linked to regional ground water systems exhibit less seasonal fluctuation in water table and stream flow discharge than do wetlands that are perched or otherwise isolated from regional ground water.

2.2.2 Hydrologic Factors Affecting the Water Table

Groundwater occurs in many types of geologic formations; those known as aquifers are of vital importance. An aquifer is a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. It is able to store and transmit water (Arora, 1996 and Todd, 1980). The principal hydrologic properties of the water-bearing stratum, affecting the water table, are porosity, effective porosity or specific yield, specific retention, permeability and direction and maximum ease of
percolation. These factors control the entrance of water into water bearing formations and their capacity to hold and transmit it.

Porosity $n$, of a rock or soil is a measure of contained voids expressed as a ratio of the volume of the interstices to total volume of the stratum. Specific yield $S_y$, is the ratio of the volume of water in an aquifer which can be drained by gravity (or by pumping from wells) to the total volume of the saturated aquifer. Specific retention $S_r$, is the volume of water that cannot be drained out to the total volume of the saturated aquifer.

$n = S_y + S_r$.

High porosity does not necessarily lead to specific yield because the same rock or soil mat have low permeability and water may not easily drain out. For example, Arora (1996) notes that clay has 45% porosity and 3% specific yield but sand, which has a lower porosity of 35%, has 25% specific yield.

Coefficient of permeability of permeability is the discharge per unit area of soil mass under unit hydraulic gradient. Permeability is the ease which water can flow through a rock or sol mass. Storage coefficient $S$, of an aquifer is the volume of water released from a prism unit cross sectional area as the water table drops by a unit depth. It is also called storativity. Storage coefficient usually lies between $1 \times 10^{-5}$ and $1 \times 10^{-3}$. The storativity of an unconfined aquifer is equal to the specific yield (Arora, 1996, Murty, 1998).

### 2.2.3 Vertical Distribution of Groundwater

Vertical distribution of groundwater is shown in fig 1 below. Groundwater is further divided into two major zones, the saturation zone and zone of aeration. The aeration zone is further sub-divided into three categories; soil water zone, intermediate vadose zone and capillary zone.

**Saturation Zone**

This is the zone in which the soil is saturated and it is called the phreatic or groundwater zone. This zone lies below the water table. As the water percolates down it fills the pores
in the water bearing strata and they become saturated. The surface of saturation of an aquifer is known as the water table.

Division of Subsurface Water

Fig 1: Distribution of subsurface water.

Zone of Aeration

Aeration or vadose zone lies between the ground surface and water table. The soil in this zone is unsaturated and may contain both air and water. Capillary forces against gravity hold water in this zone. The vadose zone is further divided into three sub-zones.

Soil water zone

This zone is just below ground surface. Plant roots take water from this zone for transpiration.
Capillary fringe zone

This zone is just above the water table. The water in this zone is by capillary action. The height of the capillary fringe zone depends upon capillary rise, which is dependant on the particle size of the soil.

Intermediate zone

The intermediate zone lies between the soil water zone and the capillary fringe zone. However, in some formations it is absent and the soil water zone lies above the capillary fringe zone.

2.2.4 Wetland Water Balance

Various models for water balance of wetlands have been developed. They reflect the recharge and discharge relationships of wetlands and the surrounding catchments. An illustration of water balance for wetlands is shown in fig 2.

The general approach of research on wetland hydrological system is to determine natural recharge, discharge characteristics and recharge, discharge relations that develop when wetlands are cultivated. Recharge of wetlands includes groundwater recharge as well as rainfall on the wetland. Discharge comprises of evaporation, transpiration and stream flow, which is the sum of surface drainage and subsurface flow. The dynamics of discharge and recharge lead to change in wetland water storage and are all expressed on the water table of the wetland.
Wetland Water Balance

\[
\Delta S = Gr + P - (Q + Eo + Et).
\]

Agricultural activities occurring on the wetland directly affect the two components of discharge, as highlighted in fig 1. Response of the wetland to rainfall is also a function of activities occurring at the surface. However, groundwater recharge of the wetland is not significantly affected by human activities done in the wetland but it is influenced by those carried out in the wetland catchment. Research should therefore focus on water management methods that minimize water abstraction and practices that enhance recharge of wetlands by rainfall.

2.3 EFFECTS OF SHALLOW WATER TABLE ON PLANT GROWTH

Shallow water table results from poor drainage of agricultural land combined with continued deep percolation of water into the soil. The water table is raised to near the surface of the soil and the soil pores within the root zone are filled with subsoil water. The air circulation within the root zone is totally stopped. This phenomenon is termed water logging (Arora, 1996 and Basak, 2003). When the water table comes to 1500 mm
below the surface of the soil, the land is said to be water logged. Water rises by capillary action to the root zone and when this is prolonged, the soil become alkaline and is damaging to crops.

Water logging has several effects on crops and soil properties, some of which are summarized by Basak (2003) as follows. Due to water logging dissolved salts come to soil surface and when water evaporates the salts are deposited there, a process called salinization. The soil becomes alkaline and alkalinity inhibits plant growth. Lack of aeration is another problem that results from water logging. Microorganisms and bacteria die in anaerobic conditions and this results in minimum break down of complex compounds into simple compounds used by plants. Water logging, besides killing the microorganisms, lowers their activity through temperature reduction and consequently the plans do not get their requisite nutrients. Diseases are prevalent in waterlogged soils and such soils also pose tillage problems. Development of root growth is also restricted to aerated top layer of the soil.

Shallow water table therefore results in lower yields and death of crops in extreme cases. Cultivation of crops on wetlands therefore requires drainage of water in parts that are water logged. However, the proper depth of drainage systems should be used so the right quantity of water is drained and to ensure that the water table remains at manageable level, in terms of frequency of watering or irrigation.

2.4 RESEARCH ON WETLANDS

In Zimbabwe documented research on wetlands started in the early twentieth century, when White settlers began commercializing agriculture. Worldwide, a breakthrough on wetlands was made at the Ramsar Convention which was held in 1971. Zimbabwe like many Southern Africa countries has adopted recommendation that were resolved at the Convention pertaining to wetlands. The Convention recognizes the economic, cultural and scientific and recreational importance of wetlands and does not ban their use but advocates for their wise use (Shaw et al, 2004).

Sustainable utilization of wetlands is not any easy task; wetlands systems are fragile and require care if they are not to be destroyed. They occur within geomorphologically
marginal setting and low rainfall (Whitlow, 1984). Gully erosion, stream invasion and desiccation are all ever-present dangers both from human activity and from processes of natural landscape formation. Giesan (1995) also argues that over drainage of wetlands soils may cause irreversible drying, loss of organic matter and fertility and acidification. In view of the above considerations, it is apparent that the effects of any activity (grazing, cultivation and drainage, water wells, etc.), on the water table of wetlands should be thoroughly investigated to ensure their sustainable utilization.

Cultivation and drainage are common activities in Zimbabwean wetlands and several researchers have studied their effects on the water table level. Balek et al (1995) observed that cultivation of wetlands had no significant effects on catchment hydrology but affected evapotranspiration regime and it a factor that may affect downstream yields. It has been argued by Balek and Perry (1973) and Bell et al (1987) for Zambia and Zimbabwe respectively, that evapotranspiration loss is the most significant factor influencing water balance in wetlands. Wetland would therefore naturally dry up due to evapotranspiration loss rather than stream flow discharge if they have natural ecosystems. If utilization causes water abstraction less than that which occurs naturally, then wetlands should not desiccate. Changes in natural vegetation must be analyzed with respect to changes in evapotranspiration and surface drainage and their effects on the water regime of wetlands.

2.4.1 Water Table Monitoring

The water table is the locus of points where the hydrostatic pressure equals atmospheric pressure. Above the water table, in the vadose zone, soil pores may contain either air or water; hence it is referred to as the zone of aeration. In the phreatic zone, below the water table, interstices are filled with water, sometimes this is called toe zone of saturation (Murty, 1998).

The effects of all agricultural activities occurring on the wetland are reflected on the water table of the wetland. The activities influence both recharge and discharge dynamics. Other activities that happen within the catchments also influence the wetland groundwater system. Observation wells are usually used to monitor fluctuations of
groundwater. Observation wells are small diameter pipes (25 mm to 50 mm) installed vertically into the ground. They are useful for determining the depth of the water table from the ground level (Murty, 1998). The depth of observation wells varies with the purpose of study and the expected depth of the water table. For wetlands shallow observation wells are used because the water table is close to the surface.

Groundwater level fluctuation across the wetland follows the general slope of the wetland area as evidenced by the work that was done by Mharapara et al (1995). The researchers documented groundwater fluctuations in the period 1987 to 1989 for the research at Makaholi Experiment Station. The observation wells were drilled in a straight line from the top to the lower end of the wetland. The lowest water table was recorded at the top, lower in the middle and shallow at the down slope end. However, the location of observation wells in a straight line could have introduced some bias. A more representative trend would have come out if observation wells were scattered.

Bell et al (1987) recorded runoff and groundwater fluctuations for Chizengeni wetland. From May to September 1986, the water table level had an average drop of 350 mm, 280 mm and 460 mm for the margin, upper and lower end of the wetland, respectively. The lower part had the greatest depth depletion instead of the expected gradual drop of the water table from the top to the bottom end of the wetland. Moreover, the 460 mm average depletion at the lower zone compared to 350 mm at the margin end has significant implications. Change of land use could be the factor responsible for this trend. The gardens are located in the lower zone. If the 460 mm drop was mainly due to drainage, then farmers should have been recommended to use the margin zone of the wetland without any drainage.

Faulkner and Lambert (1987) also monitored the water table fluctuations for the same wetland studied by Bell and others, the Chizengeni wetland. Estimating an increase of 30% over grazing for arrange of vegetables, the researchers show that if 10 ha are intensively cultivated and irrigated then the water table level in the non wetland zone would fall an additional 50 mm, 2.9% of the average fall of 1270 mm. It appears from their work that there is closed supply of water from the aquifer to the wetland yet there could be other abstractions occurring along the way. In other words, the 50 mm drop they
predicted could have resulted from hydro-geological factors governing groundwater flow. The results could have been more representative if the observation wells were driven into the wetland as opposed to the aquifer, which is located several meters from the wetland.

The researchers further predicted that with 60% increase in evapotranspiration and 10% of total area irrigated, there would be a 17% depletion of groundwater than would have naturally occurred. Little is known about recharge characteristics of the wetland. Discharge information becomes more useful when substantiated with recharge information estimating 17% depletion does not say anything about sustainability or optimality of utilization of the wetland resource. Determining recharge of the wetland and subsequently its capacity to supply water for cropping is important for development of optimal utilization plan.

Andrieni (1993) unlike most researchers integrated recharge information when he studied ground water fluctuations in four different wetlands. He concluded that water use by gardeners was not dramatically higher than consumption by undisturbed wetland vegetation. It was also documented that the relative water supply decreases as the period of utilization increases. The concept of Relative Water Supply (RWS) was developed by Levine (1982a), which was defined as the ratio of supply to demand. In his dissertation, Andrieni (1993) described the irrigation system’s supply, $Su$, by the expression:

$$ Su = G_r + R - ET_n. $$

For irrigation systems the expression for demand, $D$, is:

$$ D = ET_c. $$

$$ \text{RWS} = \frac{Su}{D}. $$

Where $R$ - rainfall on the wetland.

$ET_n$ - evapotranspiration from natural wetland vegetation.

$G_r$ - groundwater recharge.

$ET_c$ - evapotranspiration from crops.
The effect of human induced water drainage, using the ridge furrow system, is not accounted for in the expression for demand. Use of ridges and furrows certainly has an effect on demand and excluding it results in overestimation of RWS.

The first two terms in the supply expression, $R$ and $G_r$, do not vary greatly over time, which implies that the significant terms in RWS are $\text{ET}_n$, $\text{ET}_c$ and the volume drained by furrows, $V$. To maintain $\text{RWS} > 1$ for a utilized wetland, taking account of drainage, $\text{ET}_c + V < \text{ET}_n$. This is, however, partially valid considering that the rainfall records continued decreasing in the past few years. It is important to determine the recharge capacity of wetlands before any plans to exploit the resources are developed.

Andrieni (1993) recorded a RWS of 1.5 for the most intensively exploited of the four wetlands. However, the specific cause of drop of RWS is not pointed out; is it due to increase in demand or due to decrease in supply. Wetland management plans would then be oriented towards the causative factor to ensure continued utilization. A critical value of RWS must have been determined and used as an indicator for sustainable utilization. In addition, in comparing the four wetlands, the researcher should have closely studied the various types of land use, their extent and intensity. Differences in RWS could have been explained considering land use apart from water management and cropping practices.

Considering the research work that has been done, it is clear that depletion of ground water in wetlands is due to two factors; consumptive use by crops and drainage. It is necessary to determine which of the two is greater so that minimizing the factor that contributes more to water loss from the wetland can reduce water abstraction from the wetland. This information is useful for improvement of productivity of wetlands. More work also has to be done on recharge characteristics of wetlands. This information can then be used to determine the amount of water available for use during the dry season and the subsequent cropping program and cropping intensities. Discharge information alone does not suffice; the difference between recharge and discharge is more important in preventing desiccation.
CHAPTER THREE
MATERIALS AND METHODS

3.1 DESCRIPTION OF STUDY AREA

The research was carried out in Intunjambili wetland, one of the several wetlands found in the catchment of Tuli River. The wetland is located 20°27′S, 28°41′E and is 1500 m above sea level. This area falls in region four of Zimbabwe’s ecological farming regions. It is therefore characterized by low annual rainfall, ranging from 400mm to 600 mm and the mean temperature is above 20 °C. Rains are received in summer from October to March and they are often unevenly distributed over the season. As a result crop failures are prominent but crops grown on wetlands survive. Wetland farmers are therefore more food secure when compared to dry land farmers. During the dry months crops can only be grown in wetlands or under irrigation. However, irrigation is expensive for communal farmers.

Intunjambili wetland is one the largest wetlands in the catchment with an estimated area of 30 ha. The wetland is perennial and it is also easily accessible. Cultivation of crops and other activities such as fetching domestic water occur throughout the year in the wetland. Different methods are used to manage water in the wetland and analysis of these methods is comparable since they are in the same wetland. In addition, various land uses that include pastures, gardens, gum-tree plantations and virgin land are found, making it a potentially good site for research on effects of land use and other aspects on groundwater.

The one-meter profile depth, obtained during drilling of observation wells, showed that the top 200 mm have a mixture of clay and sand particles. The organic matter content in the topsoil was high. Below the 250 mm depth the soil changed to clay up to a depth of 500mm below which sand particles became more dominant. The soils are derived from granite rocks that form an impermeable barrier, resulting in water accumulation.
3.2 ZONING OF INTUNJAMBILI WETLAND AND LOCATION OF OBSERVATION WELLS

Land use was used as the major parameter for zoning the wetland. The extent of different land use pattern was established and the wetland was categorized into three zones, zone A, zone B and zone C, as shown on the map in figure 3. Zone A is the up slope end of the wetland where grazing is the main activity. Dry land fields and gum-tree plantations were found this zone. Two observation wells were driven into this area. The area was relatively dry and its water table was therefore expected to lower than that of the other two zones.

Zone B was in the middle of the slope. This was where most cultivation occurs; using different methods to lower the water table so that crops grow on properly aerated soils. Five observation wells were drilled in this zone. Their location was determined by various factors such as slope but water management practices were the main criteria.

Observation well 9 was located where 200 mm to 350mm drainage furrows were used for growing vegetables. Vegetable beds 1m wide were used with the furrows. The location of this was down slope of well No 8 and well No 7 in field S. Well No 8 was located where maize was grown without any water management methods. Well No 7 was driven to serve as a reference well for both well No 8 and well No 9. Well No 7 was drilled up slope of the two wells in field S. Two wells were drilled in field T, which is also in zone B. Well No X and well No Y, were located where vegetables were grown on raised beds, without any furrows.

In the lower end of the slope, zone C, three observation wells were drilled. These wells were put for comparison of the water table fluctuations in this zone and the other two zones. This zone had limited activities; there were no gardens and it was only used for grazing in dry months of the year. However, this zone was compacted by both man and animals like zone A although to a lower extent. Compaction is an important factor influencing the response of the water table to rainfall. Streams draining the wetland also flow across this area and they
Fig 3: Zoning of wetland.
influence the level of the water table as well. Observation well No 10 was driven down slope of the wells in field S and upslope of well No 11 and well No 12. The aim was to find out if cultivation has any significant effect on water loss through evapotranspiration i.e. wells in field S, compared to evapotranspiration from natural wetland vegetation i.e. well No 10. Well No 11 also served the same purpose. It is located down slope of wells in field T.

3.3 DETERMINATION OF WATER TABLE

3.3.1 Observation wells
Observation wells are small diameter pipes (25 mm to 50 mm) installed vertically into the ground. Observation wells are useful for determining the depth of the water table from the ground level. Water enters the pipe through the entire section of the pipe located below the water table (Murty, 2002). 50 mm diameter observation wells were driven 1m deep into the wetland.

3.3.2 Water table level measurement
The level of the water table was measured using a 1200 mm long 32 mm diameter pipe. The measuring pipe was sealed at one end with a loss plastic material. When it is inserted into the 50 mm diameter observation well with the open end, air is entrapped when it reaches the water surface and the air pushes the plastic up, producing a sound at the same time. The level of the water table is then read from the scale along on the pipe. The method of water level measurement is illustrated in figure 4.

The method gives slightly higher readings but the error is consistent. The error in measurement of the water table arises because the plastic does not readily respond as would occur with an electron probe. The tip of the pipe goes into the water to give an appreciable response. An electron probe is recommended for measuring the water table level.

3.4 RAINFALL MEASUREMENT
Three rain gauges were used to measure rainfall in the wetland. Their locations are shown on the sketch map for the wetland. Rainfall measurements were taken everyday at 8 a.m. The average value of the three was used for to investigate how the wetland responded to rainfall.
Data was collected for sixty-six days, starting on the 19th of January 2005 to 25 March 2005. At that of the season enough rainfall had been received and the wetland had significantly recharged to a water table depth of less than one meter. The data consists of rainfall and water table level measurements. Microsoft excel was used for data preparation and subsequent data analysis.
CHAPTER FOUR
ANALYSIS OF RESULTS AND DISCUSSION

The depth of water table is influenced by several factors. Among them are the location of the observation well and activities occurring on the surface. Activities include type of land use, water management practices on cultivated areas and the types of crops grown in gardens. Different forms of land use have various impacts on the water regime of the wetland. These include both top land or catchment land use and wetland land use. Catchment land use affects recharge of wetlands than water abstraction from wetlands whereas wetland land use affects both (Ingram, 1991). All these factors affect the response of different parts of the wetland to rainfall as well as the rate of depletion of groundwater from the wetland.

4.1 ZONE A

In zone A, the upland portion of the wetland, the major types of land use are grazing and eucalyptus plantation. There are dry land fields as well. Two wells were drilled in this zone, well 1 and well 2. Groundwater fluctuation in this zone is shown in figure 5.

The water table remained lower than 1000 mm in observation well 1 during the period of data collection. This is partial due to its location upslope since water drains under the influence of gravity. The low water table in well 1 could have also resulted from rapid water abstraction by gum-tree plantations that were found in the area. Phreatophytes (deep-rooted plants that obtain their water from the water table or a layer of the soil just above it) have unlimited access to water as long as the wetland does not dry out completely. They therefore transpire at their maximum rate throughout the year (Hough, 1986). In observation well 2, the water table remained above 1000 mm for eighteen days after the first rains.
Rapid depletion of groundwater resulted from phreatophytes. Ingram (1991) also notes that the effect of plantation on margins of wetlands causes desiccation. Coppicing, especially in eucalyptus, further accelerates water loss. This, however, is a controversial issue. Clearly, the species, planting population and wetland recharge capacity are all important factors. However, the fact that the wetland was still recharging cannot be ruled out. This implies that water continued flowing down the slope and thus lowering the water table in this zone A. Groundwater permanently rises in zone A after the zones located down slope have been fully recharged.

The water table record for well 2 shows that groundwater started rising three days after the major rains, reaching a peak of 880 mm on the seventh day. The response to rainfall was not immediate due to low infiltration rates in the zone resulting from livestock soil compaction during grazing. Animal trampling and soil compaction may have a dramatic impact on infiltration and erosion. Hough (1986) noted that trampling by large numbers of cattle reduced porosity by up to 50 percent and permeability by up to 90 percent, at Coweeta, North Carolina in the USA. Soil compaction measurements done by Sibanda (2005) in Intunjambili wetland showed that pastures were more compacted than ungrazed areas. Rainfall in this area gathers on the surface and flows as overland flow. However,
this part of the wetland only responded to rainfall above 20 mm. Rainfall less than 20 mm was not effective enough to cause a rise in the water table. This could have resulted from various causes. Antecedent moisture content of the zone could have been causative factor. When the initial soil moisture content is low, rain falling on a particular land first has to recharge the topsoil and subsoil before deep percolation begins. As the water percolates some of it is lost through evaporation and transpiration before it reaches the water table. The average water table level for zone A was 854 mm.

### 4.2 ZONE B

The fluctuations of groundwater in zone B are shown in figure 6. The response to the first rainfall is not clear due to absence of water table data prior to the first rainfall event. The water table remained high (around 200mm from the surface) in all the five wells although the rainfall was decreasing. The rainfall that continued falling after the first 20 mm major rains was adequate to compensate for the water loss through evaporation, transpiration and drainage, thereby maintaining a constant water table. Inflows from the surrounding rocks also replenished water loss from zone B.

![Fig 6: Groundwater fluctuation for zone B.](image)

The water table continued dropping to below 200 mm for all the wells six days after the rainfall that was received on the fifth day of data collection. Thereafter, groundwater
depletion showed different trends for various wells. In well 9, a rapid drop of 280 mm was noted on day 16. This was attributed to water drainage by furrows that ran down the slope which were used by farmers to lower the water table. Giesan (1995) documented that furrows can lead to over drainage. In contrast, Mharapara et al (1995) suggested that furrows and ridge system conserve water. The effect of furrows on the water table depends on their orientation with respect to slope, their depth among other physical factors. Farmers used 200-300 mm deep furrows. The water table in observation well 9, however, remained high (300 mm from the surface) throughout the period of data collection although rapid depletions were noted, indicating that the area had a higher potential of water loss by drainage. The water table remained high in observation well 9 because farmers were irrigating vegetables daily and the rapid drops in water table recorded occurred when farmers changed frequency of irrigation.

The water table in well 7 depleted at the fastest rate in zone B, string from a high of 160 mm on day 2 to a low of 880 mm on day 66. This well was located in maize field upslope of well 8 and well 9. Water loss was therefore due gravitational pull and abstraction by maize, which is higher than that of vegetables. The water table in the well responded to rainfall even when it had reached a depth of 800 mm on day 50, which indicates that there are in-flows onto the wetland. 12 mm rainfall was received on day 50 but the water rose by 40 mm in well 7. Runoff from the surrounding rocks resulted in a recharge of 40 mm, 28 mm higher than the rainfall that was received. The same trend was noted in all the observation wells in zone B.

Water table fluctuations for well 8, well Y and well Z were in the range 400 mm to 600 mm from day 49 up to the end of data collection. In well 8, however, the water table was the highest for zone B at the beginning of data collection. It depleted steadily without any rapid drops and responded to all the rainfall events. The area had a maize crop in broad beds that ran across the slope. Water loss from the area was therefore minimal. Well Y and well Z were located in field T and they also had a steady depletion of ground water. Well Z was located in the an area where raised one meter wide vegetable beds were used whereas well Y was in the garden area where vegetables were planted on plain beds. The use of the raised beds resulted in the water table for well Z remaining lower than that of well Y. The presence of sugar-cane rows close to observation well Z could have also
contributed to deletion of water in this well. The two wells Y and Z responded immediately to rainfall.

4.3 ZONE C

Groundwater fluctuations for zone C are shown in figure 7 below. Zone C is the lower part of the wetland and it is only used for grazing during the dry months of the year. There are no gardens in this zone. Three observation wells were drilled in this zone.

![Groundwater fluctuations for zone C.](image)

The water table in all the three wells in this zone responded to all rainfall events that were recorded. However, the water table in well 12 did not rise in response to rainfall that was received on the 50th day owing to its depth. Rainwater was lost to transpiration and evaporation before it reached the water table. The depth of groundwater was initially low in observation well 12 mainly due its location close to a gully head. It remained lower than that of the other two wells throughout.

The water table for well 10 and well 11 was at the surface at beginning of data collection. This could have resulted from a number of causes. The wells were located in the core part of the wetland and all the runoff coming from the surrounding rocks flows towards this
zone. When runoff gets to this zone flow is retarded by grass that was densely covered the soil. Subsurface water also emerged at this part of the wetland. The water table started dropping as soon as the rainfall stopped. Subsurface flow could not meet transpiration losses that were at a peak rate. The effect of transpiration was shown by a sudden reduction in the rate of water depletion around day 15. The rate of water loss reduced because less roots were accessing water when the water table reached 400 mm depth. Water loss by transpiration was accelerated by active growth of grass that was in turn enhanced by nutrients leached from the nearby gardens. Farmers used fertilizers such ammonium nitrate in their gardens.

The water table in zone fluctuated between 400 mm and 600 mm after it had steadied three weeks after the major rains. There were noticeable rapid drops however, due to underground water influence and subsurface delayed recharge.

4.4 COMPARISON OF THE ZONE B AND C

The average fluctuations of the water table for the three zones are shown in figure 8. Zone C initially had the highest water table but the rate of discharge from this zone was higher than that of zone B. The rapid drop of groundwater was attributed to the density of vegetation in this zone. Zone C had dense cover of native vegetation compared to zone B although it was all native vegetation. Ingram (1991) suggested that density and species of vegetation influences water loss through transpiration. The water table of zone C depleted steadily but faster than that of zone B up to day 25 when discharge from the two zones became uniform resulting in constant difference in the water table depths up to day 65. Recharge and discharge from the two zones, B and C, were equal from day 25 to end of data collection. Zone B had an average groundwater depth of 400 mm in field S and 429 mm in field T and it remained higher than that of zone C, which had an average of 508 mm, because farmers were irrigating gardens.
Fig 8: Zone average water depth.
CHAPTER FIVE
CONCLUSION

The data collected was insufficient for concrete conclusions to be drawn. Some more informative analyses of results such as determination of correlation between rainfall and the rise of the water table were not done. However, the analyses groundwater fluctuation results that were collected led to the following conclusions.

Cultivated areas responded immediately to rainfall and greater than grazing areas and virgin parts but depletion of the water table in cultivated areas was rapid soon after the rainfall had stopped. Use of furrows in the gardens caused rapid depletion of groundwater. In fields where broad beds were used, the water table depleted at a lower rate than where furrows were used. Irrigation in the gardens recharged the groundwater and the water table for zone B remained high.

Dense grass cover in zone C reduced water flow and this kept the water at the surface. Water rate of water abstraction by grass from this zone was higher when the water table was close to the surface but reduced as the water depth dropped. Water that infiltrated and recharged the wetland emerged in zone C. The stream passing through zone C drained the wetland.

Plantations of gum-trees negatively impacted on the water regime of the wetland. Soil compaction and livestock trampling particularly in zone A also negatively impacted on the water table of the wetland.

Runoff from the surrounding rock outcrops significantly recharged the wetland. The water table had noted rises without rainfall. This was a result of natural groundwater fluctuations or it was caused by delayed subsurface recharge from the surrounding catchments.
CHAPTER SIX
RECOMMENDATIONS

The change of water storage in the wetland is result of human interaction with the wetland system. The recommendations that were developed followed from the discussion of the results and conclusions that were drawn.

6.1 GENERAL RECOMMENDATIONS

1. Water table measurements should be done for areas where gardens are located, at least for one season prior to the cultivation of the particular portion of the wetland. The water table measurements can be substantiated with simulation for different weather conditions.

2. Farmers should not cultivate where the water table is close (less than 300 mm) to the surface.

3. Down slope furrows should be used for lowering the water table.

4. Phreatophytes (gum-trees and sugar-cane) should not be planted in wetlands.

5. Stocking intensities should be reduced.

6. Ridges that run across the slope should be constructed in zone A to facilitate water infiltration.

7. Shifting planting dates to prevent tillage problems associated with water logging.

6.2 GUIDELINES FOR WATER MANAGEMENT PRACTICES

Proper water management practices should take into account the following factors:

- Slope.
- Depth of water table.
- Physical soil characteristics.
- Layout of water management system.
- Type of crops to be grown.

Further research needs to be done on the five factors outlined above for the wetland so that comprehensive data base for water management can be developed for Intunjambili wetland. Soils of the wetland need to be tested for parameters such as porosity and the rooting characteristics of the crops grown also need to be studied. This calls for research
by specialists from different fields and with such effort the wetland can be used productively without any fears of desiccation.
REFERENCES


APPENDICES

APPENDIX 1

Statistical Analysis of Water Table Measurements
Student-t Test @ 95% Confidence Limit.

Table 2. Average water depth for the three zones.

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<th>2</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>Y</th>
<th>Z</th>
<th>10</th>
<th>11</th>
<th>12</th>
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<td>332.06</td>
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<td>362.70</td>
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<td>640.08</td>
<td>420.16</td>
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<tr>
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<td>15.43</td>
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<td>19.23</td>
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<td>429.61</td>
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APPENDIX 2

Groundwater Fluctuation For intunjambili Wetland
(mid January 2005 to end of March 2005)