Conservation Farming Managements in Savanna Woodland Environments in the Eastern Province of Zambia

An interrelated efficiency evaluation of vegetative erosion control managements compared to non vegetative erosion control

By

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Abstract

In the Savanna Woodland hills in the Eastern Province of Zambia, soil erosion along slopes constitutes a serious problem for agriculture. To alleviate this problem, farmers use different forms of conservation farming management to reduce these problems. This paper investigates the effectiveness of three different conservation management methods, both on the occurrence of visible signs of erosion in the fields and on the resulting nutritional status of the soil in the fields. The methods compared were “simple conservation farming”, which uses hand-made level bands placed between fields vertically to the angle of the slope, “vetiver conservation farming”, which uses Vetiver grass to stabilize these earth ridges, and “agroforestry conservation farming”, which uses earth ridges between the fields supported by trees. In addition, by relating measures of nutrient status to visible signs of erosion, this paper focuses on soil nutrient changes as an indication of soil erosion along slopes.

Fields were inspected for visible signs of erosion. Because all measures of visible signs of erosion taken (denuded pebbles, denuded roots, gullies, rills, hard pans) were highly correlated, the first principal component was used as a combined measure of erosion. Soil sampling was carried out on different slope transects and slope positions. The soil samples were analyzed for P and N, pH and particle size composition. The results of the study indicate a higher concentration of nutrients at the base of eroded fields. In fields with more signs of erosion, the content of phosphorous increased significantly more with distance from the top of the fields. The results from the study also demonstrate a significant correlation between field management and field erosion protection capacity. The extent of visible signs of erosion tended to be related to management method, with agroforestry conservation farming demonstrating significantly less signs of erosion. The concentration of phosphorous was also affected by management method, with agroforestry conservation farming preserving significantly more nutrients at the top of the fields than vetivier conservation farming. Simple conservation farming resulted in low levels of phosphorous all along the slope of fields, resulting in the content of phosphorous being eight times higher at the top of fields with agroforestry conservation farming than in fields with simple conservation farming. The fields with agroforestry conservation farming in this study used *Cajanus cajan* to stabilize the earth ridges. The results indicate a somewhat lower level of phosphorous close to this plant than expected, which would be the result of *C. cajan* being able to fixate nitrogen and therefore effective in absorbing phosphorous.

The findings of this study demonstrate the importance of conservation farming to protect fields against erosion and thereby preserve the nutrient status of the fields. It demonstrates that agroforestry conservation farming using *C. cajan* was the most efficient of the studied methods. Further studies are needed to evaluate additional methods and to generalize the results also to other areas.

Keywords: Zambia, Kawoozi Camp. Chipata. Enrichment ratio, soil gradient, slope position, soil nutrients, conservation farming.

1 Introduction

Most people in Zambia live in rural areas and depend on small scale agriculture (MAFF 1998). One of the most crucial problems in these agricultural areas today is depleted soils resulting in declining yields. Soil erosion is one reason for this problem (Lal, 1985; Ovuka, 2000) along with hilly areas, such as the study area, having the highest rates of productivity decline (Scherr et al., 1996).

The crucial factor is lack of rainwater, which is a problem during the dry season. During these long periods with almost no rain the soils dry out, and so, binding material and nutrients are easily driven away by wind erosion (Hudson, 1971). The drought also makes the water permeability of the soils very low as, when it finally rains, the rainwater does not absorb into the soil but flushes down the surface (Åkerman, 2001). The rain periods generally last over a couple of months; however most rain normally falls during only a few days.

Soil erosion due to excessive water is most active in areas were rainfall is uneven throughout the year, and then impetuous when it rains, and, therefore, do not infiltrate into the soil. While the water is travelling rapidly over the soil surface, it removes soil materials and nutrition down slope and away from the field. The soil nutrition is swept away by the water and the soils lose their fertility, resulting in nutrient depletion (Lal, 1976; Moore, 1978, 1979). Soil nutrient depletion and fertility decline are hence caused by soil erosion creating differences in nutrition content of the soil through out the slope depleting the upper and middle parts of the fields (Morgan, 1995; Ovuka, 2000).

Soil fertility refers to all soil characteristics that influence plant growth and can limit the yield. Soil nutrient status is one indicator of soil fertility (Gachene, 1995; Ovuka, 2000). Research on development of resource management strategies to improve soil fertility has been substantial in African countries (Braun et al., 1997; Ingram, 1994). Depletion of soil nutrients is one of the most serious threats to agricultural production and food security in sub-Saharan Africa with the highest depletion in mountainous and highly populated areas (Sanchez et al., 1996; Stoorvogel el al., 1993; Whiteside, 1998).

Even very stable soils, which are not properly covered by vegetation, will be eroded when exposed to intensive rainfall during the rain season. Since the Savanna Woodland systems are environmentally sensitive, the loss in soil fertility due to erosion is one of the major threats to food security in these areas (Brown et al., 1994; Pimentel et al., 1995). According to Lal (1988), effective ground cover, such as grass and trees, is the key to prohibit enhanced erosion processes. Moreover, the downward flow of water, which transports small soil particles and nutrition away from the fields, is hindered through the use of planted vegetation (Åkerman, 2001). Furthermore, the planted vegetation gives the water a chance to infiltrate into the soil, where it is of great importance for the agricultural outcome, while decreasing the erosion effects of the water.

This study focuses on how different forms of vegetation planted between the cultivated fields affect the erosion and compares these managements to one another and the erosion in the uncultivated Savanna Woodland.

2 Objective and Means

The aim of the study is to investigate the impact of soil erosion by rainwater and how the soil erosion affects the soil nutrient status in a rural area with typical Savanna Woodland (SW) hill environment, through on-farm studies, in the Eastern Province of Zambia.

The study is directly looking at the relationship between soil nutrients and soil erosion. The study is also looking at the ability to control soil erosion in fields by using different vegetative erosion protection managements. The intention is to investigate what management is giving the best protection against erosion in the study area environment, in order to promote prolonged yields and possible food security in the area.

Special focus is placed on:

- If soil erosion has negative effects on soil nutrient status.
- If erosion protection management has an effect on soil nutrient status and erosion.
- If the spatial variation of soil nutrient contents and enrichment ratio within fields differ depending on erosion protection management.

In view of the above, the overall objective of this study endeavors to investigate the impact of soil erosion by water on soil nutrition and soil particle movement. This study is based on the assumption that nutrition is depleted by erosion which leads to loss in soil fertility and that depletion in fertility might be a threat to food security. This study is limited to look at how different managements could protect agricultural land in poor Savanna Woodland hills against soil erosion in order to maintain soil nutrients for the small scale farmers in these environments.

3 Scientific Background and Theory Review

Soil erosion is defined as the removal of surface soil material by wind or water (Morgan, 1988). Erosion should be looked at as a process of landscape denudation, as soil erosion is a natural phenomenon and should be recognized as a problem only when there is an accelerated process within a geological short term time scale. Erosion can also be looked at according to its immediate climatic and vegetation controls, and how raindrop impact, flow generation, and sediment resistance affect the processes (Hudson, 1971).

The raindrops create a splash effect moving the small soil particles down a slope (Fitzpatrick, 1992). This downwards movement of the soil particles is strengthened by the down slope flow generation of the rain water that sweeps the soil down slope along with the water. This process is largely dependent on the water retention capacity and erodability of the earth. If the soil is dried out, it will not be able to infiltrate much water, resulting in a strong flow of water over land. Soil erosion by water is most active where rainfall can not infiltrate into the soil. It then travels fast over the surface and is able to carry away soil materials and nutrition. According to Morgan (1995), this is why the overland flow is the main denudation process in areas with a wet dry climate. The dried out soil will not contain much binding material since the plants can not live without water and leaving the smaller binding soil particles to be transported away by wind erosion when the soil falls apart (Rowel, 1994). As small particles are also carried along with large amounts of water flow over the surface, this even causes soil erosion on low gradients.

Severe soil erosion also forms gullies that eat themselves through the soil horizons of the fields, transporting soil particles away. By this, gullies play an important part in the down hill total sediment removal (Fitzpatrick, 1992).

Soil loss can reduce potential soil productivity for many agricultural crops (Baver, 1950; Jacks et al., 1939; Neol, 1943). Numerous reviews have reported a negative relationship between erosion and soil productivity (FAO, 1984; Lal, 1981; Stocking et al., 1985; Williams et al., 1983). Sandy savanna soils, such as the soils in the study area, are very vulnerable to erosion. They are often infertile and the nutrition is commonly concentrated in the top soil profile.

This type of horizon is easily affected by erosion because of high rates of water erosion due to impetuous and strong rainfalls. Furthermore, the soils are poorly structured with low infiltration rates and are located in steep, long slopes which are cultivated without adequate soil conservation (Lal, 1976; Moore, 1978, 1979). However, according to Lal (1988) vegetative ground cover, such as grass and trees, is effectively prohibiting enhanced erosion processes (Lal, 1988). The erosion will however not be lessened through higher precipitation if the natural vegetation is removed. In this case the erosion will just be increased and the landscape and the farming soils will be swept away (Hudson, 1971).

Erosion, causing the loss of plant nutrients, causes damage to the soil that often is irreversible (Bramble et al., 1985; Engelstad et al., 1961; Frye et al., 1982; McFarlane et al., 1991; Pierce et al., 1983; Kilewe, 1987) and erosion, therefore, is a major problem concerning the sustainability of agriculture (El-Swaify et al., 1992). Phosphorus is difficult to dissolve in water and follows the transportation of sediments in surface running water. When rain falls, nutrition bound to soil particles is transported down hill (Zobisch, 1995). This nutrition loss is corresponding particularly well to P bound to calcium (Fitzpatrick, 1992) making phosphorous a significant indicator of soil erosion and interesting for studying soil erosion.

If there is very little P at the top of the field compared to the bottom, it is an indication of strong erosion. P is bound to the sediments that are transported (Tengberg, 1997); hence, P is telling how the sediments are moving in the slope (Figure 1). Furthermore, other nutrients are bound to the sediments why the P removal is an indication of the transportation of small soil particles and nutrition through erosion as a total (Verity, 1990). With high erosion the P is lower at the top of the field than it is at the sedimentation area at the bottom (Gachene, 1995; Ovuka, 2000).

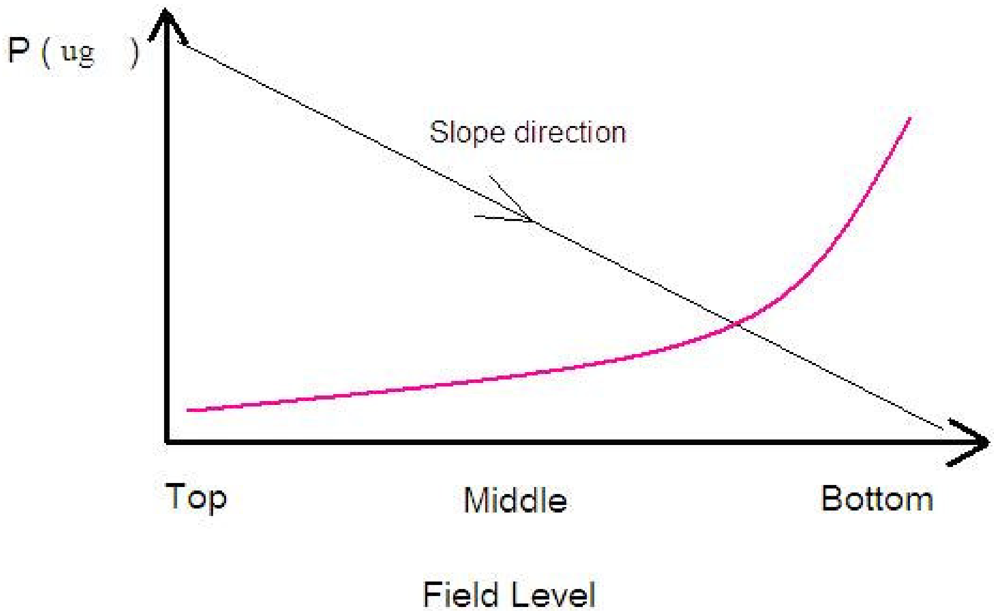


Figure 1. P in a field unprotected against erosion. The arrow shows the slope direction.

The fields with little erosion protection management will show P content curves that are steeply pointing upwards at the bottom of the fields. Were there is better erosion protection, though, the curve is more even throughout the field and shows less P at the bottom of the field (Figure 2).

This means that there is a positive slope of the relationship between P content and row number in these fields through the more effective erosion protection. The sedimentation area at the bottom of the field contains less P compared to fields with less erosion protection. P in the middle of the field is, however, still expected to be low since the field is in a slope and the middle of the field is unprotected against erosion. This unprotected area induces some erosion in all of the different fields irrespective of management since the erosion protection is situated at the top of the field (Gachene, 1995).

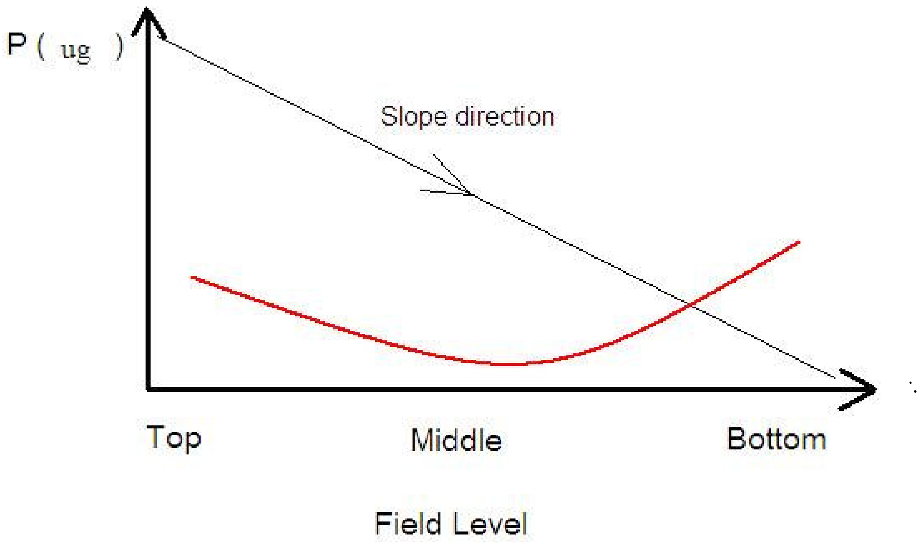


Figure 2. P changes in a field moderately protected against erosion. The arrow shows the slope direction.

In a field where the protection is highly efficient there is some nutrition sedimentation at the bottom of the field as the field is in a slope and the middle of the field is unprotected against erosion (Hudson, 1971). However, P is higher at the top of the field than it is at the base. This is an indication that the erosion protection at the top is efficient (Figure 3) and that there will be a positive slope of the relationship between P content and row number in the field using Mixed model statistical method.

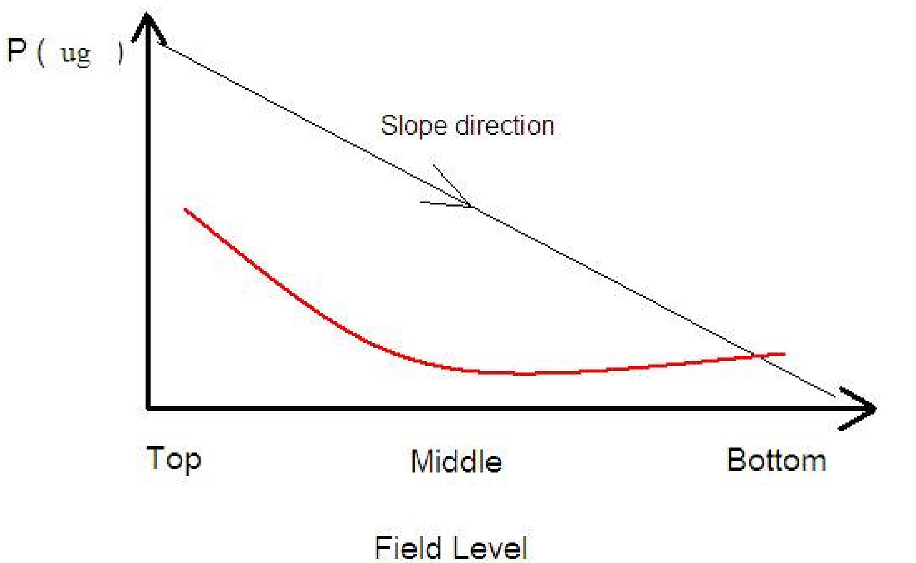


Figure 3. P changes in a field efficiently protected against erosion. The arrow shows the slope direction.

The erosion development can be slowed down by protection in the cultivated areas from vegetation cover that will hinder the erosion to transport soil particles and organic matter from the fields. Today, it is done by using grass and trees that are supposed to protect the fields from the erosion effect of wind and water (Åkerman, 2001).

4 Description of the Study Area

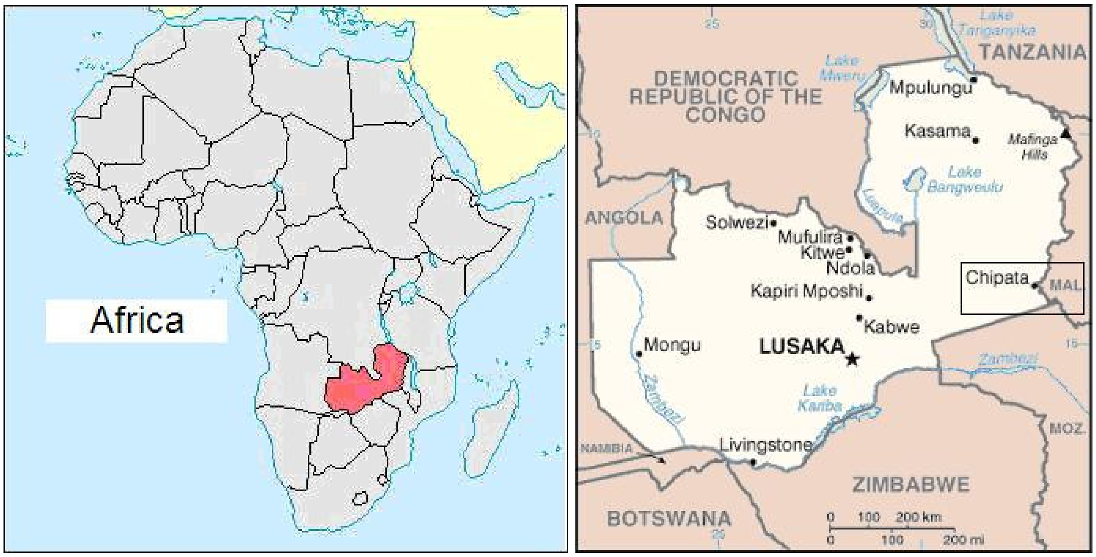


Figure 4. Africa map regarding location of Zambia and regarding the study area. (NE, 2004; CIA, 2004)

The study area is located in Eastern Province of Zambia in South East Africa (Figure 4). The population in Zambia is about 10 million people (CIA, 2004). Only 7% of Zambia constitutes arable land and only 0.03% is covered by permanent crops. Only a tiny fraction (0.06 %) of the arable land is irrigated (CIA, 2004).

4.1 *The Eastern Province of Zambia*

The Eastern Province of Zambia is located at the border of Malawi to the east and Mozambique to the south and covers an area of 69 kkm^2 (Figure 5; Phiri, 1998; Appendix 1).

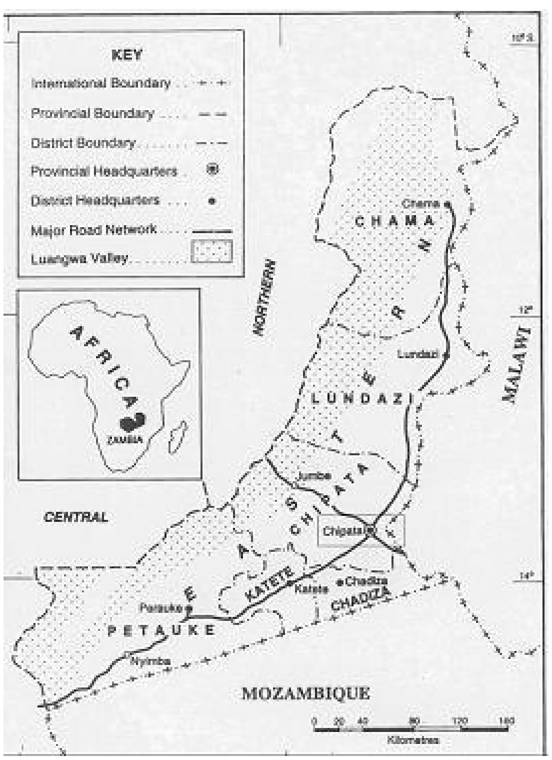


Figure 5. Eastern Province regarding the study area


Figure 6. Chipata.

4.2 *Description of the People in the Study and the Study Area Environment*

The administrative centre of the Eastern Province is Chipata (Figure 6). The population in the province was approximately one million in 1990. The per capita land availability is 8 ha, which would have been sufficient if the population was evenly distributed but the people live in villages and due to the typography much of the land is useless for agriculture (Phiri et al., 1998). This study focuses on the fields of small scale farmers in the mentioned rural area in the village of Domisa in the Kawoozi camp, approximately 3 km south of Chipata (Appendix 2). The village is placed on a hillside located on the longitude S 14°41'28.4" and latitude E 32°37'19.7".

Small scale farmers constitute 95 percent of the population. The farmers rely only on hand driven technology and family labor of 5 to 6 people occupying land holdings of 0.5-5.0 ha making them economically vulnerable to environmental changes (Stocking, 1985). All the cultivation is done within the corn land, called Munda, which is the focus area of this study, and where the study fields are located (Appendix 3). The people live below, in the village area, called Masala, where the houses are located in the center of the village (Appendix 3). Just below the village is the Dimba Garden located (Appendix 3).

The Dimba garden floods during the wet season and is rich in organic matter giving good conditions for growing bananas, sugar canes, papaya and mango (Phiri et al., 1998). Next to the Dimba Gardens, at the very bottom of the valley, is the fish pond area, called Dambo (Appendix 3). The study area is, as is common for this part of Africa, dominated by the Savanna Woodlands biome. The study area hill is situated at an altitude between 1055 and 1156 meters above sea level (Appendix 3). This forms a mountain related sub tropical climate with three seasons and an irregular distribution of rainfall during December to March. The rest of the year is in almost total absence of rainfall and hence a dry period and April to August is the cold period.

The average temperature varies between 15° and 18° during the coldest months of June and July. During September through to October, which is the hot and dry season, there is an average temperature of between 21 ° and 26°C (Phiri et al.,1998; CIA, 2000). Only during the brief rainy season water is there sufficient water and soil-water storage being low during the dry season (Phiri et al., 1998). The Eastern Province is situated on the higher parts of a plateau and the surrounding area of Chipata is situated on granite bedrock. The bedrock has eroded and there are typical talus processes with Thor formations and Inselbergs (Phiri et al., 1998). The oldest rocks are volcanic being 2.5 billion years old and have been unaffected by organic processes since Precambrian times. This old structure is partly covered by ancient sedimentary rocks, and together they constitute the basement complex. These give the basic components of the eastern soil (Phiri et al., 1998; Appendix 4).

The soils in the Kawoozi camp, and the whole of Chipata area, are red sandy loams keyed as a mix between Acri/Luvi and Alisols (Appendix 5 A and B). These are dark reddish sandy loams or sandy soils. These soils are easy to till but are low in nutrients and have a low water holding capacity with a tendency to form hard pans (Phiri et al., 1998). The acidity in the area of the study is slight to moderately severe (Appendix 6). Although not a morphological measurement, the pH is one of the most important measures for determining the condition of a soil (Boul, 1980). Acidity is part of this study and is the focus of the acidity tool kit Pilot Study (Pilot Study). The soil layers in the eastern province consist mostly of washed-out acid soils that are low in nutrients and not fit for agriculture (Phiri et al., 1998).

4.3 *Erosion in the Eastern Province of Zambia*

Soil erosion is a serious problem in most parts of the sub tropic climate zone, where the study is located. The erosion can be very fierce and sweeps away soil layers. This is indicated by the loss of topsoil nutrients due to the force of water and wind working on the erodible soils and the average yearly rainwater runoff being 125 mm in the study area (Appendix 7). The geomorphology in the study area is distinguished by the Savanna Woodland highland hills that are very sensitive to erosion due to the steep topography. At the base of the area, there is an undulation plateau (Appendix 8) and there are hills, ridges and minor escarpments in the study area. The fields are located on a mountain slope with an angle between 4˚ to 20˚.

The Eastern Province and the Chipata areas are, due to their geomorphology, sensitive to erosion. The erosion is very irregular with an average of c. 900 mm rain falling nearly exclusively during the months of December to March (Appendix 9). The rest of the year is in almost total absence of rainfall and hence being a very dry period. Only during the brief rainy season water is there sufficient water with soil-water storage being very low during the dry season. The scoring for soil erosion is valued among the highest in Zambia (Appendix 10). The soils are not well suited for water storage as they are sandy (Phiri et al., 1998). The vegetation in the Eastern Province is, as general for this part of Africa, characterized by the Savanna Woodland biome (Appendix 11). The Savanna biome wet-dry climate permits a dense lower layer of grass and a higher layer of trees widely scattered over the woodland. The Savanna Woodland is sensitive to human influences and is easily affected due to being cut down, resulting in accelerated erosion.

4.3.1 Savanna Woodland – SW

Savanna Woodland (SW) is the natural environment in the study area. The SW is normally covered by grass and trees. The SW in the study area is pushed back to the steep hills. This area is still covered by trees and grass. The SW hill area is very important for erosion control protecting the down slope corn land from water flushing from the steep hills (See Figure 7). The Savanna Woodland hills are diminishing rapidly because of the trees are gradually being cut down for carpeting, fires and building material, leaving the hills unprotected from erosion in this area. This erosion affects the agricultural area indirectly and is therefore investigated in this study.

4.4 *Erosion Control used in Kawoozi Camp*

Soil erosion can result in the decline of soil nutrient content but also in the reduction of moisture retention capacity. This is because it reduces the level of organic matter in the soil and reduces the rooting depth of plants. Reducing soil moisture and fertility will lead to diminished productivity of the land. This may make the soils in the area useless for farming and the process is hard to reverse (Raussen, 1997). On cultivated lands, soil erosion and loss of soil fertility may be accelerated by inappropriate farming practices. The rain water run off from the fields rushes down the slope and, if it is not stopped by any hindering forces on the slope, carries all the soil down to the bottom of the valley. Nutrient losses are controlled by carrying out proper soil management practices (Gachene, 1995). In the Kawoozi Camp, several different soil and water conservation techniques are practiced in order to control erosion. Simple Conservation Farming (SCF) uses earth ridges at the top of the field to reduce erosion by water. More advanced forms of management techniques uses vegetation to support the earth ridges. This study is focused on two forms of vegetation erosion protection used in the camp: Vetiver Conservation Farming (VCF) and Agroforestry Conservation Farming (ACF), which are compared to simple conservation farming management and to erosion in the uncultivated Savanna Woodland hills.

4.4.1 Simple Conservation Farming - SCF

Simple conservation farming (SCF) is the minimum form of conservation farming used in the Kawoozi Camp. This management uses level bands, made by hand hoes, to hinder erosion. The level bands are placed between the fields vertically to the angel to the slope. The earth ridges are renewed every year (Figure 8).

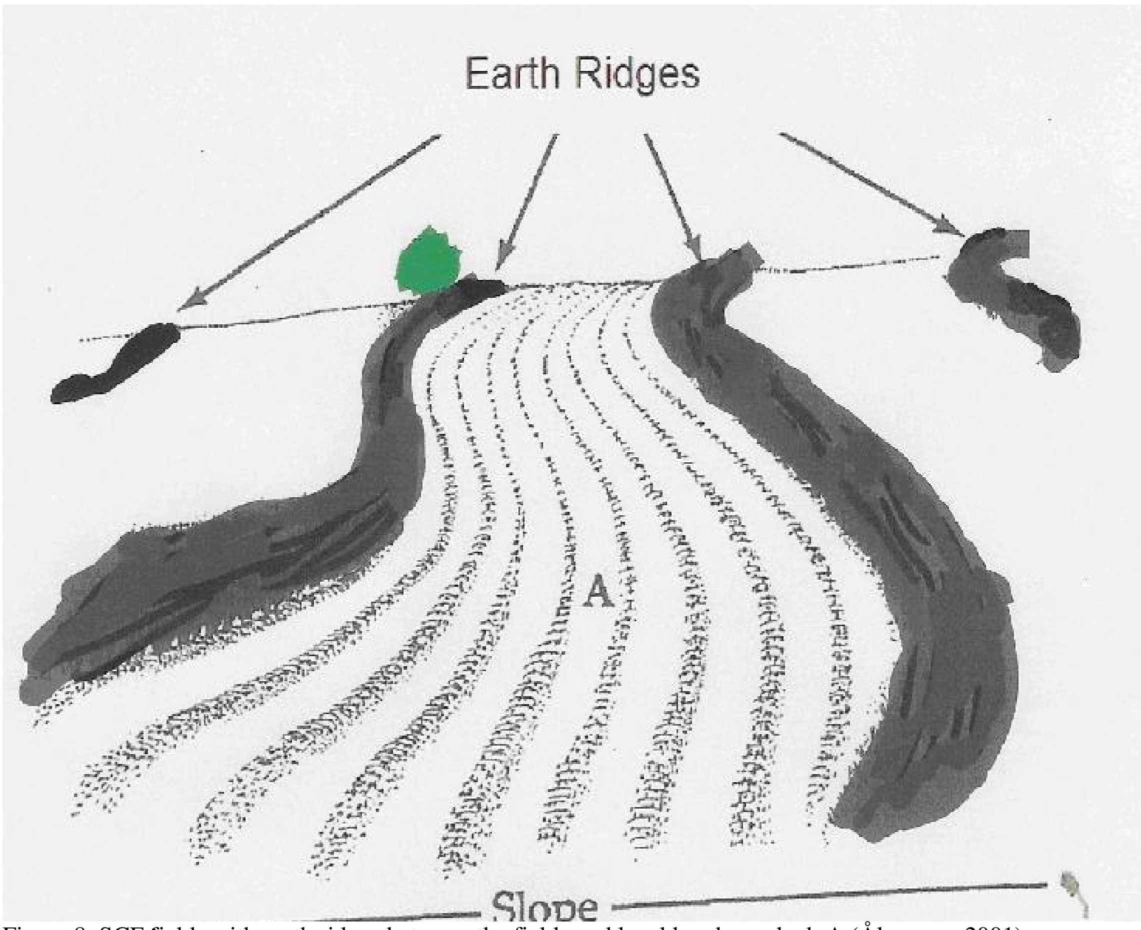


Figure 8. SCF fields with earth ridges between the fields and level bands marked; A (Åkerman, 2001).

The erosion protection hinder the downward flow of water to transport small soil particles, organic matter and nutrition down the slope and away from the fields (Figure 8). Without protection, more than 50 percent of the water is lost by the overland flow. Hindering the water and making it infiltrate into the soil is of great importance for the agricultural outcome (Åkerman, 2001).

4.4.2 Vetiver Conservation Farming - VCF

The Vetiver Conservation Farming (VCF) management uses Vetiver grass (*Vetiveria zizanioides*) to protect the fields in the camp against erosion supporting the earth ridges between the fields. In the study area, the Vetiver grass is planted as grass rows 0.3 to 0.5 m apart on the earth ridges. Vetiver grows quickly and forms root systems that protect the earth ridge and hinders erosion effectively (Figure 9), providing a better infiltration capacity of the soil at the earth ridges and helps to reduce the overland flow in itself.

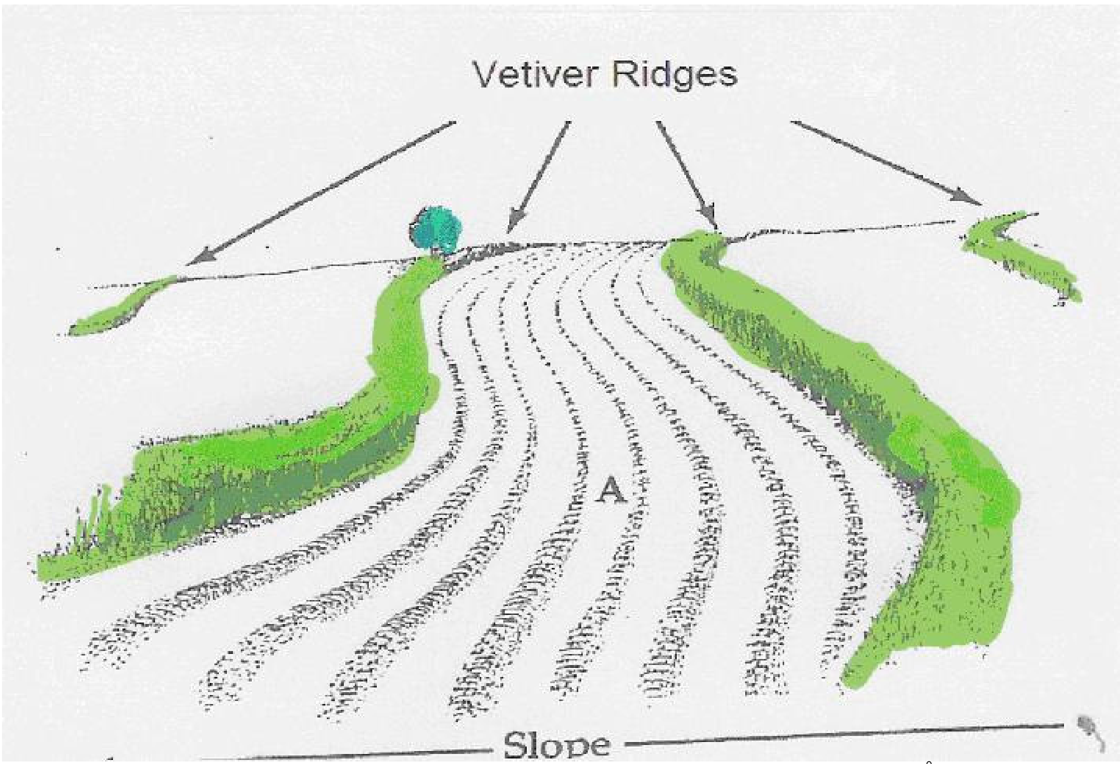
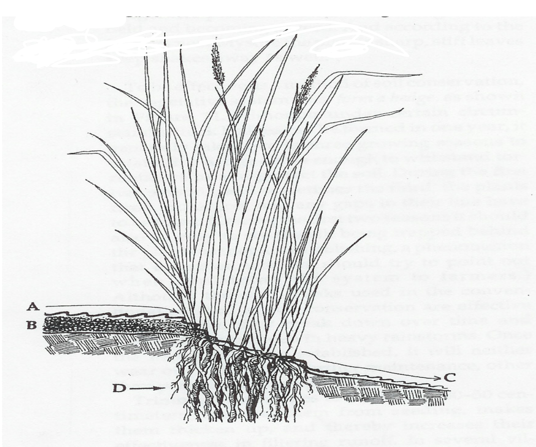


Figure 9. VCF fields with Vetiver covered earth ridges. Level bands in the field marked A (Åkerman, 2001).

The grass roots (Figure 10 D) and leaves grow fast and are therefore quickly established (Åkerman, 2001). The plants grow densely and protect the soil particles (Figure 10 A) from moving further down the slope by the aid of water (Figure 10 C) and are collected by the plants (Figure 10 B) that support the earth ridge (Figure 11).



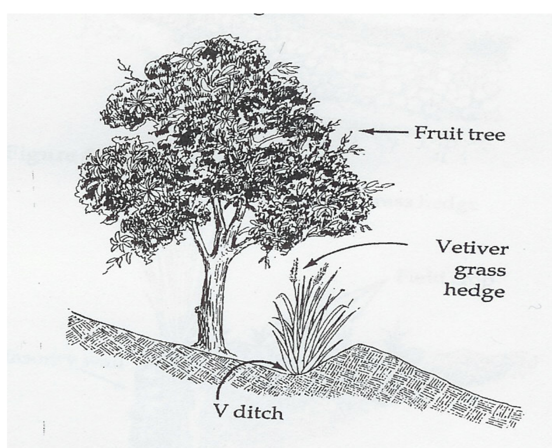


Figure 10. Vetiver protecting the soil (Åkerman, 2001). Figure 11. Vetiver support ridge (Åkerman, 2001).

4.4.3 Agroforestry Conservation Farming – ACF

Agroforestry Conservation Farming (ACF) fields are equipped with the same level bands that are used as in the SCF fields, however, the earth ridges are supported by trees planted in tree roads (Figure 12).

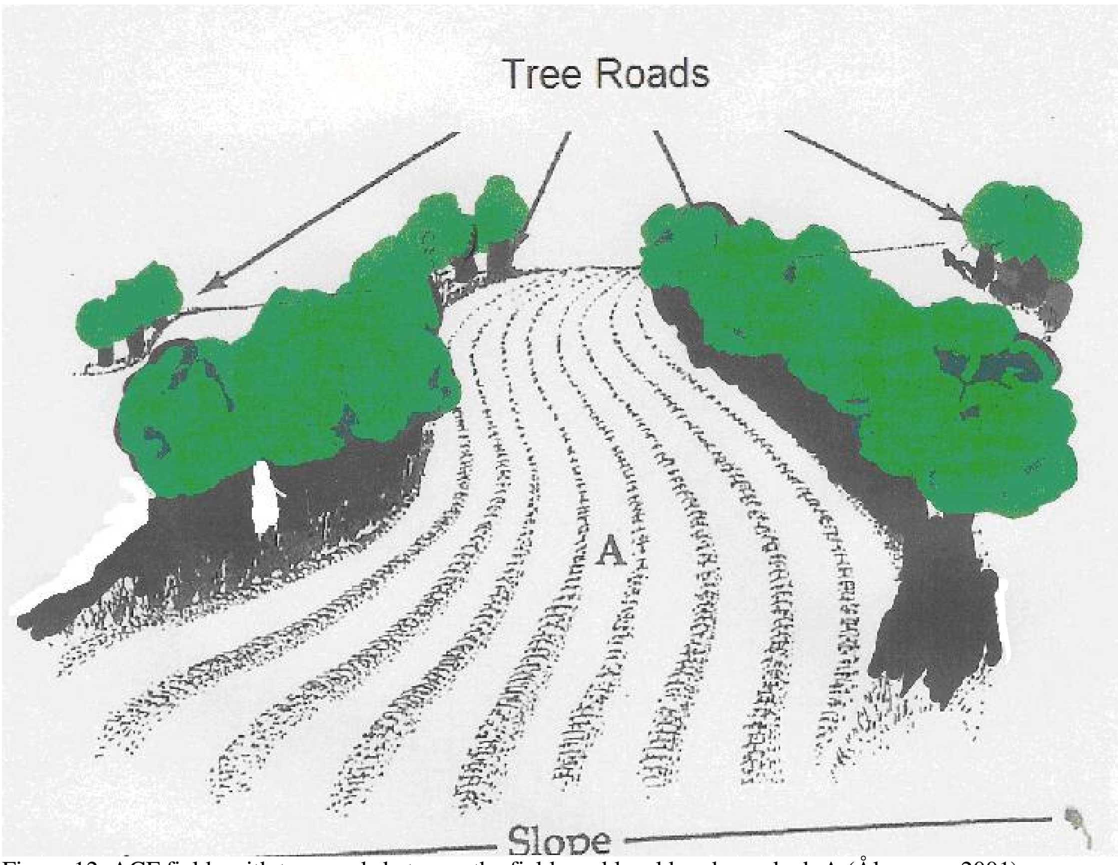


Figure 12. ACF fields with tree roads between the fields and level bands marked; A (Åkerman, 2001).

There are many different tree species used for tree roads in the Kawoozi Camp. The trees normally have both deep roots, that make them resistant to drought, and shallow roots that are forming a protection against erosion of the top soil.

The species used in this study is *Cajanus cajan*. *C. cajan* is by definition not a tree, but a Pigeon Pea herb of the *Papilionoidae* family (Simute, 1992). However, it functions as a tree and is frequently used for its capacity for hindering erosion. It grows quickly and has a strong shallow root system that stops flood water from flushing the hill (Phiri et al., 1998). It is also used for its nitrogen fixating ability (Rocheleau, 1998). The trees in the study are planted between 0.5 and 1 meter apart and grow to a height of 2 - 4 m. The canopy of the trees is between 1.5 an 2 m wide. The trees in the fields in the survey are planted as seedlings or as seeds directly into the ground.

5 Method

5.1 *Fields Selection Method*

The fields were selected in steps. First, a selection of fields with similar land-use and topography were selected, to minimize variation caused by other factors than the erosion management. All of the selected cultivated fields had been planted with maize and had been without any use of manure, fallow or animals for at least three years – as this could affect the results of the P analysis. The farmers had all used phosphorous (P) as fertilizer. Phosphorous had been applied as grains in holes 5 cm into the ground together with the seed in order to let the seed use all of the P in the fertilizer. The fertilizers were applied before the rainy season together with the seed. In order to avoid possible influence from the fertilizer, all the samples were taken at a minimum distance of 30 cm from the maize stocks.

The selected fields had a slope that were 5˚ and lower (SFC) or 6˚ and higher (ACF, VCF). The angles in the VCF and ACF fields are steeper than those in the SCF fields to ensure that any positive effect of the ACF and VCF management was not due to a lower slope of the fields and consequently a slower run-off (Schroeder, 1984). Second, for the selected fields the owners were asked if they wished to participate in the study. Three fields each of ACF, VCF and SCF managements were randomly selected by letting the owners pick a piece of paper from a hat. The people with a cross on their papers were chosen for the study. The number of crosses on the papers corresponded to the numbers of fields needed for each management study and the number of papers to the amount of interested farmers. In addition sampling was carried out at one place in the uncultivated Savanna Woodland.

5.2 *Field Methods*

Visible signs of erosion are used in order to complement the laboratory measurement of erosion. The erosion was evaluated by observations and measuring visible differences that have appeared through water and wind erosion in the field during the last rain season. The study was focused on measuring denuded pebbles and roots, gully- and rill erosion plus the size of hard pans since these visible signs are easy to use as indicators of erosion in the field. All of these measurements are indicators of how much soil has been transported from the field since its last cultivation. This information is of value when judging the accuracy of the laboratory analysis method. It also gives an overview of the erosion situation by itself and hence is a quick way to obtain a good idea of the situation while working in the field. The measurement of the visible erosion was done with a gauge. Each visible sign of erosion was investigated and measured at the second level of the middle row in each field in order to avoid variations caused by location. The measurements are presented in centimeters for denuded pebbles and roots as well as rills and in meters for gullies and hard pans.

5.2.1 Denuded Pebbles

The pebble erosion was measured in centimeters. The value is counted as the height of the pebble over ground that is denuded (Figure 13). Denuded pebbles show how much soil has been transported from the field during the last rain season.

Figure 13 Pebble erosion measured as the denuded height in centimeters over the ground.

5.2.2 Denuded Roots

The denuded roots were measured in centimeters. The value is counted as the height of the root over ground that is denuded (Figure 14). Denuded roots show how much soil has been transported from the field during the last rain season.

Figure 14. Root erosion measured as the denuded height of the root in centimeters over the ground.

5.2.3 Gully and Rill Erosion

Gullies and rills are formed from streams of water that transport sediment from the fields. The soil is largely affected where the forms of erosions appear and are also a strong indication of general erosion as the field is poorly protected against the flushing streams of rainwater in the wet season (Lal, 1988). The size of the gully erosion was measured in m^3 by multiplying the length, width and depth of it. The size of rills was estimated in cm^3 in the same manner (Figure 15).

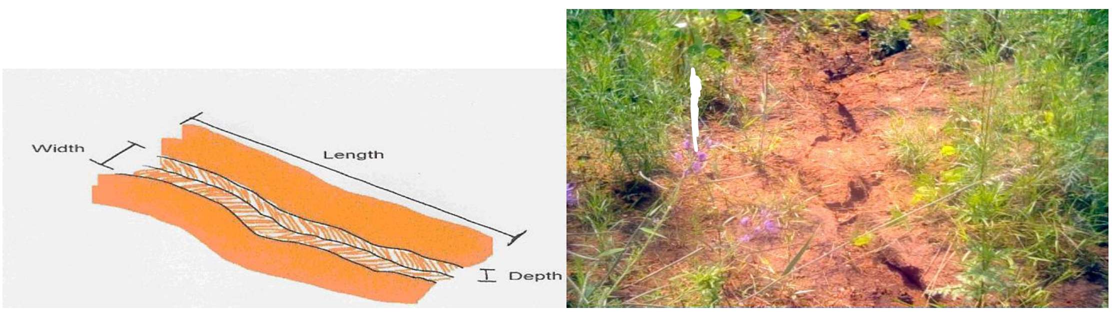


Figure 15. Gully and rill erosion measured through width, length and depth of the formation.

5.2.4 Hard Pan

Hard pans are denuded areas in the field. Over years, they are formed through ploughing the upper soil horizon. The layers, under this frequently used soil, are then hardened by salts. The size of hard pans was measured in m^2 by multiplying the length and the breadth of it. This measure will be proportional to the area (Figure 16).

Figure 16. Hard Pan measured in meters as the denuded area in m on the ground. 、

5.2.5 Sampling Method

The fields were generally about 28 m long and 20 m wide. Samples were taken at four levels in the field from the bottom to the top, 7m apart. This was done to obtain estimate concerning the change in nutrient levels with height of the fields; a high level of erosion was expected to result in a loss of nutrients high up in the fields and an accumulation lower down in the fields. Three samples 10 m apart were taken from each level to get a statistical accurate value for each field; making three lanes from bottom to top. One lane was taken in the middle of the field and then one 10 m to the right and 10 m to the left. Top soil was taken from all 12 spots in the field and at 15 cm depth at the middle lane of row two (Figure 17).

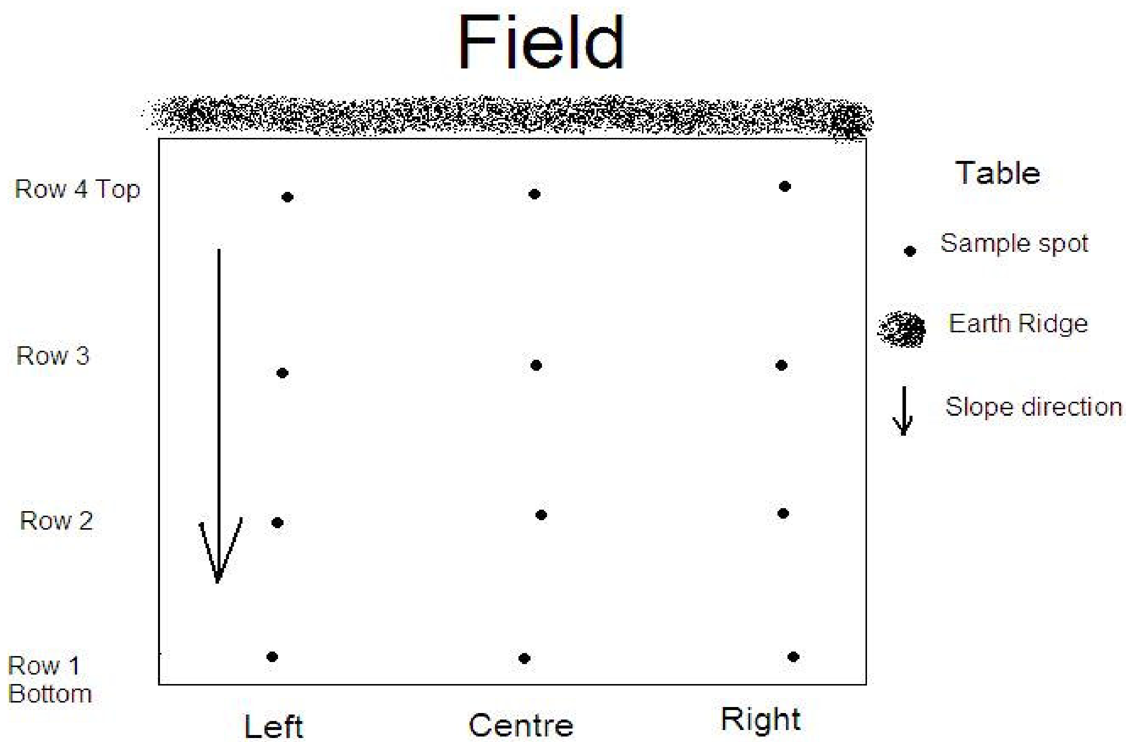


Figure 17. Field with sample spots.

The top soil was collected for phosphorous (P) and nitrogen (N) analyses. The sampling was on done on 15 cm depth, for texture analysis, with an auger, 1 m long and 5 cm wide, that was forced into the ground by a sledge hammer.

5.2.6 Soil Texture

The soil, taken with an auger at a 15 cm depth, testing texture is of interest as a high content of clay at 15 cm will have a negative effect on the erosion, whereas, a high content of sand will let the water through the horizon and minimize the erosion effects of the rainwater.

5.2.7 Angle Measurement of the fields

The angle was measured looking at the top of the field using a clinometer (Figure 18). The angle measurement was done by letting one person walk to the top of the field and another person of the same length, standing at the base, looking at the head of the person at the top and measure the slope angle in the field.


Figure 18. Mr. Phiri is measuring the slope angle.


Figure 19. Semi structured interview with Mr. Botha.

5.2.8 Interviews

Interviews were conducted, following a check list, with the farmers together using an interceptor in order to understand the management, history and practices of the fields and to follow the limitations in the study (Mikkelsen, 1995; Figure 19; Appendix 12).

5.3 *Laboratory Methods*

The methods used for the laboratory analysis were selected according to availability of resources for laboratory work. Phosphorous (P) was measured regarding calcium bound P (Miller, 1982). The nitrogen (N) was analyzed through the Macro Kjelldahl Method (Miller, 1982). Soil Texture was determined from dry sieving of dried soil (Miller, 1982). After twelve days testing the P methods, it was obvious that one method would work given that filtration was employed instead of centrifugation of the samples. This is the appropriate material and apparatus used for this method at the UNZA Soil Science Department.

5.4 *Statistical Analysis Methods*

The different measures of erosion will inevitably be correlated with each other. In order to create one common measure of the extent of erosion, the different measures of erosion were combined using Principal Component Analysis (PCA) (Jolliffe, 1986). The first Principal Component was compared with the original measures of erosion using Spearman Rank Correlation. ANOVA was performed to compare the effect of the different treatments. A Linear Contrast was used to compare one of the treatments with the rest. Several measures of nutrient status were taken in the same field. These measures will not be statistically independent. Therefore a Mixed model (Allan et al., 2001) was used to compare measurements of P between different fields. In this analysis, fields and columns within fields were used as random factors and an autoregressive covariance was used within columns.

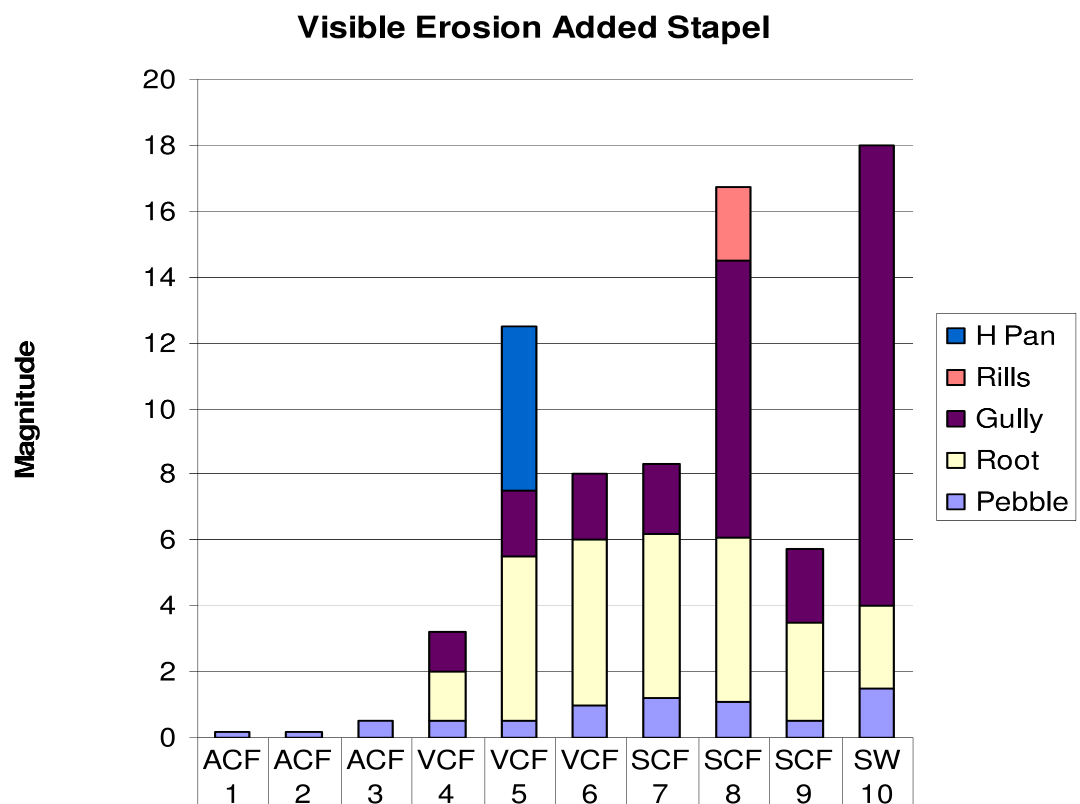
The fixed factors are field management, the row number plus the interaction between field management and row number; this interaction checked the slope of the relationship between P content and row number which differed between the different field managements. In addition, Mixed model was used to test the relationship between the level of P and row number for particular managements and for individual fields. The slope of the relationship between P content and row number was used in subsequent analyses, as a measure of the extent to which P was eroded out from the fields; a high value indicating that nutrients were preserved higher up in the fields. Mixed model was used with REML Estimation and Satterthwaite's Degrees of Freedom Method. Because data existed for no more than one column in Field 9 linear regression was conducted in this field.

6 Results

6.1 *Visible Signs of Erosion*

There was significant difference in the visible signs of erosion between the ACF fields and the rest of the fields. The ACF fields have significantly less visible signs of erosion than the SCF and VCF fields (Table 1).

Table 1. Visible erosion. ACF, VCF, SCF fields and SW.



	ACF 1	ACF 2	ACF 3	VCF 4	VCF 5	VCF 6	SCF 7	SCF 8	SCF 9	SW 10
H Pan	0	0	0	0	5	0	0	0	0	0
Rills	0	0	0	0	0	0	0	2.25	0	0
Gully	0	0	0	1.2	2	2	2.1	8.4	2.25	14
Root	0	0	0	1.5	5	5	5	5	3	2.5
Pebble	0.2	0.2	0.5	0.5	0.5	1	1.2	1.1	0.5	1.5

Because the different signs of erosion were highly correlated, a common measure was created using principal component analysis. The first principal component represents the strength of erosion and was correlated positively with all measures of erosion and is hence a good common measure of the erosion in the fields (Table 2).

Using One Way ANOVA the difference approaches significance ($F(2, 6) = 4.68$, $P=0.06$, $N=9$) and a Contrast Test show a significant difference ($t = -2.7$, $P = 0.03$, $N = 9$) between ACF and the SCF, VCF and SW fields in the study.

There is an absence of rill and gully erosion as well as denuded roots in the ACF fields plus of hard pans, therefore, the visible signs of erosion are limited to denuded pebbles (Table 1). The staples for the three ACF fields are, therefore, lower compared to the SCF, VCF and SW fields in the study.

The VCF fields all have gullies and rather severely denuded roots. VCF Field 5 is the only field that has a hard pan. The hard pan covers 5 m^2 that is approximately 8 percent of the total field area. The VCF fields do not show as few and low signs of visible erosion as with the ACF fields. However, they are lower than the SCF management. The SCF fields show the most signs of visible erosion of the erosion protected fields (Table 1). The visible signs of erosion in the SCF fields are varying among the SCF fields. The Savanna Woodland hills are dominated by a vast gully in the field; furthermore, there are denuded pebbles and roots. SW has the most visible signs of erosion in this study.

Table 2. Correlations between Visible Signs of Erosion and the change in Soil P content with height of the field, calculated using Spearman Rank Correlation.

Correlations concerning Visible Signs of Erosion and Soil Phosphorous Analyses

			Principal Component Nr 1	Deriative of P Content Curve	Denuded Pebbles	Denuded Roots	Gullies	Rills	Hard Pans
Spearman	Principal Component Nr 1	Correlation Coefficient	1,000	-,900**	,931**	,813**	,901**	,524	,058
		Sig. (2-tailed)	,	,000	,000	,004	,000	,120	,873
		N	10	10	10	10	10	10	10
	Deriative of P Content Curve	Correlation Coefficient	-,900**	1,000	-,822**	-,767**	-,849**	-,290	-,406
		Sig. (2-tailed)	,000	,	,004	,010	,002	,416	,244
		N	10	10	10	10	10	10	10
	Denuded Pebbles	Correlation Coefficient	,931**	-,822**	1,000	,652*	,825**	,300	-,120
		Sig. (2-tailed)	,000	,004	,	,041	,003	,399	,741
		N	10	10	10	10	10	10	10
	Denuded Roots	Correlation Coefficient	,813**	-,767**	,652*	1,000	,682*	,364	,364
		Sig. (2-tailed)	,004	,010	,041	,	,030	,301	,301
		N	10	10	10	10	10	10	10
	Gullies	Correlation Coefficient	,901**	-,849**	,825**	,682*	1,000	,412	,000
		Sig. (2-tailed)	,000	,002	,003	,030	,	,236	1,000
		N	10	10	10	10	10	10	10
	Rills	Correlation Coefficient	,524	-,290	,300	,364	,412	1,000	-,111
		Sig. (2-tailed)	,120	,416	,399	,301	,236	,	,760
		N	10	10	10	10	10	10	10
	Hard Pans	Correlation Coefficient	,058	-,406	-,120	,364	,000	-,111	1,000
		Sig. (2-tailed)	,873	,244	,741	,301	1,000	,760	,
		N	10	10	10	10	10	10	10

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

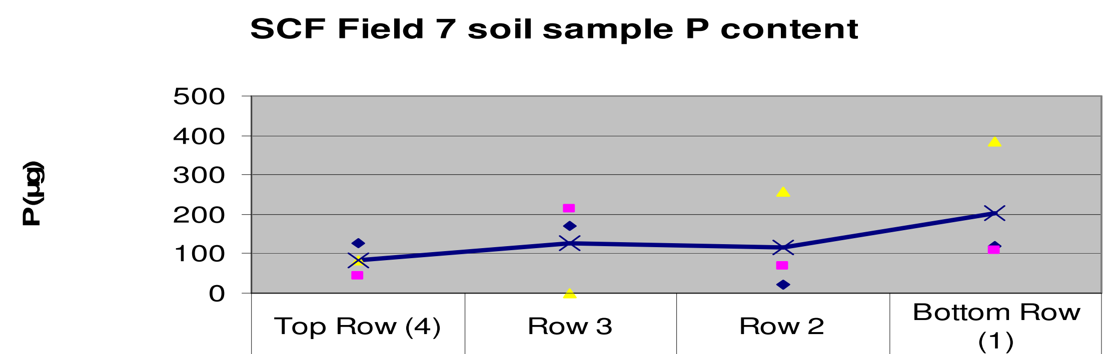
The visible signs of erosion indicate a highly significant correlation between denuded pebbles (Correlation coefficient 0.931, P<0.0001, N=10), denuded roots (Correlation coefficient = 0.813, P=0.004, N=10) and gullies (Correlation coefficient = 0.901, P<0.0001, N=10) and the principal component. The results for rills and hard pans are not well correlated or significant. These two visible signs of erosion are both represented by only one value each in all of the fields in the study (Table 2). The common measure of visible signs of erosion, calculated as the first Principal Component of a PCA including all individual visible signs of erosion, was significantly correlated to the phosphorous analyses. In these analyses I used the change of the phosphorous with row number calculated with the Mixed model analyses for individual fields. The correlation for denuded pebbles is 0.822 (P=0.004, N=10), for denuded roots 0.652 (P=0.04, N=10) and for gullies 0.825 (P=0.003, N=10). Thus the visible signs of erosion correspond extremely well to the phosphorous analysis of the soil samples (Table 2). The correlation coefficient between the common measure of visible signs of erosion and the soil sample phosphorous analyses is 0.9 (P < 0.0001, N=10).

6.2 *Laboratory Analysis of Soil Samples*

6.2.1 Phosphorous Analysis of Erosion in SCF fields

In SCF Field 7, there is a difference between the content of P in the field. At the bottom P is 170 % higher than at the top of the field (Table 3). The Mixed model indicates that Field 7 has a negative slope of the P curve of the field of - 36.10 (F (1, 68.8) =1.53; P=0.25; N=12), The relationship was not significant, however, it is indicating a negative slope of the relationship between P content and row number in the field.

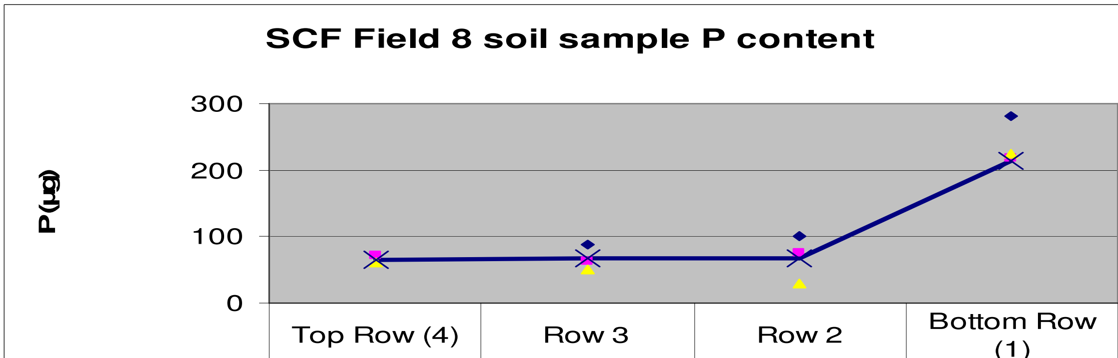
Table 3. P content from the top to the bottom in SCF Field 7.



	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Left	128	170	20	118
Center	45	213	70	110
Right	84	0	259	385
Mean	85	127	116	204

Field Level

Table 4. P content from the top to the bottom in SCF Field 8.

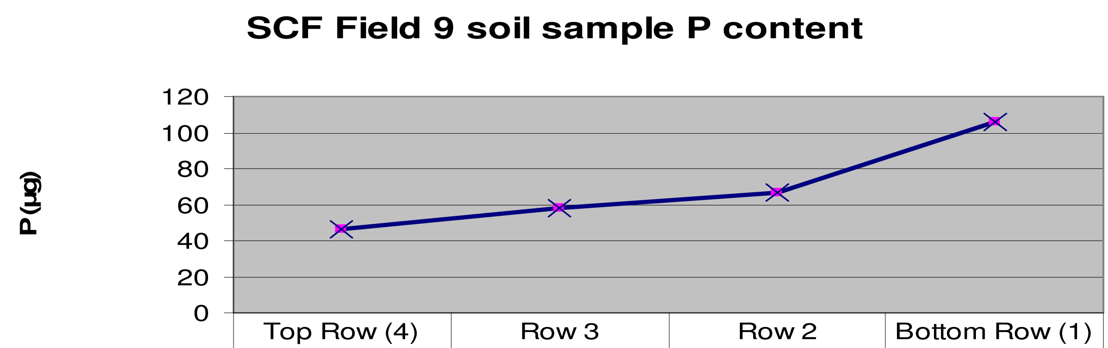


	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Left		88	100	281
Center	72	63	76	219
Right	60	50	29	224
Mean	66	67	68	214

Field Level

In SCF Field 8, there is a significant difference between the top of the field and the bottom. P is more than 200 % higher at the bottom (Table 4). The Mixed model indicates a significantly negative slope of the relationship between P content and row number in the field: - 55.92 (F (1, 6.2) =13.22; P<0.02; N=11).

Table 5. P content from the top to the bottom in SCF Field 9.

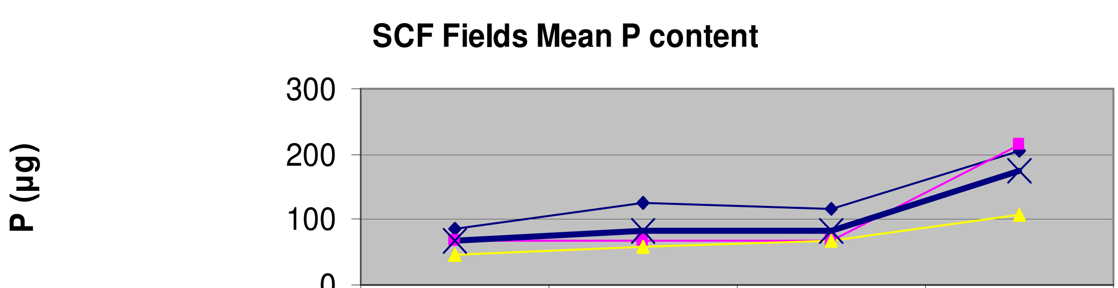


	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Left				
Center	46	58	67	106
Right				
Mean	46	58	67	106

Field Level

SCF Field 9 shows a difference between the bottom and the top of the field. P is more than 130 % higher at the bottom than it is at the top (Table 5). The Mixed model indicates that Field 9 has a negative slope of the P curve of – 18.9 (t=3.88; P=0.06; N=4) indicating a negative slope of the relationship between P content and row number in the field.

Table 6. P content from the top to the bottom in the SCF fields.



	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Mean Field 7	85	127	116	204
Mean Field 8	66	67	68	214
Mean Field 9	46	58	67	106
Mean SCF Fields	66	84	84	176

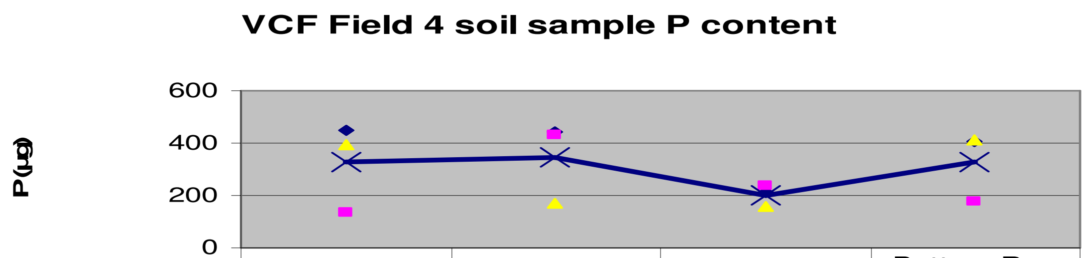
Filed Level

The joint graph of all the SCF fields show a trend of significantly higher P at the bottom of the fields than at the top. The Mixed model indicates a negative slope of the relationship between P content and row number in the SCF fields that is significant: - 41.75 (F (1, 21.6) =8.10; P<0.01; N=27). The P content is about 170 % higher at the bottom for the SCF fields (Table 6).

6.2.2 Phosphorous Analysis of Erosion in VCF fields

The VCF fields have a higher degree of P at the top of the fields than the fields with SCF management. There is not the same difference in P between the top and the bottom of the fields as there is in the SCF fields.

Table 7. P content from the top to the bottom in VCF field 4.

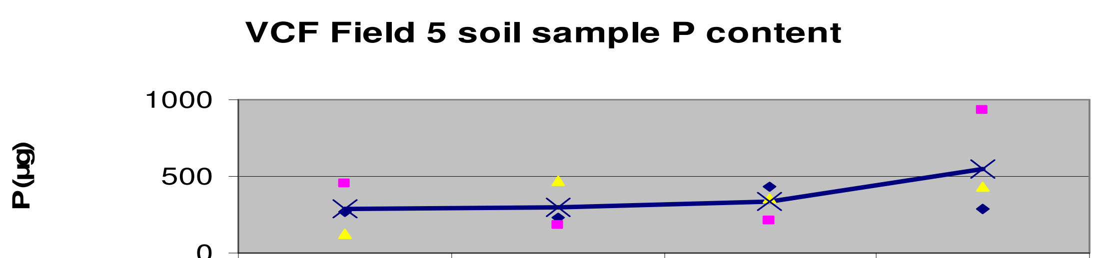


	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Left	449	443	211	404
Center	135	432	234	173
Right	394	168	155	413
Mean	326	348	200	330

Field Level

VCF Field 4 shows a distinctive difference from the SCF fields. P is comparably even throughout the field (Table 7). The Mixed model indicates that Field 4 has a positive estimation of the P curve of + 17.53 (F (1, 6.8) =0.29; P=0.6; N=12) indicating a positive slope of the relationship between P content and row number in the field.

Table 8. P content from the top to the bottom in VCF Field 5.

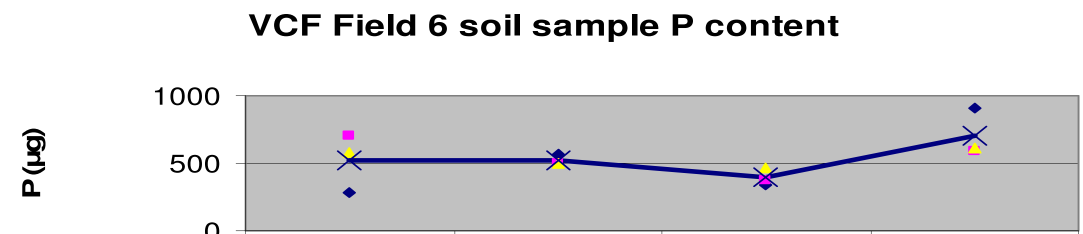


	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Left	273	233	433	292
Center	450	181	214	933
Right	129	472	355	431
Mean	284	295	334	546

Field level

VCF Field 5 shows a pattern that is more reminiscent of the SCF fields than VCF Field 4. P at the bottom is more than 90 % higher than at the top of the field (Table 8). The Mixed model indicates that Field 5 has a negative estimation of the P curve of – 80.43 (F (1, 5.89) =4.26; P=0.09; N=12) indicating a negative slope of the relationship between P content and row number.

Table 9. P content from the top to the bottom in VCF Field 6.

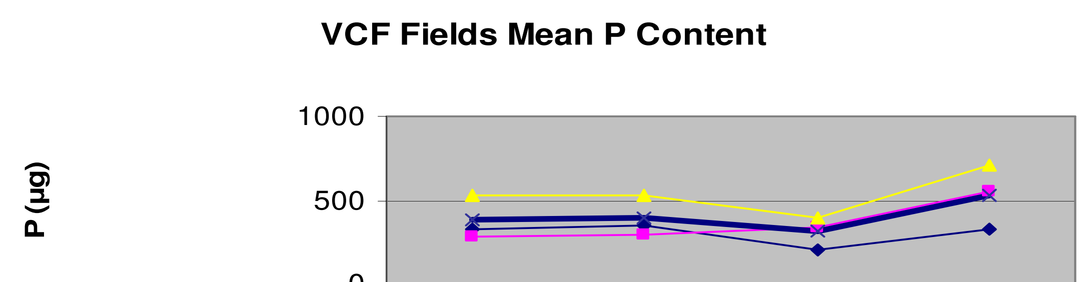


	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Left	289	571	336	911
Center	707	498	380	592
Right	583	501	464	613
Mean	526	523	393	705

Field level

The graph for VCF Field 6 indicates better erosion protection than in VCF Field 5. The difference in P between the top and the bottom of the field is about 30 % (Table 9). The Mixed model indicates that Field 6 has a negative estimation of the P curve of – 24.48 (F (1, 5.66) =0.58; P=0.48, N=12) indicating a negative slope of the relationship between P content and row number.

Table 10.VP content from the top to the bottom in VCF fields.



	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Mean Field 4	326	348	200	330
Mean Field 5	284	295	334	546
Mean Field 6	526	523	393	705
Mean VCF Fields	379	389	309	527

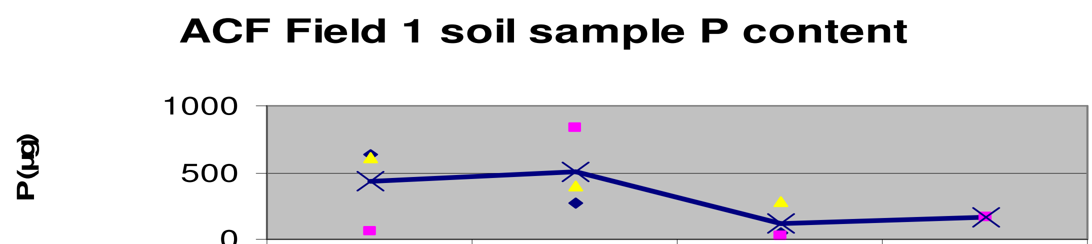
Field Level

VCF fields have generally more P at the top of the field than the SCF fields. This is applicable for all VCF fields. The VCF fields, however, show a variety of P patterns (Table 10). The Mixed model indicates that the VCF fields generally have a negative estimation of the P curve of - 30.01 (F (1, 20.4) =1.92; P=0.18; N=36) indicating a negative slope of the relationship between P content and row number in the VCF fields. However, the slope of the curve is not significant. In the mean graph of the VCF fields, P is about 40% higher the bottom than at the top of the field.

6.2.3 Phosphorous Analysis of Erosion in ACF fields

In the ACF fields there is less P at the bottom of the field than there is at the top. This pattern differ the ACF fields from the SCF and the VCF fields in this study. The P content at the top of the fields is in all ACF fields is higher than at the bottom of the field. P at the top of ACF field 1 is higher than in the rest of the field. P is 170 % higher at the very top than it is at the bottom of the field (Table 11). The Mixed model indicates a significantly positive slope of the relationship between P content and row number in ACF field 1: +169 (F (1, 5.33) =12.13; P<0.02; N=10).

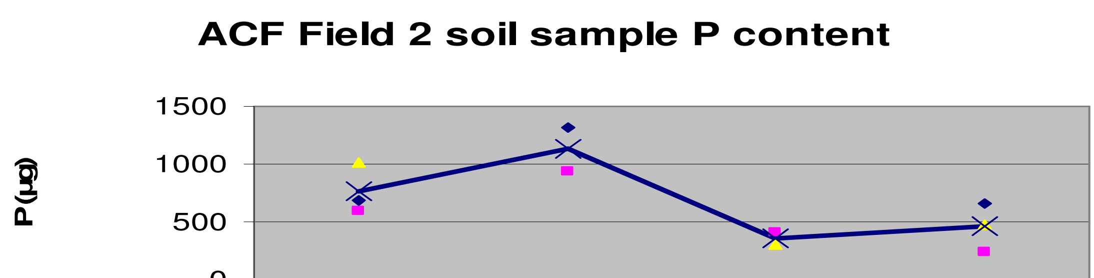
Table 11. P content from the top to the bottom in ACF field 1.



	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Left	640	270	42	
Center	64	840	21	161
Right	615	401	281	
Mean	440	506	114	161

Field level

Table 12. P content from the top to the bottom in ACF field 2.

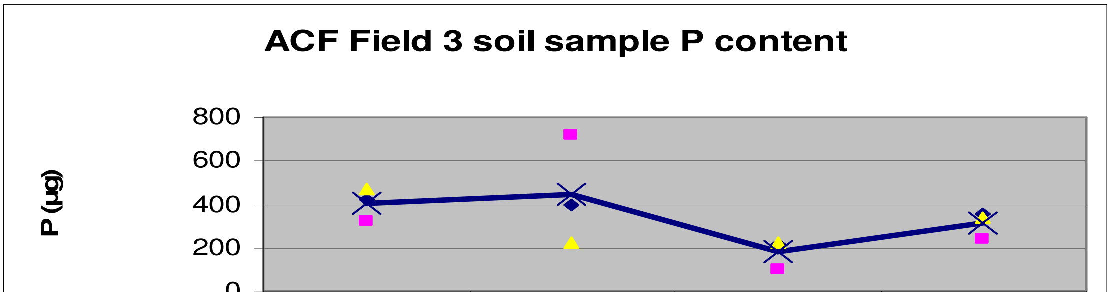


	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Left	686	1316		658
Center	591	935	408	237
Right	1013		301	468
Mean	763	1126	355	454

Field level

ACF field 2 has more than a 60 % higher phosphorous content at the top of the field than at the bottom (Table 12). The phosphorous content in this field is higher than in any of the other fields. The Mixed Model indicates a significantly positive slope of the relationship between P content and row number in ACF field 2 is: + 259.07 (F (1, 4.65) = 42.91; P<0.02; N=10).

Table 13. P content from the top to the bottom in ACF field 3.



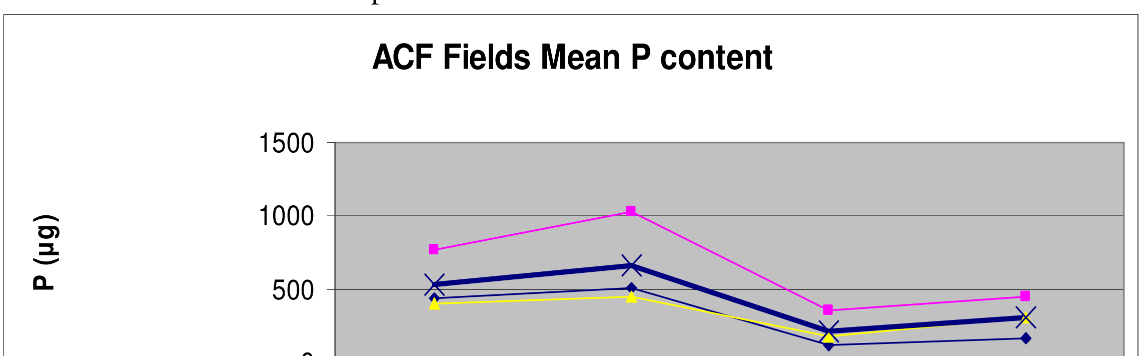
	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Left	419	396	216	358
Center	319	715	100	236
Right	468	225	224	340
Mean	402	445	180	311

Field Level

P in the sedimentation area of ACF field 3 is not as low as it is in the rest of the ACF fields (Table 13). The phosphorous content at the top of the field is, however, 25 % higher than at the bottom. The Mixed Model indicates a significantly positive slope of the relationship between P content and row number in ACF field 3: + 69.96 (F (1, 7.53) = 5.63; $P<0.05$; $N=12$).

The general impression of the ACF fields is that P at the top of the fields is significantly higher than P at the bottom. P is as an average more than 70 % higher at the top (Table 14). The Mixed model indicates a highly significant positive slope of the relationship between P content and row number in the ACF fields: +146.97 (F (1, 19.6) = 28.11; $P<0.0001$; $N=32$).

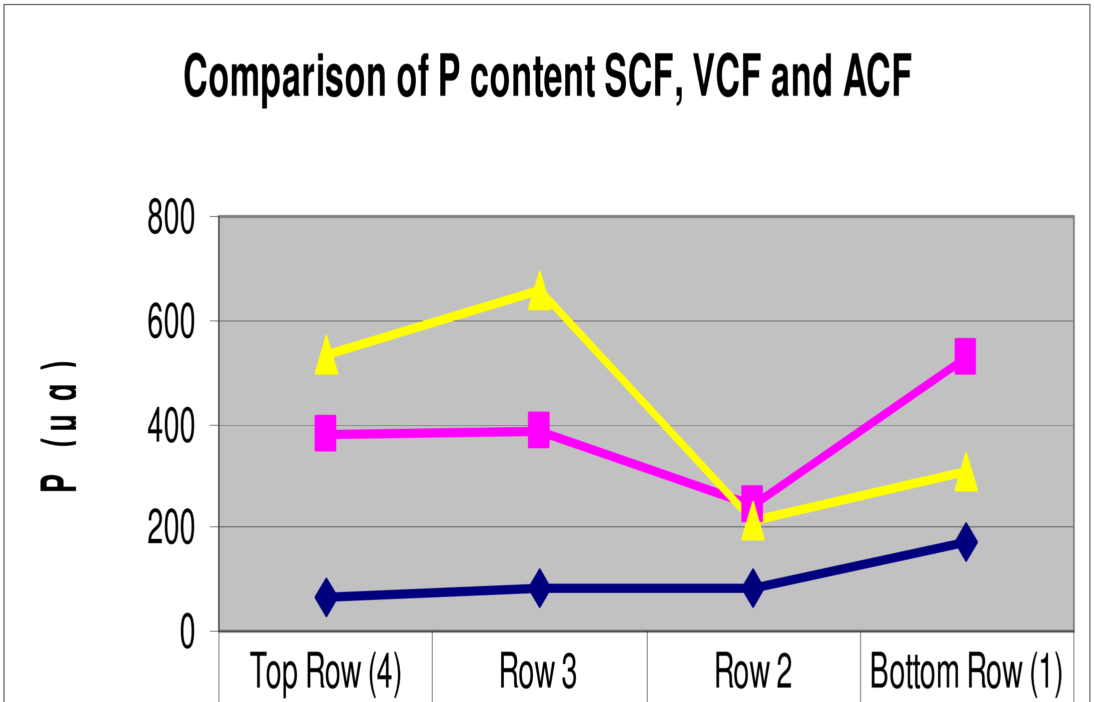
Table 14. P content from the top to the bottom in the ACF fields.



	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Mean Field 1	440	506	114	161
Mean Field 2	763	1025	354	454
Mean Field 3	400	445	180	311
Mean ACF Fields	535	659	216	309

Field Level

Table 15. Comparison of P content between SCF, VCF and ACF.



	Top Row (4)	Row 3	Row 2	Bottom Row (1)
SCF	65	84	83	174
VCF	378	387	242	527
ACF	534	658	216	308

The sedimentation of nutrients at the bottom of the fields compared to P at the top is low in ACF fields in comparison to the other fields in this study (Table 15). The enrichment ratio is significantly higher in the ACF than in the SCF fields.

It is only in the ACF fields that there is a significantly higher P at the top of the field than at the bottom. P at the top of the ACF fields is higher than in the SCF fields with a value that is 720 % larger than P at the top of the SCF fields.

The Mixed Model shows that the slope of the relationship between P content and row number differs between the different managements ($F(3, 62.5) = 15.03$; $P<0.0001$; $N=107$) with a positive slope for ACF: +146.97 and negative slopes for SCF: -41.75, VCF: - 30.01 and SW: - 163.51.

The SCF fields show the lowest P status of a mean value of 65 µg of phosphorous at the top of the field. The VCF fields generally have a higher value of 380 µg phosphorous and the ACF generally stay at 530 µg phosphorous but are at the highest over 760 µg phosphorous.

6.2.4 Nitrogen Analysis of Erosion in ACF fields

The graph for ACF Field 1 shows a higher content of N at the top of the field than at the bottom. The N at the bottom is the next lowest in the field, which indicates that the transportation of nutrients is low in this field. The N is more than 30 % lower at the bottom than at the top in this field (Table 16).

Table 16. N content from the top to the bottom in ACF Field 1.

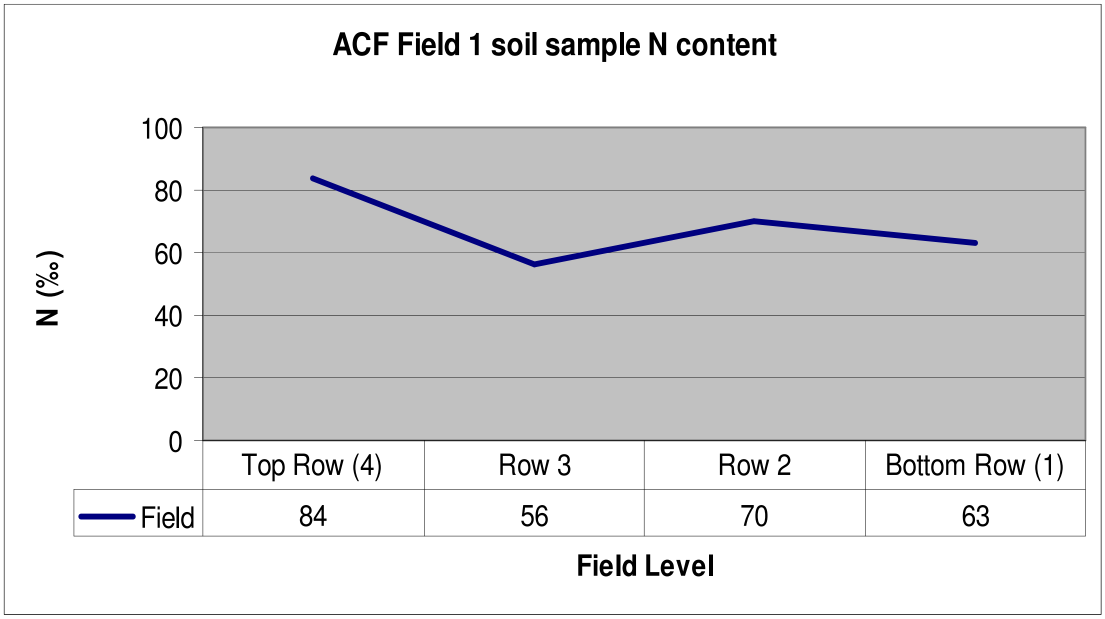
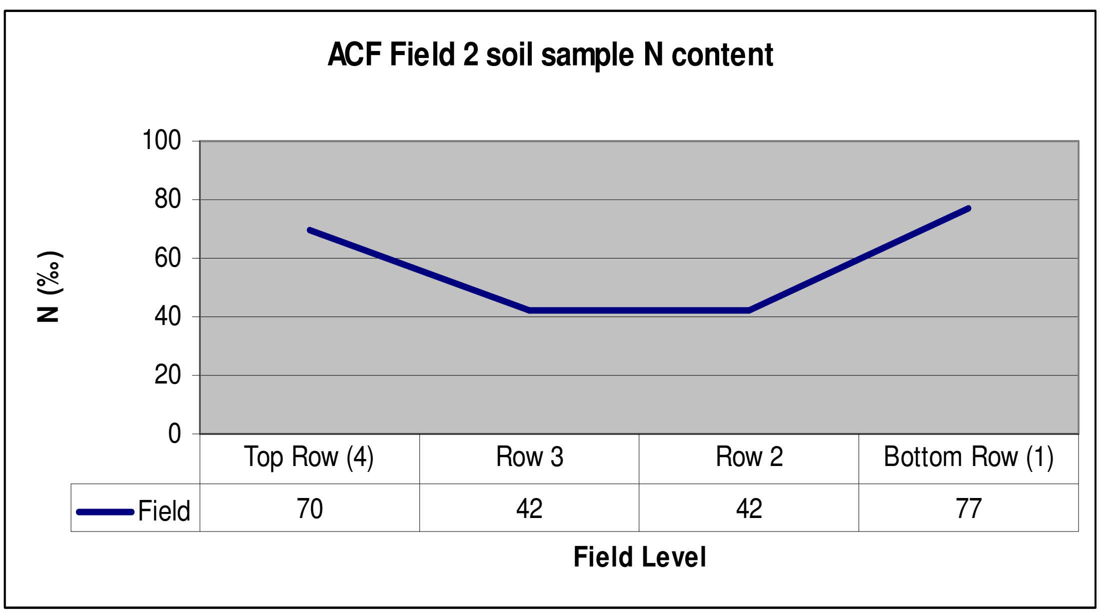
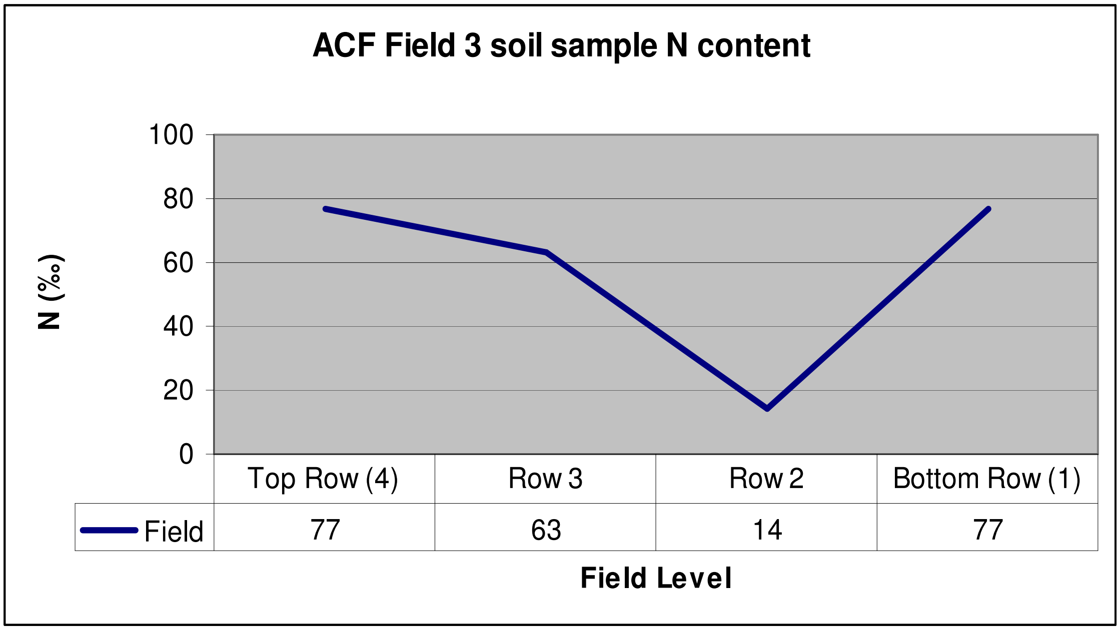


Table 17. N content from the top to the bottom in ACF Field 2.



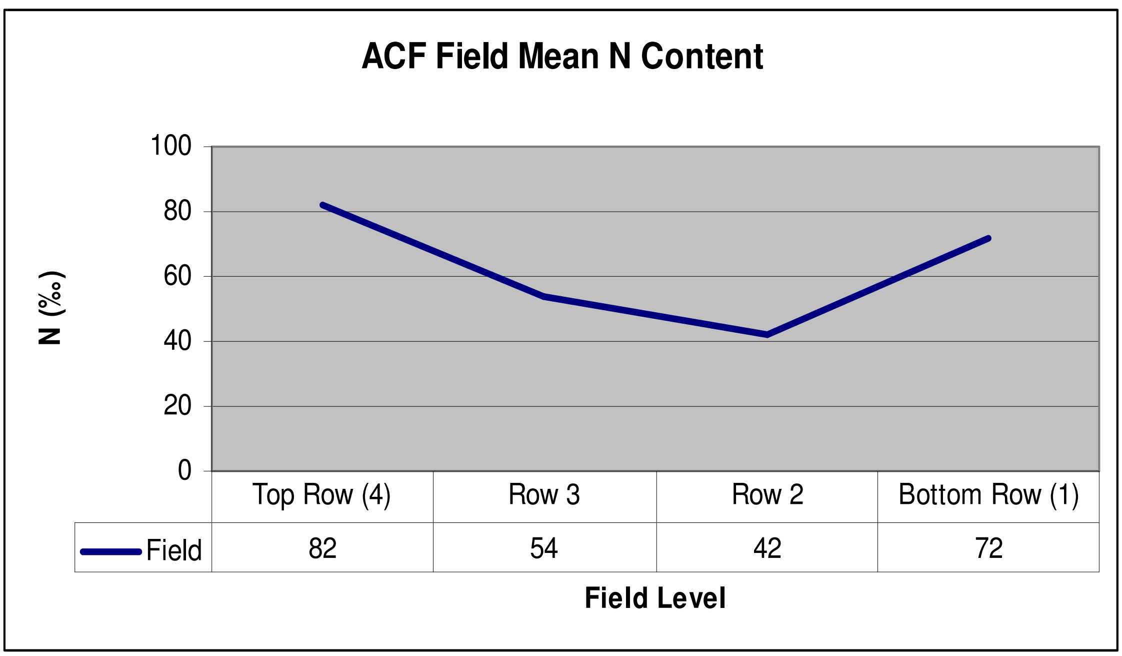
The graph for ACF Field 2 shows high N at the top. This pattern is different compared to the phosphorous analysis of the ACF fields that generally have a higher N content at the top of the field than at the bottom (Table 17).

Table 18. N content from the top to the bottom in ACF Field 3.



The graph for Field 3 shows that N at the top of the field is the same as the bottom and the rest of the field. There is a dip in the middle that indicates erosion in this part (Table 18).

Table 19. Nitrogen content from the top to the bottom in the ACF fields.

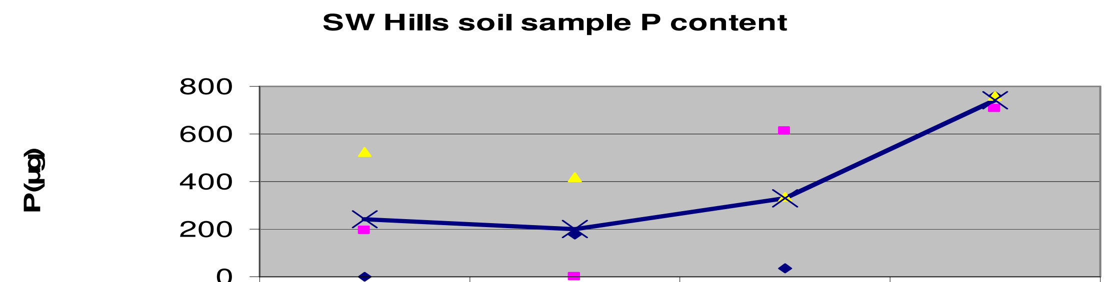


The mean N graph for the three ACF fields shows that N at the top of the field is about 15 % higher than N at the bottom (Table 19). The graphs from the N analyses of the ACF fields all show on a relatively high content in the very top of the field. The graphs in the Nitrogen fields do not follow the P pattern with falling content at the very top of the field. Contrary to the others, the N is rising at the tree road at the top of the fields.

6.2.5 Phosphorous Analysis of Erosion in the Savanna Woodland

The amount of P in the Savannah Woodland is concentrated to the sedimentation areas on the slope. P at the bottom of the field is 200 % higher than P at the top (Table 20). The Mixed model indicates a significantly negative slope of the relationship between P content and row number in the SW hills: - 163.51 (F (1, 7.7) =7.00; P<0.03; N=12).

Table 20. P content in the Savanna Woodland hills.



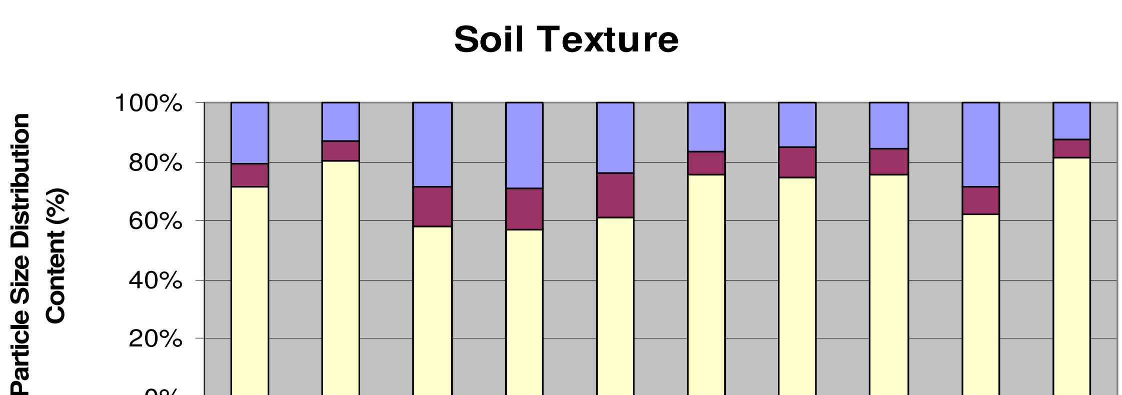
	Top Row (4)	Row 3	Row 2	Bottom Row (1)
Left	0	176	38	758
Center	196	0	612	704
Right	521	420	337	756
Mean	239	198	329	740

Field Level

6.2.6 Soil Composition on 15 cm depth

The textures at 15cm depth are Sandy Clay Loams (SCL) and Loam Sands (LS) in the ACF fields, SCL and Sandy Loams (SL) in VCF fields, and SL in the SCF fields plus SL in the Savanna Woodland hills. The sand content is about 60 % or more on 15cm depth in all the fields in this study (Table 21).

Table 21. Texture; Sandy Clay Loam (SCL), Loamy Sand (LS) and Sandy Loam (SL).



	ACF 1 SCL	ACF 2 LS	ACF 3 SCL	VCF 4 SCL	VCF 5 SCL	VCF 6 SL	SCF 7 SL	SCF 8 SL	SCF 9 SL	SW SL
Clay %	21%	13%	28%	29%	24%	17%	15%	16%	28%	13%
Silt %	8%	7%	14%	14%	15%	8%	11%	9%	9%	6%
Sand %	71%	80%	58%	57%	61%	76%	74%	76%	62%	81%

7 Discussion

In this study an on-farm approach was used. The results describe the complex reality where factors affecting soil productivity interact and can, therefore, be the basis for practical work in the study area. Soil productivity depends on chemical, physical and biological properties as well as climate, management and other factors. Therefore, determining the effects of soil erosion on soil productivity is difficult. Furthermore, interactions between soil properties, the kind of crop and the climate conditions need to be taken into consideration (Kenneth et al., 1985; Lal, 1988; Williams, 1985). FAO (1984) states that the relationship between soil erosion and productivity is hard to investigate since soil erosion and productivity are not independent variables and that productivity could be dependent from factors such as soil salinity, flooding and climatic change. Soil characteristics cause effects on yields (Daniels et al., 1989; Gilliam et al., 1985; Stone et al., 1985) and also have to be taken into consideration. Furthermore, soil erosion is interrelated with other environmental factors, and change in one variable induces effects in others.

Nevertheless, many researchers have attempted to quantify a relationship between erosion and soil productivity. Most of the studies on land use in Africa have been carried out in semi-arid environments (Thomas et al., 1994; Tiffen et al., 1994; Östberg, 1995; Dahlberg, 1996; Kinlund, 1996) and some of these scientists have questioned if there is negative landscape development due to erosion (Dahlberg et al., 1996; Leach et al., 1996; Thomas et al., 1994; Tiffen et al., 1994). The major discussion concerns the effects on land resources (Thomas et al., 1994). The disagreement is commonly based on differences in the perceptions of the environment and how to interpret the findings. Leach et al. (1996) claim that there are opinions of negative environmental changes in Africa that are misleading and even proclaim that environmental management has improved over the last 40 years.

Many studies have looked at how overgrazing, fuel crises and removal of natural forest and soil erosion have affected the environment (Batterbury et al., 1999; Dalhberg, 1996; Fairhead et al., 1998; Gary 1999; Preston et al., 1997; Tiffen et al.,1994). These kinds of investigations could be misleading if they are generalized and if extrapolation is made from only a few studies. Environmental history and physical conditions can differ considerably from place to place, making general conclusions difficult (Tiffen et al.,1994) Furthermore, with these condition in mind, an extrapolation could present the wrong picture of the environmental situation (Gary, 1999).

Despite there not being a total consensus concerning the effects of erosion on soil productivity, soil erosion is generally considered to be a serious threat to food production over much of Zambia. Water erosion is associated with the removal of plant nutrients. Soil carrying the most fertile nutrients, which are necessary for plant growth, is lost through erosion (Barnett et a1., 1972; Batchelder et al., 1972; Belay, 1992; Cook, 1982; Engelstad et al., 1961; Eck, 1968; Gachene, 1986; Knoblauch et al., 1942; Lal, 1976; Miller, 1983; Sanchez et al., 1980). Most eroded soils in Zambia, such as the soils, acrisols and luvisols, in the study area, have unfavorable subsoil characteristics, which are unsuitable for plant growth. Fertilizers cannot compensate for surface soil loss in these soils and continuous accelerated erosion may lead to irreversible soil degradation. Apart from most small scale farmers not having the economy to buy the fertilizers, they are also generally considered to be an unsuitable substitute for bad soil nutrition status (Gachene 1995; Kilewe, 1987; Mukui, 1991). This nutrition that is lost is, as described, corresponding particularly well to P bound to calcium (Fitzpatrick, 1992) making phosphorous a significant indicator of soil erosion and interesting for studying soil erosion.

The results from the laboratory phosphorous content soil analyses in this study indicate that nutrients are transported by water erosion and are sedimentary at the bottom of the fields. This is a general pattern; however, in the ACF fields, large quantities of phosphorous stay at the top. The ACF fields have a significantly higher P content at the top of the fields than at the bottom. This indicates that ACF is a good management for erosion control, as it effectively hinders nutrition from being transported to the bottom of the field. The mixed model indicates a highly significantly positive erosion protection in the ACF fields: the slope of the relationship between P content and row number was + 146.97 indicating a positive slope of the relationship between P content and row number showing that ACF offers good erosion protection.

This result is supported by the Nitrogen analyses showing how N in all the ACF fields is at least as high at the top of the field as it is at the base. However, the N soil analyses show a difference to the P analyses curves. The P curves, for the ACF fields, are dipping at the very top of the fields, whereas, the N curves show on the highest content at the very top. The rain period was just over at the time of the study and the trees in the study area were blooming. Therefore, the absorption of P by the *Cajanus cajan* could affect the P content at the very top of the fields where they are planted resulting in the dip at the very top of the P curves. The *Cajanus cajan* that is highly phosphorous absorbing and nitrogen fixating through mycorrhiza, do not generally absorb N from the soil but instead appreciable amounts of P. The absence of a dip at the top of the N analyses indicate that the P curves are dipping at the very top of the ACF fields due to the high absorption of P from the soil by the *Cajanus cajan* mycorrhiza processes. The study indicates that negative result distortion by P absorption, might be avoided through soil sampling at a distance minimally corresponding to the width of the root systems of the plant.

P at the top of the ACF fields is, despite the negative result distortion by the mycorrhiza P absorption of *Cajanus cajan*, significantly higher than in the SCF fields. This indicates that ACF, in this study, is a better erosion protection than SCF. The Mixed model procedure show that the relationship between the different managements and erosion is significantly correlated with an individual erosion protection capacity that is significantly positive for ACF were the slope of the relationship between P content and row number is +146.97 and negative for SCF (- 41.75), VCF (- 30.01) and SW (- 163.51). The texture results at fifteen centimeters depth, with sand content of about 60% and higher, indicates that this is not due to differences in the deeper soil horizon. All fields have a high sand content and, therefore, the water is transported latterly well in all the fields.

Several statistical analysis methods have been employed to relate signs of erosion to management, P content to management and erosion to P content. In order to investigate the internal correlation between the visible sign of erosion and the interrelated correlation between the different forms of managements in the laboratory soil analyses plus the correlation between the field and laboratory analyses, the Mixed model statistical method and Principal Component Analysis have been engaged as very efficient tools. These statistical methods have shown that the results are mathematically interchangeable and that there is a high correlation between and significance in the results in this study. Each of these analyze methods indicate that the ACF fields in this study are more effectively protected against erosion than the fields with the other forms of management or in the uncultivated Savanna Woodland.

In the SCF fields, level bands and earth ridges are used in order to protect the fields from erosion. This management is the most common, as well as the simplest form of conservation farming used in the Kawoozi Camp. It is employed on 80% of the erosion protected fields in the camp as a basic management. The fields with simple conservation farming are the most exposed to erosion in this study. The Mixed model indicates a negative erosion protection capacity in the SCF fields that is significant with a positive slope of the relationship between P content and row number of - 41.75. The P content is approximately 170 % higher at the base of the SCF fields than at the top of the fields. There is a significant difference in the visible signs of erosion between the ACF fields and the rest of the fields. Using One Way ANOVA Difference Approaches and sequential Contrast Test show a significant difference. The ACF fields have significantly less visible signs of erosion than the SCF and VCF fields.

The general indications for visible signs of erosion and the phosphorous analyses show a high correspondence according the Mixed model and the Principal Component Analysis. The correlation for denuded pebbles is 0.822, for denuded roots 0.652 and for gullies 0.825. The correlation coefficient between the visible signs of erosion and the soil sample phosphorous analyses is 0.9. Both are indicating that there is poor protection against erosion in the SCF fields. The signs of visible erosion for the different managements also indicate a difference in erosion protection capacity between the managements. The SCF and VCF fields do not indicate a sustainable erosion control for this environment.

For the VCF fields there is a strong correspondence between the laboratory analyses and the visible signs of erosion, both indicating a varying capacity of erosion protection among the VCF fields. The Mixed model procedure indicates that the SCF fields have a negative estimation of the P curve of - 41.75 indicating a negative erosion protection capacity in the SCF fields. The mean graph of the VCF fields P is about 40 % higher the bottom than at the top of the field and there are problems. Gullies and denuded roots are both found in all the VCF fields.

This study indicates that the Vetiver grass is not a satisfactory vegetative erosion protection for the environmental circumstances in the study area. The soils in the study area are not optimal for agriculture. They are poor in nutrients and the fields are strongly sloped. In order to manage good erosion control in this environment the fields need a strong vegetative protection against the erosion such as is provided in the ACF fields. The nutrition status show that the lowest P content is at the top of the SCF fields in this study, whereas, the VCF fields generally have almost six times higher nutrition status at the top of the field than the SCF fields. Furthermore, the ACF fields generally have an eight times higher status than the SCF fields and as much as about eleven times at the most.

The Savanna Woodland hills give an indication of inadequate erosion protection according to both the phosphorous analysis and the visible signs of erosion. The visible signs of erosion in the Woodland hills are alarming. Past and current cultural practices have reduced the natural protection cover and as a result, the land is being subjected to severe soil erosion losses (Barber, 1983). The denuded roots and pebbles, as well as the large gully, indicate that the SW hills are experiencing rather strong erosion that is clearly having a negative effect on the soils. This possibly could disturb the agricultural areas as a total and good erosion protection management, such as tree roads of *Cajanus cajan*, is therefore recommended in the Savanna Woodland environment. The results also indicate that the erosion in the Savanna Woodland hills is grave which could cause problems to the agricultural area situated below the hills.

8 Conclusion

The variation in soil nutrient content was to a large extent explained by variation in visible signs of erosion. The correlation coefficient between the visible signs of erosion and the analysis results using Mixed model on the soil sample phosphorous analyses was 90%. Also individually the visible signs of erosion are significantly correlated to the phosphorous analyses. This demonstrates that erosion is a major determinant of the conservation of nutrients in the fields. Thus, the study confirms that soil erosion has negative effects on soil nutrient status and that soil erosion protection therefore can have positive effect on soil nutrient status.

The analyses of variation in soil nutrient content demonstrated effects of land management. For SCF the difference in P content between the top and bottom of the field was large, suggesting high erosion in these fields. This study suggests that the Vetiver grass is not a satisfactory vegetative erosion protection for the environmental circumstances in the study area. The ACF fields had a higher P content at the top of fields than at the bottom, suggesting a good ability to withstand erosion. This conclusion is is also supported by the nitrogen analysis, showing that the content of N was somewhat higher at the top than at the bottom of the fields. The importance of appropriate erosion management is also confirmed by the enrichment ratio. The nutrition status at the upper part of the ACF fields is generally seven times higher in phosphorous content than the SCF fields and 40 % higher than the VCF fields. This higher value of P in the higher part of the AFC fields was shown in spite of the variation of P with slope in these fields indicating that samples taken close to the top of the fields may be affected by the uptake of P by mycorrhiza of *Cajanus cajan.*

The ACF fields had, despite the negative result distortion by the P absorption of *Cajanus Cajan*, a significant difference in phosphorous content at the top compared to the other managements and slope positions. The P content is at an average more than 70 % higher at the top of the ACF fields than at the bottom. This is also supported by the nitrogen analysis. N for the ACF fields is about 15 % higher at the top than at the bottom.

The analyses also suggested that visible signs of erosion differed between field management types. The soil sample laboratory analyses results are supported by the field observation of visible signs of erosion. There is a significant difference in the visible signs of erosion between the ACF fields and the rest of the fields. The ACF fields had significantly less visible signs of erosion than the SCF and VCF fields.

This study only concerns parts of the biophysical aspects that affect soil fertility and possibly food security, namely soil nutrition and more specifically the content of P and the movement of soil particles in the study area fields. The results are of value for giving agricultural advice in the district where the study is performed. They show the essential role land management has on nutrient status and the movement of soil particles in the field with the intention of prolonging crop yields in the Kawoozi Camp. Additional studies are required to generalize these results to other areas, though, the overall conclusion in this study is that tree roads of *Cajanus cajan* functioning well as vegetative erosion control management for the hilly Savanna Woodland environment in the study area.

9 Recommendations for MFS Students

In order to perform a good MFS, it is recommended to have a very clear picture of what the study will be covering before the journey to the MFS country. The method and the theoretical background should be set and the planning and schedules should be ready in forms of check lists and an open but ready made calendar.

The situation in the MSF country might be unpredictable giving reason to the planning needing to be open for changes and adaptations. Therefore, it is a good idea to give all planning a flexible margin. It is recommendable to keep methods open in case they are not applicable in the study area. In such cases, it is important to be prepared with alternative methods that do not change the intention and means of the study.

Knowledge of the context in the MFS area is very helpful. Making friends within and outside the study is a good way to understand how to interact with the people involved. Humbleness is a way to handle the lack of knowledge and is useful in many situations.

It is very helpful to have communication links arranged before leaving the home country. Communication methods might not be available to the study area and transportation might be hard to arrange on the site if not organized prior to arrival.

Finally, it is strongly recommended for a student writing the MFS as a thesis to be aware. The MFS reports are generally written in a descriptive manner and the person writing the report is present in the presentation of the study. Since this is not the academic norm it is therefore imperative to talk to everyone involved in the thesis to make sure that the right format is used from the beginning and that both the supervisor and the examiner agreed on the particular format. Failure to recognize this will be cause for a re-write, which is, naturally, extremely time consuming.

10 References

Åkerman, J. 2001. Biological Measures in Soil Conservation. The Vetiver grass as an example, Lund University, Lund.

Allan, E. and Rowlands, J. 2001. Mixed Models and Multilevel Data Structures in Agriculture, The University of Reading, Statistical Services Centre

Banda, D. 2002. Extent of Soil Acidity and Lime Requirements of some EEOA facilitation areas in Eastern and Northern Provinces of Zambia, Department of Soil Science School of Agricultural Sciences University of Zambia, Lusaka.

Batterbury, S.P.J. and Bebbington, A. 1999: Environmental histories, access to resources and landscape change: An introduction. Land Degradation and Development 10: 279-289.

Barnett, A.P., Carreker, J.R, Abruna, F., Jackson, W.A. Dooley, A.E. and Holladay, J.H. 1972. Soil and nutrient losses in runoff with selected cropping treatments on tropical soils. Agron. J. 64: 391-395.

Batchelder, A.R and Jones, J.N. 1972. Soil management factors and growth of maize on topsoil and exposed subsoil. Agron. J. 64: 648-652.

Baver, L.D. 1950. How serious is soil erosion. Soil Sci. Soc. Amer. Proc. 15: 1-5.

Belay, T. 1992. Effects of erosion on properties and productivity of eutricnitosols in Gununo area, southern Ethiopia. In Erosion, conservation and small-scale farming, Eds. H. Hurni and K. Tato. Geographica Bernensia, Berne, Switzerland: 229-242.

Boul S.W., Hole F.D., McCracken R.J. 1980. Soil Genesis and Classification. The Iowa State University Press, Ames.

Bramble B.M., Fosberg. M.A, Walker D.J. and Falen, AL. 1985. Changes in soil productivity related to changing topsoil depths on two Idaho Palouse soils. In: Erosion and soil productivity. ASAE Publication 8/85, Michigan, USA: 18-27.

Brown L.R. and Kane H. 1994. Full House - Reassessing the Earth's Population Carrying Capacity, W.W. Norton and Company, New York

Braun, A., Smaling, E.M.A., Muchugu, E.J. and Corbett, I.D. 1997. Maintenance and improvement of soil productivity in the highlands of Ethiopia, Kenya, Madagascar and Uganda: An inventory of spatial and non-spatial survey and research data on natural resources and land productivity. African Highlands Initiative, International Centre for Research in Agroforestry, Nairobi.

CIA, 2004. Central Intelligence Agency [Online]. Available URL: http://www.cia.gov/ [Accessed 11 March 2004]

Cook, K. 1982. Soil loss: A question of values. J. Soil Water Conservation. 37: 89-92.

Dahlberg, AC. 1996: Interpretations of Environmental Change and Diversity - A Study from North East District, Botswana. Dissertation No. 7. The Department of Physical Geography, Stockholm University, Sweden.

Dahlberg, A.C. and Blaikie P. 1996. Changes in landscape or in interpretation? An environmental history from North East District, Botswana.

Daniels, RR, Gilliam, J.W., Cassel, D.K. and Nelson, L.A. 1989. Soil erosion has limited effect on field scale crop productivity in the Southern Piedmont. Soil Sci. Soc. Am. J. 53: 917-920.

Eck, H.V. 1968. Effect of topsoil removal on N-supplying ability of Pullman silty clay loams. Soil Sci. Sac. Amer. Proc. 32: 686-691.

EEOA, 2002. The Use of Agricultural Lime in Conservation Farming, Lusaka.

El-Swaify, S.A. and Fownes, J.H. 1992. Erosion processes and models: Applications in the Tropics. In Erosion, conservation and small-scale farming, Eds. H. Humi and K. Tato. Geographica Bemensia, Beme, Switzerland: 135-149.

Engelstad, O.P., Shrader, W.D. and Dumenii, L.C 1961. The effects of surface soil thickness on com yields. As determined by a series of field experiments in farmer operated fields. Soil Sci. Sac. Am. Proc. 25: 494-497.

FAO, 1984. Erosion and soil productivity: A review. FAO Consultants' Working Paper No. l, FAO, Rome.

Fairhead, I. and Leach, M. 1998: Reframing Deforestation - Global analysis and local realities: studies in West Africa, Routledge, London.

Fitzpatrick, E.A. 1992. An introduction to Soil Science, Longman Scientific and Technical, Harlow.

Frye, W.W., Ebelhar, S.A., Murdock, L.W. and Blevins, KL. 1982. Soil erosion effects on properties and productivity of two Kentucky soils. Soil Sci. Soc. Amer. J. 46: 1051-1055.

Gachene, C.K.K. 1986. Nutrient losses in eroded soil material from some Kenyan soils. In Soil and Water Conservation in Kenya, Eds. D.B. Thomas, E.K. Biamah, A.M. Kilewe, L. Lundgren and B.O. Mochoge. Dept. of Agric. Engin., University of Nairobi: 34-37.

Gachene, C.KK. 1995. Effects of soil erosion on soil properties and crop response in Central Kenya. PhD Thesis, Department of Soil Sciences, Reports and Dissertations 22, Uppsala, Sweden.

Gary, L.C. 1999: Is land being degraded? A multi-scale investigation of landscape change in south western Burkina Faso. Land Degradation and Development 10: 329-343.

Gilliam, J.W., Cassel, D.K., Daniels, RB. and Stone, J.R 1985. Interrelationships among soil erosion, landscape position and soil productivity in the North Carolina Piedmont. In Erosion and soil productivity. ASAE Public. 8/85, Michigan, USA: 75-82

Hudson N, 1971, Erosion, Keyspoles Ltd, London

Ingram, J.A. 1994. Soil fertility research in East Africa. CAB Abstracts. CAB International, Wallingford.

Jacks, G.V. and Whyte, R.O. 1939. The rape of the earth. Faber and Faber, London.

Jolliffe, I. T. 1986. Principal component analysis, Springer series in statistics, Springer-Vig, New York

Kasuta, E. 1993. Country Gender Analysis. Zambia, Stockholm.

Kenneth, G.R and Follet, RF. 1985. A research strategy for assessing the effect of erosion on future soil productivity in the VS. In: Soil erosion and conservation, Eds. S.A. El-Swaify, W.C. Moldenhauer and A. Lo. Soil Conservation Society of America, Ankeny, Iowa: 691-702.

Kinlund, P. 1996. Does Land Degradation Matter? Perspectives on Environmental Change in North-Eastern Botswana, Almqvist and Wiksell, Stockholm.

Kilewe, A. 1987. Prediction of erosion rates and the effects of topsail thickness on sail productivity. Ph.D thesis, Department of Soil Science, University of Nairobi.

Knoblauch, H.C, Koloday, L. and Brill, G.D. 1942. Erosion losses of major plant nutrients and organic matter from Collington sandy loam. Soil Sci. 53: 369-378.

Lal, R. 1976. Soil erosion on alfisols in Western Nigeria. N. Nutrient elements losses in runoff and eroded sediments. Geoderma 16: 403-417.

Lal, R .1981. Soil erosion problems on alfisols in Western Nigeria. VI. Effects of erosion on experimental plots. Geoderma 25: 215-230.

Lal, R.1985. Soil erosion and its relation to productivity in tropical soils. In Sai1 erosion and conservation, Eds. S.A. EI-Swaify, W.C. Moldenhauer and A. Lo. SCSA, Ankeny, Iowa: 237-247.

Lal, R. 1988. Soil erosion control with alley cropping. In Land conservation for future generations, Ed. J. Rimwanich. Bangkhen, Bangkok: 237-245.

Leach, M. and Mearns, R. (eds.) 1996. The Lie of the Land: Challenging Received Wisdom of the African Environment, The International African Institute, London.

McFarlane, D., Delroy, N., Vreeswyk, S. and van-Vreeswyk, S. 1991. Water erosion of potato land in Western Australia. I. Factors affecting soil loss and the effect of soil loss on productivity. Austr. J. Soil Water Conserv. 4: 33-40.

MAFF, 1998. SCAFE introduction. Republic of Zambia, Ministry of Agriculture, Food and Fisheries, Field Service Department, Lusaka

Mikkelsen, B. 1995. Methods for Development Work and Research Guide for Practitioners, Sage Publications. New Delhi.

Miller, R.H. 1982. Methods of Soil analysis. Part 2 Chemical and Microbiological Properties,. American Society of Agronomy, Madison.

Miller, M.H. 1983. Soil limitations to crop productivity in Canada. Can. J. Plant Sci. 63: 23-32.

Moore, T.R. 1978. An initial assessment of rainfall erosivity in East Africa. Tech. Comm. No. 11, Dept. of Soil Sci., University of Nairobi.

Moore, T.R. 1979. Rainfall erosivity in East Africa. Geog. Ann. 61A: 147-156.

Morgan, R.P.C. 1995. Soil Erosion and Conservation. Longman, Harlow.

Morgan, RP.C. 1988. Measurement of soil erosion. In Soil erosion and conservation, Ed. D.A. Davidson, Longrnan Scientific and Technical, UK: 140-161.

Mukui, H.M. 1991. Effect of topsoil removal and the growth of wheat. MSc thesis in Land and Water Management. Dept. of Agric. Engin., Univ. of Nairobi.

NE, 2004. National Encyklopedin [Online]. Available URL: http://www.ne.se/jsp/notice_board.jsp?i_type=1 [Accessed 11 March 2004]

Neol, O.R 1943. The influence of soil erosion on fertility losses and on potato yield. Amer. Potato J. 20: 57-64.

Ovouka, M. 2000. Effects of soil erosion on nutrient status and soil productivity in the central highlands of Kenya. Department of physical geography, Gothenburg.

Östberg, W. 1995. Land is Coming Up: The Butunge of Central Tanzania and The Environments, Stockholm Studies in Social Anthropology, Ordgruppen, Stockholm.

Pimentel D., Harvey C., Resosudarmo P., Sinclair K., Kurz D., McNair M., Crist S., Shprtiz S., Fitton L., Saffouri R., and Blair B. 1995. Environmental and Economic Cost of Soil Erosion and Conservation Benefits, Science 267: 1117-1123.

Phiri, C.L. and Tengnäs B. 1998. Agroforestry Extension Manual for Eastern Zambia, Nairobi.

Pierce, F.J., Larson, W.E., Dowdy, RH. and Graham, W.AP. 1983. Productivity of soils. Assessing long-term changes due to erosion. J. Soil Water Conserv. 38: 39-44
.
Preston, D., Macklin, M. and Warburton, 1. 1997: Fewer people, less erosion: The twentieth century in southern Bolivia. The Geographical Joumal163: 198-205.

Raussen, T. 1997. Integrated soil fertility management on small scale farms in Eastern province, of Zambia. MAFF Zambia, Nairobi.

Rocheleau, D. 1998. Agroforestry in Dryland Africa, ICRAF, Nairobi.

Rowel, D.L. 1994. Soil Science Methods and applications. Longmans Scientific and Technical, Essex.

Schroeder, D. 1984.Soils Facts and Concepts, International Potach Intitute, Bern.

Sanchez, P.A. and Cochrane, T.T. 1980. Soil constraints in relation to major farming systems of tropical America. In Priorities for alleviating soil-related constraints to food production in the tropics. IRRI, Los Banos, Phillipines: 107-140.

Sanches, P.A., Izac, A-M. N., Valencia, I. & Pieri, C. 1996. Soil fertility replenishment in Africa. In: Breth, S.A. ed. Achieving greater impact from research investments in Africa. Sasakawa Africa Association, Mexico City.

Scherr S.J. and Yadav S. 1996. Land Degradation in the Developing World: implications for Food, Agriculture, and the Environment to 2020, Food, Agriculture and the Environment, Discussion Paper 14, International Food Policy Research Institute.

Simute, S. 1992. Agroforestry Manual for extension officers with emphasis on small scale farmers in eastern province, Zambia. RCSU and SIDA, Ndola.

Stocking, M. and Peake, L. 1985. Erosion-induced loss in soil productivity: trends in research and International cooperation. Paper presented to IV International Conference on Soil Conservation, Maracay, Venzuela, Nov. 1985.

Stone, J.R, Gilliam, J.W., Cassel, D.K., Daniels, RB., Nelson, L.A. and Kleiss, H.J. 1985. Effect of erosion and landscape position on the productivity of Piedmont soil. Soil Sci. Soc. Amer. J. 49: 987-991.

Stoorvogel J.J., Smailing E.M.A and Jansson B.H. 1993. Calculating soil nutrient balances in Africa at different scales, l.Supra-National Scale, Fertiliser Research 35: 227-235.

Tengberg, A., Stocking, M. and Deschen, S.C.F. 1997. The impact of erosion on soil productivity - An experimental Design applied in Sao Paolo State, Brazil, Geografiska Annaler 79A: 95-107.

Verity G.E. and Anderson D.W. 1990. Soil erosion effects on soil quality and yield, Canadian Journal of Soil Science 70: 471-484.

Whiteside M. 1998. Living Farms - Encouraging Sustainable Smallholders in Southern Africa, Earthscan, London.

Williams, J.R 1985. The physical components of the EPIC model. In Soil erosion and conservation (Eds. S.A. EI-Swaify, W.C Moldenhauer and A. Lo). SCSA, Ankeny, lowa: 272-284.

Williams, J.R, Renard, K.G. and Dyke, P.T. 1983. A new method for assessing erosion's effect on soil productivity. J. Soil Water Conserv. 38: 381-383.

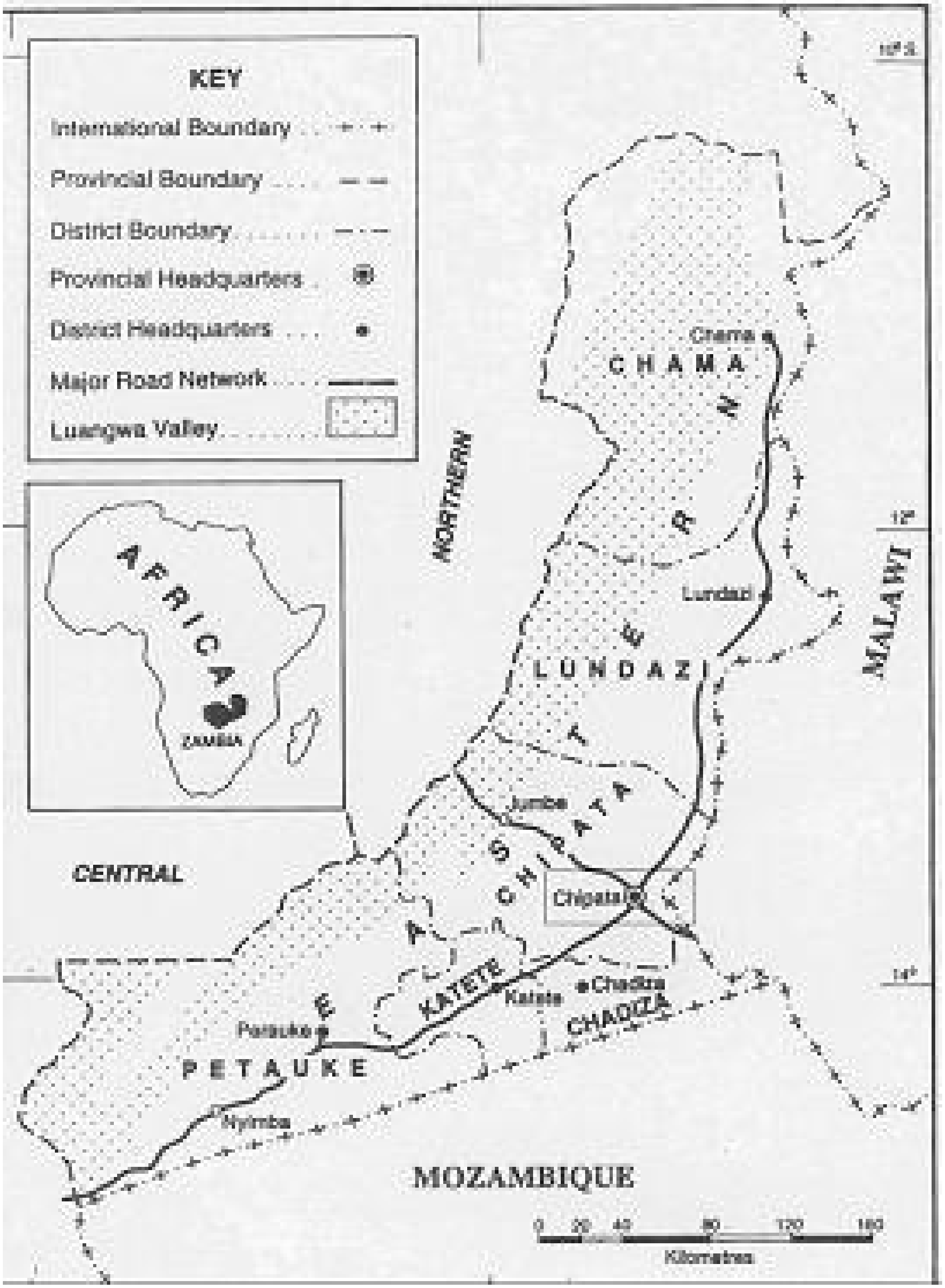
Thomas, D. S. G. and Middleton, N. J. 1994. Desertification: Exploding the Myth, John Wiley & Sons, Chichester.

Tiffen, M., Mortimore M. and Gitchuki, F., 1994: More people, less erosion-environmental recovery in Kenya. John Wiley. Cbichester.

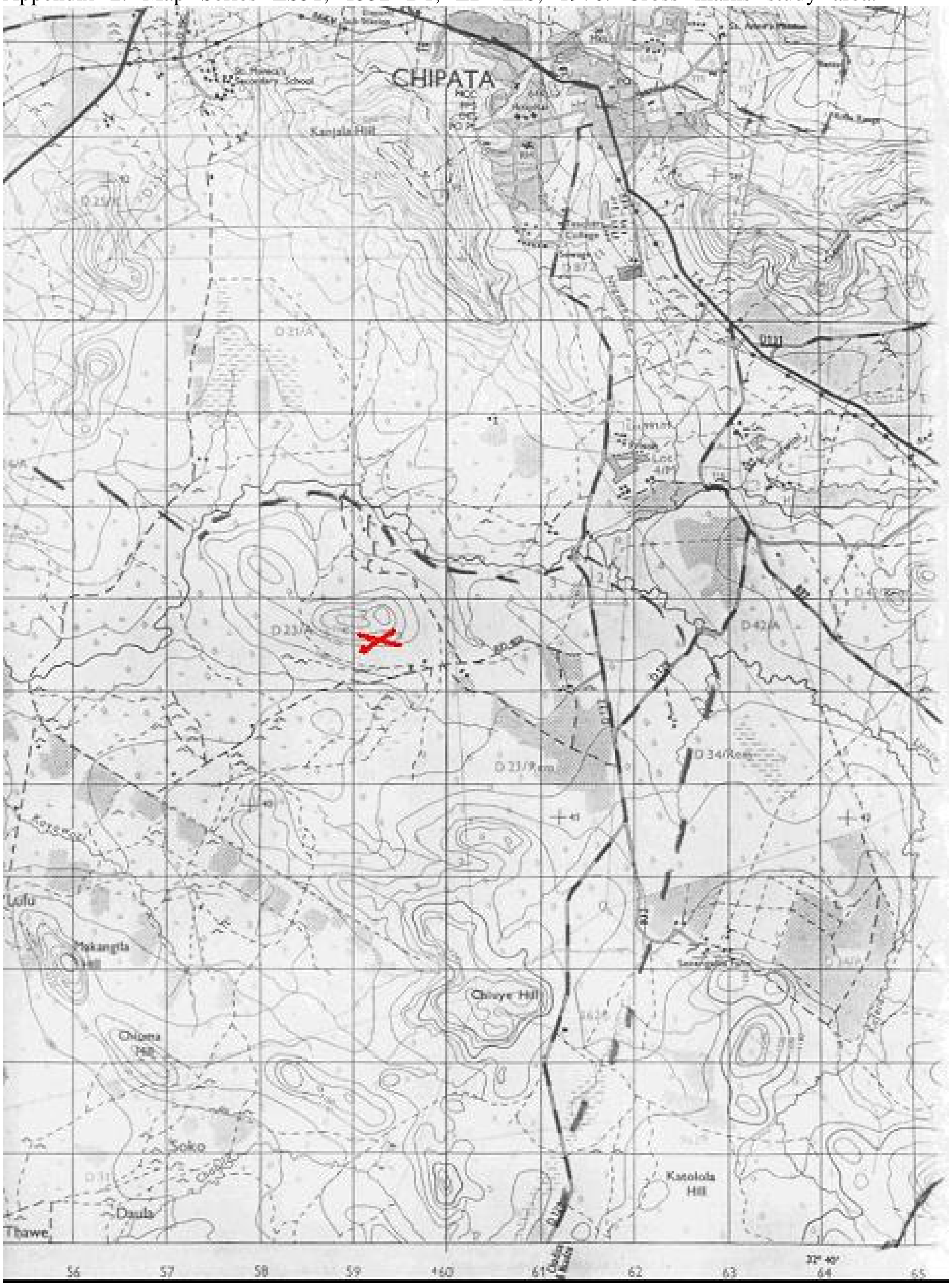
Zobisch, M.A. , Richter C. , Heiligtag B. ,Schlott R. 1995. Nutrient losses from cropland in the Central Highlands of Kenya due to surface runoff and soil erosion. Soil and Tillage Research, 33, 2: 109-116.

11 Appendix

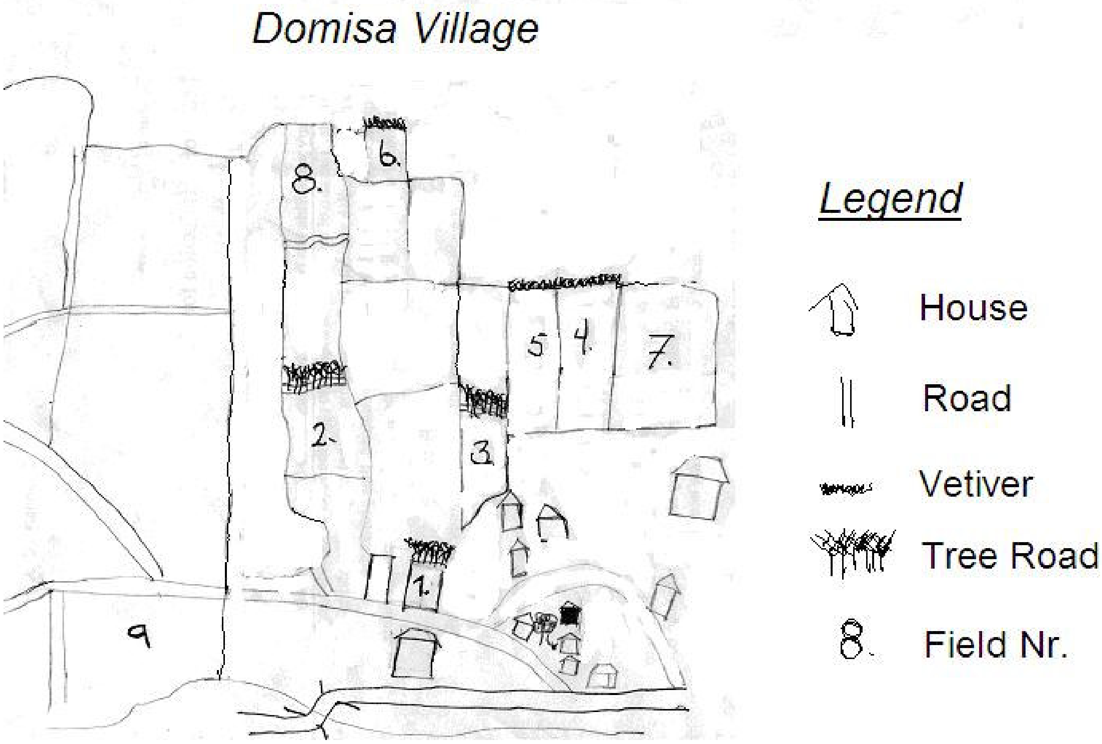
Appendix 1. Eastern Province of Zambia regarding the study area.



Appendix 2. Map Series ZS51, 1332 D1, ED IZS, 1976. Cross marks study area.



Appendix 3. Map and Transect of study area.
Pencil drawing by Camp Extension Officer of Domisa village. Study fields are numbered.



The transect starts at the top of the mountain where the study was performed. The GPS was showing; S 14°41'28.4" and E 32°37'19.7". The heading is south; 192° and the elevation is 1156 meters above sea level. This is the Woodland Hills. The soil is composed of stony bleached gravel and stones. The vegetation is composed of scattered trees such as; Brestigia Specieformis, Folias Saligina, Hissing Trees, Terocapas Angoresis and Stacinos Inoqua.

10 m from the top the gradient is 12° and the elevation is 1151 mos. This is also the Woodlands Hills. The soil is composed of stony, bleached gravel. The vegetation is composed of scattered trees such as; Brestigia Specieformis, Folias Saligina, Hissing Trees, Terocapas Angoresis and Stacinos Inoqua.

90 m from the top the gradient is 20° and the elevation is 1130 mos. This is the Forest Land, called Nkalango. The soil is composed of stony, bleached gravel. The vegetation is composed of scattered trees such as; Brestigia Specieformis, Folias Saligina and Hissing Trees.

180 m from the top the gradient is 14° and the elevation is 1104 mos. This is also the Forest Land, called Nkalango. The soil is a dark reddish sandy loam. The vegetation is composed of scattered semi dense trees such as: Brestigia Bossei, Deprorinkas Conrocapon, Folias Saligina, Duiker Berry and Brestigia Longiforia.

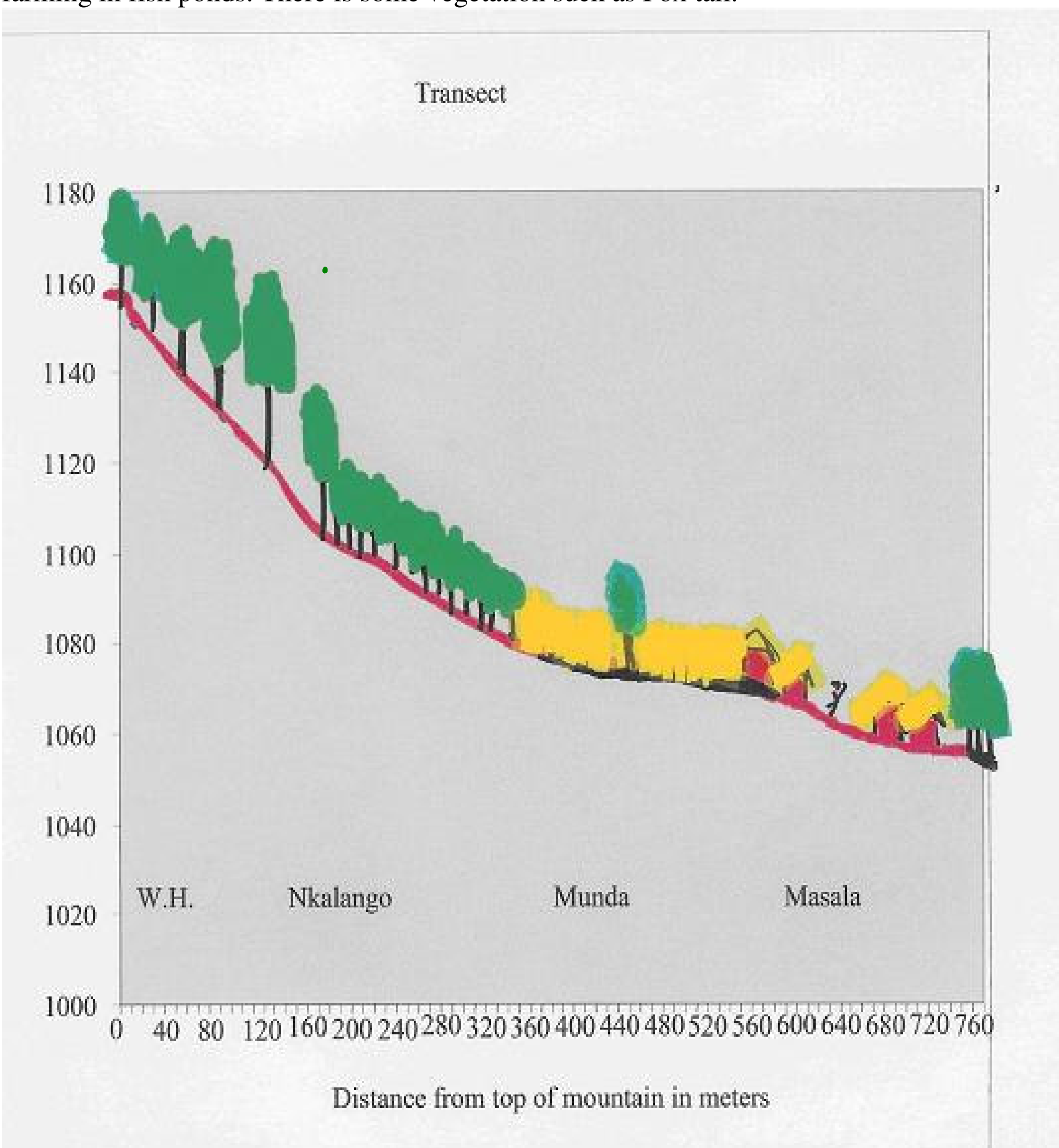
280 m from the top the gradient is 10° and the elevation is 1090 mos. Again, this is the Forest Land, called Nkalango. The soil is a dark reddish sandy loam. The vegetation is composed of densely grown trees such as; Brestigia Bossei, Bahinia Batesiana, Oapaka Sasibarika, Fracotia Indica and grass; Hyperenia Espipi.

350 m from the top the gradient is 7°-8° and the elevation is 1086 mos. This is the Corn Land, called Munda. The soil is a dark reddish sandy loam. The farmers grow different crops here such as; maize, ground nuts, low peas, sweet sorghum, cassava and sun hemp.

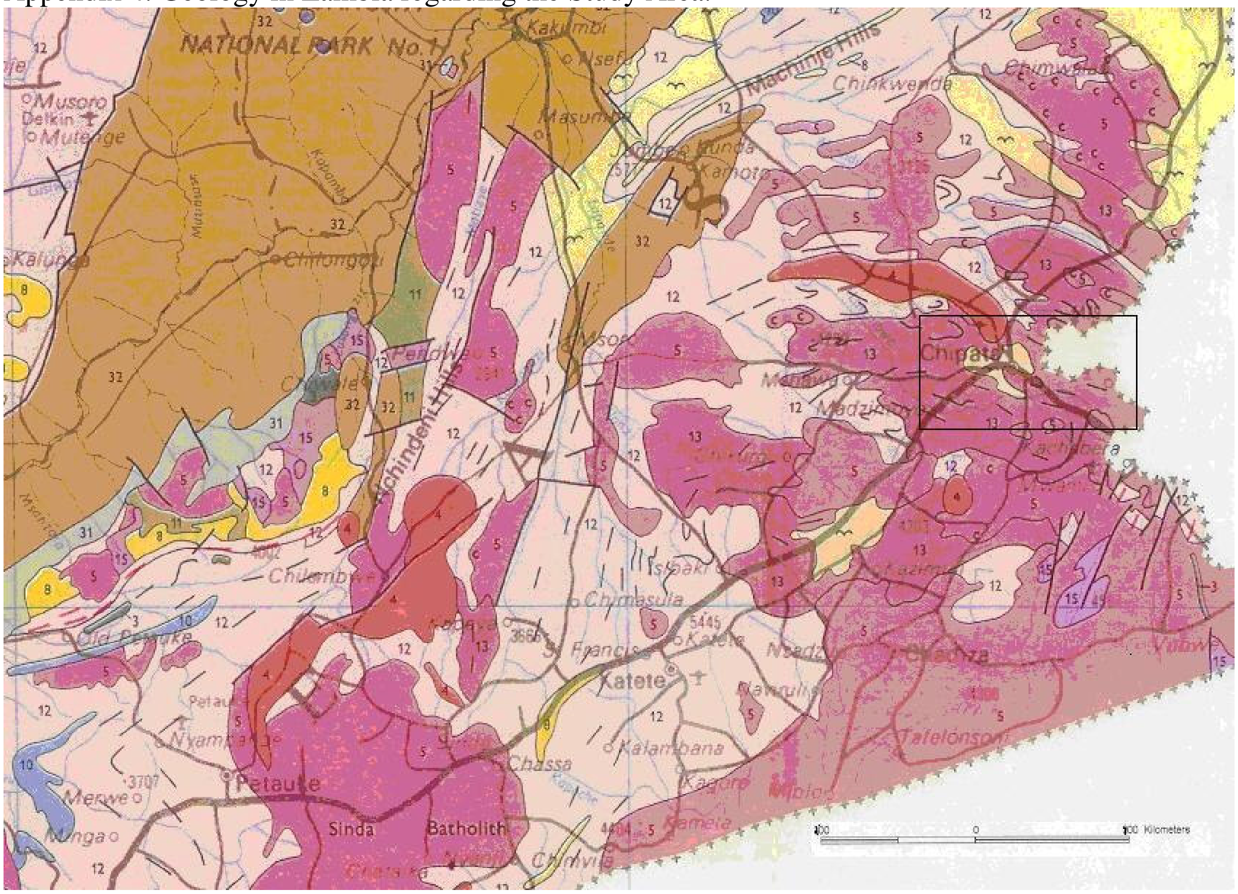
550 m from the top the gradient is 12° and the elevation 1082 mos. This is the Housing Area, called Masala. This is where the farmers live and keep their animals.

730m from the top the gradient is 0° and the elevation is 1056 mos. This is the Vegetable Garden, called Dimba. The soil is a dark brown loam. This is where farmers have their gardens in the wet fertile soil. Fruits and vegetables are grown here, such as; bananas, sugar canes, papaya and mango.

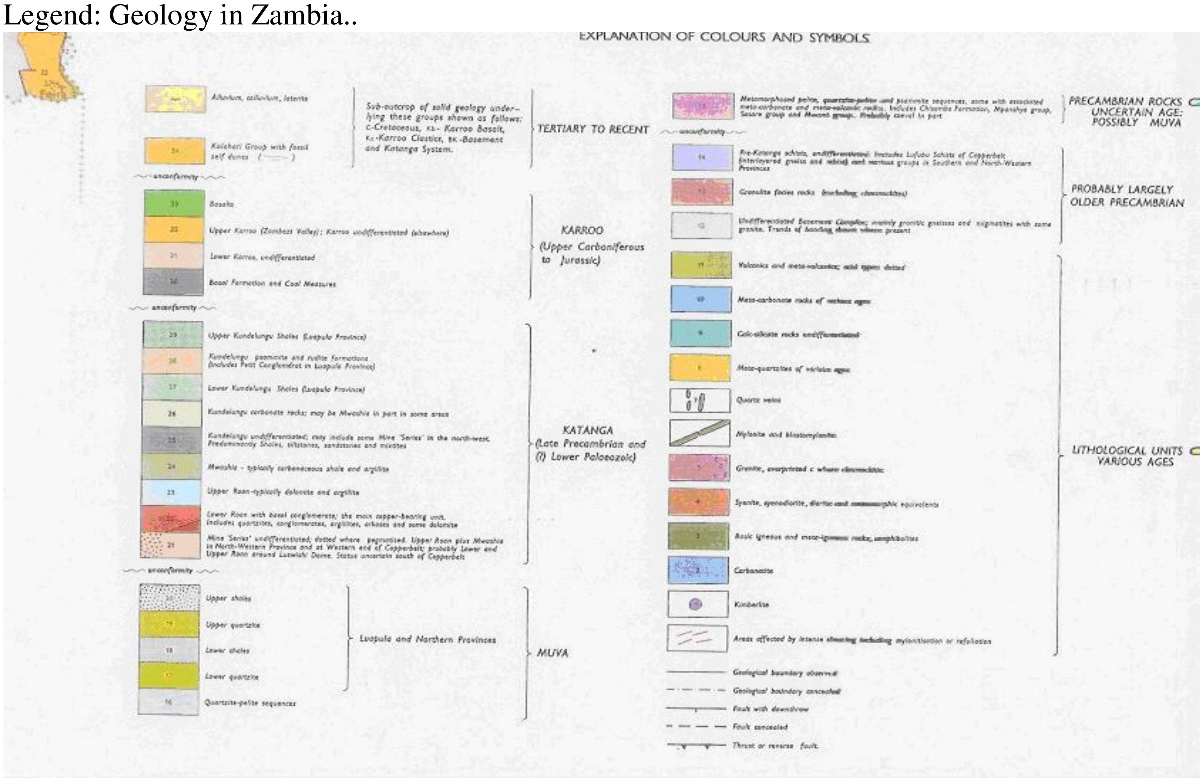
770 m down from the top the gradient is 0° and the elevation is 1055 mos. This is the Wet Land, called Dambo. The soil is a dark brown loam. The villagers use this area for fish farming in fish ponds. There is some vegetation such as Fox tail.



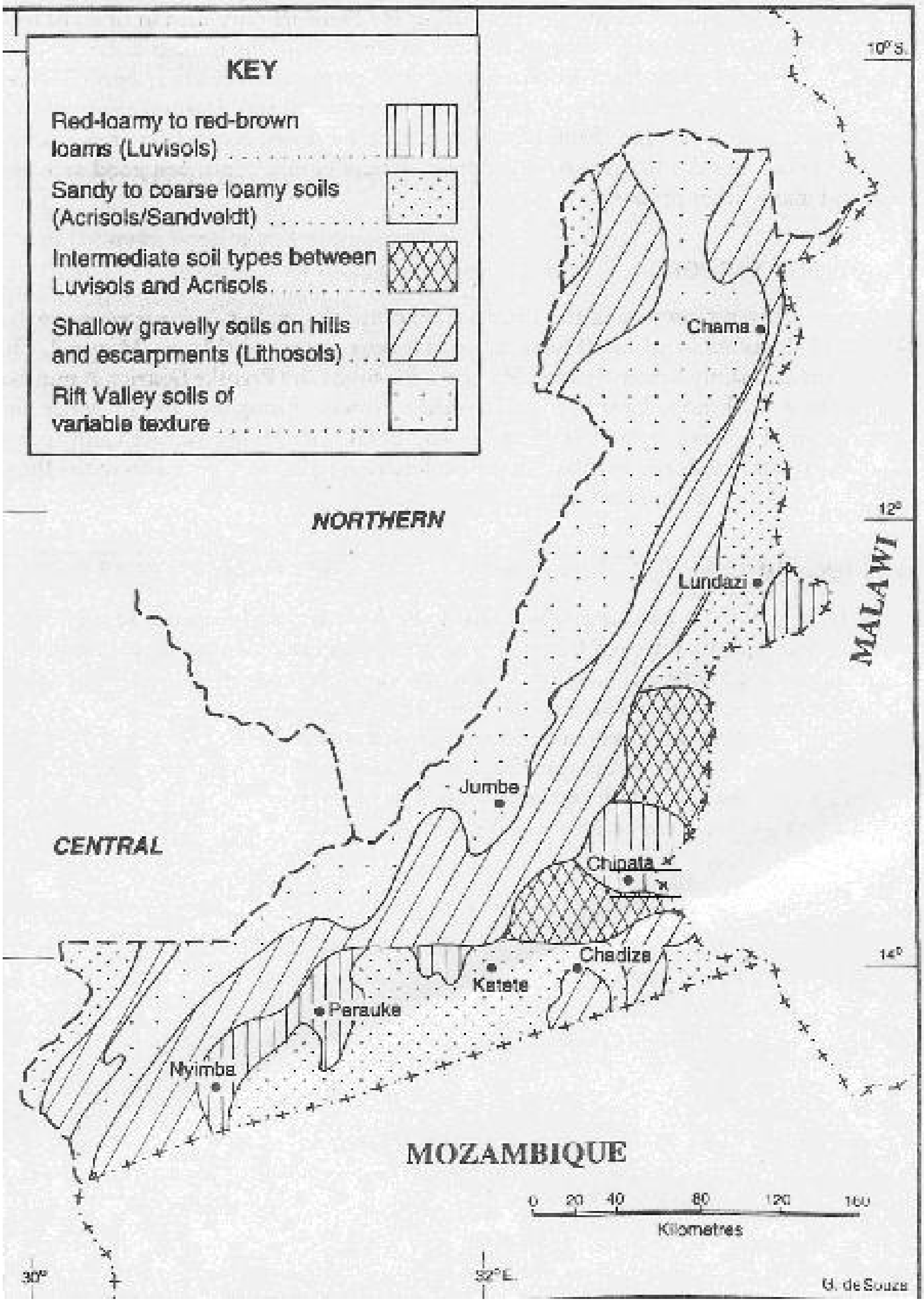
Appendix 4. Geology in Zambia regarding the Study Area.



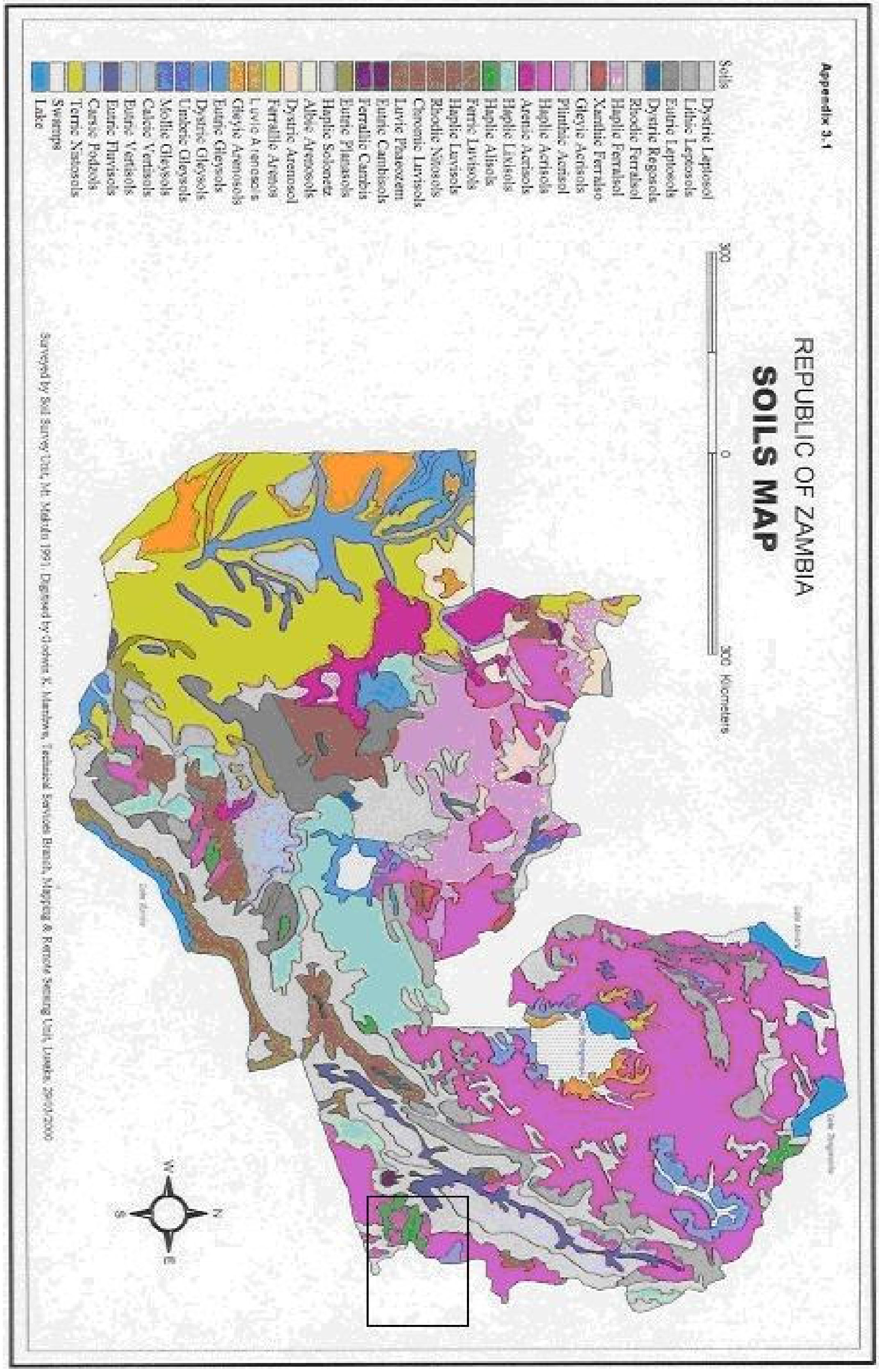
Legend: Geology in Zambia..



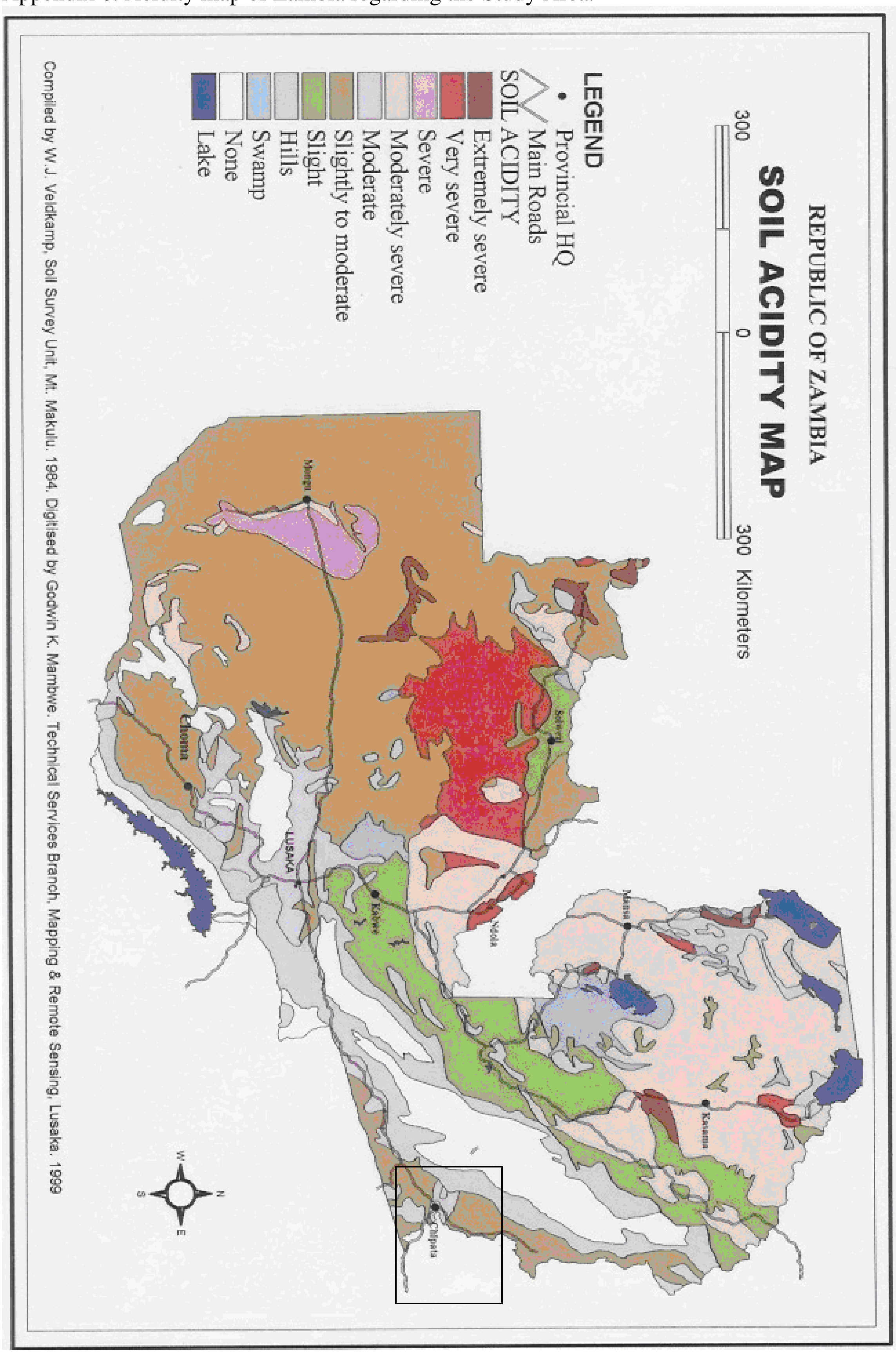
Appendix 5 A. Soils in Eastern Province, Zambia regarding the study area (Phiri et al., 1998).



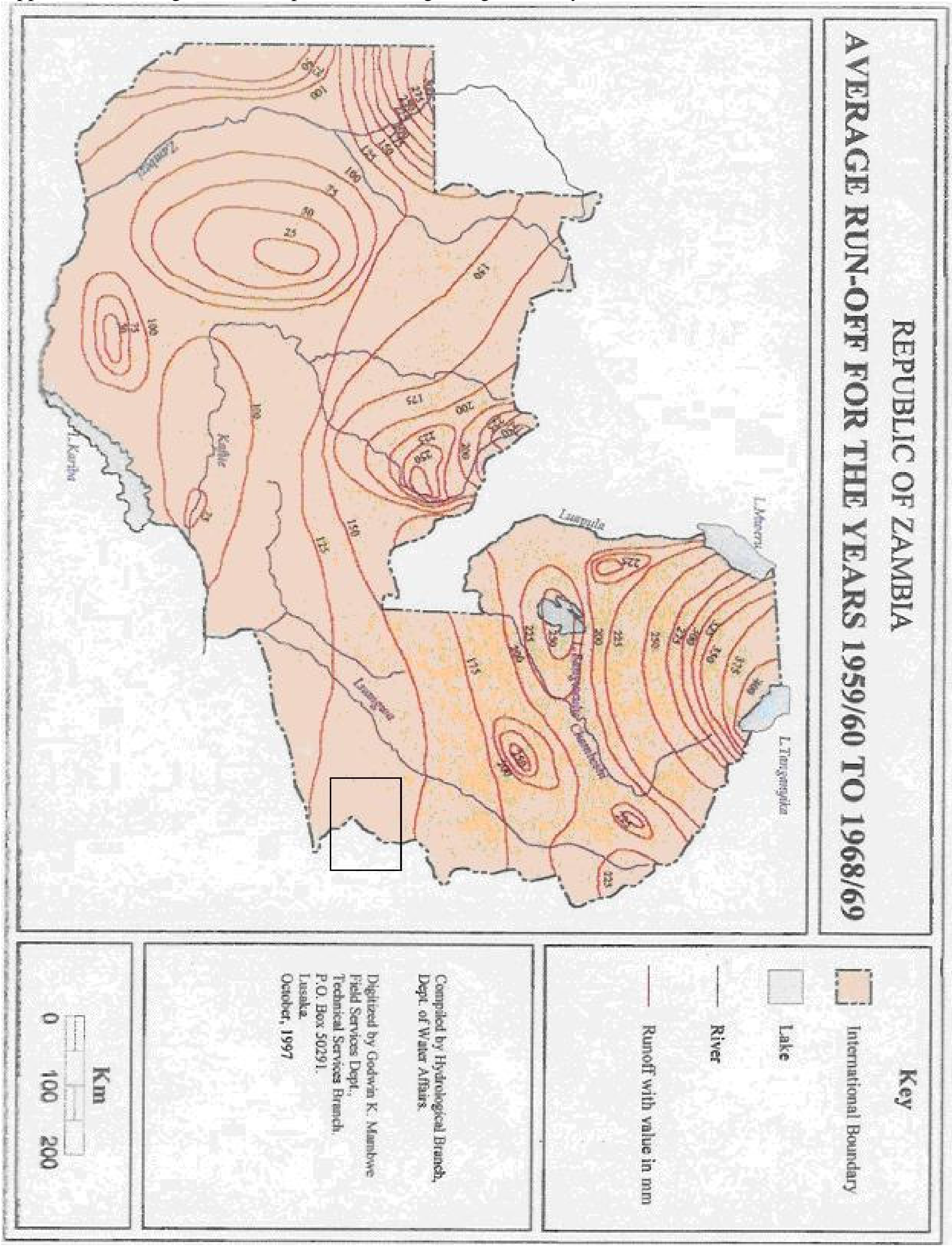
Appendix 5 B. Major Soil types of Zambia regarding the Study Area.



Appendix 6. Acidity map of Zambia regarding the Study Area.



Appendix 7. Average run off map of Zambia regarding the Study Area.



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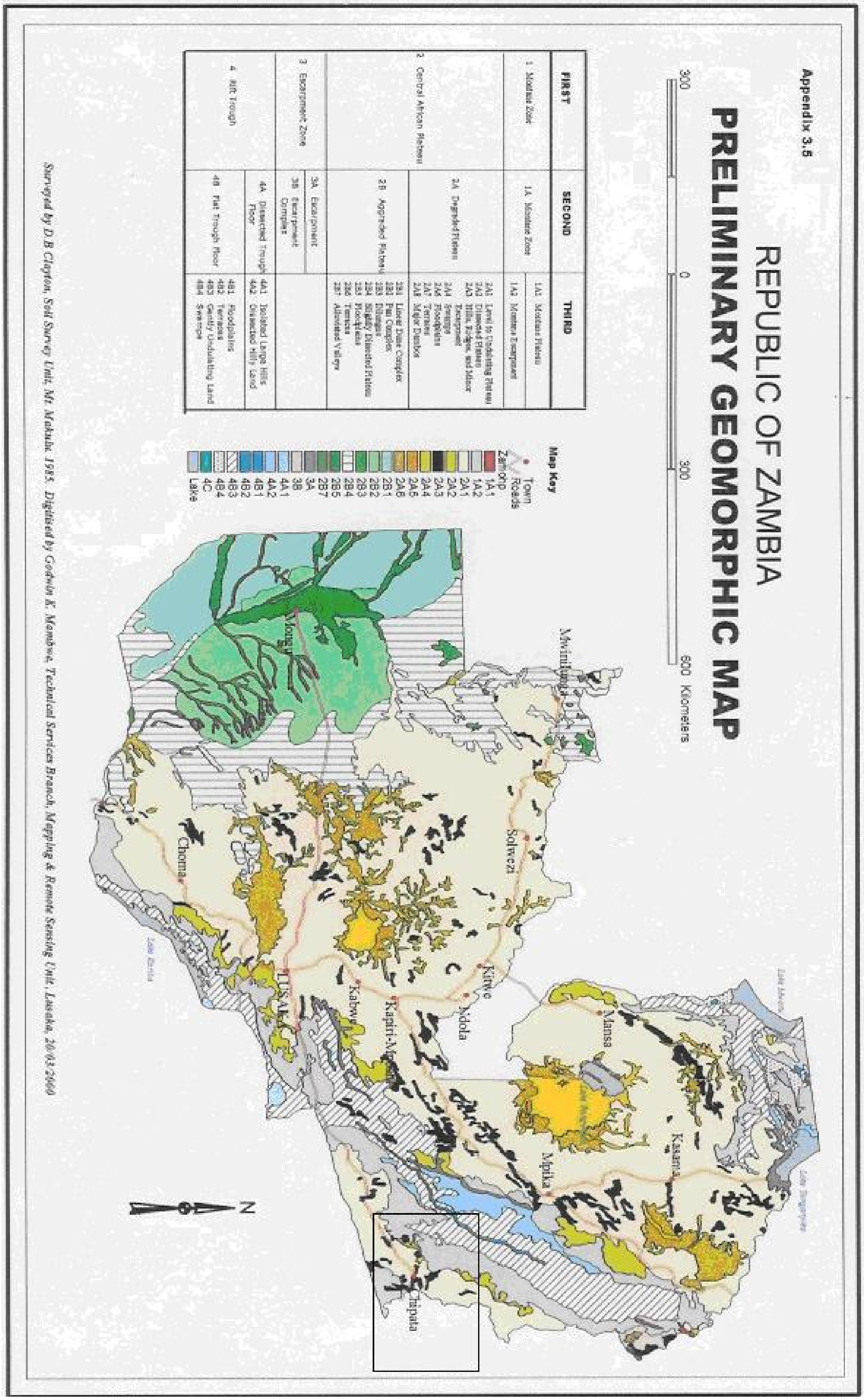
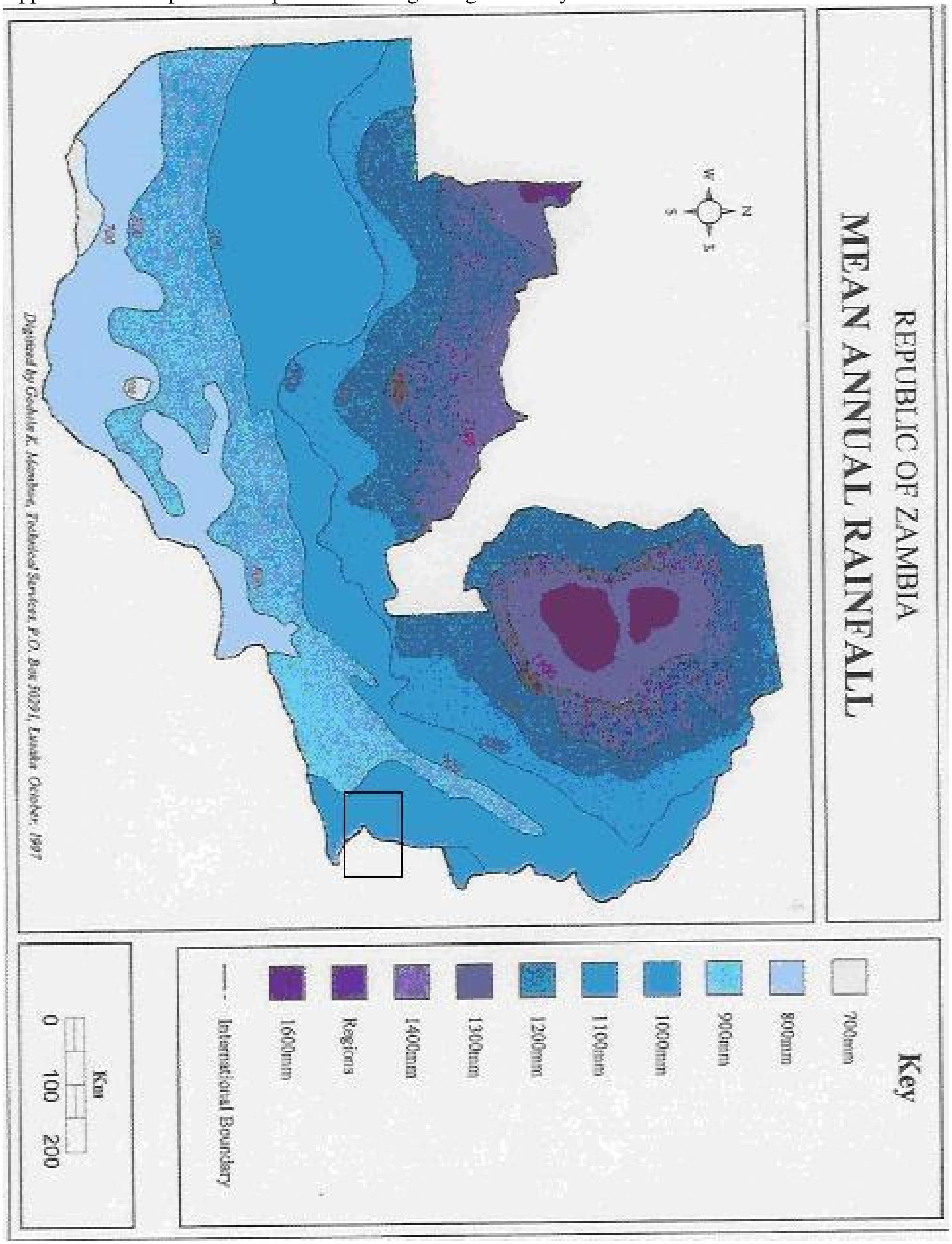
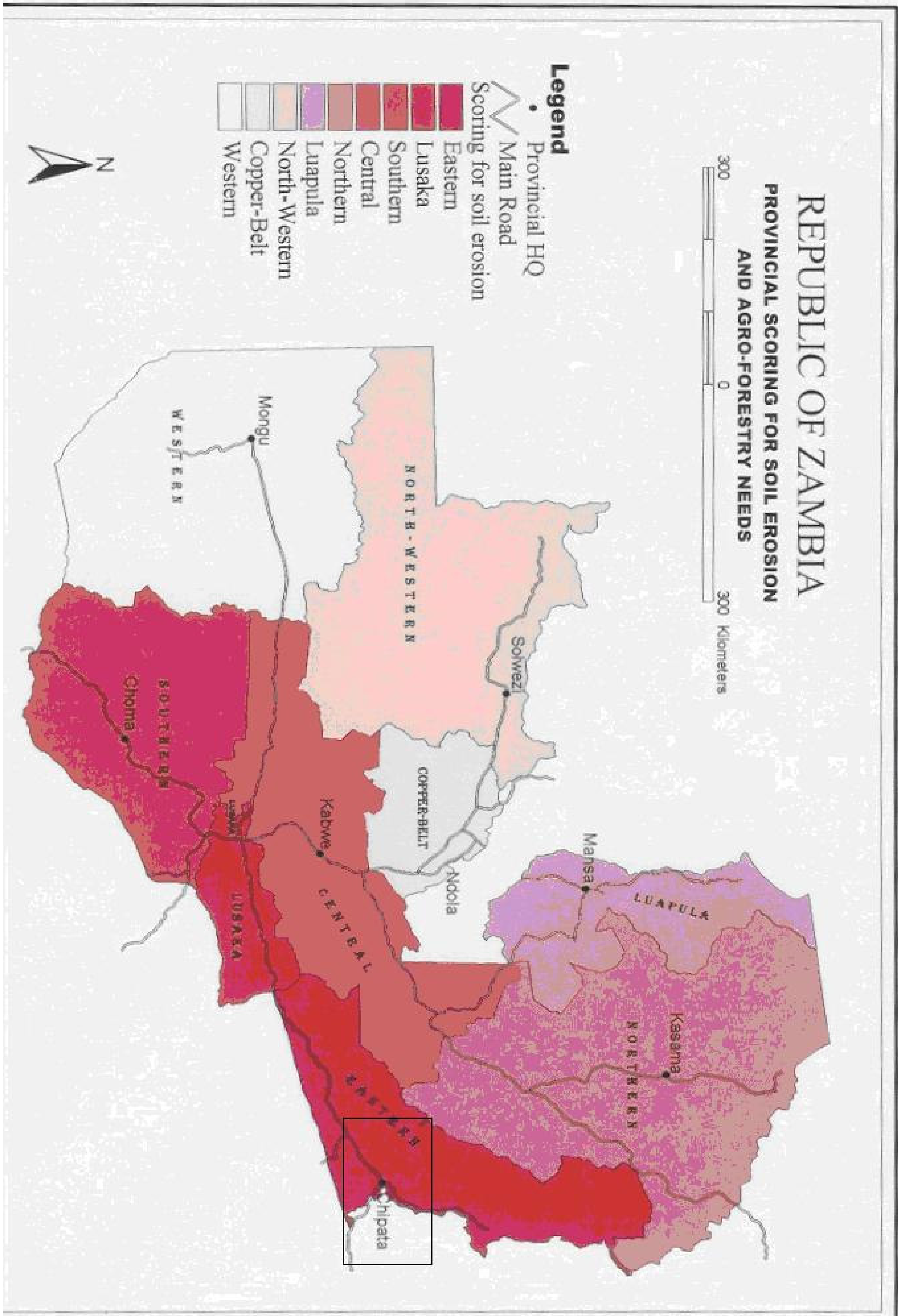
Appendix 8. Geomorphology in Zambia regarding the Study Area.



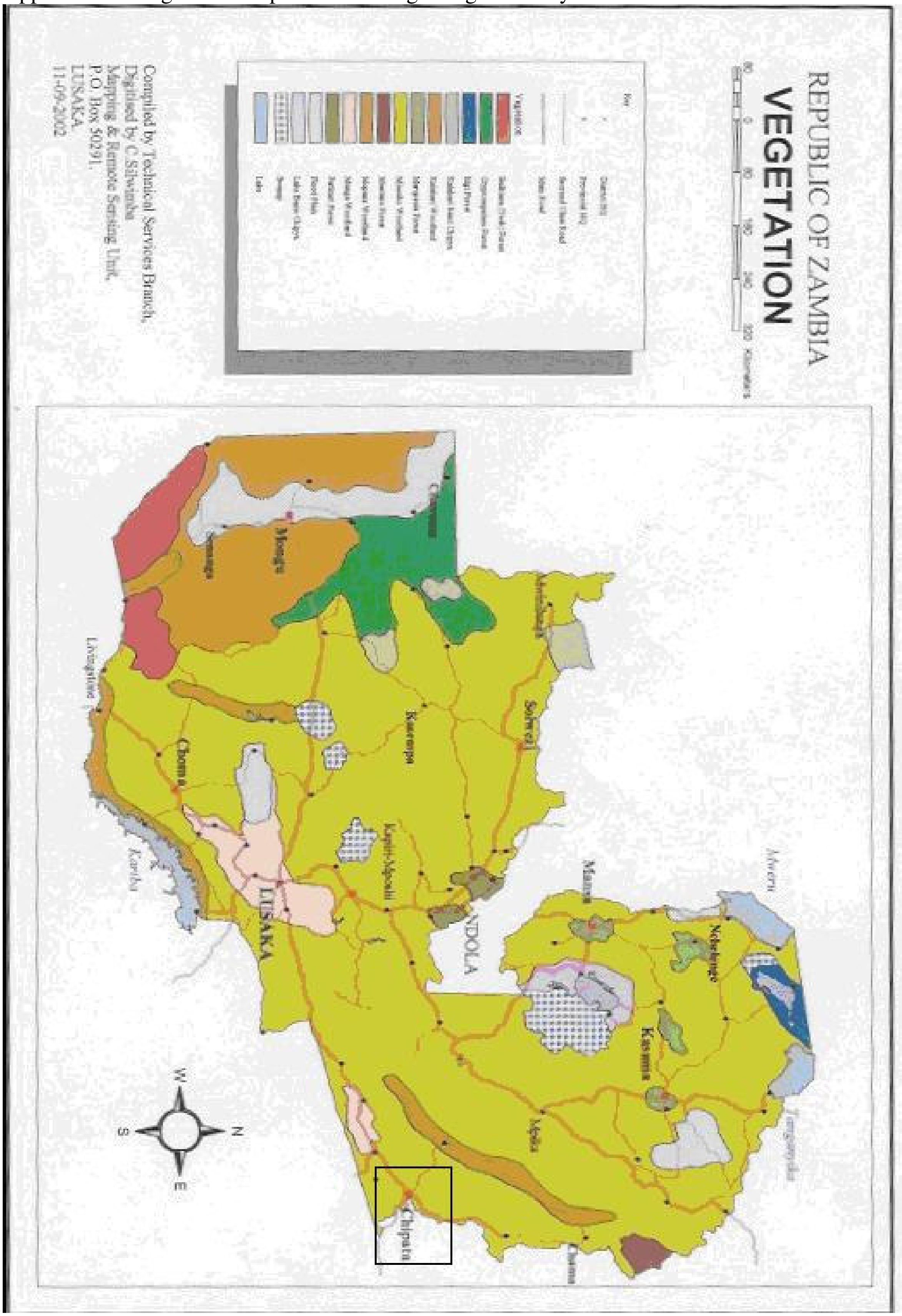
Appendix 9. Precipitation map of Zambia regarding the Study Area



Appendix 10. Soil erosion map of Zambia regarding the Study Area.



Appendix 11. Vegetation map of Zambia regarding the Study Area.



Appendix 12. Interview Check List.

Check list

Check list for Field Study of soil

1. Chose which three fields depending on the social groups
2. Soil type
3. Texture
4. Acidity
5. Geomorphology
6. Geology
7. Precipitation
8. Vegetation
9. Erosivity
10. Air Photography
11. GIS
12. Slope data concerning macro forms
13. Hydrology including micro forms
14. Morphology including micro forms
15. Morphometri especially regarding erosion forms.
16. Remote photographs
17. Slope length
18. Slope angel
19. Present cultivation practices
20. Visible erosion signs; rills - gullies; measure dept width!
21. Draw map and take pictures of soil profile on the chosen spots
22. Draw map and take pictures of the catena as a whole
23. Extension Officer that assists in understanding on the soil structure and local knowledge of the physical geography

Check list on vegetation

1. What crops are present on the field now?
2. What trees; species?
3. How old are the trees?
4. How are the trees planted?
5. How narrow are the trees planted?
6. What is the use for the trees?
7. What is the use for the crops: what is the land management?
8. What land management techniques are used?
9. What land management techniques have been used in the past?
10. What land preparation technique is used?
11. What land technique would you like to use for your farm?
12. In what way have you chosen the management technique?
13. What resources have you received for implementing these management techniques?

Farmer Questions; physical questions:

1. What practices were done on the fields during the last years according to:
- Animal; if so, where?
- Crops; what is the cropping calendar
- Labor; what is your working calendar; for the year; for the day
- Manure; if so, where?
- Fertilizers; is so, where?
- Fallow?
8. Labor; what is your working calendar; for the year; for the day
9. How has fertility changed over the years?
10. How have the crops been growing?
11. What is your impression of the soil and land?
12. What is the history of the soil and land use?
13. How has fertility changed since the change in management?
14. What problems do you have?
15. What are the possibilities for the future?
16. What do you see as difficulties?
17. What do you want help in administrating?

Gear

1. Plastic bags
2. Labels for outside bag and inside
3. Gauge
4. Small shovel
5. PEHAMETER pH-kit.
6. LaMotte; pH, P, N, K meter-kit.
7. Maps:
- Land maps
- Geomorphology
- Acidity
- Erosivity
- Precipitation
- Soil
- Vegetation
- Geology
8. Auger
9. Clinometer
10. Water Container - clean water for tests
11. Vehicle for transportation
12. Tape recorder
13. Note material
14. PRA methodology material
15. Road map for the field study area
16. GPS for Transect

12 Pilot Study

PEHA Tool Pilot Study

By

Daniel Jinnefält

Abstract

This pilot study is focused on evaluating a pH meter kit, called PEHA used for checking acidity in the field and the possible need for liming. Acidity is one of the major problems in depleted soils and is an important value for determining the condition of a soil (Boul, 1980). In order to investigate the functionality, accuracy and usefulness among extension officers, the kit was used in field circumstances and was compared to laboratory analyses of the soils in the field.

The kit was easily managed in the field. The extension officers found the kit to be simple and useful in their work. However, the PEHA meter kit was an inadequate instrument for measuring pH and the need for liming. More than 50 % of the fields indicated a need for liming through the PEHA analysis. However, the laboratory analysis indicated that there was not a low pH in the fields. The kit has to be adjusted before using it under field circumstances and could thereafter be a good instrument in fieldwork.

1 Introduction

Conventional farming systems applied on small-scale farms in Zambia have resulted in severe acidification of the soils. Predominately, farmers used to follow Chitemene - slash and burn - systems of farming exclusively. These semi-nomadic systems worked well when the population pressures were low and the abandoned Chitemene circles were able to regenerate over 20 to 25 years before being farmed again. However, over the past 3 decades maize cultivation has become increasingly important in the study area by either grown as a mono-crop or intercropped with beans, pumpkins etc.

Communities have also tended to settle in proximity to cities and towns where they can benefit from the many facilities provided. This has had a radical effect on the farming systems with a tendency to cultivate the same fields for longer more intense periods than previously. As a result, acidity levels build up rapidly and productivity declines. Inevitably farmers are forced to abandon their fields and encroach virgin or secondary woodland where the destructive cycle is repeated. Farmers wishing to remain close to town often clear land on nearby hillsides that are subject to severe erosion hazards (Phiri, 1998).

The soil layers in the Eastern Province consist mostly of sand and washed-out acid soils. These soils, if eroded, are low in nutrients and are very sandy and hardly fitted for agriculture (Phiri 1998). The acidity in the area of the study is slight to moderately severe (Appendix 8). Despite not being a morphological measurement, pH is one of the most important values for determining the condition of a soil (Boul 1980).

2 Objective and Means

This pilot for checking acidity in the field has been performed for the ASP/MACO/UNZA. The aim of the pilot study has been to evaluate a pH meter kit, called PEHA and evaluate:

- how well it is performing under field circumstances.
- how easy it is to determine the need of lime for the farmers and the extension officer with this tool.
- how accurate is the PEHA tool, is in itself, compared to a laboratory measurement of the soil acidity.

3 Theory

Acidity is a measure of the hydrogen ion concentration in solution form in the soil. The level of acidity is referred to as the pH of the soil. The lower the pH, the higher the acidity. Using testing for active acidity, the pH of most soils in Zambia falls within the following range:

Table 1. Acidity in pH (EEOA 2002).

Acidity	pH level
Neutral Soils	6.1 – 7.0
Slightly Acid Soils	5.0 – 6.0
Acid Soils	4.5 – 4.9
Acid Soils	Below4.5

Few plant species are adapted to acid or alkali soils. However, most plants including all the main annual crops grown in Zambia will not grow to their greatest potential if the pH of the soil is above 7.5 or below 5,0. In the Eastern Province of Zambia, very alkali soils are rare, however, slightly acidic and acid soils are common (Banda, 2002). The pH in the Chipata area ranges from 4.7 to 6.0 (EEOA 2002; Appendix 8).

When pH levels fall below 4.5, minerals, aluminium and manganese are released into the soil solution in concentrations that become toxic to the growing plants. At the same time other important minerals required for plant growth such as phosphorus, calcium and magnesium are fixated in the soil and become unavailable to the plants. The ideal condition for agriculture is a pH between 6 and 7 for most crops. However, a pH down to 5 is still efficient for some crops (EEOA 2001). Soil acidification and the rate at which this occurs depends on erosion as a number of complex and interrelated factors.

3.1 *Parent material and soil acidity*

Soils are formed from the weathering of rocks. These processes are active over millions of years. Rocks are roughly classified as acid or basic. Acid rocks such as granite, gneiss and sandstone consist mainly of quartz. These do not weather easily and usually produce pale acid soils with a larger proportion of sand (EEOA 2002).

Basic rocks such as basalt and calcareous sedimentary rocks weather more readily and produce larger amounts of clay and iron and give rise to darker red and brown soils. In the study area in the Eastern Province granite is predominant, hence, the soils being rather naturally acidic and easily leached. However, there are some basic influences that give the soil some darker components especially in the lower sedimentation area of the hills (EEOA 2002).

3.2 *Climate and soil acidity*

The amount of rainfall is the most important natural factor responsible for acidity, and for erosion. As rainwater moves down the soil profile a process called leaching occurs. The water absorbs carbon dioxide from the atmosphere and forms weak carbonic acid. Organic acids are also formed as the percolating water comes into contact with humus (EEOA 2002).

The downward movement or leaching of the water causes a slow but persistent down slope removal of calcium, magnesium, phosphorous and other basic elements from the clay and organic matter particles in the root zone. As the bases are removed, hydrogen and aluminium take their place causing the soil in the leached root zone to become more acidic (EEOA 2002). Therefore, leaching and acidification are, just as erosion, greater where annual rainfall is higher than where it is low. Based on this fact, 3 major climatic soil zones or Agro-ecological Regions are recognized in Zambia (EEOA 2002).

Table 2. Major Agro-ecological regions in Zambia (EEOA 2002).

Agro-Ecological Region III	Regions experiencing annual rainfall above 1000mm	Highly weathered strongly leached soils. Very acidic with low content of Calcium and Magnesium and high levels of Aluminium.
Agro-Ecological Region II	Region experiencing rainfall between 750 -1000 mm	Less strongly weathered and leached. Medium to slightly acid soils except over acid parent material. Leaching is sufficient to cause washing of clay from top soil to sub soil.
Agro-Ecological Region I	Regions experiencing rainfall below 750 mm	Medium soils. Hardly any leaching.

The study area in the Eastern Province of Zambia has a medium rainfall of approximately 900 mm per year and belongs to Region II, hence, experiences acidity to a moderate extent. However, the leaching is quite efficient and a large amount of small soil particles are washed down from the top to the bottom of the slope (EEOA 2002).

3.3 *The removal of trees & natural vegetation*

Plant-litter from natural vegetation combined with the activity of micro-organisms add organic matter to the soil. When virgin soil is brought into cultivation, its organic matter decreases quickly due to oxidation and stabilizes after 2 or 3 seasons at a lower level (EEOA 2002). Lower organic matter increases the level of aluminium in the soil solution. Percolation of rainwater through the soils will be faster when the protective tree canopy has been removed (EEOA 2002).

As we have seen the vegetation also has a high influence on the erosion of the soil. When the erosion becomes higher the acidity will develop even quicker since erosion causes buffering nutrients to leach of the soil and move down the slope (EEOA 2002).

3.4 Burning

In Region II, where acid leached soils are dominating, farmers used to follow the slash and burn systems of farming, so called Chitemene, exclusively. This means that the farmer would burn the residues on the field each year in order to use the nutrition from the ashes for the crops. When the soil was emptied the farmer simply moved to another area and started a new field that was burnt in order to get nutritious ashes (EEOA 2002).

In the study area, the burning is still in operation as it is a way of hunting mice that are living in the fields. The farmers do not prefer to burn the fields, however, mice hunters burn down the remains of the maize at night. The burning residues are easily moved by wind emptying the fields of nutrients resulting in the rise of acidity. This also weakens the protection against erosion since the soil is completely exposed to the wind and the rain. Therefore, the soils, become depleted and low in organic matter. This forces the farmers to move to new areas and abandon their fields and farms (EEOA 2002). These semi-nomadic systems worked well when the population pressure was low and abandoned Chitemene circles were allowed to regenerate for 20 to 25 years before being farmed again. However, over the past 30 years the population has increased by more than 200 % (Phiri 1998). Furthermore, maize cultivation has become increasingly important by either growing as a mono-crop or intercropped with beans, pumpkins sun hemp and other crops (EEOA 2002).

Communities have also tended to settle in the proximity to cities and towns where they can benefit from the many facilities provided. This has had a radical effect on the farming systems with a tendency to cultivate the same fields for longer more intense periods than previously.
As a result, acidity levels build up rapidly and productivity declines (EEOA, 2002). Inevitably farmers are forced to abandon their fields and encroach virgin or secondary woodland where the destructive cycle is repeated. Farmers wishing to remain close to town often clear land on nearby hillsides that are subject to severe erosion hazards (EEOA, 2002).

3.5 *Cultivation*

It is a well established fact that the use of continuous cultivation tends to acidify soils as well as intensify the erosion. This can happen gradually or rapidly depending on the apparent material of the soil, rainfall, topography and the farming system that is used (EEOA 2002). Seasonal plowing, ridging, overall cultivation by hoe and the burning of residues expose the topsoil to erosion. Under these conditions, surface soil containing phosphorous, calcium, nitrogen and applied nutrients, are washed from the field, exposing more acidic underlying layers of top soil and sub soils. This process will occur faster when the land is sloped (EEOA 2002).

A maize crop that yields grain contains high amounts of minerals that buffer the pH in the soils. A substantial proportion of these nutrients are stored in the residues. This means, the basic nutrients that buffer the pH in the soils do not reach the crops and the acidity rises. When trying to substitute these elements with fertilizers more acidification occurs while the nitrogen in the fertilizers causes a lower pH in the soil (EEOA 2002).

The formation of proteins and nucleic acids by plants and animals require a source of nitrogen. The largest reservoir is the atmosphere. Plants cannot use nitrogen in gas form; and instead, secure the nitrogen in fixed form as nitrate ions, ammonia or urea (EEOA 2001). All these forms are acidic and cause further acidification of the soil where fertilizer is used. This is a serious problem that is common on large farms. However, it is unusual for small scale farmers to have the finances needed to buy supplements for the soil, therefore, the effects from fertilizers in negligible in the study area (EEOA 2001).

3.6 *Liming of Acid soils*

It has been argued that the application of lime can increase crop yields by reducing the adverse effect of acidity. Data is available on this subject showing responses to liming for groundnuts, soybeans, field beans, maize, cotton, and wheat (EEOA 2001). However, few smallholders utilize liming. There are a number of reasons for this. The SSF generally have no information on the effects of lime and lack the finances to cover the costs that the lime would create. The ASP has an interest in looking at the benefits of liming as there is a general census that the use of lime would be of interest for small scale farmers as well (EEOA 2001).

4 Method

4.1 Laboratory method

The pH of the soil samples was measured through using Testing for active acidity. Firstly, the soil was soluted; 2 g of 2 mm sieved soil was put into 10 ml of distilled water and filtrated (Miller, 1982). The equipment was then calibrated with a pH 4, pH 7 and pH 10 solution. The pH instrument was then put into the solution. After this the pH was read on a digital display on the instrument.

4.2 Field Method

The pH was measured directly in the field by taking a topsoil sample and using the PEHA METER. The equipment is fitted into a box that contains a small spoon for taking a soil sample, an indicator flask and a colour/pH measurement tool (Figure 1).

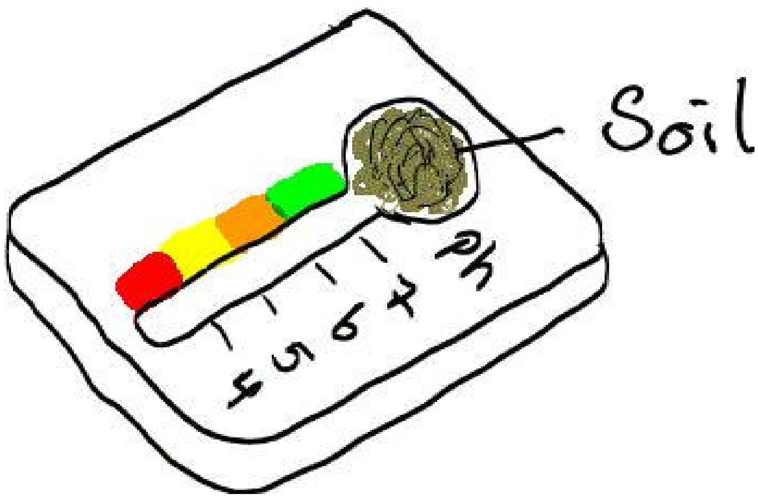


Figure 1. The PEHA soil acidity tool. The soil/indicator solution is compared to the tool color.

The colour/pH measurement tool shows the pH level of the soil sample. The extension officer or a farmer put the soil sample into the tool. A couple of drops of indicator fluid was then dripped onto the soil and allowed to stand for several minutes. When the allocated time had passed, the liquid that was coming from the liquefied soil was compared to the colors on the pH/colour measurer on the tool. The color of the soil sample that corresponds to the closest color on the chart indicates the level of acidity.

During the process, the soil sample reacts with the indicator the soil texture and color of the soil is determined. The farmer, with a chart that is brought with the equipment into the field, performs this task. The chart assists the farmer in identifying if the soil is a sandy, loamy or clayey soil (Figure 2). The farmer then determines what colour the soil has in comparison to the colour given on the chart. The chart in this way indicates how to determine the texture and colour and then indicates how much liming this kind of soil needs if the pH is below 5. If the pH is over 5 no liming will be required (Figure 3).

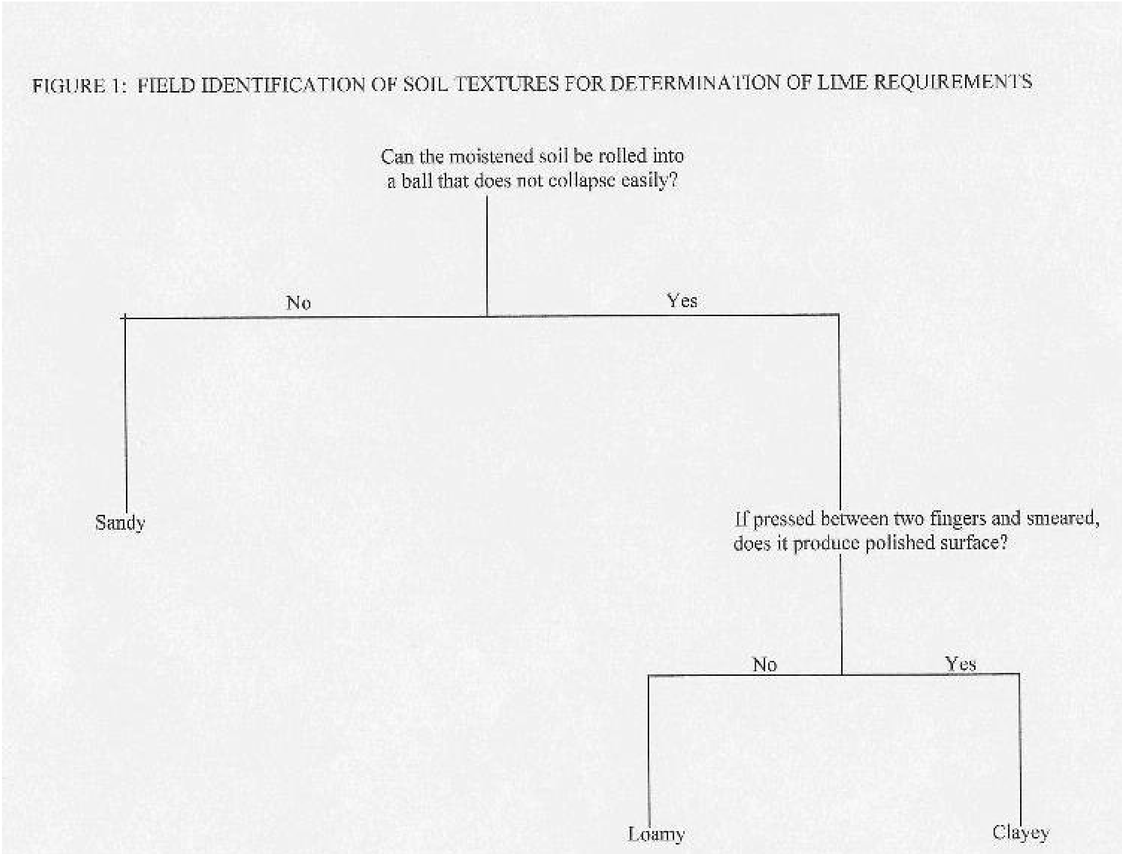


Figure 2. Chart determining texture and color of the soil by Soil Science Department UNZA.

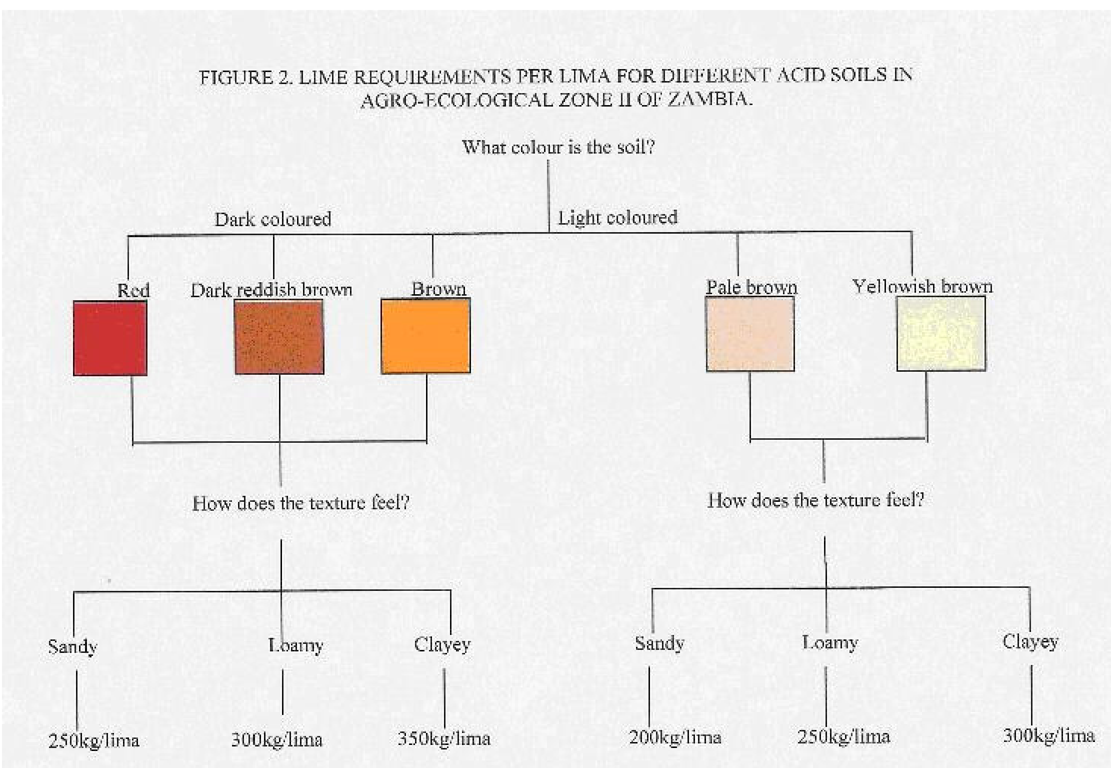


Figure 3. Appendix A 2. Chart determining color of the soil by Soil Science Department UNZA.

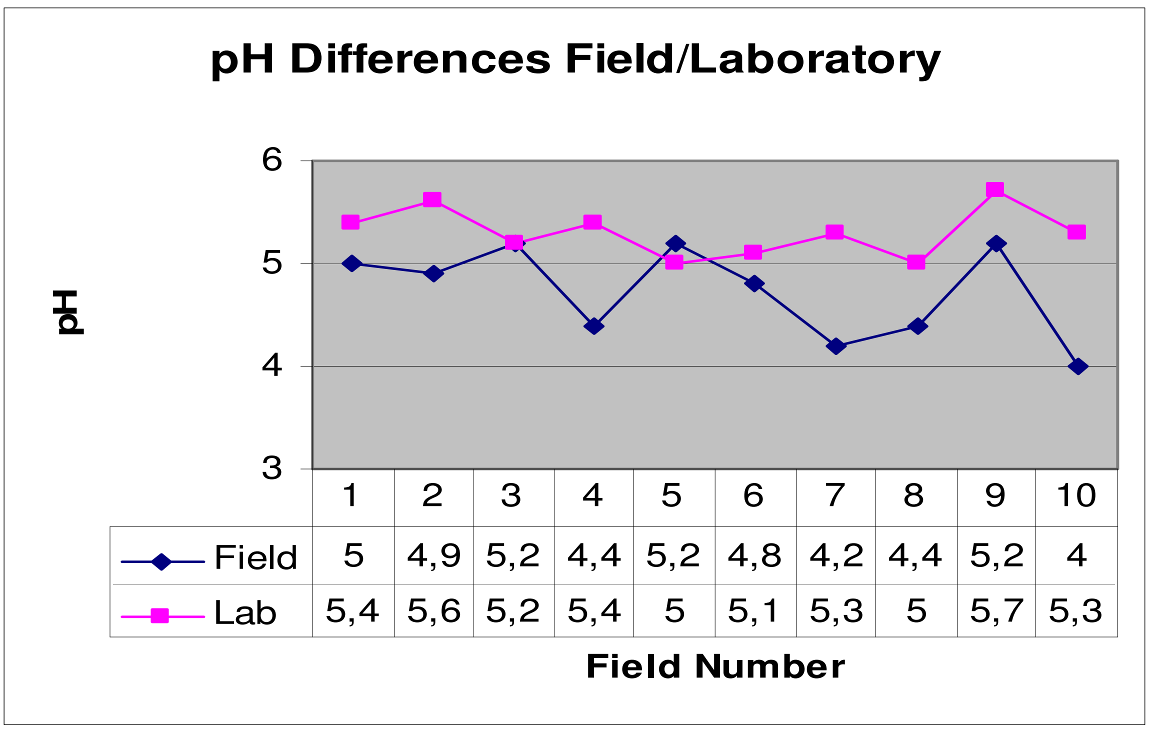
5 Results

The PEHA meter kit was taken into this study as a Pilot for the ASP in order to evaluate how well the PEHA meter is performing under field circumstances; how easy it is to determine the need of lime for the farmers and the extension officer; and to see how accurate the PEHA tool compares to a laboratory analysis of the soil acidity.

The PEHA meter and the chart are easy to handle in the field. The kit is easy to carry and wash and the equipment is easy to bring to and around the field. The chart was laminated in order to prevent it from getting destroyed by water and soil. This proved to be ideal in keeping the chart intact in the field. The farmers found the PEHA meter kit easy to operate and useful. It was voiced in interviews that they were interested in using such equipment. There were no problems what so ever in operating the chart and the PEHA kit.

The acidity in the fields was measured through the PEHA METER and in the laboratory through the Laboratory pH meter using Testing for Active Acidity. The results correspond with each other quite well, however, the field results are a slightly lower than the laboratory results.

Table 3. pH Differences between Field and Laboratory.



The fields in the Eastern Province are not in any need of lime, according to the pH measured in the laboratory. However, according to the PEHA meter, more than half of the fields were in need of some of acidity treatment. This means that the PEHA meter in more than half of the cases gave the wrong information to the farmer or the extension officer. Naturally, this result is not favourable and the PEHA kit is in need of adjustment to be useful in the field (Table 3).

6 Discussion

The human factor in the pilot study corresponds well to the hopes for the acid testing equipment. The people in the village greatly appreciate the function and use for the PEHA chart kit and hope to see this tool for measuring acidity as soon as possible. However, the comparison between the pH measured with the PEHA meter in the field and the pH analysis in the laboratory shows that the PEHA meter kit gives the wrong picture of the condition of the field. At least half of the fields clearly show a pH under 5 with the PEHA meter kit despite the actual pH being above pH 5 in all of these cases.

These results are not favorable. A judgement due to the equipment might lead to a mistreatment of the fields. In this case, more than 50 % of the farmers would have been advised to lime their fields, despite, the laboratory analysis showing that the pH values were acceptable in all of the fields. Liming to this extent is relatively harmless; however, the financial effects for the small scale farmer would be more serious. Setting aside the economical factor, a critical point of view should be set to the implementation of liming in the small-scale fields in the study area. The fields are located on rather steep slopes with low pH and environmental consequences. The high precipitation together with the maltreatment of using mono cropping and the insufficient erosion protection create bad soils with low pH.

The notion of imposing the use of lime will result in creating further deepening problems. The yields with lime may, in the first years, be perceived as better, however, in time, the acidity will be worsened and lime will not be sufficient to control the acidification. This would not be an advantageous way of helping the farmer. There is no need for liming in this area. The pH is still acceptable and can be improved with good management. It is likely that pH will worsen if the farmers continuously use mono cropping with SCF protection or no erosion protection as they have been for the last three decades.

It is, however, not liming that is needed in the study area, but a general grip of the whole agricultural situation. Acidity and erosion, both, in these fields have to be adjusted by the implementation of far more sophisticated managements than have been examined in this study. There is a great need for multi-cropping, with soil covering species, in the fields. This is in order to protect the fields against the erosion effects of the rains and to give a better biological ecosystem in the fields hindering acidification. Better crop rotation is needed in order to stop the soils from suffering the mono cropping system acidification. More trees are needed in the fields, mainly as tree roads but also in the fields themselves. Naturally, this would not be acceptable for a modern cultivation using tractors; however, there are no tractors in the Kawoozi Camp. The fields are cultivated by hand hoes giving room for the possibility of trees in the field that will effectively protect against erosion, and moreover, fertilize the fields.

The most important factor, though, is putting an end to the burning of the fields after the cropping is finished and the cutting of trees in the Savanna Woodland hills. Without this type of protection there will, in the long run, be no agriculture. When the organic matter is lost and the protecting vegetation is gone there is nothing that can suitably protect the soil from erosion and acidity.

7 Conclusion

This study is a pilot for evaluating a pH meter kit, called PEHA checking acidity in the field. The kit showed to be easy to manage in the field. The people in the village highly appreciated the method and found out quickly how it could be useful in their management of the farms. However, the PEHA meter kit was inferior in measuring pH and the need for liming. In more than half of the fields the result from the PEHA analysis showed that there was need for liming. In the laboratory analysis, it showed that the fields had no problems with acidity. The kit has to be adjusted before using it in the field and will there after be a good instrument in fieldwork.