A PRE-LIMINARY SURVEY ON SOIL MANAGEMENT PRACTICES AND LAND UNITS ON SOIL ORGANIC CARBON OF SMALL-SCALE COMMUNAL FARMERS IN NORTH-CENTRAL NAMIBIA.

M. Sc. Thesis

In the

International Master´s programme

“Landscape Ecology and Nature Conservation”

by

Josefina Krebs

March 2014

Supervisors:

Dr. Niels Thevs

Ms. Lena Bloemertz

Declaration

I, the undersigned, hereby declare that the work contained in this thesis is my own intellectual work and that I have not previously or in part submitted it to any university for a degree.

Date, place: Signature:

Abstract

Introduction: Soil management practices play an influential role on soil organic carbon sequestration on micro- and at the landscape level. There is a need to promote soil organic sequestration on communal small-scale farms in North-Central Namibia, as this will not only result in improved soil quality which transfers to high crop yields and sustained food productivity but will also assist in mitigating climate change through the reduction of agricultural Greenhouse gas emissions in poor societies. **Methods:** Interviews were conducted with small-scale farmers in North-Central Namibia in the regions of Omusati and Oshana, whereby 29 small-scale farmers located in the various soil groups were interviewed about their means of improving soil quality, for instance, the use of fertilizer, grazing, tillage and an estimate of average annual yields. To determine as to how far management practices impact soil organic carbon sequestration, secondary data on studies done in similar climatic conditions or close has been made use of. **Findings:** Small-scale farmers make use of a local classification system for land management, where the land is theoretically divided in land units which are especially significant for cropping and are defined mostly by soil colour, soil texture and landform. There are various methods used by communal small-scale farmers for improving soil quality, such as kraal rotation, use of livestock manure and household waste. Other techniques for soil improvement, for example, crop residue retention need to be promoted in the region. The use of livestock manure is a vital soil amendment which is highly used in the region by livestock owners but care needs to be taken in the application and storage of this amendment to reduce greenhouse gas emissions and to ensure that the necessary nutrients are taken up by the crops. To ensure effective soil management by small-scale farmers and a continuous sequestration of carbon in the region, it is of importance to develop and improve farming techniques and technologies within farmer resource constraints.

Table of Contents

List of figures

List of tables

List of acronyms

CDM	Clean Development Mechanism
UNFCCC	United Nations Framework Convention on Climate Change
GHGs	Greenhouse gases
SOM	Soil Organic Matter
ITCZ	Intertropical Convergence Zone
FAO	Food and Agriculture Organization
CCD	Convention to Combat Desertification
SOC	Soil Organic Carbon
IEK	Indigenous Environmental Knowledge
IK	Indigenous Knowledge
NCN	North-Central Namibia
ILUs	Indigenous Land Units
CMS	Crop Multiplication System
CT	Conventional Tillage
CR	Clean Ripping
TR	Tied Ridging

Chapter 1: Introduction

1.1 Soils, farming and climate

Africa suffers from geologically induced and inherently low soil fertility (Rufino et al. 2007) and due to poor soils and erratic rainfall, sub-Saharan Africa is a difficult environment for agriculture (Nana-Sinkam, 1995). Thus, according to Snapp et al. 1998, the improvement of food production and soil resources in the small-scale farm segment of Southern Africa is a huge challenge. Therefore, to ensure food security, sustaining crop productivity is essential through soil management and biodiversity conservation (Nabhan et al. 1999). Moreover, Lal (n.d.) signifies that, apart from maintaining food security, agriculture ought to be a vital solution to environmental issues of climate change, for example by crop residue retention and compensation of farmers through the trading of carbon credits. Thus, soil organic carbon can be commoditized and it´s not only valuable to farmers for soil quality improvement but it is also of value to society for providing ecosystem services for climate change mitigation and reducing soil erosion. Nonetheless, Namibia´s climate has been generally arid for many millions of years and as a result, there is a lack of deep soils around the country and low levels of nutrients in most of the soils is evident (Mendelsohn et al., 2009). Moreover, Namibia is also faced with a scarcity of water in most parts of the country, with only perennial rivers flowing during the rainy season after heavy rainfall, such as the Cuvelai drainage system, in the North-Central regions of Namibia. In addition, the landscape of Namibia is a result of the variable climatic conditions, highly influenced by the Intertropical Convergence Zone (ITCZ) and the Subtropical High Pressure Zone. Thus, the aridity of the country is an attribute of the dominancy of the Subtropical High Pressure Zone. Furthermore, the Cuvelai drainage (North-Central Namibia) system is a flat landscape “floodplain” which is densely populated due to the relatively fertile soils and access to water (Mendelshohn et al., 2009). (*Ibid*) Namibian soils vary considerably, from the deep Kalahari sands, the clayey and the salty soils in the Cuvelai, to the mica-rich soils found in most of the rocky areas. Even though these dissimilarities occur at the macro level, a high degree of differences can be noticed at the micro level. Thus, for simplification, areas are classified according to their dominant soil type. Nevertheless, the predominant use of land in Namibia is agriculture with small-scale farming on communal land taking up to 250,700km², which is 30.4% of Namibia´s total land area of 824,000km² (Mendelsohn et al., 2009). Thus, this study looks at soil management and land use practices of small-scale farmers of North-Central Namibia and the classification of the environment through local knowledge for the suitability of the various land uses. It is important to identify management practices that increase landscape carbon stocks for the efficient landscape carbon management in the region. Nonetheless, Alex Verlinden has done a great deal of research in North-Central Namibia, which includes understanding indigenous knowledge (IK) and the role of indigenous land units (ILUs) for communal farmers.

1.2 Potential of soil management practices on soil carbon sequestration

Soil infertility is a limiting factor for small-scale farmers, and unsustainable farming practices contribute further to environmental degradation. Thus, improving soil organic carbon in the landscape enables well natured grazing areas and high crop yields on tropical dry lands as well as a reduction in GHG emissions. The recognition of soil management practices that improves soil organic carbon on the crop fields, grazing areas and woodlots in North –Central Namibia, would enable a landscape carbon management stock support and a community conservation of soils. These could improve farmers' livelihoods by increasing crop yields and earning carbon credits. To improve the productivity of the land for small-scale farmers and improve soil quality in the region, farmers have to adapt or integrate other strategies to their existing ones, such as the use of biochar and genotype crop species that combines grain yield with high root and leaf biomass, with a low nitrogen harvest and high net nitrogen to the soil (Snapp et al. 1998).

The Clean Development Mechanism (CDM) of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) allows a signatory country that emits carbon above the agreed-upon limits to purchase carbon offsets from an entity that uses biological means to absorb or reduce greenhouse emissions (Perez et al. 2007). According to Schmidt et al. (2011), soils can also store enormous amounts of carbon and globally, soils store at least three times as much carbon as the atmosphere or what can be found in living plants. Nevertheless, through the use of CDM in agriculture, the outcome may be increased crop productivity, income, food security and the conservation of local natural resources is anticipated in arid and semi-arid regions. The payments are to be provided to farmers who adapt carbon sequestering land management practices since rain fed agriculture and pastoralism provide a large part for farmers' livelihood. Thus, the enrichment of soil organic carbon in the soils will augment productivity and ensure food security. Although, a purely carbon-market approach may not be applicable to small-scale farming systems in developing countries, a multilateral approach for mobilizing resources under existing mechanisms such as the already mentioned Kyoto Protocol, Convention to Combat Desertification (CCD) and the Climate Change Convention can be utilized (FAO, 2004). However, carbon sequestration in dry soils is hindered by inconsistent rainfall and high temperatures (FAO, 2004; Perez et al. 2007). Although soil organic carbon is highly sensitive to climatic changes and changes in the local environment and since feedback between soil organic carbon and climate are not fully understood, it is known that molecular structure of soils is not the primary determiner of soil organic matter (SOM) stability, but environmental and biological controls (Schmidt, 2011). Conversely, when it comes to permanence of carbon sequestered, dry soils are less likely to lose carbon than wet soils as soil mineralization is limited by a lack of water (FAO, 2004). Nonetheless, in agricultural systems, soil organic level tend to be variable and dependent on management practices, thus, the use of the right management practices can turn a farm from a carbon source into a carbon sink (Chan, 2008). Moreover, the effectiveness of a particular management practice in increasing soil carbon is site specific and dependent on local factors such as climate, soil types and land management practices.

It is thus important to understand the soil biophysical processes and the application of practices that slows down soil oxidation and increases carbon fixation and storage in dry soils (Perez et al. 2007), such practices may include; the use of biochar, reducing the frequency or intensity of tillage, soil and water conservation practices, and the use of crop varieties that produce large root biomass and fix biological nitrogen.

1.3 The overall framework of the Syngenta project

The study is part of a bigger project, spearheaded by the University of Basel in Switzerland. For the initial enquiry, two masters' students worked on the project, mainly focusing on management practices and the other on soil quality of the landscape. The aim of the project is to create a basis for Landscape Carbon Management (LCM) in North Central Namibia, rather than only focusing on improving SOC on croplands. These should result in the reduction of Greenhouse Gas (GhG) emissions and contribute to combat climate change, provide increased sustainable yields, and generate an income for the farmers through carbon credits. Overall, the intention is to find intervention mechanisms to increasing soil quality and improving the livelihood of small-scale farmers in North-central Namibia.

Figure 1 below provides an impression on the focus of the two master students and the overall project which looks at the Identification of potential intervention mechanisms for improving small-scale farmers' livelihood and reducing land degradation with the

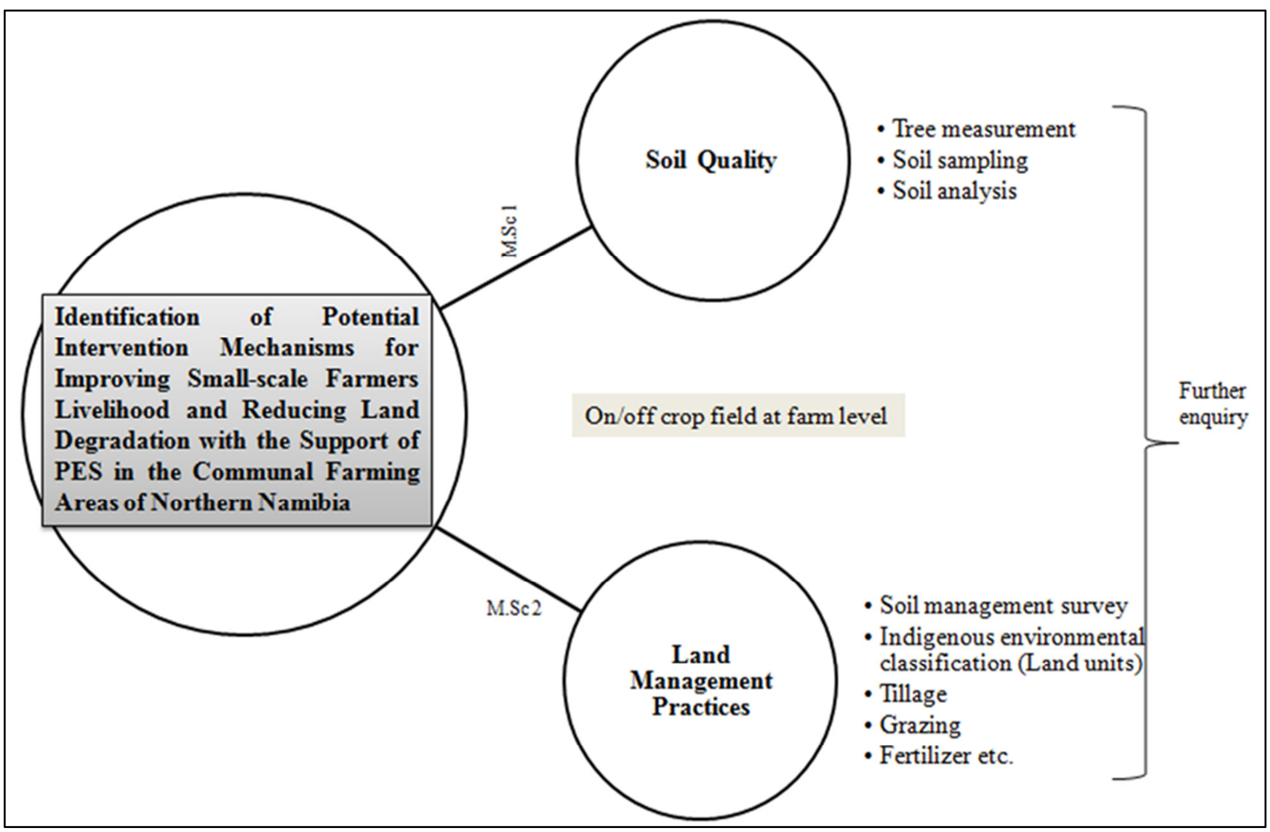


Figure 1: An analytical framework for the inventory of data on land management practices and soil quality in North-Central Namibia.

support of payments for ecosystem services (PES). Since this was only a preliminary survey, the results present information for further investigations into a successful implementation of the project.

1.4 Research Question(s)

1. Which are the existing soil management and land use practices of small-scale farmers?
2. What criteria are used by the farmers to differentiate land units?
3. In how far do farming practices impact soil organic carbon sequestration?

The following looks at the location of study area, introduction of the area where the study has been conducted and how the farms were selected in the study area and then move on to chapter 2 which looks at Methodology and Chapter 3, reviewing of existing knowledge concerning soil management and land use practices and the locally used soil classification system.

1.5 Location of study area

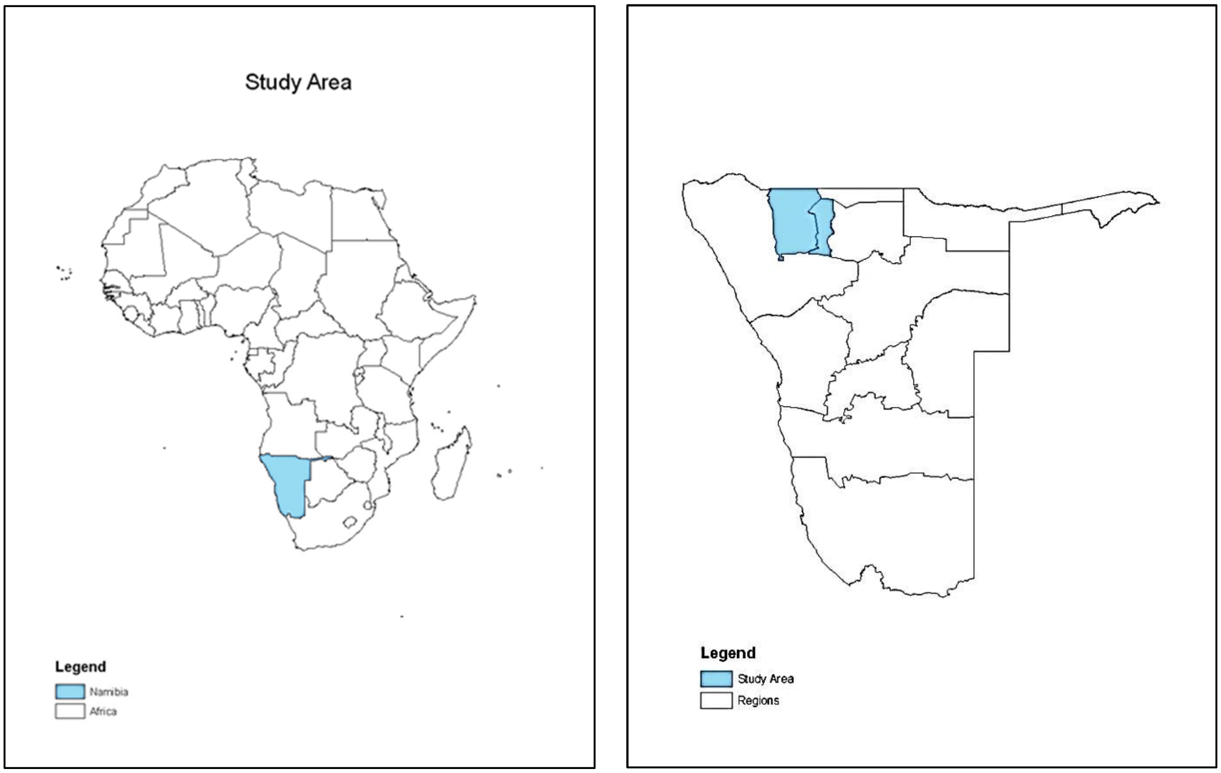


Figure 2: Political map of Africa indicating Namibia and map of Namibia highlighting the research regions.

Figure 3: Aerial image of North-Central Namibia depicting the four main farms.

1.5.1 Introduction of study Area

1.5.2 Soils and Climate of North-Central Namibia

Soils in the northern communal areas of Namibia have a low inherent crop production potential, apart from this, the harsh climatic conditions and the farmers´ inability to restock nutrients lost under continues cultivation limits sustainable food production (Ngolwe and Fleissner, 2002). In the northern central regions, the climate is sub-tropical in the northern part and more semi-arid south of the Cuvelai. There are variations in rainfall, occurring during the summer, from October to March. Due to high variations in rainfall patterns, crop production is unstable either due to an inadequate rainfall, and/or an early or late onset of rainfall. The main crop produced is pearl millet, which is a rain-fed crop and makes up the staple food of the population in Northern Namibia. North-Central Namibia lies within the dominant landscape of the Cuvelai drainage system. Most of North-Central Namibia is characterised by poor sandy soils unsuitable for crop production due to their low nutrient content, high salt content, and poor water holding capacity. According to Rigourd et al. (1999) the soils in the North-Central Division vary from sandy to sandy loam, with an average sand content of 87% and clay content of 9.5% and 3.5% of silt. Thus, soils in the region are poor in nutrient and have a poor water holding capacity. Nonetheless, there are areas where soils are more fertile due to a mixing of the clayey soils transported water and sandy soils transported by wind on the eastern part of the region, and this is a result of the climatic variations in the past, of wet and dry climatic periods (Mendelsohn et al., 2000). Thus, Mendelsohn et al. (2011) indicates that the nature of the soils in the Cuvelai depends on their processes of deposition, reworking or influence, either by water, wind or evaporation. Moreover, the dominant soils that can be found in the North-Central Namibia are Haplic calcisols, Eutric cambisols, and Cambic arenosols (Mendelsohn et al. (2009).

1.5.3 Population Density

North-Central Namibia is the most densely populated area in Namibia, with a population of about 844,500 people according to the 2011 population census. The Oshana region currently has a population of 174,000 people and Omusati region comprises of 242,900 people. People settled in the Cuvelai about 600 years ago due to the relatively fertile soils of cambisols and calcisols on higher grounds as a result of the mixing of the aeolian and alluvial sediments and due to the presence of freshwater in shallow wells (Mendelsohn et al., 2011).

1.5.4 Selection of farms in the study area

Due to the large geographical demarcation of the northern regions, four farms, from 4 different villages within Omusati and Oshana region, falling within the above mentioned dominant soils groups, were selected during the initial phase of August 2012, to determine soil and land management practices and determine the potential for the soils to sequester carbon under various land uses and land use practices. In addition to the four farms, several farms within the vicinity willing to participate in the survey were also included. The results of the survey will enable the identification of soil management and land use practices with high landscape carbon-stocks. Moreover, the selection of land units for the establishment of the baseline data was based mainly on the following criteria: soil parent material, type of crop grown and vegetation cover. Existing local level differentiation of land units was equally taken into consideration and served as a starting point for the differentiation of ecological units. In total, 29 small-scale farmers have been surveyed on soil and land management practices and on the determination of the local land use classification system.

Chapter 2: Methodology

2.1. Methods and instruments

Interviews

Semi-standardized interviews (where a number of pre-determined questions and thematic topics are formulated and outlined) were made use of. Thus, a semi-structured questionnaire was administered to 29 farmers from four villages, namely: Olweege, Oonkima, Oshinyadhila no.4 and Iiputu (see appendix 1 for the questionnaire). This method allows the interviewer to probe far beyond the prepared standardized questions (Berg, 2001).

Secondary data

Already existing data on the local land use classification system and on soil organic carbon and land use management has been referred to.

Identification of land units and mapping of farmland

For the identification of land units at farm level, farmers provided an orientation of their farm, indicating the various land uses and means of identifying them. During the field orientation, GPS points were taken covering the different identified land units and characteristics of the various land units were noted down such as crops grown, soil texture and soil fertility (see appendix 2).For the mapping of farm land, google images has been used for digitization in arcGIS 10.2.

Yield measurements

To determine yield, the top and bottom circumference of the traditional storage baskets were measured with a measuring tape. The calculations however do not include data from all farms, as they were not all accessible for measurements. The yield calculations only make use of the 2012 harvest. Although this data has been collected in August 2012, it is still referred to as the 2012 harvest as only planting took place in 2011 and harvested in 2012. And since there is no annual data or records of how much yield farmers get, this study has to rely on the data provided by the farmers. The following formula has been used for calculating yield.

Formula:

$$V = \frac{\pi}{6} h * (3R_1^2 + 3R_2^2 + h^2)$$

V=Volume; h=height of traditional storage basket ('eshisha');
R_1=radius (circumference/PI/2) on top;
R_2=radius (circumference/PI/2) at the bottom.

The volume in litres was multiplied with the reference weight of 858 grams per litre to derive the actual dry weight.

Limitations

- Focus group discussions (FGDs) was not possible to do, which would have provided more insights into the theme
- Time (data collection was conducted in 2 weeks)
- Funding – there were not enough funds available to conduct fieldwork longer.

Population sampling

Convenience sampling (accidental or availability sampling) was used to get respondents, as it was easier and more convenient in this case to interview farmers close at hand or easily accessible and willing to participate to be part of the study.

2.2 Data Analysis

Qualitative research refers to the "meanings, concepts, definitions, characteristics, metaphors, symbols, and descriptions of things" (Berg, 2001). Since this study is based on qualitative data, content analysis has been found to be useful in analysing the textual data of this study. Nonetheless, both qualitative and quantitative forms of content analysis have been used to analyse the data. The quantitative content analysis has been used for themes where respondents fall within more than one theme or sub-theme and this was done through tally sheets to determine frequency. Thus, Berg (2001); Prasad (2008) defines content analysis as an objective coding system that is used to analyse unobtrusive data such as interviews and field notes. In addition, a more general interpretative approach was used were the data taken was coded according to the pre-identified themes and/ or issues. Furthermore, new themes and/ or issues that developed or identified in the field were added. For the analysis, coding was done looking at commonalities, similarities, and differences and is categorically arranged in accordance to these arrays. Since the data does not contain too much content, and since it is important to look for themes and categorise or detect arising themes in the texts, it was better to make use of the human eye, thus, no computer software was used for the coding of data and tally counts were done the old fashion way for tabulation.

Chapter 3: Literature Review

3.1. Farming in North-Central Namibia

The FAO (2001a) defines a farming system as "a population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate". In Northern Namibia, communal farmers make use of agro-silvo-pastoral systems where they are involved in crop production of mostly Pearl millet, Sorghum and Maize and rearing of livestock, mainly for subsistence. According to Mendelsohn et al. (2006) and Sweet et al. (2000), the farming system in northern Namibia is one of communal land where farmers have exclusive rights to small areas that usually surround their farmstead and the livestock is largely grazed on open access commonage pastures and woodlands. There is however a decline in commonage pastures due to an increase in homesteads. Mendelsohn et al. (2009) states that, communal farming is mostly characterised by low input, for instance, equipment's and fertilizer resulting in low yield output. Apart from low input agriculture, crop yields in North-Central Namibia are influenced by poorer growing conditions (extreme climatic conditions) in comparison to the regions in the North-Eastern Namibia for instance (Mendelsohn et al., 2006). The figure below provides an impression of average crop yields per square kilometre in Northern Namibia. The wetter parts (north-east) have greater yields of mostly maize and sorghum.

Of the input, labour is regularly the major input in the form of weeding, ploughing, rearing of animals and harvesting of crops. Moreover, harvests are consumed at home or sold at local markets and in good years, surplus harvest can be stored for use during periods of food shortages, whereby, livestock can be used as capital investment, for draught power, milk and meat production and for other cultural purposes (Mendelsohn et al., 2009; Sweet et al., 2000). However, the farming system is limited by poor soil fertility in most areas and without intense management and the application of fertilizer, large areas of the Kalahari sands are not suitable for cultivation. Moreover, the patches that are more fertile have been farmed for decades and much of their original nutrient has been lost (Mendelsohn et al. 2006). Thus, according to Matanyaire (1996), small-scale farmers in North-Central Namibia are constrained mostly by:

1. Drought
2. Lack of draft power
3. Lack of improved seed and
4. Lack of fertilizer

Generally, only 2.8% of farmers make use of chemical fertilizer regularly and the most commonly used is the N-P-K compound fertilizer and 88% of small-scale farmers in North-Central Namibia either make use of manure sometimes or on a regular basis (Matanyaire, 2006). Other management options common in the region is the practice of intercropping, where farmers mostly make use of cowpea to intercrop with pearl millet. And according to Grace (1998), the practice of intercropping is most substantial in rain fed semi-arid areas characterised by low fertility especially with nitrogen depleted soils. In contrast, the practice of crop rotation is unusual in the region.

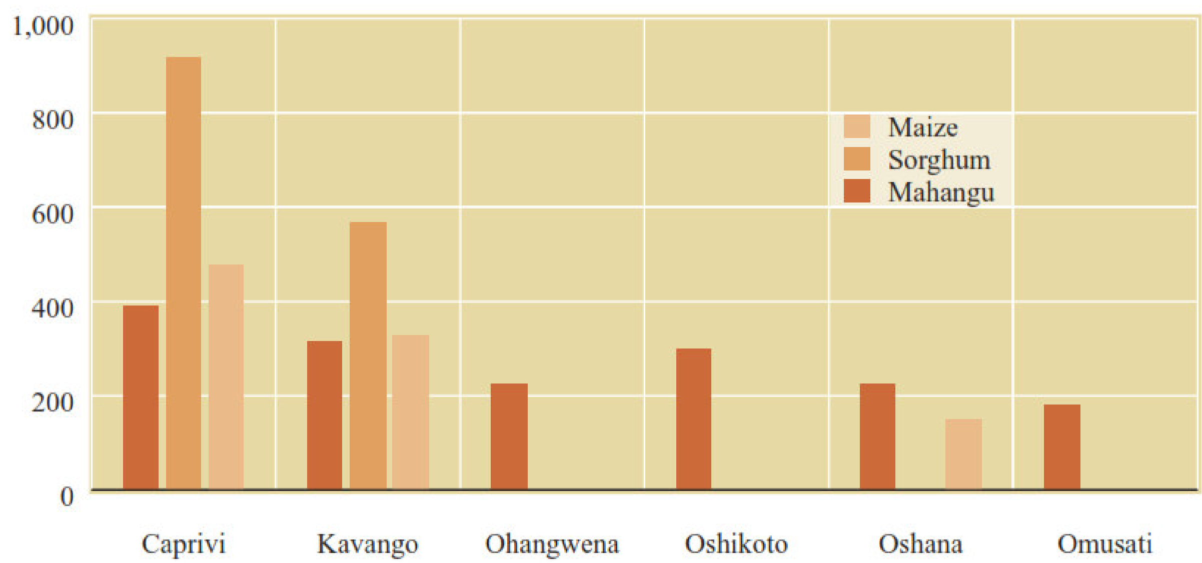


Figure 4: Average yields of mahangu (pearl millet), sorghum and maize in Northern Namibia. (Mendelsohn et al., 2006)

Communal areas in Namibia occupy 48% of the total farming area and land tenure is based on unclear boundaries (Sweet et al., 2000). Although grazing areas are based to open access rights, cropping areas are usually allocated to individual farmsteads. *Ibid*

Livestock numbers differ significantly and the ownership of livestock is strongly tilted with a small number of farmers owning large flocks of livestock and the majority possessing few animals or none at all. The herding of livestock is relaxed during the dry season as the livestock has access to crop residues and farmers with large numbers of livestock have "cattle posts", away from the village and croplands. The main forage resource for livestock is rangeland grazing and crop residues are an important substitute during the dry season (Sweet et al., 2000). The most crop residues used as fodder for livestock are of pearl millet and sorghum, although they are not cultivated specifically for that purpose.

3.1.1 Conservation Agriculture in Northern Namibia

Some communal farmers in Northern Namibia are in the course of adapting conservation agriculture methods to increase yields as a result of climatic changes (Tjaronda, n.d.). Conservation agriculture makes use of three basic principles of minimum soil disturbance, covering soil and mixing and rotating crops (Mudamburi et al., 2012). Farming practices such as the use of disc harrowing for soil preparation and poor rangeland management results into topsoil losses. The shift to conservation agriculture or "Crop Multiplication System" (CMS) will assist farmers to maximise yield potential on their field (Schlecter, 2014). These techniques and technology involve favourable ploughing implements for dry land crop production. The approach uses technology that involves mechanical ripping and furrowing of the soil in the first year for deep penetration to shatter compaction and furrowing for in-field water harvesting and in the following year, a draught animal ripper that can be used along the same lines to allow concentrated fertility and moisture build up (Tjaronda, n.d., Bezuidenhout, 2011). This way of farming increases yield irrespective of good or bad rainy season as moisture and fertility are retained in the soil. And even without the use of fertilizer and manure, the use of ripper furrower methods has produced good yields (Tjaronda, n.d.). Rod Davis and Gerhard Baufeld have been working on these new techniques for conservation agriculture to improve yields and reduce soil degradation for mostly small-scale farmers in Namibia. Dry land crop production has been applied in northern Namibia with an average rainfall of 350-400mm summer rainfall, yields declined over the years to 350kg and less pearl millet per hectare but with the introduction of CMS, yield has increased to levels of 2500-3000kg/ha and currently to as much as 4660kg pearl millet/ha (Schlecter, 2014; The Namibia economist; Bezuidenhout, 2011). The ripper furrower implement is used for soil preparation as well as for seeding corn, bean, pearl millet and sunflower and it has several other benefits such as reducing labour and minimizing wind, water, and soil erosion.

The following thus explains how farmers in North-Central Namibia deal with low and poor soil fertility and the variability in climatic conditions that have shaped the environment in the region.

3.2. Farmers in North-Central Namibia

According to Newsham (2009; 2011) and Verlinden et al. (2006), Farmers in Northern Namibia make use of a classification system in making decisions about crop and livestock farming, which is drawn upon a sophisticated understanding of the productive potential of their environment. This land classification system has offered communal small-scale farmers in North-Central Namibia, adaptive capacity to climatic variations to a certain extent. These climatic variations are habitual in the region. Newsham (2011) points out that the understanding of agro-ecological dynamics enables farmers to adapt cropping and livestock grazing strategies to climatic variability. In addition, Verlinden et al. (2006) indicates that this knowledge system is widespread within North-Central Nambia and is not specific to gender, neither wealth nor age. Moreover, this classification system is a referral of land use, soil and land management, as management practices differ in accordance to land use. Furthermore, Sillitoe (1998) argues that, indigenous knowledge of farmers is parochial and culturally relative, and its local embeddedness is intrinsic to its success, whereby science strives for a generic and global perspective. Thus, an understanding of this system will assist communities, extension workers, research and developmental agencies, as it provides useful knowledge for the efficient planning of activities. However, it is important that the understanding of local knowledge and practices to correlate with scientific knowledge is not taken for granted in developmental initiatives. As this may run the risk of misinterpreting the significance of local knowledge and promote interventions based on misunderstanding, which anthropologists' term as 'scientific arrogance' (Sillitoe, 1998). *(Ibid)* The result may be ineffective practical interventions, by focusing narrowly on scientifically defined issues and failing to account for the broader processes at work. Nonetheless, the better understanding of local perceptions and use of the land will enable the strengthening in adaptive capacity of the indigenous knowledge system to climatic variations.

Thus, local agro-ecological knowledge connected with soil and land management of communal farmers, combined with agricultural science, is crucial to advance the adaptive capacity and resilience of farming for communal small-scale farmers to climatic variability and climate change. Nonetheless, the "indigenous land use units" are classified according to specific criterions, which assists farmers in deciding, what crop to plant, where and under which expected growing season (Newsham, 2011). To understand this knowledge system, Verlinden and Dayot (2005) and Verlinden and Kruger (2007), classifies "indigenous" land units according to soil properties, hard pan, vegetation and landform. These land units, require certain indicators of soil depth and texture, structure of vegetation, species, and elevation or depression of the landform. This knowledge system not only provides land units favourable for crop farming but also provides land units conducive for livestock grazing, since dissimilar land units have different seasonal qualities and potentials for cropping and grazing.

Nonetheless, Newsham et al. (2009) points out that local knowledge in North-Central Namibia can be linked with agricultural science as it is not static and not closed up to innovation, especially in the form of new agricultural technologies. Particularly since those technologies that have been adopted by farmers, such as draft power and tractors, have been modifications of existing practices which are compatible with the land unit system. In addition, it is interesting to mention the unpublished Phd. work of Lukas Nantanga in Newsham and Thomas (2009) who talks about `cultural logic` of knowledge transfer and acquisition in the Ovambo society which is to; add, substitute and graft. Thus, a new technique does not necessitate the abandonment of a previous technique; they can be used in conjunction. Furthermore, Seely et al. (2006), stipulate that, when a soil management professional moves towards understanding the basis for farmers' management and decision making, the more pertinent becomes their support to farmers in soil management and conservation.

Additionally, since this study looks at local knowledge about their soils and environment of small-scale farmers in North-Central Namibia, there is a need to mention the concept of ethnopedology as it provides an idea to an outsider as to where the farmer is coming from. This is because ethnopedology studies local knowledge, beliefs, perceptions, uses, classification and management of soils by local people (Barrera-Bassols et al., 2003). (*Ibid*) It makes use of kosmos-corpus-praxis approach, where the kosmos looks at the belief system of local people of the biotic and abiotic environment. The corpus focuses on the knowledge or cognitive system and the praxis derives from the experiences of local people with their environment and how they manage their resources as a result of experience. It is thus of importance to understand the belief system, combined with what they know as a result of their experiences and what they have learned as a result of generational knowledge transfer as this makes up their way of life. With this information, it is easier to understand for instance, management practices of small-scale farmers and for appropriate interventions or knowledge co-production between local farmers and extension officers to be meaningful and effective in reaching their goals.

3.3 Land management practices

As already mentioned above, North-Central Namibia is characterised by sandy soils, poor in nutrients and SOM content. But at field level, the soils are heterogeneous, with dissimilar textures which require different management practices. Due to the poor soils, farmers manage their soils intensively to realise useful yields (Mendelsohn et al., 2006).

To improve soil fertility, manure use (mainly of cattle and goat) is one of the common practices amongst communal farmers (Rigourd et al., 1999). *(Ibid)* Depending on the availability of manure, it is applied on the crop field in the form of “dry kraal powder” and few farmers mix it with straw or grass. Moreover, the application of manure is usually done between November and December, and this requires labour and manure is not always adequate, especially when cattle remain at the cattle post. Additionally, the use of fertilizers in the region is limited due to the costs. Also, communal farmers erect ridges and plant their crops on top of the ridges. One of the important aspects of erecting ridges is eliminating excess water in waterlogging soils. Ridges are made during the soils or field preparation either by animal drawn implements or by tractor (Ridgourd et al., 1999). The use of animal drawn implements for field preparation is timely and the farmer can control plough depth, whereby tractors are fast but may cause delay for a farmer as they are not always available when needed. What's more, the constant use of animal drawn implements and tractors on waterlogged or hard dry soils needs to be eluded to avoid the formation of hard pans.

Chapter 4: Results

4.1 Field management

4.1.1 Kraal (through livestock corralling) and homestead rotation.

In *Figure 5*, the black dotted lines indicate where the old kraal was and the standing poles are the new erected kraal. The practice of kraal rotation is done by farmers with livestock, mainly cattle and goats/and or sheep. This is done on a yearly basis on whitish looking soil areas which the farmers would like to improve and make productive for crop production. Although livestock mostly stays at the cattle post, after the harvesting period is over, livestock graze for about 3 months at the farmstead. Thus, the livestock gets to produce the manure required for the productivity of the land during this period of time. The production of manure in the kraal occurs at night, as during the day, the livestock grazes within the crop field and pasture area. The manure is a mixture of dung and pee, which accumulates steadily, depending on the number of livestock. Farmers with a variety of livestock, goats, cattle and sheep, are having different compartments in the kraal separating the livestock. Thus, the amounts of manure differ in composition and quantity.

"***At the unproductive areas, if one wants to cultivate there or turn it into a crop field we have to put up a kraal first to improve soil fertility*.**" (Farmer Interview)

Figure 5: Soil amendment through kraal rotation.

Figure 6: Accumulation of livestock manure as "dry kraal powder".

Homestead rotation was a common practice in the region which is usually done after a number of years; usually a homestead is moved away from flood prone areas to higher ground or to renew the homestead when they are old or has been at a specific area for too long. As a result, the soil were the homestead has moved from are more fertile, supposedly due to the decomposition of the wooden building material, the household wastes and human faeces. Only 5 of the respondents (farmers) make use of kraal rotation and 6 of the respondents made use of homestead rotation. As a result, etathapya and erunda are unit areas of land which are productive areas where a homestead or kraal has been before. The practice of homestead rotation has totally declined due to new concrete structures of the farmstead and kraal rotation is still an important practice for farmers with livestock.

4.1.2 Use of organic and inorganic fertilizer

Farmers mostly make use of organic amendments such as animal manure from cattle and goats often in a combination with household waste for soil improvement. Very few farmers make use of inorganic fertilizer and this is mostly because it is costly. Farm C for instance makes use of organic and inorganic manure every year, a 50kg of Omnia Nutriology inorganic fertilizer which costs about N$50.00. Although the cost may seem quite reasonable, most farmers are unable to afford this. Such costs are afforded by small-scale farmers who also have an income through formal employment. The figure below shows that most farmers apply manure (mainly of goat and cattle) on some areas before the onset of rainfall and ploughing. According to the farmers, the amounts of manure applied are low and inadequate and a farmer has to make a decision as to where exactly to apply the available manure. Since farmers generally try to cultivate on the whole field, the application of manure is done at some areas, mostly at areas that look more whitish, loosing fertility or where they expect to gain higher yields. Apart from the use of manure, using household waste including wood ash from the cooking areas is also quite common.

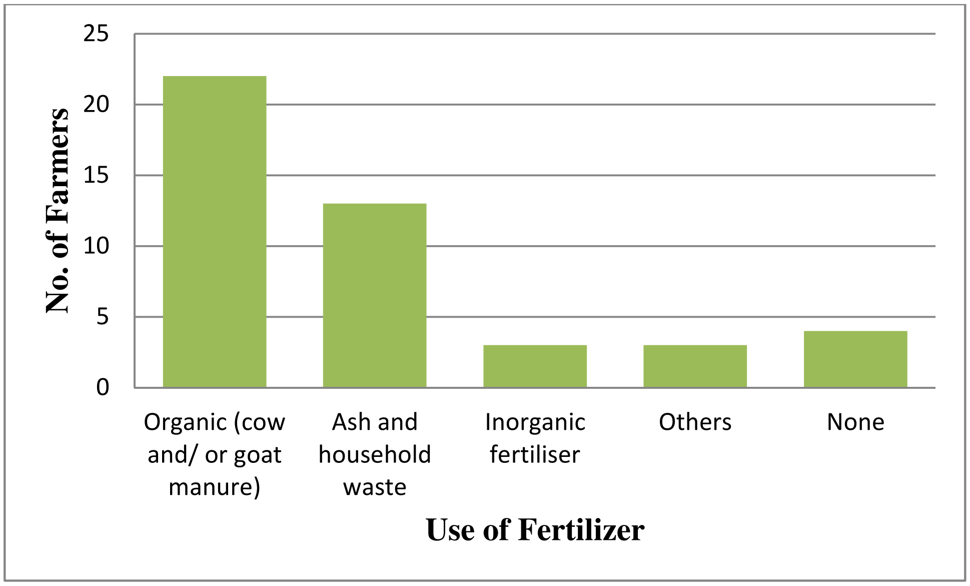


Figure 7: Types of soil amendments

4.1.3 Cropping patterns

The planting of crops is not done in relations to the recycling of nutrients into the soil but includes cultivation where leguminous crops are planted separately on areas where soils are too poor or unsuitable to support other crops. Nonetheless, the farmers plant the crop field extensively to outbalance crop failure and to ensure that they derive some food, to sustain the household. Small-scale farmers plant their crops mainly depending on the landform or elevation. High-lying areas such as the iitunu or omutunda (see *Table 3*), are mostly intercropped with the staple crop omahangu (pearl millet) and other crops such as omapungu (maize), watermelon, pumpkin as well as sorghum which are planted at low densities (see *Figure 8*). Sorghum is mostly planted at the low-lying areas such as the ondombe (see *Table 3*) at the edge of the fields. Although, sorghum is able to tolerate a high amount of water, when the accumulation of water is too high especially when seasonal flooding occurs, sorghum is unable to ripen. The intention of planting in this manner is for the farmer to increase the chance of deriving yield from the different land unit areas and from the various crops. Bambara nut and cowpea are annually planted as monocultures, at very poor fertile areas with white bare sandy soils, where manure is not applied. Farmers mostly do not make use of crop rotation; crops are planted at areas which are suitable for them.

Figure 8: Common method of (inter)cropping in North-Central Namibia

This indicates a more mixed method of cropping but some land units are dominated by monocultures. The mixing of leguminous crops such as cowpeas and Bambara nut enables the nitrogen fixation from the air and use it for their own growth and when the legume crop is harvested or dies, the nitrogen fixed in the roots becomes available in the soil (Ngolwe and Fleissner, 2002). However, in most cases Bambara nut and cowpea are planted separately as monocultures.

4.1.4 Field preparation (tillage)

Small-scale farmers indicate that they have difficulties preparing their fields for cultivation during the beginning of the growing season as tractors are scarce and as a result delays seeding. Nonetheless, the farmers mostly make use of tractors but prefer to make use of draft (animal) power. Some farmers make use draft power due to financial constraints although they would like to use tractors. Otherwise, there are farmers that make use both in a growing season, either because they prefer to make use of draft power on some soil textures, such as the more clayey soils which are easily compacted or starts off with draft power until a tractor is available. Either ways, the use of draft power is less common nowadays as tractors are more efficient with regards to time and most small-scale farmers indicate that donkeys have become rare in the region. Small-scale farmers making use of draft power make use of cattle for the work, but the use of cattle for draft power is uncommon as they provide other important uses for farmers.

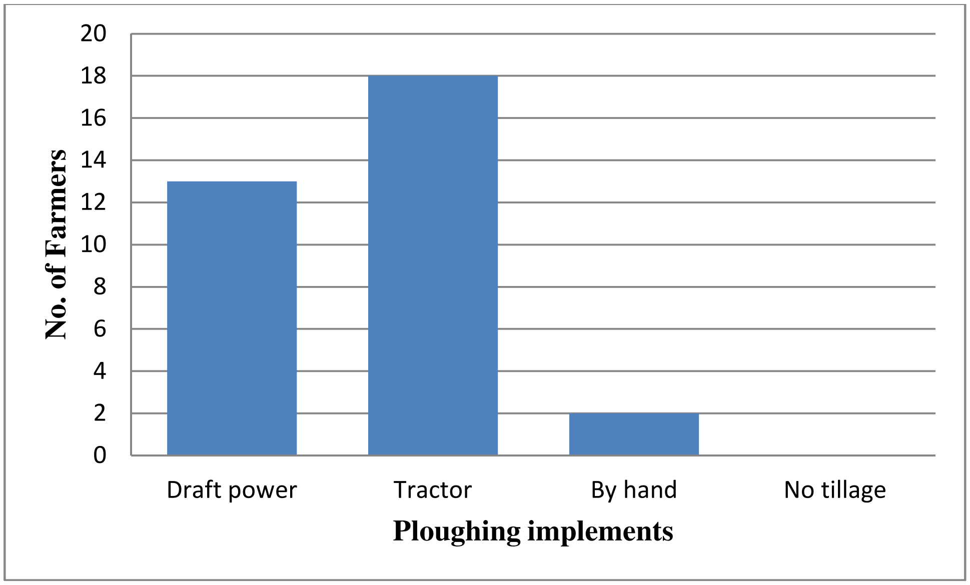


Figure 9: Types of ploughing implements for field preparation

Figure 10 below shows that small-scale farmers slightly prefer using draft power as opposed to conventional tillage. These are some of the reasons provided by the farmers as to why they would prefer draft power;

- Provides better yield
- Tractors are too expensive
- Reduces water erosion
- Reduces soil compaction
- Soils ploughed by tractors require constant application of fertilizers.

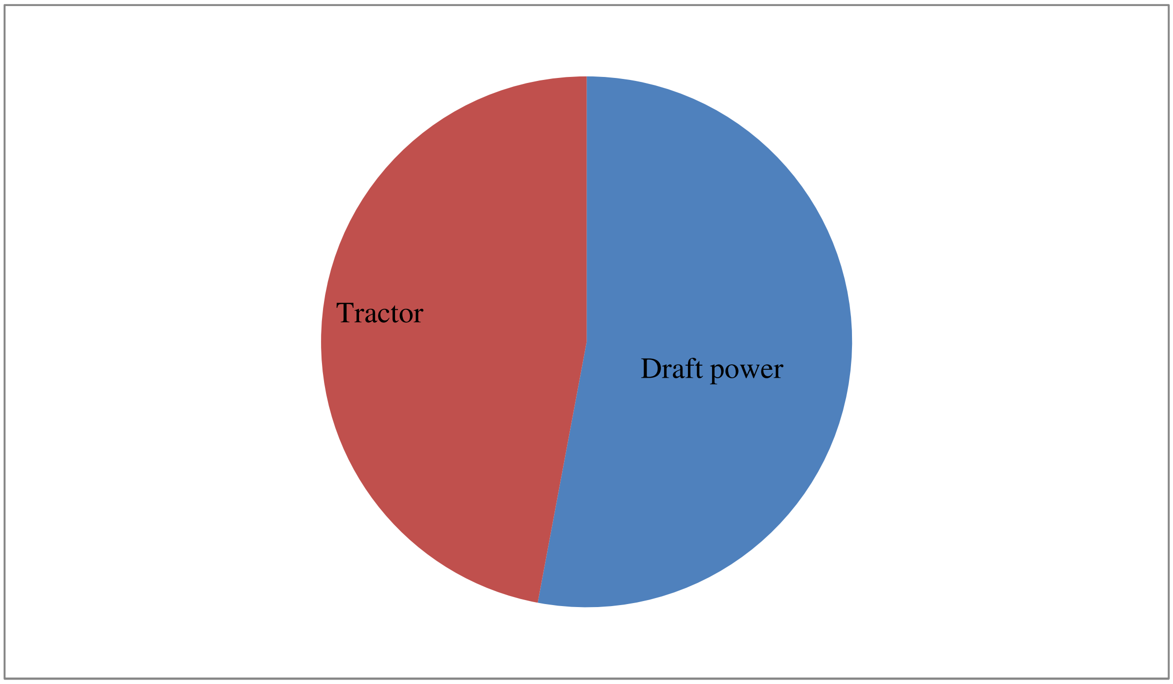


Figure 10: Farmers' preference of ploughing implements

**The data includes farmers using both or using either tractors or draft power but prefers the alternative due to certain reasons or does not use the alternative due to certain reasons.*

4.1.5 Livestock Management

Livestock is very important for small-scale subsistence farmers as it contributes substantially to their livelihood through selling, trading (either alive or as meat), for manure production and for labour on the crop field(s).

With regards to livestock grazing, farmers with livestock around their farms usually graze the livestock within their fences (on-farm) after harvest and during harvest time, the livestock grazes at the communal grazing areas (off-farm). There is however no consistency used in the grazing of the livestock. Grazing areas are used as long as there is grass available for the livestock. Some grazing areas look quite impressive with a lot of tall and short grasses but some grass is avoided by the livestock. In other parts there are no grasses but bare whitish soil.

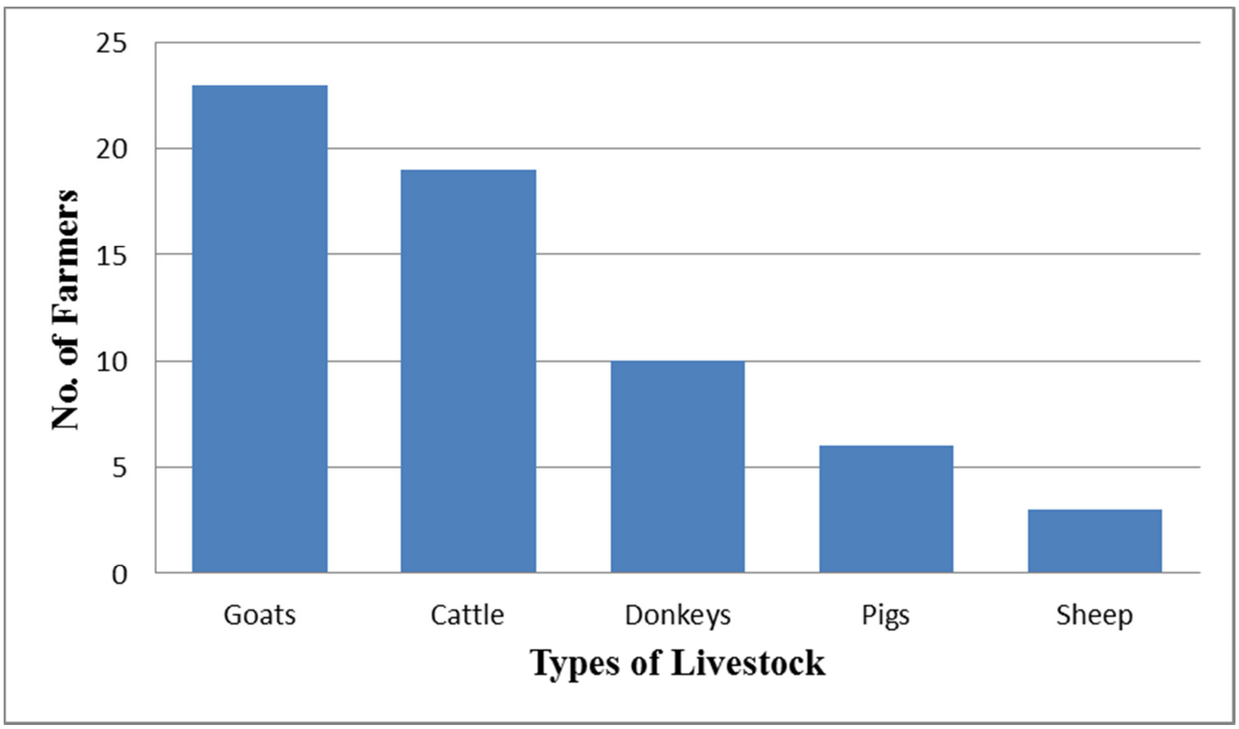


Figure 11: Types of livestock owned by small-scale farmers in North-Central Namibia

Nonetheless, grazing areas have declined due to an increase in population and settlements. The respondents indicate that grazing areas availability has generally increased, since livestock are kept at the cattle post by those owning a substantial amount of livestock. Only a few livestock are kept at the homestead or are only around the farmstead for a couple of months after harvest. During floods, some farmer’s livestock is taken to graze at higher grounds which are less affected by flooding and have palatable grass available. Thus, the management of livestock on grazing areas or the lack thereof due to the grazing of livestock on-farm and off-farm can be seen as an opportunistic feeding strategy (Rufino et al. 2007) which is possibly a consequence of the annual productivity of the land.

Farmers mostly own goats and cattle and very little farmers own sheep. Goats and cattle are important as they play a huge role in the production of manure. Table 1*: Livestock numbers at farm level.* below provides an overview of the amount of livestock that the farmers own. At least 5 farmers out of 29 do not own any livestock at all and in terms of manure production, they rely on cow or goat dung from the livestock that comes to graze on their crop fields.

Table 1: Livestock numbers at farm level.

Live-Stock	FARMS																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Goats	7	13	27	10	4	2	12	50	0	0	0	0	7	30	0	12	5	6	0	6	116	1	10	5	6	-	-	4	7
Sheep	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	84	0	0	0	0	0	0	0	0
Cattle	34	8	40	0	0	16	0	258	0	100	0	59	9	15	0	17	6	5	7	0	249	1	19	-	10	-	0	0	0
Donkeys	0	0	0	0	0	0	0	30	0	5	0	0	4	0	0	0	1	3	0	0	18	2	8	-	0	0	0	4	0
Pigs	2	3	1	2	0	0	0	0	0	0	0	0	0	11	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Total	*43	24	68	12	4	19	13	338	0	105	0	59	20	56	0	29	12	15	7	6	467	4	37	5	16	0	0	8	7

- Since the respondents were mostly women, they were either not aware of the number of livestock or were not at liberty to disclose the information in the absence of their husbands or male head of the household.

*reflects only the number of livestock that was present at the farmstead during interview. Livestock at the cattle post not included, livestock numbers there are not known.

Farmers do not have hay to provide for the livestock during periods of stress. Only one farmer (farmer C) made use of "Lucerne" and rocky salt that the livestock could leak during periods of scarce fodder supplies. To cater for a period when there is a lack of fodder for the livestock, farmers store sorghum and millet stalks (crop residue) for later consumption by their livestock. Moreover, when there is no adequate grass, some farmers make agreements with other farmers that have no livestock but have grazing space on their fields, for their livestock to browse there. Thus, it is beneficial to have a cattle post, where livestock graze when fodder runs out at the farmstead.

4.2 Yields

The focus was mostly on pearl millet (pennisetum glaucum) which is the staple food in North-Central Namibia. According to Matanyaire (1996), pearl millet is sown on an average area of 3.5ha per farmstead. Overall, Mendelsohn et al. (2006) indicates that most farmsteads cultivate between 1 to 4 hectares and the average size area cultivated is 2.7 hectares in Oshana and 3.2 hectares in Omusati, thus, the average weight of pearl millet per farmstead in Oshana is about 760kg and about 970kg in Omusati. The difference in crop yield in Omusati and Oshana can be attributed to field size cultivated and in Omusati, production occurs on a larger area compared to farmsteads in Oshana. The only small farms that have higher yields are those, where crops are intensively fertilized and irrigated (Mendelsohn et al., 2006).

Nonetheless, crop yields are largely related to rainfall patterns and soil conditions. During heavy rainfall or floods, yields are usually low on crop fields which are affected by flooding, example, crop fields which are characterised mainly by ondombe (see *table 3*) usually have low yields both during floods and during periods of little or no rainfall. Farming practices such as, weeding, crop thinning, the use and non-use of fertiliser also has an influence on how much is derived from the field.

Figure 12: Traditional yield storage basket

Bouma (2002) indicates that "a potentially high quality soil can have low yields as a result of poor management and a low quality soils may have high yields due to excellent management". Thus, communal farmers have potential to gain higher crop yields with poor soils, as long as they follow soil and crop management techniques for crop and soil improvement.

Farmers store their yields in the hand made storage baskets, although not all farmers are able to fill up a single one. Mendelsohn et al. (2006) stipulates that the traditional storage baskets have storage capacity ranging between 0.7 – 2.0 tons. However, yield is influenced by a number of factors (see 4.1.9). When a farmer is unable to fill atleast one storage basket, it is regarded as a bad yield for the farmer. This would mean buying or trading from other farmers that have a surplus from their previous harvest or buy maize meal from the supermarkets. But when there is flooding or drought, farmers receive governmental assistance when the crops have failed and their livelihoods are compromised.

Table 2: 2012 harvested yields (dry grain of pearl millet)

Farm	Yield in Kg	Area of crop production in hectares	Yield in Kg/ha
A	*2825.8	4.40	642.2
B	1125.1	4.20	268
C	1150.7	3.00	384
D	6458.6	7.7	839

* For this farm, not all storage baskets could be measured, but derives a large number of yield as they still had a full storage basket of yield from 2009 and 2010 harvest was sold.

- Only four of the storage baskets for farm D were calculated, the measurements for the fifth basket could not be measured.

Although farm B has a bigger area for crop production, it derives less yield compared to Farm C. This may be attributed to the location of farm B, which is in the southern part of the cuvelai, which is influenced by evaporation and thus their soils are salty and Farm C also combines organic and inorgani fertilizer. Farm D has the most yields per unit area. This could be attributed to the number of livestock for manure production, and access to labour available for the farmstead.

4.3 Farmer socio-economics and constraints

The data below includes persons residing at the farmsteads all year long and those residing elsewhere but contribute financially to the farmstead. Due to urbanisation, a large number of the young population has migrated to urban areas in search of greener pasture, leaving farmsteads at the rural areas inhabited by old people. Due to this trend, the farmstead income is mostly based on the pension of the old persons. There are 17% of the farmsteads which have persons employed in the formal sector. These includes the education sector but there are also those formally employed in miniature jobs such as a cleaning jobs and their salary or wage has to feed a homestead of 5-8 persons. Only 8% of the farmsteads sell some of their crops as yields are usually high. These are farmsteads that have persons employed in the formal sector, who are able to make use of organic (have large numbers of livestock) and inorganic fertilizer for their fields on a yearly basis. Moreover, 10% of the farmsteads have no source of income, because the children are too young to seek employment and the adults are not old enough to get pension. Thus, some of the farmsteads with no employment (13%) and no access to pension make use of other means to generate income, such as selling firewood and fish from the oshanas, as well as home-made traditional liquor (ombike), , or providing services such as ploughing other people's fields by animal power (draft power).

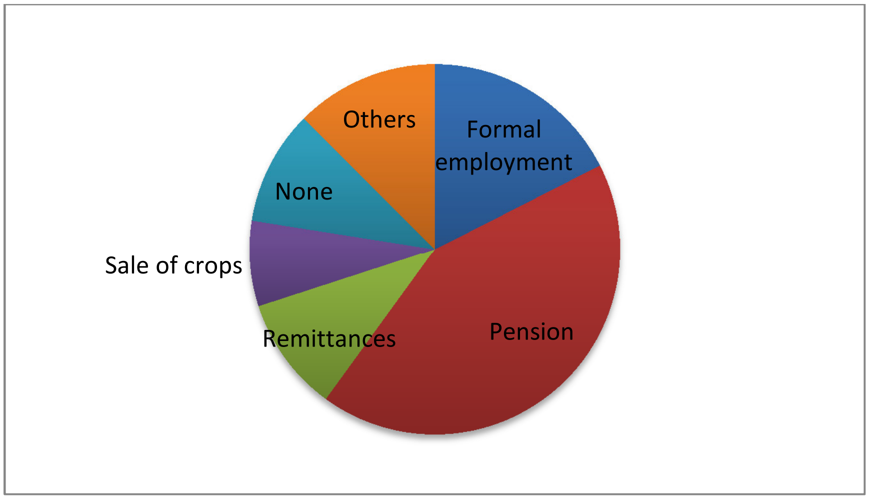


Figure 13: Means of revenue for farmers´ livelihood

The first most difficulty experienced by farmers is a lack of fertilizer, followed by birds, and a lack of labour. Other contraints include ploughing which is expensive and not timely, as tractors are unavailable when needed and this may be an attribute of less machinery available to meet the demand. Pests such as army worm (Spodoptera frugiperda) and locusts decreases yields and labour force is missing as the youth has moved to urban areas. The extreme climatic conditions of the region results into either a scarcity of water which is inadequate for livestock and crop production or there is an abudance of water which damages crops. As a result of urbanisation and poor education, as well as low employment opportunities within the rural communities, the youth has gone away for school and work, reducing labour force for the crop field. Only old people are left to tend to the daily and seasonal labour at the farmstead. Because of this, crop fields have been made smaller and the rest had been abandoned and converted into bush or grasslands to be left fallow or serve as pastures. This decline of cultivated land due to a lack of workforce results into a drop of output and productivity. To deal with poor soils with no fertilizer and flooding events, some farmers gather soils from the termitaria hills to improve soil productivity and also to elevate their fields.

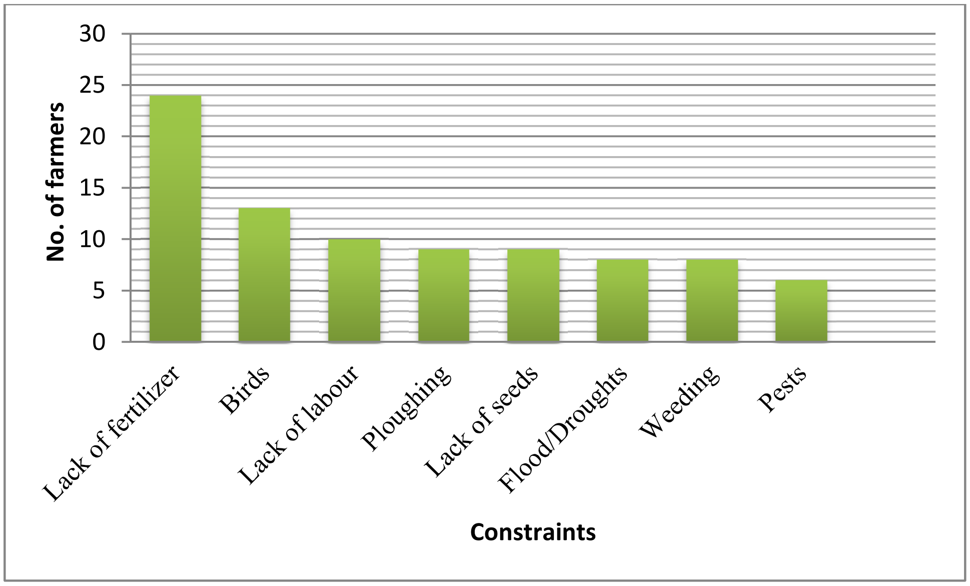


Figure 14: Farmer constraints

4.4 Land use units:

4.4.1 Introduction

Land use units resemble an environmental classification system based on indigenous knowledge (IK) which has been used in the region for hundreds of years and has been passed down from one generation to another. Warren and Cashman (n.d.) defines IK as "the sum of experience and knowledge of a given ethnic group that forms the basis of decision-making in the face of familiar and unfamiliar problems and challenges. According to Verlinden and Dayot (2005), land units are thus an indigenous classification system used by farmers in North-Central Namibia for resource management, via the classification and utilization of their environment which they base on indigenous environmental knowledge (IEK) that they have and not only on ethnopedology and soils alone. Moreover, Verlinden and Dayot (2005) and Newsham and Thomas (2009) characterises indicators of the indigenous land units by physical and perceptual criteria. The physical being soil colour, texture, elevation, depression, vegetation and the presence of termitaria. Perceptual criteria's are not easily identifiable such as soil-water movement, ease or difficulty of working the soil, use of land for grazing or non-agricultural activities such as pottery and building. This study therefore used literature by Verlinden (2005; 2006; 2007) and Newsham (2009; 2011) for the identification of land units at farm level, with the orientation and naming of the different land units and their uses by the farmer. Nonetheless, Schuler et al. (2006) and Barrera-Bassols and Zinck (2003) also found that farmers all around the world differentiated their soils according to the obvious morphological parameter, mainly of topsoil colour, and followed by soil texture. Thus, soil colour and textural properties are the farmers' basis to identifying fertile or potential productive areas and soil texture is an important soil parameter for the farmers to use in determining the suitability for different land uses and appropriate crops (Nethononda and Odhiambo, 2011).

4.4.2 Farmers criteria for determining land units

For the identification of land units and for making decisions regarding crop selection and management of livestock as well as for other agricultural uses, farmers in North-Central Namibia mostly make use of the following parameters;

- Soil colour
- Soil texture
- Elevation (topography)

Table 3 below shows land units that have been identified from the twenty nine (29) farmers, from the villages of Oshinyadhila no.4, Oonkima, Olweege and Iiputu respectively. The table indicates the various land units with types of crops mainly planted, soil characteristics, topographical features.

4.4.3Defined land units and their uses:

Table 3: Identified land units and their uses according to the communal farmers' classification in North-Central Namibia.

Land use unit	Land use/crop	Soil fertility	Elevation	Main features	Use of fertilizer
Ehenge	Cowpea	Low	Low	Whitish bare sandy soil, poor in nutrients	None
Ehenene	Sorghum	High clay content	Low	Flood-prone	None
Ethatapya/Erunda	Millet	High	High	Areas where a kraal or homestead have been before	Occasionally
Ondombe	Sorghum	High clay content	Low	Low elevation, hardened or compacted, flood-prone	None
Omutunda	Millet, Sorghum, Maize, cowpea Watermelon	Moderate	High	High elevation	Occasionally
Oshiitunu/iitunu		Moderate	High	Higher elevation	Occasionally
Ekwatha	Sorghum, Millet*	High, high clay content	Low	Depression, plenty of weeds	None
Oluma	Sorghum	Low	Low	Depression, hard pan, low yields	None
Oshiifukwa	Bambara nut	Low	High	Bare sandy soil	None

*planting depends on the intensity of rainfall

Chikowo et al. (2009) points out that, even though, “the low-lying areas with Vertisols can constitute locally productive soils in otherwise largely unproductive areas, these soils are often not fully exploited due to excess water problems during periods of high rainfall as high clay contents prevent the rapid drainage and cause erosive floods”. However, due to a limitation of suitable soils for crop cultivation in the western Kalahari, crops are planted on lower grounds, either in old pan systems, interdune valleys or along old drainage lines where the soil is richer in clay and holds more water and nutrients. Moreover, the crop fields occupied by one single farmer are heterogeneous land areas with a high degree of variation in soil fertility and soil qualities which also determine crop suitability and emphasis on management and labour allocation. Mtambanengwe and Mapfumo (2005) recognise the spatial and temporal variability of soil fertility within crop fields and farms. (*Ibid*) These soil fertility gradients can however be attributed to physically well-defined field environments such as, termite mounds, homestead surroundings and areas under tree canopies. High management priority is put on the more “fertile” and well drained areas where millet is planted (the omutunda and erunda), since these areas are known to provide bigger and higher crop yields. Additionally, Mtambanengwe and Mapfumo (2005) also found that the farmers’ perceptions of sandy soils and soils that are light in colour as unproductive. Therefore, first priority is put on the more productive soils (darker in colour) and these farmer perceptions were found to be consistent with the laboratory findings, whereby soil organic carbon was significantly higher at the “more fertile” areas compared to the labelled unproductive areas.

4.4.4 Importance of land units for farmers

Farmers make use of their knowledge and experience for the selection of suitable soils for crop production and grazing. The selection of land units in North-Central Namibia has a lot to do with the climatic uncertainties, especially of rainfall patterns in the region. The different uses of the soils are determined by soil properties and it is these soil parameters that make up the land units. The farmers are aware of areas which are having poor or relatively fertile soils and this helps to determine suitable crop production. For instance, land units characterised by sandy soils are used for the production of legumes such as cowpea and low-lying areas are mostly used for the production of sorghum during periods of high rainfall as sorghum is able to tolerate more water and the staple crop millet is produced at the high-lying areas due it its low levels of water tolerance in comparison to sorghum. Farmers prefer to have more than one land unit on their farm as it offers variability and resilience to rainfall variation. However, this classification of land uses does not offer resilience to drier climatic conditions in the case of drought. Thus, it is important to consider the use of irrigation schemes during water deficient periods and rainwater harvesting during periods of water adequacy. It is important for farmers to have more than one land units as it provides with heterogeneity and for the production of different crops under suitable conditions.

4.4.5 Management of land units

The management of land units is done differently. The crop fields with areas which are easily compacted make use of draft power instead of a tractor and the more sandy areas are ploughed by tractor, such as what is done at farm B. All units where leguminous crops such as Bambara nut and sorghum are cultivated are not fertilized. Only on high-lying areas such as the omutunda where pearl millet is cultivated is occasionally fertilized on a yearly basis. Weeding is done two to three times on the whole field but this usually depends on the weed invasion, which is said to be more prominent on areas applied with manure. Anyhow, this division of land provides site-specific management.

Chapter 5: Discussion

5.1 Discussion

5.1.1 Potential for soil carbon sequestration in the region

The potential of soils to sequester carbon from the atmosphere should vary at the different land units. Not just because of different soil management practices having diverse effects on soil organic carbon but also due to natural variations in soil productivity. It is however imperative that the soil management differs depending on soil texture and crop variety. Apart from the use of organic fertilizer (manure) by small-scale farmers in North-Central Namibia, the use of biochar could be an essential ingredient to augment productivity on agricultural land in North-Central Namibia. When this intentionally pyrolysed biomass is used as a soil amendment, it does not only improve soil fertility but can help mitigate climate change through carbon sequestration as it can store carbon in soil for decades and centuries. Although biochar is a useful part of sequestration and mitigation strategies, it is of vital importance to understand the variation in its decay rates (Schmidt et al., 2011). Moreover, its application needs to be assessed site-specifically, as it could be causing negative effects as well, such as diminished nutrient uptakes.

5.1.2 Management of organic fertilizer (animal manure), nutrient retention and possible Greenhouse gas emissions

The small-scale communal farmers in North-Central Namibia mostly make use of organic fertilizer (manure from livestock). Thus, animal manure is an important resource on smallholder farms, as nutrients are concentrated from common rangelands (Chikowo et al. 2009). The use of animal manure on farmland is a sustainable way of crop production and in improving soil quality. This is because; animal manure contains the most nutrients (such as carbon, phosphorus, nitrogen) essential for plant growth and according to Chivenge et al, (2007), the use of manure can counter the adverse effects of tillage. Thus, with adequate and well fed livestock availability, there can always be a production of manure. The problem experienced by small-scale farmers with the application of manure on the crop field is the lack of it, due to a shortage of livestock of cattle and goats available. Amongst the sampled group, only one farmer made use of both inorganic and organic fertilizer in combination. Some farmers have no or very little livestock and those with larger numbers of livestock; the livestock are kept at the cattle post and only kept at the farmstead for a short period. As a result, the cattle post has a large volume of manure being blown away by the wind. Since the cattle posts are distant from the farmsteads; the transportation of manure from the cattle posts to the farmsteads is an expensive activity for the farmers. Thus, means of manure transportation and storing need to be considered. For on-farm-nitrogen-recycling, covered storage may be a promising solid cattle manure management system, especially for farmers with larger numbers of livestock at the cattle post. This is because; the poor management of animal manure may result into nitrate leaching and losses of methane, ammonia and nitrous oxide into the atmosphere (Rotz, 2004). Nonetheless, Shah et al. (2012), and Meisinger and Jokelo (2000) specify that the application of manure at the onset of rainfall or immediate irrigation can drastically suppress ammonia emissions by moving ammonium nitrogen into the soil since the soils are a good sink for ammonia in comparison to non-irrigated applications. Moreover, immediate irrigation after land application of anaerobically stored (covered storage) manure lessened ammonia emissions extremely. Thus, there is a need to improve the nitrogen use efficiency of animals to diminish nitrogen excretion and retain the nitrogen contained in manure, pending its application to the land, and the timing in application is critical to avoid nitrogen and ammonia losses and making it available to the crop (Rotz, 2004). The manure of the farmers in North-Central Namibia is produced by livestock kept in a kraal with no roof and then left on the ground where later crops are planted, or the manure is taken out of the kraal and spread on a specific area in the field. According to Shah et al. (2012), the manner of animal manure handling determines the losses, and there is a need for effective management techniques to reduce nitrogen losses, and make it available to the plant after field application are yet to be understood.

Moreover, Shah et al. (2012) and Rufino et al. (2007) demonstrates in a study conducted, testing three contrasting manure management techniques on the carbon and nitrogen losses, that covering (covered storage) the solid cattle manure with an impermeable or air tight plastic sheet reduces nitrogen and carbon losses during storage notably. Nonetheless, high losses were noticed from the stockpiled and composted heaps. Moreover, with covered storage, it is demonstrated that even after field application, the manure decomposes more rapidly and more nitrogen is available for plant intake, not only during the year of application but also for the following year. To sum up, manure is an important soil amendment for small-scale farmers in North-Central Namibia and several studies have shown that manure that is covered during periods of non-use enables the manure to remain of good quality until its applied to the soil and should only be applied to the soil on the onset of rainfall or at the root of the crops that the nutrients are available and taken up by the crops. So far, farmers leave manure on site like at the cattle post or in the kraal at the farmstead until it's needed during the growing season or just left to be blown away by the wind as at the cattle post. Small-scale farmers in North-Central Namibia conduct several soil management practices, the most common and valued being organic fertilizer (manure) from livestock waste, mainly cattle. Therefore, the management of manure pre-application and during application is vital to ensure that there are no losses and that nutrients are taken up by the crops.

5.1.3 Tillage and soil organic carbon

With field preparation, tillage influences the amount of soil organic carbon. Thus, it is imperative to consider techniques of tilling (ploughing) fields with less possible loss of soil organic carbon. Small-scale farmers mostly make use of conventional tillage which increases soil erosion, disturbs soil structure, enables the creation of hardpans and reduces soil-water conservation. This is because tractor operators do not pay attention to the depth at which they plough, the fertile topsoil is buried deeper, and the infertile soils brought to the surface where seeding is taking place. Moreover, without aggressive application of fertilizers, this may result in a decrease of yield and an increase in soil erosion.

Chivenge et al. (2007) conducted a study 30km north east of Harare, Zimbabwe where they evaluated disturbance of soil during the preparation of land for cultivation. They compared three techniques, namely; conventional tillage (CT), clean ripping (CR), and tied ridging (TR) and they found that, for CT the smallest amounts of soil organic carbon remains in the soils compared to the other tillage practices. Furthermore, at lower intensity of soil disturbance in the clayey soils, the total soil organic carbon remained higher or even increased. They however found no significant difference in the total soil organic carbon for the sandy soils due to tillage. Moreover, Feller and Beare (1997) in Chivenge et al. (2007), indicate that the non-significance may be due to the low clay content which is crucial for the physical protection of soil organic matter by mineral association. Since tillage does not affect soil organic carbon in sandy soils, it is unlikely that the use of conservation tillage or no tillage at all, would influence soil organic carbon in the sandy soils, thus, a suitable management practice is necessary. Tilling with a ripper furrower in North-Central Namibia has been successful for a number of small-scale farmers as it provided higher yields even for farmers who do not have access to organic or inorganic fertilizer and this tilling method conserves soil moisture and has several other benefits for famers. Since only very few machineries of this kind exist, it is essential to manufacture more, so that many more farmers are able to make use of this technology without experiencing delays during the growing season.

Given that there is an interactive effect between a management and soil texture on the stabilization of soil organic carbon and since a significant difference in tillage was not found on sandy soils, Chivenge et al. (2007) suggests that the use of mulch ripping combined residue retention had greater soil organic carbon than clean ripping in the absence of residue management.

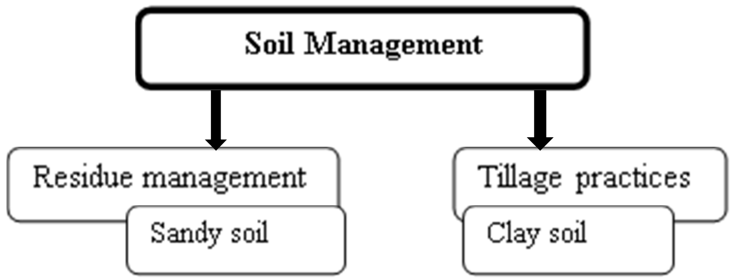


Figure 15: Interactive effects between management and soil texture on soil organic carbon stabilization. Adapted from: Chivenge et al. (2007)

Ultimately, it is essential to put emphasis on residue management for areas with sandy soils and areas with more clayey soils to take care of tillage practices. Moreover, residue retention is also essential as it provides protection for the soil against wind and water erosion. Nonetheless, since crop fields are also used for grazing after harvesting, farmers with no livestock find it difficult to manage their crop residues (Chivenge et al. 2007) as the farmers with livestock make use of their farms for the sustenance of their livestock (see: 4.1.10). Thus, crop residues as soil amendments are competing with the use as fodder for livestock, for construction as well as for cooking. On the contrary, studies have also shown that conservation tilled croplands do not necessarily result into carbon sinks but carbon sequestration, and this depends on the depth of soil sampling and analysis, crop management and the time-span of low-intensity tilling (Johnson et al. 2007). Reduced or no tillage however has a positive influence on soil erosion. Although a few farmers make use of inorganic fertilizers and tractors for land preparation which damage soil structural stability and consume energy, Johnson et al. (2007) indicates that with such farming methods, with exceptions of the formerly mentioned, the farmers are more aligned towards organic agriculture and their management practices for instance of animal manure application can contribute to the sequestration of soil organic carbon. Although the ownership of livestock is a strong determinant for farm SOC and nitrogen management, some farmers in North-Central Namibia do not own livestock or own very little to make a significant difference in manure production. The use of inorganic fertilizer is uncommon due to financial constraints. Nonetheless, Mtambanengwe and Mapfumo (2005) stipulate that it is necessary to have soil management options that focus on efficient and sustainable utilization of locally available resources and the combined effort of applying management practices will not only play a role in improving soil fertility which translates into highly productive land with higher yields, it will also assist in the mitigation of climate change by reducing greenhouse gas emissions from agriculture. The change from conventional tillage to conservation tillage (reduced or no tillage), combined with the application of organic amendments to the soil will enable a high soil carbon on the crop fields at farm level. All of this shows that, farming practices play a significant role on soil organic carbon sequestration on agricultural land and on increasing agricultural productivity, but improvement in farming practices is still essential. Therefore, efficient conservation management practices such as crop residue retention, conservation tillage such as the ripper-furrower which has been successful for a number of small-scale farmers in the region needs to be promoted in North-Central Namibia. For the first year, the tractor ripper-furrower can be used to break the hard pan and in consequent years, small-scale farmers can make use of the animal drawn ripper-furrower (Mudamburi et al., 2012). The use of animal drawn ripper-furrower would be most cost-sufficient for the farmers and as a result, investment in donkeys for instance is necessary. However, this study did not specifically look at what ploughing/tilling implements the farmers are currently using, thus, it may be interesting to look at specific tilling implements under conventional and conservation tilling, used by the various farmers and determine if there is any variation in soil quality and yield, assuming that there are farmers using conventional tilling implements such as the disc harrow and those using ripper-furrower (tractor or animal powered).

5.1.4 Residue retention and livestock fodder

As already mentioned above, crop residues compete with so many other uses, cooking, fodder, and construction. Mtambanengwe and Mapfumo (2005) found that in Zimbabwe, crop residue is used as an alternative dry season fodder for the livestock or livestock bedding during the rainy season, thus competing as an organic amendment to the crop field. Lal (2005) stipulates that the removal of crop residues from crop fields for the use of, for instance fodder for the livestock is attributed to the socio-economics of the small-scale farmers. Furthermore, this exercise is amongst some of the unintentional practices by farmers which contribute to the depletion of the soil organic carbon pool and soil degradation. Thus, it is necessary to find alternative sources of fodder and for fuel, in order to reduce deforestation and the usage of cow dung which could be used as a soil amendment. Some options could be to cultivate fodder crops such as Tree Lucerne, which would provide great fodder for livestock and Mostert et al. (n.d.), De Kock (2012); Environment Bay of Plenty specifies that Tree Lucerne can grow on dry land, as it is drought-resistant and only requires rainfall of about 500mm, it is nitrogen fixing and it grows on deep sandy soils, degraded soils, and also offers other benefits of preventing soil erosion and providing firewood. In Namibia, Tree Lucerne is not well-known and still remains to be fruitful to small-scale farmers.

5.1.5 Farmer constraints

Economic difficulties of small-scale farmers make it difficult for the use of inorganic fertilizers, thus, Snapp et al. (1998) stipulates that the tightening economic constraints of farmers increase their reliance on biologically fixed nitrogen and nitrogen cycling. It is therefore important to develop technologies and techniques within farmers' means. Moreover, in drier areas, nutrient cycling can be enhanced through livestock systems as it can be found in North-Central Namibia. Thus, access to both organic and inorganic fertilizer, labour to work on the fields and birds foraging on the crops are some of the difficulties that farmers in the region experience. In addition, climatic conditions play an important role, with dry climatic conditions and flooding events influencing the environmental conditions of the region.

5.1.6 Land use system

Land units are based on topographical features, soil colour being the number one determinant, soil structure and elevation. These features are used in the classification of the environment by small-scale farmers in North-Central Namibia. The concept of land units or the indigenous environmental classification system in the context of soil carbon sequestration is somewhat crucial, since crop and soil management is site-specific and site specific management techniques may be more efficient than techniques applied on a larger spatial area. Thus, soil management (such as crop residue and fertilizer application) with a high turn-over of soil organic carbon at a relatively small area is more conducive. This not only increases soil organic carbon, but also higher yields on a small unit area. Thus, this knowledge system is important in the utilization and management of land by using the land according to what it is suitable for and allocating suitable management techniques in accordance to its productivity. Therefore, it is of importance to better understand this knowledge system to ensure agricultural productivity and soil carbon sequestration in the region. It is also imperative to ensure that this knowledge system is persistent and resilient to climatic variations. This study however does not determine as to how far this knowledge system has really worked for the people with regards to climatic variation and to how far it would withstand future climatic changes. It is however evident that the system does not offer much protection when it comes to extreme climatic changes like during floods or periods of drought. Nonetheless, Schuler et al. (2006) indicates that the integration of local soil knowledge, petographic information and cropping practices would allow for a compilation of information for effective land evaluation. It is also necessary to consider small-scale irrigation schemes for the region, which will make use of harvested rain water and this may be combined with the ripper-furrower system. This system is invented for dry land agriculture and in North-Central Namibia, it helps with ripping the hard pan at a depth of 60cm and forms furrows for in-field rainfall harvesting (FAO- Save and Grow Factsheet 1). This system offers several benefits and since it has the potential to produce higher crop biomass, the farmers may be able to use crop residue fodder for livestock and still retain crop residue soil cover.

5.1.7 Yield

For the yield calculations, there was just one reference measurement for the dry weight of pearl millet. Thus, the result is not representative as due to different quality of yields amongst the farms, it can be assumed that there is some variation in dry weight. However, it provides an estimate about how much is obtained from the crop fields, at least of the four main ones, but it may be vital to have a database where yearly yields of farmers are recorded, that there is a compilation of data on yield available per farm (for mainly millet and sorghum) to monitor yield fluctuations. And for this, farmers could note how much yield they get out in a growing season or non-growing season and the information could be taken to a local office for compilation and record keeping. It is also of interest to investigate the composition and calorific value of pearl millet for instance, to determine how much carbon is stored in the crop.

Chapter 6: Conclusion

The goal of this study was to determine management practices on agricultural soils which are mostly characterised by poor sandy soils. The aim was to assess soil management practices of small-scale farmers that may augment soil carbon sequestration on crop fields and grazing land. The results show that there is potential for communal farmers to improve soil quality through management practices. The use of organic amendments to the soil increases soil organic matter; manure for instance improves water retention capacity of the soil, reduces soil erosion and improves crop growth. Thus, a good management of agricultural soils can inhibit GHGs emissions from agriculture and at the same time, provide food security for the local people. Thus, it is vital to establish a landscape carbon management scheme and sustain food productivity in the region. Some of the challenges posed may be;

- Ensuring soil carbon storage and longevity of soil carbon stocks since it is labile and sensitive to changes in an already unstable environment
- The extreme climatic conditions; aridity and flood occurrences
- Designing a soil organic carbon sequestration project that maximizes the returns on investment for farmers in the different ranges of the economic scale, while at the same time avoiding marginalization of disadvantaged farmers.

The use of organic matter technologies have been promoted in Southern Africa but adoption of such technologies by small-scale farmers has been unsuccessful. For the successful implementation and adoption of technologies and techniques to improve food production and enhance soil carbon sequestration, a feasibility assessment for the long term efficacy of technologies and techniques must be established and these strategies must be effective within farmer-resource constraints. Therefore, management practices that would be more profitable and efficient to farmers may be more appropriate to promote. Perez et al. (2007) indicates that it is important to understand the social, spatial, and sectoral variations in potential profitability in order to design a carbon credit scheme that contributes to the improvement of livelihoods.

The passed-on knowledge used by small-scale farmers in North-Central Namibia has assisted them in decision-making on crop production and farming in general. Their understanding of the crop needs assists them to decide on areas suitable for crop production as well as making decisions under climatic variability and socio-economic constraints. Although, farmers make use of tractors to prepare the land, because of less time and labour required, they are also aware of the implications of deep ploughing to the soil. This is why; land units such as the ondombe with more clayey soils are ploughed by animal power (donkey and cow) to avoid soil compaction. This indicates the knowledge that communal farmers have about their environment and for the development of a sustainable land management system in region, it is imperative to have a detailed understanding of the local knowledge about their soils and management.

The use of conservation tillage should also be encouraged, by promoting and making conservation tillage implements such as the ripper-furrower available to small-scale farmers. And with a combination of several management practices of manure application, appropriate crop rotation systems, residue management would amplify soil carbon sequestration on crop lands and instigate a management system of landscape carbon stocks. Moreover, a study conducted in North-West China by Liu et al. (2013) at an area with rainfall between 300-600mm and 90% of rain fed crops, indicate that to a depth of 0-60cm SOC increased with time through the application of manure and crop residue and the long-term application of organic manure has positive effects in building carbon pools in dry land farming areas. Additionally, Srinivasarao et al. (2013) also came to the same conclusion. Thus, it is vital to understand the dynamics of farming practices and soil organic carbon needs. The production of crops on poor soils in the North-Central regions has to emphasize on organic inputs and nutrient recycling (Ngolwe and Fleissner, 2002) and as already mentioned, nutrient management strategies will depend on the resources available at the farm and how they are managed.

Furthermore, the frequent occurrences of floods and droughts are critical calamity for the region and have a negative influence on crop production and carbon sequestration. Thus, the productivity of the land in semi-arid and arid regions is limited by climate. Assessments which look at connections between management practices, soil and climate are still necessary in determining efficient sustainable agricultural practices that would turn agricultural land from a carbon source to a sink, especially in arid and semi-arid regions. It is also important to establish small-scale irrigation schemes that cultivation takes place not only during the rainy season but also during the non-rainy seasons or during drought periods. Thus, rainwater harvesting is a good option to undertake regionally, and water can be harvested during the rainy season and flooding events, that this water can be used for irrigation. Nevertheless, it is necessary to conserve soil-water availability and nutrients.

In regard to fertilizer, manure from the cattle posts needs to be transported from the cattle post to the farmsteads for example, packing them in sacks and transporting them by donkey cart. And for farmers with large numbers of livestock, that can produce large bodies of manure, can sell the manure to farmers without livestock. Another way would be that small scale farmers cultivate collectively. This may be beneficial as farmers put resources together, for example, farmers with manure, draft power and/or tractors put these resources together and at the end distribute the harvest amongst them. Through resource and labour sharing, communal farmers may be able to apply for a loan as a group, and to purchase technologies that they may need. The sharing of resources and labour enables efficiency and higher yields. For communal farmers to leave crop residues in situ as a soil amendment, it is important to promote the production of fodder plants for livestock, preferably plants that would grow in poor soils and with little water. The use of appropriate soil management practices, results in improved soil fertility, reduces erosion and preserves soil moisture.

References

1. Barrera-Bassols, N., and Zinck, J.A., (2003). Ethnopedology: A worldwide view on the soil knowledge of local people. Geoderma. 111 (3-4), 171-195.
2. Berg, L.B. (2001). Qualitative research methods for the social sciences. 4th edition
3. Bezuidenhout, R. (2011.04.13). Miracle yields in arid Namibia. Simple conservation guidelines could quadruple yields. Farmer´s Weekly.
4. Retrieved from: http://www.farmersweekly.co.za/article.aspx?id=6165&h=Miracle-yields-in-arid-Namibia on 19.03.2014 @ 00:50
5. Bouma, J. (2002). Land Quality indicators of sustainable land management across scales. Agriculture, Ecosystems and Environment. Elsevier
6. Chan, Y. (2008). Increasing soil organic carbon of agricultural land. Primefact 735, (pp1-5).
7. Chivenge, P.P., Murwira, H.K., Giller, K.F., Mapfumo, P., Six, J. (2007). Long-term impact of reduced tillage and residue management on soil carbon stabilization: Implications for conservation agriculture on contrasting soils. Soil and tillage research. Elsevier
8. Chikowo, R., Corbeels, M., Mapfumo, P., Tittonell, P., Vanlauwe, B., Giller, K.E. (2009). Nitrogen and Phosphorus capture and recovery efficiencies and crop responses to a range of soil fertility management strategies in sub-Saharan Africa. Springer
9. De Kock, G.C. (2012). Lucerne-King of fodder crops. Agricultural Research Institute. Grootfontein
10. Desjardins, R.L., Smith. W., Grant. B., Campbell. C., Janzen. H., Riznek. R. (2002). Management strategies to sequester carbon in agricultural soils and to mitigate greenhouse gas emissions. Presented at the International Workshop on Reducing Vulnerability of Agriculture and Forestry to Climate Variability and Climate Change. Ljubljanu, Slovenia, Oct. 7th – 9th
11. Environment Bay of Plenty. Uses and Management of Tagasaste (Chamaecytisus palmensis). Sustainable options.
    Retrieved from: http://www.boprc.govt.nz/media/29167/LandManagement-090526-Factsheet19.pdf on the 24th March 2014 @ 22h53
12. FAO. (2001a). Farming systems and poverty. Improving farmer's livelihoods in a changing world, by J. Dixon, A. Gulliver & D. Gibbon. Rome, and World Bank, Washington DC.
13. FAO. (2004a). Carbon Sequestration in Dry land Soils. World Soils Resources Reports No. 102. Rome, Italy.
14. FAO. Farming systems that grow and save: Crop production intensification will be built on farming systems that offer a range of productivity, socio-economic and environmental benefits to producers and to society at large. Save and Grow. Factsheet 1. Retrieved from: http://www.fao.org/ag/save-and-grow/pdfs/factsheets/en/sg-farming-systems.pdf on 26.03.14 @ 00h29
15. Grace, P.R. (1998). Management options to increase soil organic matter and nitrogen availability in cultivated dry lands. In management of nutrients and water in rainfed arid and semi-arid areas. Proceedings. Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture (pp. 40). Austria

16. Johnson, M.F.J., Franzluebers, A.J., Weyers, S.L., Reicosky, D.C. (2007). Agricultural opportunities to mitigate greenhouse gas emissions. Environmental Pollution.
17. Lal, R. (2005). Enhancing crop yields in the developing countries through restoration of the soil organic carbon pool in Agricultural lands. Land Degradation and Development. DOI: 10.1002/ldr.696
18. Lal, R. (n.d). Crop residues and Soil carbon. Carbon Management and Sequestration Center. The Ohio State University, Columbus, OH 43210 USA
19. Liu, E., Changrong, Y., Mei, X., Zhang, Y., Fan, T. (2013). Long-term effect of manure and fertilizer on soil organic carbon pools in dry land farming in North-West China. DOI: 10.1371/journal.pone.0056536. PLOS
20. Matanyaire, C.M. (1996). Pearl millet production system(s) in the communal areas of Northern Namibia: Priority research foci arising from a diagnostic study. In Leuschner, K., Manthe, C.S. (Eds.), Drought-tolerant crops for Southern Africa: proceedings of the SADC/ICRISAT regional sorghum and pearl millet workshop, 25-29 July 1994, Gaborone Botswana
21. Meinsinger, J.J., Jokela, W.E. (2000). Ammonia volatilization from dairy and poultry manure. Managing nutrients and pathogens from animal agriculture
22. Mendelsohn, J., Jarvis. A., Roberts. C., Robertson. T. (2009). Atlas of Namibia. A portrait of the Land and its People. Sunbird Publishers
23. Mendelsohn, J., El Obeid. S., Roberts. C. (2000). A profile of North-Central Namibia. Gamsberg Macmillan Publishers
24. Mendelsohn, J., El Obeid. S., De Klerk. N., Vigne. P. (2006). Farming systems in Namibia. RAISON
25. Mendelsohn, J., Weber. B. (2011: The Cuvelai Basin its water and people in Angola and Namibia. Development Workshop publication
26. Mostert, T., Johr, G., Smith, R. (n.d.). Tree Lucerne: Cream of the crop. Retrieved from: http://www.adessus.com/pdf/issue1/Spectator%20-%20Page%208%20-%20Tree%20Lucern.pdf on the 24th March 2012 @ 22h48
27. Mtambanengwe, F., Mapfumo P. (2005). Organic matter management as an underlying cause for soil fertility gradients on smallholder farms in Zimbabwe.
28. Mudamburi, B., Ogunmokun, A., Kachigunda, B., Kaurivi, J. (2012). A comparison of conventional and conservation tillage tillage implements used for crop production in Omusati Region of Northern Namibia. IPCBEE vol. 37. IACSIT Press
29. Nabhan, H., Mashali, A.M., Mermut, A.R. (1999). Integrated Soil Management for Sustainable Agriculture and Food Security in Southern and East Africa. FAO. AGL/MISC/23/99
30. Nana-Sinkam, S.C. (1995). Land and Environmental degradation and desertification in Africa. FAO Corporate Document Repository.
31. Nethononda, L.O., Odhiambo, J.J.O. (2011). Indigenous soil knowledge relevant to crop production of smallholder farmers at Rambuda irrigation scheme, Vhembe District South Africa. African Journal of Agricultural Research Vol. 6 (11)
32. Newsham, A.J., Thomas, D.S.G. (2011). Knowing, farming and climate change adaptation in north central Namibia. Global Environmental Change. Elsevier

33. Newsham, A.J., Thomas, D. (2009). Agricultural adaptation, local knowledge and livelihoods diversification in North-Central Namibia. Tyndall Centre for Climate Change Research. Working paper 140
34. Ngolwe, A., Fleissner, K. (2002). Soil fertility management for sustained crop production. Ministry of Agriculture, Water and Rural Development. Directorate of Agricultural Research and Training, No. 51

35. Perez, C., Rancoli, C., Neely, C., Steiner, J.L. (2007). Can carbon sequestration markets benefit low-income producers in semi-arid Africa? Potentials and challenges. Agricultural systems. Elsevier
36. Prasad, D.B. (2008). Content Analysis: A method in Social Sciences Research in Teoksessa: Lal Das, D.K, Bhaskaran, V. (toim) (2008). Research methods for Social work. New Delhi
37. Rigourd,C., Sappe, T., Talavera. T. (1999). Soil fertility and minimum tillage equipment trials in the North Central Namibia, in Kaumbutho P.G, Simalenga. T.E (ed). Conservation tillage with animal traction. A Resource Book of Animal Traction Network for Eastern and Southern Africa (ATNESA)
38. Rotz, C.A. (2004). Management to reduce losses of nitrogen in animal production. Journal of Animal Science
39. Rufino, M.C., Tittonell, P., Van Wijk, M.T., Castellanos-Navarrete, A., Delve, R.J., De Ridder, N., Giller, K.E. (2007). Manure as a key resource within smallholder farming systems: Analyzing farm-scale nutrient cycling efficiencies with the NUANCES framework. Livestock Science 112
40. Schlecter, D. (2014.03.04). Namibia: Dry land crop production – 500 – 1000 percent yield increase. New Era Newspaper.
Retrieved from: http://allafrica.com/stories/201403071313.html on 18.03.2014 @ 22:27
41. Schuler, U., Choocharoen, C., Elstner, P., Stahr, K., Zarei, M., Hermann, L. (2006). Soil mapping for land-use planning in a karst area of N Thailand with due consideration of local knowledge. WILEY. DOI: 10.1002/jpln.200521902
42. Schmidt, M.W.I., Torn, S.A., Abiven, S., Dittmar, T., Guggenberger, G., Janssens, I.A., Kleber, M., Kögel-Knabner, I., Lehmann, J., Manning, D.A.C., Nannipieri, P., Rasse, D.P., Weiner, S., Trumbore, S.E. (2011). Persistence of soil organic matter as an ecosystem property. Vol. 478, doi: 10.10.38/nature10386. Macmillan Publishers Limited.
43. Shah, G.M., Shah, G.A., Groota, J.C.J., Oenemab, O., Lantinga, E.A. (2012). Irrigation and lava meal use reduce ammonia emission and improve nitrogen utilization when solid cattle manure is applied to grassland. Agriculture, Ecosystems and Environment 160
44. Shah, G.M., Groot, J.C.J., Oenema, O., Lantinga, E.A. (2012). Covered storage reduces losses and improves crop utilization of nitrogen from solid cattle manure. Springer
45. Sillitoe, P. (1998). Knowing the land: Soil and Land Resource evaluation and indigenous knowledge. Soil Use and Management

46. Srinivasarao, Ch., Venkateswarlu, B., Lal, R., Singh, A.K., Kundu, S. (2013). Chapter-Five – Sustainable management of soils of dry land ecosystems of India for enhancing agronomic productivity and sequestering carbon. Vol. 121. ScienceDirect
47. Sweet, J., Burke, A. (2000). Country pastures/ Forage resources profiles. Retrieved from:http://www.fao.org/ag/agp/AGPC/doc/Counprof/Namibia/namibia.htm on 17/03/2014 @ 23:43.
48. The Namibia Economist. Retrieved from: www.economist.com.na/2011-12-07-11-05-31/agriculture13099-communal-farmer-harvest-bumper-manahangu-crop on 19.03.2014 @ 00:18
49. Tjaronda, W. (n.d.). Conservation agriculture in Northern Namibia yields good results. New Era Newspaper. Retrieved from: http://ctaseminar2008.cta.int/pdf/ClimateChangeNamibia2.pdf on 19.03.2014 @ 00:10
50. Verlinden, A., Dayot, B. (2005). A comparison between indigenous environmental knowledge and a conventional vegetation analysis in north central Namibia. Journal of Arid Environments. Elsevier
51. Verlinden, A., Seely, M.K., Hillyer, A. (2006). Settlement, trees and termites in Central North Namibia: A case of indigenous resource management. Journal of Arid Environments. Elsevier
52. Verlinden, A., Kruger, A.S. (2007). Changing grazing systems in Central North Namibia. Land Degradation and Development. DOI: 10.1002/ldr.769
53. Warren, M.D., Cashman, K. (u.d). Indigenous Knowledge for Sustainable Agriculture and Rural Development. International Institute for Environment and Development. Gatekeeper Series No. 10

Appendixes

1. Questionnaire

2. Field sheet and farm orientation: Farmer identification of land units

3. Farmstead Maps (Farm A, B, C, D)

Appendix 1

Questionnaire

Questionnaire

This study looks at soil management practices in the North-Central region which enhances soil carbon sequestration on agricultural dry-land of small-scale farmers. The intention is to identify and promote management practices that improve soil quality and increase yields, for the substance of food productivity and mitigating climate change.

Information gathered will solely be used for the purpose of this study.

Date of study: 04 August 2012 until 18th August 2012

Josefina Asino
Student: M.Sc. Landscape ecology and Nature Conservation
University of Greifswald

Region:	
Constituency/Oshitopolwa	
Village/Omukunda	
No. of farm:	
Name of farmer :	
Year of Settlement:	

Coordinates:

1. General information

1.1 Gender

M	F

1.2 Age

18 – 25	25 - 32	32 - 39
39 - 46	46 - 53	53+

2. Land use and soil management practices/ elongitho lyevi

2.1 What type of livestock do you have on farm premises?

Livestock	Tick	No.
Goat		
Cattle		
Donkey		
Chicken		
Pig		
Sheep		
Other		

2.2 Do you have a cattle post or is the livestock around all year long? Omuna ohambo nenge iimuna yoye opo hayi kala pegumbo omvula ayihe?

____
____
________.

2.3 Where do you normally graze, inside your fence or outside? Oholithile peni, omeni lyohofa nenge okondje?

____
____
____________________________.

2.4 Are there any food supplements apart from the normal grazing area? Iimuna oha mu yi hawaleke iikulya yilwe yuunongononi nenge oha yi li owala melundu?

____
____
____.

2.5 If there is no food supplement, are grazing areas enough for your livestock? Ngele kapuna iikulya yuunongononi, show a tala omahala gokulithila oga gwana iimuna oku napa?

____
____
____.

2.4 Do you think the grazing area capacity has increased or decreased? Sho watala ehala lyokulithila olya indjipala nenge olya shonopala?

Increased	**Stable**	**Decreased**

2.6 If decreased, what are the measures you have taken to avert the situation? Ngele olya shonopala, owu na shi wa ninga po opo wuli indjipaleke?

____
____
____.

2.7 What do you think should be done to stabilize the situation? Oshike wuwete tashiningwapo shi hwepopaleke onkalo?

____
____
____.

2.8 What are the challenges faced during that period of no fodder for your livestock? Omaudhigu nenge omashongo geni hamu mono pethimbo ndino lye shonopalo wuulithilo?

____
____
____.

2.9 What type of crops do you cultivate and what is its importance on your livelihood? Omaludhi geni giilya hamu longo, na oya simana ngiini moonkalamwenyo dheni / mokukalamwenyo kweni?

	Tick	For subsistence	For sale
Pearl millet/Omahangu			
Sorghum/Iilyalyaka			
Cowpea/Omakunde			
Maize/Omapungu			
Bambara nut/Oofukwa			
Other /Yilwe			

-
____
____

2.10 If for sale, what type of other income sources do you have? Ngele oho landifa ouna sho hashi etamo iiyemo yilwe ishewe?

____
____.

2.11 If only for subsistence, what is your source of income? Ngele iho landitha iilya, ohomono iiyemo tayizi peni?

____
____
_____________________.

2.12 Do you think what you derive from your crop field is enough to sustain your family to the next growing season? Sho watala shi homono mepya lyoye osha gwana okupalutha aanegumbo lyoye sigo ometeyo taliya?

____
____.

2.13 If it does not sustain your family, how do you manage to reach till the next growing season?

____

____

____.

2.14 How big is the yield that you derive from your field in a growing season?

____

____

____.

2.15 What do you regard as a good yield and what is a bad yield?

____

____

____.

2.16 To what extend does rainfall and the eefundja influence your yield?

____

____

____.

2.17 What type of fertilizers do you use to improve soil fertility and rate their importance? Uuhoho wuni ho longitha oku tula mepya; meta ongushu yawo?

	Tick	**Very important**	**Important**	**Moderately important**	**Of little importance**	**Unimportant**
Manure						
Wood Ash						
Compost						
None						

2.18 How frequently are the methods mentioned above applied and how are they applied on the field? Opamalweetho gethike peni hotula omauhoho gatumbulwa pombanda mepya na omikalo dhini hamu longitha?

____

____

____.

2.19 Are there variations of soil fertility on your crop field and does it influence planting?

____

____

____.

2.20 Does the effort of soil management on the field depend on the expectations of the yield on a unit within the crop field?

____
____
____.

2.21 If yes, do you put more effort on some parts of the crop field that provides you with high yield and which units in your crop field are those?

____
____
____.

2.16 What types of ploughing methods or techniques do you make use of? Oholingitha omikaloo dhini dhoku pulula mepya?

Tractor	
Donkey	
By hand	
No tillage	
Other	

2.17 Do you think the ploughing method you use determines the yield that you obtain from your crop field?

____
____
____.

2.18 What are the cropping techniques you apply? ***Please tick*** oholingitha omikalo dhini dhoku kuna iilya?

	Yes	**No**
Intercrop		
Alley crop		
Monoculture		

2.19 Does your cropping pattern influence your yields?

____
____
____.

2.17 Do you rotate your crops? Oho lundulula Omahala mpa ho kunu, mepya lyoye?

Yes	No

2.20 Do you make use of fallow periods? Oholongitha oompito dhokwaalonga?

Yes	No

2.21 How often do you weed your field in a growing season? Ohohele lungapi momvula?

____
____
____.

2.18 What are the constraints do you experience with farming on your crop field?
Omaudhigu geni ho mono muunafaalama woye nomevi lyoye?

Labour/Iilonga	
Land availability/Uukalepo wevi	
Access to seeds/ ompito yokumona ombuto	
Access to fertilizer/ okumona uuhoho	
Weeding/Okuhelela	
Harvesting/Okuteya	
Ploughing/Okulonga	
Others, please mention	

Appendix 2

Field sheet and farm orientation: Farmer Identification of Land Units

Identification of Land use units: Ecological Site Description monitoring

Date: **Name of farmer:**

Name of village: **Responsible person:**

ILU Name:	
Longitude:	**Latitude:**

Years	**Crop(s)**	**Cropping pattern:**			**Soil fertility**	**Weeding**	**Fertilizer use**	**Soil water retention**	**Yield**	**Hard pan**	**Rainfall**	**Fallow period**	**Other Land Uses**
		Intercrop	Alley crop	Monoculture									
2011													
2010													
2009													
2008													

*__Crops__: Maize 1; Sorghum 2; Millet 3; Cowpea 4; Bambara nut 5, others 6; and **Soil fertility** is high; low; poor; **Yield** is (+; -). **Fertilizer use** & **weeding** is either frequently; occasionally; moderately; never. **Water retention** (high; low)**; Rainfall** is very high; high; low; very little, **Fallow period**; never, annually, bi-annual, tri-annual. **Other land uses**; wood resources **WR**; water **W**; grazing **G;**

Appendix 3

Farmstead maps (farm A, B, C, and D)

Document Name: FarmA

Legend

FarmA

Landuse

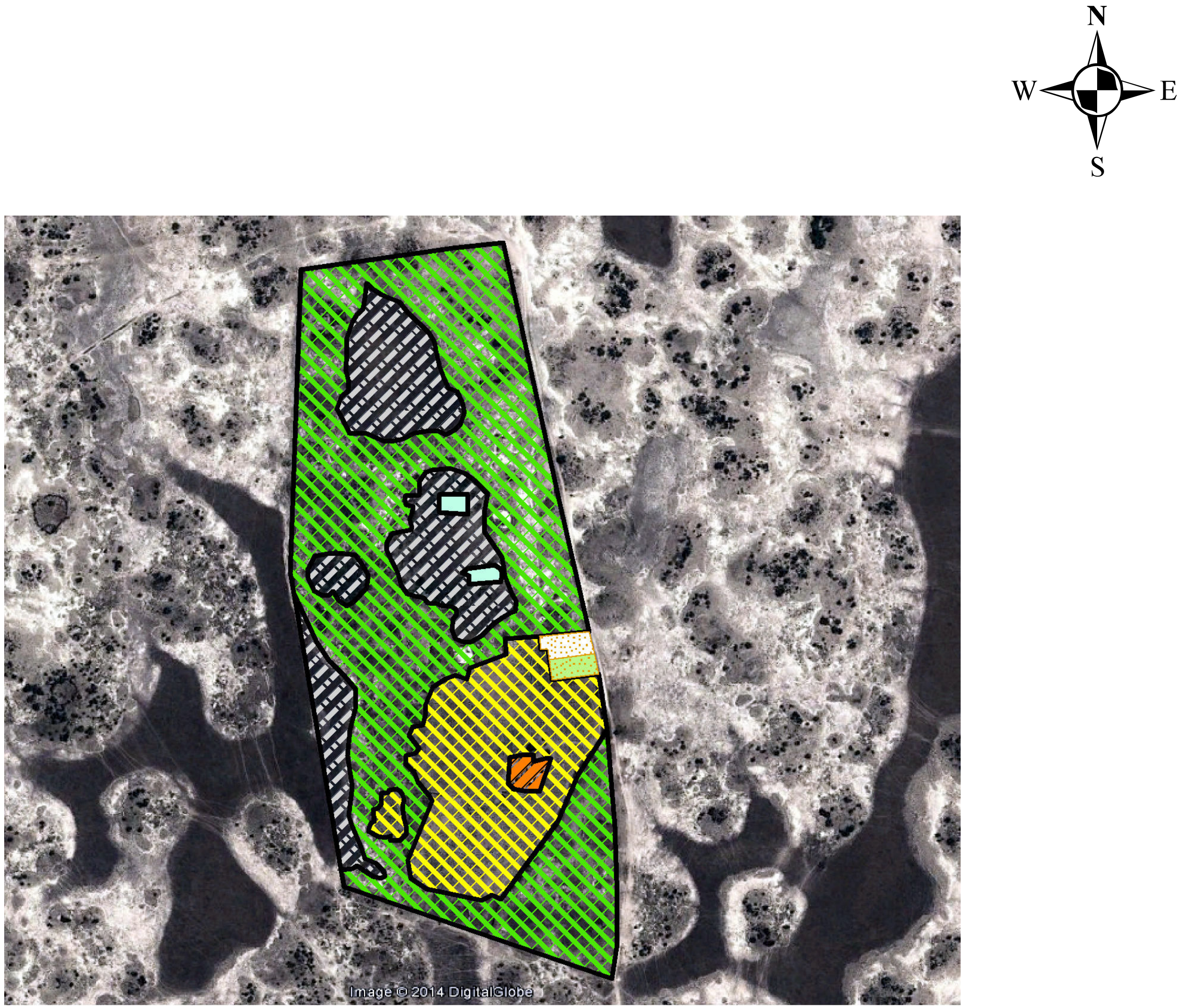
- Bushland/Grazing
- New_Pasture
- Depression
- Cropfield
- Abandoned_field
- Farmstead
- Kraal
- Thrash

0,1 0,05 0 0,1 Kilometers

1:6.000

Author: Josefina Naango Krebs

Document Name: FarmB



Legend

FarmB

Landuse

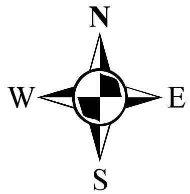
- Bushland/Grazing
- Depression
- Cropfield
- Abandoned_field
- Farmstead
- New_Kraal
- Old_Kraal

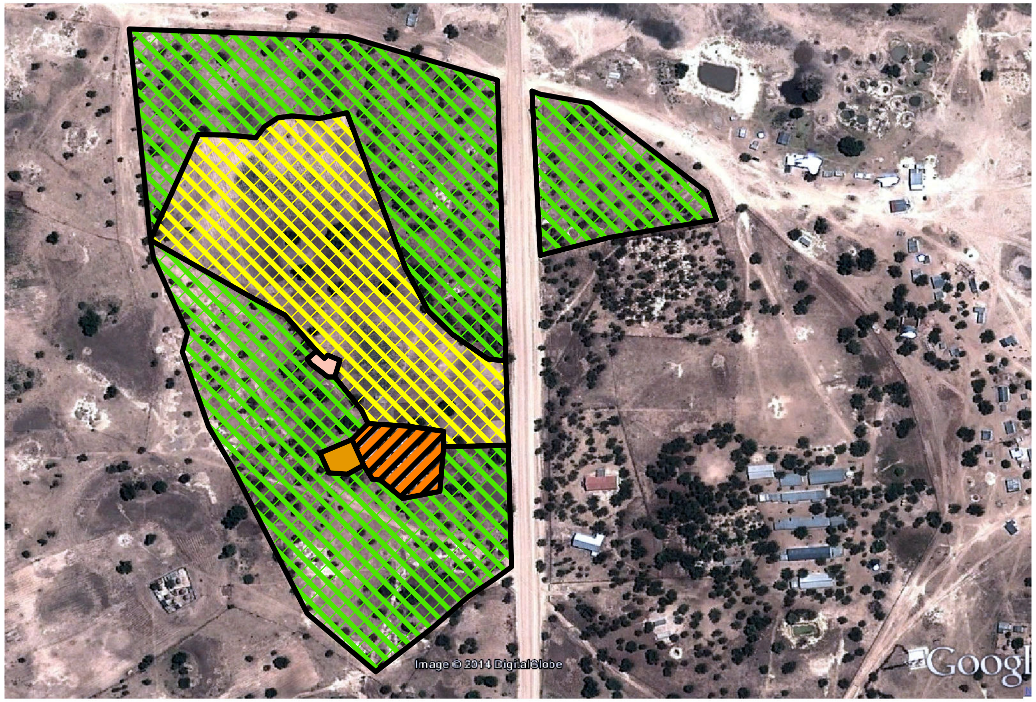
0,150,075 0 0,15 Kilometers

1:8.000

Author: Josefina Naango Krebs

Document Name: FarmC





Legend

FarmC

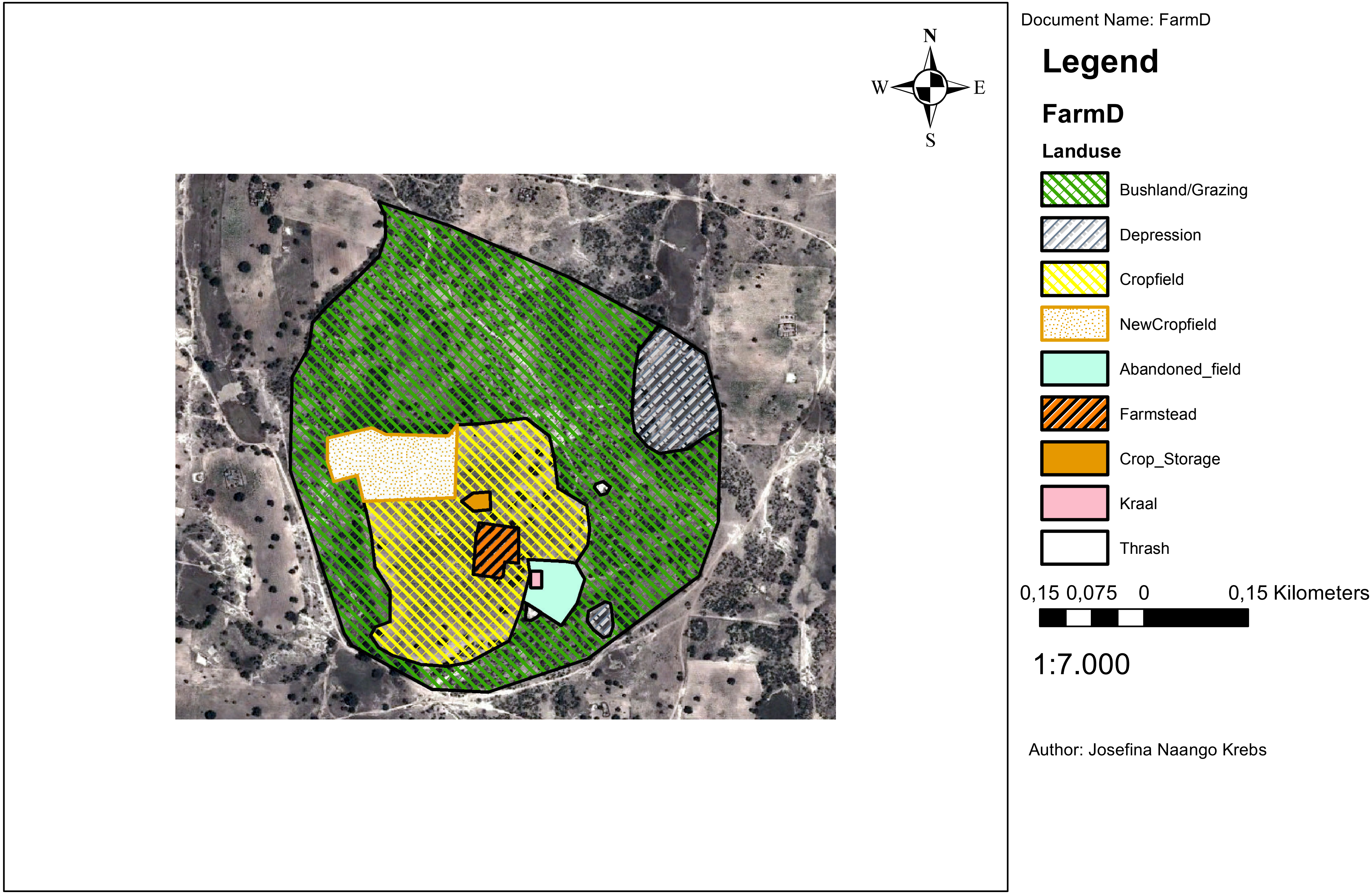
Landuse

- Bushland/Grazing
- Cropfield
- Farmstead
- Crop_Storage
- Kraal

0,1 0,05 0 0,1 Kilometers

1:6.000

Author: Josefina Naango Krebs



N
W
E
S
Document Name: FarmD
Legend
FarmD
Landuse
Bushland/Grazing
Depression
Cropfield
NewCropfield
Abandoned_field
Farmstead
Crop_Storage
Kraal
Thrash
0,15 0,075 0 0,15 Kilometers
1:7.000
Author: Josefina Naango Krebs