Investigating into soil fertility in the North Central regions

by

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Abstract

This paper is a report which intends to identify and investigate some of the fertility problems in the North Central Regions of Namibia. The report first highlights the major features and constraints of three farming systems, with special focus on fertility problems at regional and area levels. It then presents the major soil types identified by farmers and those identified by technicians at plot level. The paper aims at building a basic soil classification. Farmers' strategies to match their crop with their soils, and their fertility management practices are dealt with at farm level. The place for animal traction in fertility management is spelt out.

1. Introduction

In agronomy fertility is understood to comprise the functioning of a biological system with few but interacting components namely; soil, climate and the plant. Subject to technical, economic, social and historical determinants fertility is assumed to embrace the suitability of an environment for agricultural production (Boiffin and Sebillote, 1982).

Although the climate and the soil may be the main components of fertility, a more global perspective is required, which encompasses:

- Physical environment: climate and soil;
- Economic environment: production systems, farmers' integration into input and output markets;
- Social environment: role of livestock (farmers' strategy in keeping livestock);
- Institutional environment, property rights and regimes (for fields and pastures)

According to Memento de l'agronome, (1991) two concepts of fertility must also be presented:

- the current fertility resulting in the current yields achieved by farmers and
- the potential fertility that must be related to the maximum yields farmers could possibly achieve, with no concern for economics and risk.

Some constraints within the farming systems can be alleviated, others cannot and these prevent farmers from achieving the maximum yields.

In North Central Regions (NCR) of Namibia, both soil and climate limit agricultural production and the fertility of the biological system is relatively low.

In general soils are poor in nutrients and organic matter. Alkalinity, salinity, sodality, poor water retention capacity and water-logging are all common features. Rainfall is erratic and low, direct sunlight is extremely intense.
Plants, the third interacting component, are local drought tolerant crops such as millet, cowpeas and bambara nuts. Drought tolerance or short duration plants cope with this environment and are popular with farmers. The drought tolerance of the local millet variety should be stressed. New improved short duration varieties have been developed and widely adopted by farmers such as Okashana No.1. Other improved millet and cowpea varieties are forthcoming.

Fertility is generally decreasing in the NCR. One of the causes lies in the socio-economic environment. The population and livestock pressure on the land has increased as the labour available on the farms has decreased. Other causes are related to farming practices.

Although decreasing fertility is a general trend in the NCR, different areas face different problems related to fertility, hence the need to be area specific.

This report intends to identify and investigate some of the fertility problems in the North Central Regions.

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2. Methodology

The management of fertility determines the functioning of farming systems. Namibia has an history of a farming crisis which saw the collapse of the former system and the emerging of a new one to fit new conditions.

Following the defined global approach to fertility analysis, the approach adopted for this research was to bring together two perspectives:

- a farming system point of view and
- a soil science approach.

Practically this meant recognising the existence of both farmers' and technicians' knowledge in defining fertility. In the "Action Oriented Research (AOR)" approach adopted by the Northern Namibia Rural Development Project (NNRDP), farmer's point of view was paramount, and the farmer and the technologist were equal partners.

Another approach issue was that fertility could not be dealt with purely by soil sampling and soil profile, plot level analysis. If fertility was to be understood within the farming system, it had to be addressed at different levels. The levels adopted were:

- Regional level; for instance to cover cattle movement between posts.
- Farm level; notably looking at farmers' strategies.
- Plot level; to cover say, soil heterogeneity.

Practically, to complete this research in line with the approach presented, the following activities were carried out:

- 22 interviews, specifically on soil fertility, with farmers from 4 NNRDP pilot communities in Central, Western and Eastern areas.
- 15 sites analysed, with 42 soil samples analysed by the agricultural laboratory in Windhoek and soil profiles drawn.
- Interviews with farmers, related to soils, while conducting minimum tillage and weeding tests.
- Literature review.

Actually semi-interviews and sampling mostly covered two areas and two different farming systems identified: the one on the Western area and the one on the central Cuvalai area. Information regarding the eastern area was mostly collected "by the way" and reference is made here to a NNRDP report: "farming system study in Ekolala (next to Enhanha)" by Jocelyne Delarue.

This report first highlights the major features and constraints of the 3 farming systems, with special focus on fertility problems (regional level, area level). It then presents the major soil types identified by farmers and those identified by technicians (plot level), and aims at building a basic soil classification. Farmers strategies to match their crop and their soils, and their fertility management practices are then dealt with (mainly farm level).

3. Results and discussion

3.1 Farming system perspective

3.1.1 Common problems related to soil fertility in the three farming systems

The following fertility problems were encountered in the North Central Regions:

- Soils are sandy.
- Soils are poor in nitrogen & phosphorus.
- Soils are poor in organic matter.
- Soils have a very low structural stability.
- Soils have a poor water retention capacity.
- Soils tend to form hard pans: some inherent to the soil, others formed by repeated ploughing at the same depth.
- Although farmers are well aware of the benefits of applying manure, they do not always have the means to do so: cattle are at the cattle posts, donkeys are not kraalled and labour is not available.
- Water-logging is common although rainfall is limited.
- The water content of some soils may change tremendously over short periods from water-logging to hard crusting on the surface
- rainfall is low, erratic and falls in heavy storms, direct sunlight is intense and temperatures are high.
- farmers practice continuous cereal cropping.
- land is completely bare during the dry season.
- most of the current practices to manage fertility are labour intensive although labour is scarce in the farming system.

The first bottleneck in the farming systems is weeding. One possible solution to tackle that problem is the use of the cultivator for weeding with draft animals. It had indeed

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been successfully tested in pilot communities and its use is now an extension message.

Once the weeding constraint is tackled, soil preparation, harvesting and threshing will be additional bottlenecks needing redress. Possible solutions with regard to land preparation are currently on test in Namibia.

Further problems are fertility and marketing of both inputs and produce.

3.1.2 Specificity of the three farming systems

a) In Eastern areas (pilot community: Ekolala), a forest is established on deep sandy soils. Rainfall averages 450mm. Most of the farms are recently cleared. The population density is still low. This is a pioneer front. Cattle posts are close to the farms.
Area specific problems related to fertility are:
- the sandy soils are particularly poor in nutrients.
- the water retention capacity of these soils is very low.
- the size of the field is initially limited by the labour available for slashing and burning the forest, and also by the stumps in the field.

b) In the Central Oshana Area (pilot community: Eefa and Onamutanda) soils are relatively better, rainfall average. The fields are old with typical Oshana system and dark "clayish" soils. The population density is high. Cattle posts are far from the farms, and cattle tend to stay longer in them.

Area specific problems related to fertility:
- Population and livestock pressure on the land is high.
- The size of the field is limited by high population. Labour is available for soil preparation and weeding.
- Cattle posts are far and cattle tend to stay longer there: horizontal fertility transfer is low.
- There is a shift in draft animal power from cattle: that used to be kraalled, to donkeys, that are not kraalled.

c) In the West (pilot community: Eunda) soils are relatively better and less sandy than in the East. Mopane bush covering a very hard soil is extensive. Rainfall is poor and averages 300-350mm. Population density is low and cattle posts are relatively close. The fields are younger than Central Oshana area.

Area specific problems related to fertility are:
- Rainfall is very poor.
- A Mopane bush with its associated hard soil is widespread: it is assumed that fallow cannot be a fertility management strategy.
- Filds, though young (1-3 years) are said to be less fertile by farmers.

3.1.3 Identification of the major soil types

Scaling the analysis down to the local level (plot/site level), two important characteristics were considered and are stressed
- at the regional level, the soils are generally poor
- at the field/farm level, the soils are extremely heterogeneous: farmers face extremely different soil types on their farm and must adjust their strategy accordingly.

It is sometimes difficult to make a soil classification with regard to soil fertility since a major determinant may actually be the site and topography. There is need to report both soil types and sites in fertility classification.

3.2 Identification by farmers

This section is based on interviews conducted with farmers and presents a simple classification of soils and sites as seen by farmers.

Farmers do not always differentiate soils and sites: hence names given by farmers may characterise either a soil or a site.

To assess the quality and fertility of a soil or a site, farmers are conscious of:
- the soil reaction towards water: farmers consider soil water and not just rainfall to be the first determinant of farm yields. Water percolation and retention are important factors.
- Location of land, hence its water, retention, runoff and drainage characteristics.
- Colour of the soil. Dark and red soils are often considered good.
- Hardness of the soil and texture. Soft soils are often preferred to hard soils.

a) Soft and Deep Sandy Soils are Type No. 1. These are deep sandy and soft soils which rarely form a surface crust or hard pan. Their colour is clear to dark red. Water penetrates easily, but retention

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capacity is poor. These are mostly found in the highest parts of the field.

The following names are used by farmers:

Oshiwamboa name	**Location**
Ehenge (1A)	Eunda, Onamutanda
Omuthitu (1A)	Eunda
Efululu (1B)	Ekolala

b) Low Ground and Swamp, Loamy Sands are type No. 2. These are soils with clay content of 5 to 10%; high by Namibian standards. Their colour varies from dark grey to brown and very dark. Water does not penetrate them easily and tends to flood. These are found in the lowest parts of the field in small to large areas.

Oshiwano name	**Location**
Okashana (small area)	Eefa, Eunda, Onamutanda. Ekolola
Edhiya (small area)	Eunda, Onamutanda
Okatenhegue (small area)	Eunda
Oshana (large area)	Eefa,Eunda, Onamutanda, Ekolola

c) Waterlogged and hard-dry soils are Type No.3. These are relatively shallow soils whose hard pan is between 20 and 30cm deep. Their hard pan forms a hard crust on the surface when water evaporates and their colour varies from clear to clear grey. These soils have important drainage problems. They waterlog even after small showers. The water content of these soils varies tremendously over a short period and the water retention capacity of the soil is low. These soils have poor fertility according to farmers and are found in the low to middle parts of fields. They are common in central Cuvalai areas and in the West.

Oshiwambo name	**Location**	**Location**
Ethenene	Eunda, Onamutanda, Eefa	Eunda, Onamutanda, Eefa
Olundanda	Eefa	Eefa

d) Very hard soils in new fields are type No.4. These are mostly characterised by their hardness and are found in recently cleared fields. The soils tend to be very clear (white) in colour. Water does not penetrate them and this causes water logging. These soils have poor fertility from farmers' point of view. They are found mostly in the Western areas.

e) Good Deep and Dark Soils are Type No.5. These are deep, relatively soft soils, without hard pan and hard crust. Their colour varies from grey, to dark grey and very dark. Water penetrates easily and these soils have the best water retention capacity. These soils are considered the best for cultivation and tend to receive more manure, ashes and food residues.

Oshiwambo name	Location	English translation
Omutunda	Eunda, Eefa, Onamutanda, Ekolola	NA
Elunda	Eefa, Eunda	Former homestead, the heap of ashes and rubbish together

f) Other Unclassified Soils are such as *Oshivanda* (termite hills), which are very hard and impenetrable by water. These are especially good when mixed with other soils, a labour intensive operation.

Oshitunu refers to old termite hills, after being eroded by water and wind. They are considered to be f medium potential by farmers.

Omulonga is a soil where water settles.

Although farmers name many different soils and sites in different ways, the above groupings are considered encompassing.

3.3 Identification by technicians

A general feature of soils in the NCR, apart from those in the *Oshanas* or next to it, is their light texture which ranges from sand to sandy loam and loamy sand. On average the sand content is 87%, clay is 9.5% and silt is 3.5% respectively.
Typically, these soils:

- have a poor water holding capacity
- have a low cation exchange capacity and are generally poor in nutrients except in Calcium.

These sandy textures alone cannot explain the observed soil properties and must be

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considered in connection with compaction and surface crusting, which are important features determination of soil hardness.

Typically, clay content is low in the first horizon of the soil and tends to accumulate in deeper horizons. In turn the pH of soils always increases with depth alongside the increase in clay content. Within a field the pH of the "soft and sandy soils -Type No.1" (acidic) is lower than the one of the "good deep and dark soils - Type No.5" (neutral), and lower than the one of the "water-logged hard dry soils - Type No.3" (alkaline).

The buffering capacity must also be looked at, of which it is noted that due to low organic matter content and low clay content, most soils easily get buffered. The pH is easily altered upward or downward by acids or alkalis. This is true of non-calcareous sandy soils. Thus, although they may be slightly acidic (pH 6-6.5), the pH may be lower or higher around plant roots.

Soils that are calcareous (notably type No. 3 which contains calcium carbonates) may have low clay and organic matter content but may be well buffered. The very high pH soils are also well buffered due to a mixture of carbonates (including sodium). There is nothing that can be practically done to reduce the pH of the saline, sodic calcareous soils. They are very poor in organic matter and this facilitates leaching of nutrients hence a poor chemical fertility, and decline in structural stability of the soil.

Phosphorus is very low and averages 6 ppm, whereas an optimum for grains would range between 15 and 35 ppm. Ca, Mg, P, and K are often unbalanced. Moreover, these nutrients are always leached and concentrated in the deeper horizons, sometimes with accumulation of carbonates and salts in a compacted layer.

a) Soft and deep sandy soils (Type No.1) are always poor in K, P, Ca and often in Mg. They may have the lowest chemical fertility but this does not imply the lowest agricultural fertility since they do not tend to waterlog as Type No.3 does. They are rather acidic, although the pH increases with the depth when the percent sand decreases.

The combination of a low pH and low concentration of both Ca and K makes the availability of these nutrients for the plants low. The low pH results in a low availability of Mg for the plants.

Sodicity may be found in the deeper horizons. These soils are located in high parts of the field. Typical characteristics are:

- Sandy texture
- Low pH (acidic soils)
- Poor in nutrients (low chemical fertility)
- Found in High part of the field

They may be classified as arenosols.

b) Low ground and swamps, loamy sand soils (Type No.2) have a fair amount of silt (around 6-10%) and a high fraction of clay (for NDR) of about 20% in the deeper horizons as major characteristics. Deeper horizons are sandy clay loam soils. These soils are located in the lowest part of the fields and pastures.

Typical characteristics are highest clay content while deeper horizons are sandy clay loam. They are found in lowest areas

c) Waterlogged hard and dry soil (Type No.3), have one horizon or a thin layer where carbonates accumulate. High concentration of Ca may hamper the absorption of other nutrients. These soils have a drastic change in the profile with a hard compacted layer with a higher clay content. Carbonates tend to be accumulated in this horizon. Some possible reasons for hard crusting and hard pan formation are:

- Compaction of clay rich soils,
- Evaporation of salts and salt movement upward in profile,
- Presence of gypsum ($CaSO_4$),
- Soluble silicates such as Sodium and Magnesium (gypsum – sodium silicate + sand would form a cement),
- Presence of Oxides of Fe, Al, Mn etc
- Presence of other soluble minerals

All water-logged sites, and only them, have a high electrical conductivity in the deeper horizons. That reduces salinity. Although the surface horizon has a neutral pH, suitable for cultivation, deeper horizons are alkaline (from pH 8.5 to 10.5).

Deeper horizons are also saline due to high concentration of Na, which will limit some plant ability to absorb water. Furthermore, the high Na concentration induces a low structural stability hence the soil turns to mud easily and becomes very hard consequently. The combination of alkalinity and salinity gives these soils little potential for cultivation.

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Typical characteristics are:

- The presence of a compacted layer that prevents water to penetrate (the soil is not deep),
- An accumulation of carbonates,
- Hard crusting on the surface when water evaporates,
- Very low water retention capacity,
- Very low structural stability,
- Alkalinity and sodicity in the deeper horizons, and
- Salinity.

They may be classified as solonchak.

d) Good deep and dark soils (Type No. 5) have relatively neutral pH and this does not hamper the absorption of most of the nutrients, and is suitable for local crops.

Apart from too little P their common feature is they do not suffer from excess or lack of other important nutrients such as Ca. A major characteristic of this type is the gentle differences in characteristics between the horizons. With little hard crusting on the surface and no compacted layer, water penetrates easily down to the deeper horizons and the soil has a relatively good water retention capacity.

Typical characteristics are:

- Neutral pH,
- Relatively good concentration of the different nutrients (except P), and
- Gentle transition between the horizons allowing a good water penetration and retention.

No sample of very hard soils on new fields (Type No. 4), were analysed. Neither were any other ("non-identified") types.

3.4 Linking farmers and technician's knowledge:

Four of the soil types investigated technically can be linked with those identified by farmers.

- Type No. 1: Soft and sandy soils
- Type No. 2: Low ground, swamps and sandy loam soils
- Type No. 3: Water-logged/hard dry soils.
- Type No. 5: Good deep and dark soils.

Since no soil samples were available of the "very hard soil on new field (No. 4)" and "non identified types", (identified by farmers), it is not possible to confirm or deny the existence of such types from a technical point of view. Since, within a farm the soils are highly heterogeneous, all these different types may be found, plus some sort of transitional soils. Farmers manage their soils according to suitability for cultivation and that, they judge according to "sandyness", waterlogging qualities and other practical aspects like hardness.

Since soils and sites are linked, these can be indicated on a transect (see Figure 1). Figure 2 exposes possible assumption explaining soil evolution.

4. Farmers' management of fertility

4.1 Use of manure

Cattle and goat manure are well used by farmers to improve the fertility of their field, but donkey manure is hardly used. From the kraal to the field, manure is mostly transported in baskets and sometimes on donkey carts. The "permanent kraal" is displaced every few years to spread the fertility. At the time, the poles used for the kraal are changed and the former kraal site is cultivated. Often there is a "small temporary kraal" moved every few months over the field. This kraal was mostly be used for goats. In this case of study, manure was always applied on a site as a curative measure (when yields were poor) and never as a systematic preventive measure.

Manure was often applied as dry powder. Only a few farmers reported mixing it with straw or grass to increase its quantity. Straw and grass were preferentially given to livestock as fodder. Manure was first applied to millet plots, rarely to cowpeas and never to bambara nuts and groundnuts. When the "permanent kraal" was shifted maize was cultivated on the site to benefit from a very high organic matter content. When the "temporary kraal" was moved, either cereal (preferentially millet) but rarely cow peas were cropped.

Farmers face two problems that limit the use of manure:

- Application is labour intensive. This is probably the major reason why farmers do not apply manure more often. Manure can only be applied before ploughing to avoid losses because of the wind.
- The availability of the manure itself. Cattle tend to stay longer in the cattle posts, which sometimes develop into secondary farms.

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Donkeys are hardly kraalled and common thinking is that donkey manure is not good for the soil. This in turns does not facilitate the use of donkeys as draft animals. Goats are always kraalled at night, but produce little manure compared to the needs of the farm. Nevertheless, on some farms goat manure may be the only source of manure.

4.2 Movement of the house and use of household residues

Ashes are always spread around the homestead. This brings some nutrients to the soil, but little organic matter. Food residues, if not given to livestock, can also be spread around the homestead and this contributes to some organic matter. The homestead and its surrounding are places where nutrients and organic matter are accumulated. Every few years it is shifted and the site having a good fertility is preferentially cultivated with millet. Since brick houses are increasingly common, labour intensive, shifting cultivation is on the decline.

4.3 Ridges and soil preparation

For the last twenty years, ridges have been common in Eefa. Fewer were observed in Eunda and none in Ekolola where sandy type soils make them less necessary and more difficult to erect. Unlike western and central areas where crops are cultivated on the top of the ridges to avoid excess water, in the sandy eastern areas, farmers cultivated their crops in the furrow. Whereas in many other countries ridges are often used to concentrate chemical fertility at locations where the crop actually grows, it was not the case in the areas studied. The major reason for erecting ridges was soil water management.

Traditionally, farmers ridged the ground into small mounds. These were few square meters large and erected using a hand hoe. This practice is still in use by farmers not having animal draft power. Ridges other than mounds are increasingly in use, and this is facilitated by the use of animal power and the plough. The biggest ridges are often perennial (30-40cm high and 1.2m wide) and are maintained by a combination of the plough and the hand hoe. The medium sized (20-30cm high, 1-2m wide) are temporary and are made with the traditional plough. The smallest (20cm deep and 0.5-1m wide) are temporary and either made with the traditional plough or the hand hoe. Some furrows are simply those left by tractors which disc the fields. Ridges are important for soil and water management. The orientation of the ridges may change from one year to the other in sites with a flat or even sloppy topography. Regarding soil water management, ridges have the effects illustrated on Figure 3.

The use of animal power facilitates the erection of these ridges with an efficiency and economy not comparable to the hand hoe or tractor with disc plough. Farmers did not favour the tractor due to fear of it bringing poor soils from high depths to the soil surface.

Nevertheless farmers who want to prepare their fields early, so as to benefit from the first rain, when their draft animals are still weak, favour the tractor, provided the waiting list for tractor is not too long.

4.4 Use of fertiliser

Fertilisers are hardly used by farmers since they are not available in remote areas. The use of fertilisers on sandy soils and with low erratic rainfalls is controversial. The following arguments have been raised

- If farmers invest in fertilisers and the rainfall are very poor, the benefit in term of extra production may not be worth the cost as it decreases marginal returns.
- Since the organic matter content of the soil is very low, the nutrients brought by the fertiliser are leached to the deeper horizons and do not benefit the crop.
- Unbalanced fertiliser, notably with a too high nitrogen content may adversely affect plant growth: the aerial part may develop too quickly compared to the root system.
- Application of fertilizers in case of drought may have negative effects on the soils.

Nevertheless one obvious fertility problem in the NCR is the very low Phosphorus content. Phosphorus may therefore be acceptable.

Potassium and Magnesium may only be necessary for some “soft and deep sandy soils (Type No. 1) having a poor chemical fertility. Calcium may not be required.

Very little information is available with regard to micro-nutrients, hence it is not possible to conclude. Eventually, fertilisers may not be applied in the absence of manure.

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5. Conclusions and follow-up

5.1 Conclusions

The soils in the North Central Regions tend to be very poor in nutrients and organic matter. Furthermore some nutrients are unbalanced. This induces a poor chemical fertility. The physical fertility of many soils tends to be very low. Being mostly sandy soils their water retention capacity is low. Moreover, they tend to have a very low structural stability.

Other more specific characteristics should be stressed such as salinity, sodicity, alkalinity, and water-logging.

A basic classification would be into five soils types, soft and deep sandy soils, swamps and loamy sand soils, water-logged/hard dry soils, very hard, new field soils and good deep and dark soils. A major finding was that soils are extremely heterogeneous.

Farmers would then rather think in terms of relative properties rather than absolute properties of soils. They relate better to conditions such as, hardness, water retention, water logging etc.

Technicians should than most probably also consider these types in more relative terms than absolute terms. Thinking in these relative terms, farmers decide on their copping pattern to firstly secure their millet production. Each plot is used for the crop it is most adapted to.

Some fertility problems are general to any type of soil, such as the limited organic matter content. Some others are type specific, and should receive a special interest. This calls for follow-up work.

5.2 Future work

Farmers have been involved in this research, and the results should now be presented to them. Notably, the soil classification should be presented to them and they should either confirm it, modify it or reject it. The same should be done for the other conclusions. This would ensure that technicians have good understanding of the situation and the problems.

Moreover, this investigation was conducted mostly in the western and central Cuvalai areas. One must now check to what extent the conclusions can be extended to the Eastern areas.

Ground has been laid as a first step for farmers and technicians to begin to discuss as equal partners with common understanding.

Farmers and technicians can focus on some of the problems related to soil fertility. This requires, ranking these problems with farmers. The knowledge that the ranking by farmers may be different from that by technicians is well placed.

The main problems to be discussed could be little organic matter content, lack of phosphorus, problem of poor water retention capacity, problem of water-logging, decreasing fertility trends and how to address them.

Further investigation through interviews, soil profiles, laboratory analysis could be conducted as necessary.

Conducting such tests should help the technician in refining, diagnose and better answer farmers' constraints.

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