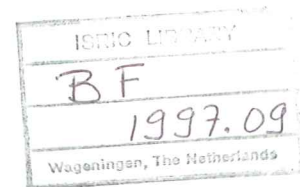


**NATURE OF THE SOIL, CULTIVATION PRACTICES AND LAND  
DEGRADATION IN SANMATENGA, BURKINA FASO**

**A.C. Loerts  
januari, 1997**



## PREFACE

In 1992 an interdisciplinary research program was started by the Wageningen Agricultural University (WAU). This program is named "Aménagement et Gestion de l'Espace Sylvo-Pastoral au Sahel (SPS)". It is carried out by WAU, in Burkina Faso represented by the Antenne Sahélienne, in co-operation with the University of Ouagadougou, Burkina Faso. The objective of the program is to determine the production level, the management type and the role of village communities in 'sustainable' management of the natural resources in the Sahel, and in particular in Burkina Faso.

The government of the Netherlands has incorporated Burkina Faso in the official aid program led by the "Directoraat Generaal Internationale Samenwerking (DGIS)" of the ministry of Foreign Affairs, since 1974. The co-operation program with Burkina Faso is directed to sustainable development of agriculture on behalf of food supply, to a wise conservation of the natural resources and to drinkwater supply. DGIS has several institutions spread all over the country which are called PEDI (Programmation et Execution de Developpement Intégré). One of these institutions is placed in Kaya, the capital of the province Sanmantenga, about hundred kilometers north of Ouagadougou.

In August and September 1996 this study was carried out in the context of a stage from the University Utrecht. The study was made as a part of a co-operation between PEDI-Kaya and the Antenne Sahélienne.

First I would like to thank my supervisor Maarten Tromp who advised me in setting up and evaluating this study. Thanks also to Paul Tholen, working at PEDI-Kaya, who helped and advised during the period in Burkina. Last but not least thanks to Philomé without whoms perfect French and Mossi I would not have been able to interview the farmers.

A.C. Loerts

Scanned from original by ISRIC - World Soil Information, as ICSU World Data Centre for Soils. The purpose is to make a safe depository for endangered documents and to make the accrued information available for consultation, following Fair Use Guidelines. Every effort is taken to respect Copyright of the materials within the archives where the identification of the Copyright holder is clear and, where feasible, to contact the originators. For questions please contact [soil.isric@wur.nl](mailto:soil.isric@wur.nl) indicating the item reference number concerned.

# TABLE OF CONTENTS

1. INTRODUCTION.....	2
2. ENVIROMENTAL CONDITIONS.....	3
2.1 LOCATION .....	3
2.2 GEOLOGY AND GEOMORPHOLOGY .....	3
2.3 HYDROGRAPHY .....	3
2.4 CLIMATE .....	4
2.5 VEGETATION.....	4
2.6 LAND USE.....	4
2.7 DESCRIPTION OF THE RESEARCH SITES.....	5
<i>Crusted middle slope (C21)</i> .....	5
<i>Non-crusted middle slope (C22)</i> .....	5
3. METHODS.....	7
3.1 INTERVIEWS .....	7
3.2 SOIL ANALYSES.....	7
<i>Texture</i> .....	7
<i>Organic matter content</i> .....	8
<i>Soil reaction (pH)</i> .....	8
<i>Cation-exchange capacity (CEC)</i> .....	8
<i>Individual exchangeable cations, sum of bases and base saturation</i> .....	8
4. SOIL EROSION.....	9
5. NATURE OF THE SOIL, RESULTS & DISCUSSION .....	10
5.1 TEXTURE.....	10
5.2 ORGANIC MATTER.....	11
5.3 SOIL REACTION (PH) .....	13
5.4 CATION-EXCHANGE CAPACITY (CEC).....	13
5.5 BASE SATURATION.....	14
5.6 INDIVIDUAL EXCHANGEABLE CATIONS .....	14
<i>Interpretation of exchangeable calcium (Ca)</i> .....	14
<i>Interpretation of exchangeable magnesium (Mg)</i> .....	15
<i>Interpretation of exchangeable potassium (K)</i> .....	15
<i>Interpretation of exchangeable sodium (Na)</i> .....	16
6. CULTIVATION PRACTICES, RESULTS & DISCUSSION.....	17
6.1 CROPS.....	17
6.2 ANIMALS.....	17
6.3 TILLAGE.....	18
6.4 FERTILIZER.....	19
6.5 MULCHING (PAILLAGE) AND CROP RESIDUES .....	20
6.6 WEEDING.....	20
6.7 SOIL CONSERVATION.....	21
<i>Stone dikes</i> .....	21
<i>Hedges</i> .....	21
7. OTHER FACTORS .....	22
7.1 CLIMATE .....	22
7.2 SLOPE OF THE LAND .....	22
8. CONCLUSION.....	24
LITERATURE.....	25



## 1. INTRODUCTION

The care of the soil is essential to the survival of the human race. At a time of rapidly increasing population and increasing food shortages it is obvious that every effort must be made to protect the soil in order to increase, or at least sustain, food production. Both water and wind erosion, but also mismanagement, have damaged the soil in such a way that it has led to soil erosion on a vast scale, that is, the physical loss of the upper layer or top soil, the most vital part necessary for healthy plant growth. Once this top layer has been lost, it has for all practical purposes gone for good.

Research indicates that the problem of soil erosion is not just a physical one. The major reasons of soil erosion are socio-economic and often mainly political. A small farmer in miserable condition cannot be blamed for damaging vegetation and soils if he tries to get a minimum of food for his family. As it is a national problem the remedy lies in the application of soil and water conservation practices through a national soil conservation program. In order to achieve sound conservation projects the precise causes of the soil degradation must be known.

In the region around Kaya, the research area of this study in Burkina Faso, land form units are found in different stages of degradation. The objective of this research is to find out the land management practices that have led to the degradation of these different land form units and the present degree of degradation. For this purpose three land form units were selected that are found throughout the research area, so that the results are representative for a large part of the research area. Of each land form unit one degraded and one none- or hardly degraded site were examined, after which these six sites were compared.

The sites are described with the use of a 'general soil information framework' (FAO), as used in previous studies in the research area. This information is supplemented by information of augerings. In case the site was sloping the augerings were made in a transect over the hillslope in order to get information about the toposequence. Furthermore land characteristics were measured and aerial photographs and satellite images interpreted to determine the state of the soil in previous years. To determine the (historical) landuse and soil management, interviews were held with the local population.

The following degraded sites were examined:

- A) An alluvial fan, on a middle slope near Tagala (coordinates 691200, 1439500)
- B) A middle and lower slope, between a laterite cap and 'bas-fond' (bottom land), near Sian (696000, 1447000)
- C) A middle slope in material of the Ante-Birimien, near Fatin. A part of this site is cultivated by a farmer who participates in a PEDI-project.

To make sure the land elements and conditions are the same the non-degraded equivalents are located next to the degraded sites.

First a description is given of the research area. This description includes position, geology, hydrography, climate, vegetation and land use. Besides this, the six research sites are described. Next, the methods used in collecting the data are given, followed by a description of soil erosion and the factors, that influence the degree of soil degradation, are discussed. These are the nature of the soil, the cultivation practices and other factors such as climate and slope. This part consists of the theory of each factor as well as the results and a discussion. Finally a conclusion is given.



## 2. ENVIROMENTAL CONDITIONS

### 2.1 Location

The study area is part of the province Sanmatenga in Burkina Faso (fig. 1). The six studied sites are situated in the southern part of the province, near Tagala, Sian and Fatin. They can all be visited within an one and a half hour drive from Kaya, the capital of the province with 30.000 inhabitants.

The site Tagala has the Universe Transverse Mercator (UTM) co-ordinates 1439500, 691200; The site Sian has the co-ordinates 1447000, 696000.

The description of the environmental conditions is taken from van Asten and van de Pol (1996) while they conducted a soil survey in the same area in 1994 and already described the environmental conditions.

### 2.2 Geology and geomorphology

Burkina Faso is part of the African shield. This shield was formed in the Precambrium and consists of rocks older then 600 millions years (Kroonenberg, 1985).

In Burkina Faso, one can find formations of the Precambrium A, Precambrium C (the Birimien) and Precambrium D (the Antébirimien). In southern Sanmatenga this is restricted to the formation of the Birimien, whereas the northern part consists of the formation of the Antébirimien.

The Birimien has a history from 2300 MA up to 1500 MA years ago. Periods of tectonic activity accompanied by some volcanic activity resulted in the formation of mountain chains, which consist mainly of metamorphic and some volcanic rocks. The altitude of these chains is about 500 meters high. One can find greenschists, schists, quartz, manganese-quartz, graphite, basalt and some pyroclasts (volcanic sediments). At the end of the Eocene (37 MA) the landscape consisted of a slightly undulating peneplain, submitted to strong weathering and leaching. During the Neogene (25-5 MA), especially its last 3 million years (the Pliocene) with its various rainy periods, pedogenetical processes created slopes with plinthite that, during drier periods, hardened into extremely hard ironstone crusts. As a result of relief inversion (by erosion) the ironstone crusts (often abusively referred to as laterite) are nowadays often present in the form as plateau's. This plinthite formation and hardening is still active nowadays. During the glacial periods of the Pleistocene arid and humid climatic conditions succeeded each other. In the early Weichselien transversal dune patterns developed (Sombroek & Zonneveld, 1971). They are now present as fixed dunes.

### 2.3 Hydrography

From a hydrographical point of view, a distinction can be made between the northern and the southern part of the province Sanmatenga. Almost all the valleys in the southern half of the province drain in the Nakambé (the former White Volta). The northern area however is part of the Niger basin (Hottin & Ouedraogo, 1975). Water, which flows only in the wet period, is partly collected in artificial lakes. Most of these lakes do not dry out during the dry season.

## 2.4 Climate

The studied sites, just as the whole southern part of Sanmatenga, fall in the subsahelian climatic zone (Guinko, 1984).

The climatic data of Kaya are given in Table 1. Temperatures in Kaya are highest just before the wet season (March, April and May) and immediately after the wet season (October). The coldest periods are in the middle of the wet season (July, August and September) and in the middle of the dry season (November until February) (Guinko, 1984).

Annual average rainfall in Kaya dropped from 762 mm in the period 1951-1967 to 638.3 mm in the period 1968-1985. Annual rainfall decreases in Sanmatenga from 650 mm at the southern border of the province to only 430 mm in the most northern part (CILLS, 1992).

Table 1: Kaya average monthly precipitation (in mm) calculated from years 1968-'85, maximum and minimum temperatures (in ° C) calculated from years 1962-'80 (CILLS, 1992).

Month	Jan.	Feb.	March	April	May	June
prec. '68-'85	0.0	0.8	6.4	6.9	37.3	95.6
max. '62-'80	32.9	35.7	38.0	39.0	38.3	35.2
min. '62-'80	16.9	19.7	22.9	25.4	25.4	23.2

Month	July	Aug.	Sept.	Oct	Nov.	Dec.
Prec. '68-'85	160	205	102	13.0	0.0	0.0
max. '62-'80	32.2	30.7	31.8	35.9	35.6	33.0
min. '62-'80	22.1	21.3	21.7	22.6	19.8	17.5

## 2.5 Vegetation

The studied sites are located in the transition zone between the Sahelian steppe vegetation and the Soudanian savanna vegetation (annex 1). Therefore its vegetation is called a Sahelo-Soudanian vegetation (Guinko, 1984).

The structure of the vegetation varies with the land form units. It differs from herbal steppes on the soils parts of hills and plateau's, via steppes with herbs, shrubs and small thorny trees in differentiating abundance (depending on the degree of erosion), to park steppe vegetation with high deciduous trees, and finally to woodlands along the valleys.

## 2.6 Land use

The province Sanmatenga is inhabited by Mossi as well as Peuhl. In former times the mossi practiced agro-sylvopastoral systems and the Peuhl pastoral systems. Some Peuhl also practiced agriculture. Because the soils were used extensively, both systems were complementary. The cattle grazed in the natural vegetation and the fallow lands, and after the harvests they ate the remnants of the harvests on the agricultural fields (Van der Hoek et al., 1993).

Since the pressure on land is increasing, these two systems are more and more becoming competitors. The competition is centered around the best soils of both systems, the lower slopes and the valleys. These are used for agriculture during the wet season and for



pasture during the dry season. Problems can arise when harvests are late and herds of the Peuhl have already arrived.

## 2.7 Description of the research sites

Three degraded land form units are selected that are found all over the research area so that the results are indicative for a large part of the research area. Of each unit a degraded and non- or hardly degraded site was examined, after which these six sites were compared. The non-degraded sites are located next to the degraded ones to make sure the landform and conditions are the same. The three degraded sites all consist (partly) of the land element "crusted middle slope (C21)". The three non- or hardly degraded sites all consists (partly) of the land element "non-crusted middle slope (C22)" (van Asten and van de Pol, 1996). This classification was determined by means of the augerings and soil analyses. Both land form elements belong to the land form unit "middle slope (C2)". Middle slopes can be found directly under the "upper slope". In this unit both erosion of light material (runoff) and deposition of coarse material (run-on) plays an important role. The slope gradient does not have to be high. The middle slope has been split up at the level of land elements, according to surface characteristics. A short description of these two land elements, according to van Asten and van de Pol (1996), is given below.

### *Crusted middle slope (C21)*

This unit is characterized by a nearly flat crusted surface, often alternating with patches of vegetation. Water runs off readily. When the crust is removed, or covered with a thin sand layer, as is the case with the patches, water can infiltrate and arable cropping is possible.

The slopes are well drained, having a slow internal drainage, but with moderately rapid run-off. The soil texture of the upper 15cm is mostly sandy loam. The CEC is very low (5-10 cmol/kg soil), base saturation is generally higher than 50%. The former A-horizon, containing organic matter, is mostly eroded away, resulting in a low organic matter content of the upper soil.

The dominant bare surface soil is directly exposed to the destructive impact of raindrops and sun baking, resulting in the formation of extremely hard and compact crusts, that restrict augering.

The most common soil within this unit is the Lixisol, which is known for its susceptibility to erosion. Another problem of these soils is that the regeneration of these soils is very difficult and the crusted areas still expands (according to interview information and satellite images), forming a threat to adjacent areas which are often still used for arable cropping.

### *Non-crusted middle slope (C22)*

The crusted areas are alternated by areas with denser vegetation. These non-crusted areas are less affected by erosion, due to better infiltration rates and the occurrence of obstacles such as vegetation.

The soils are well drained and show a variety in surface characteristics. A thin to medium thick surface crust is commonly found, but less pronounced and hard when compared to the crusted middle slope. The soil texture of the upper 15cm is mostly sandy clay loam, sandy loam according to van Asten and van de Pol (1996). Here too the CEC



is very low and the base saturation is higher than 50%. Organic matter is low, though slightly higher than on the crusted middle slope. The vegetation coverage is higher than on the crusted middle slope, this is not caused by more trees but by a higher coverage with grasses and shrubs.

This land element is used for extensive grazing by herds and some agriculture, especially on the transition to the lower slope.

The most common soil is the Lixisoil. This land element is very susceptible to erosion too. Degradation of these soils results in an expansion of the total area crusted middle slopes. What precisely leads to the degradation is not yet known.

### 3. METHODS

#### 3.1 Interviews

Interviews were held with the local population to determine the present-day and former land use, soil management and possible conservation measures on the sites. These interviews were held with 13 farmers who own ground at one of the six research sites. The interviews were conducted with assistance of an interpreter who spoke French as well as Mossi, the local language. The questions asked are given in annex 2 and a summary of the results is given in annex 3.

#### 3.2 Soil analyses

Of each site a bulk sample was taken to determine some physical and chemical characteristics of the soil. Samples were taken of the upper 15 cm of the soil. They were analyzed in a laboratory of the University Utrecht in the Netherlands. The results of the analyses are given in annex 4.

The different analyses made will be described in the following paragraphs and are mainly based on information from Landon (1984) and Boerma et al. (1995).

##### *Texture*

Particle size analyses is used to determine the proportion of different sized particles in a soil and hence its textural class. In a natural soil, the particles are held together, either by electrostatic interaction or by a variety of organic and inorganic substances. Therefore, an analytical pretreatment has to be performed for removal or reduction of these cohesive bonds in order to ensure a well-dispersed sample. These bonds are removed by treating the sample with hydrogen peroxide and HCl. The pretreated samples are wet-sieved to separate the sand fraction (2 - 0.05 mm diameter). After drying at 105°C the sand was weighted.

For the silt and clay size fractions sedimentation techniques were used; they are based on the Stokes' Law relationship between the diameter of suspended particles and their rate of settlement in a liquid at constant temperature. The procedure after pretreatment is to allow the dispersed soil to settle slowly in a column of water. The pipette method was then used to measure the soil still suspended; by choosing suitable sampling times, the measurements can be used to calculate different particle size fractions in the soil. In this case it were the fractions <2µm (clay) and 2-50µm (silt). The stove-dry soil contents were determined by weighting after evaporation of the water.

The results of the particle size analyses are given as percentages by weight of the 'fine earth' fraction of <2mm diameter. The proportions of sand, silt and clay were used together with a texture diagram to determine the textural class of the soil.

It is risky to compare the results with results of other analyses because the results are highly affected by pretreatment and by the method itself. So it is important that a standard method is used.

The limits of both soil particle sizes and textural classes, and the method of the measurement, are to a greater or lesser extent arbitrary, and the practical applicability of the results will vary. In some circumstances, finger texturing can give a better assessment of agricultural properties. Soil particle sizes and textural classes should therefore only be

used as broad indicators of likely soil behavior, unless detailed local correlation's between texture and husbandry are available, which is not the case in this study area.

#### *Organic matter content*

The organic matter content of the soil can be measured by determining the loss of weight that occurs by oxidation of organic matter at high temperatures (550°C). This method is called loss on ignition, LOI. During the glowing the crystal water, that is part of the crystal grid of especially clay minerals, disappears. Furthermore, there is a loss as a result of the dehydration of hydrated ironbonds. A correction has been made for these processes.

The used method is less accurate as the "Walkley-Black method" but quicker and cheaper and the only one possible in the lab used for the analyses. The method is especially suitable for measuring the organic matter content of a well aerated samples with a low lutum content. In this case the method was appropriate while only site A (Tagala) has a high lutum content.

#### *Soil reaction (pH)*

The pH of the soil is determined in a soil/water suspension. The measurements are made on a 1:2.5 soil : water suspension, equilibrated, and measured with a glass-Ag/AgCl electrode.

This method provides adequate information, and has the merit of simplicity. However, there are likely to be appreciable differences between samples taken at the same time from the same depth within the area of any one field, and seasonal difference may be quite marked too. For these reasons, pH can never have a precise significance in agriculture and highly accurate measurement is not required.

#### *Cation-exchange capacity (CEC)*

The CEC is estimated from the amount of a particular cation, Na in this case, that a soil can hold when leached by a buffered solution containing that cation. As leaching solution 1 M ammonium acetate buffered at pH 7 is used. The amount of sodium in the solution is measured with an ICP.

Measured CEC values often depend critically on pH. Different concentrations of leaching solutions used for washing out the excess can also produce very marked effects. Furthermore, the measured CEC values depend on the lutum and organic matter content.

#### *Individual exchangeable cations, sum of bases and base saturation*

Using an ammonium acetate extraction four of the at the absorption complex bound elements, the exchangeable cations, Na, K, Mg and Ca, are leached of the complex. The concentration of these cations in the solution is measured with the ICP.

The sum of bases is determined by adding up the amounts of exchangeable cations. The base saturation is the proportion of the CEC accounted for by exchangeable bases (if the pH of the soil would have been 7.0 !).



#### 4. SOIL EROSION

Erosion is a continuous process which is responsible for the changing pattern of the earth's surface. It refers to the removal, transportation and net loss of soil. With natural vegetation to protect the soil, the soil is usually regenerated at the same rate as it is removed. As soon as the natural protective vegetation is disturbed by, for example, cultivation the natural balance is upset and the soil becomes exposed to the direct action of the two most potent causes of erosion, water and wind. Under these conditions the soil can be washed or blown away at a faster rate than it can regenerate, resulting in a net loss of soil. This is known as accelerated erosion, or more generally soil erosion. The type of element causing erosion is mostly determined by the climate. In the savannah, which the research area is, both agents are at work.

Water erosion consists of the detachment of soil particles by the impact of raindrops and their transportation downslope. This has led to the formation of rills. In the research area however, a more common feature is the loss of a thin surface layer of the soil, classified as 'sheet' erosion. This type of erosion usually does not get enough attention. It is a slow but severe process of damaging land. The final result can be observed only after some decades.

Wind erosion can be a problem in all arid and semi-arid areas, especially here where a dry season occurs. The conditions which allow wind erosion to take place are dry loose soil with little or no vegetation, a relatively smooth surface and a wind of sufficient velocity.

These soil erosion processes are part of the process soil degradation, which refers to the changing of a given soil to one which is less fertile. Soil degradation can result from unsuitable cultural practices and mismanagement, both with and without removal or transportation of soil. The term soil degradation is used here (as in most literature) to include the results of any process- physical, chemical or biological, which leads to a reduction in the quantitative and/or qualitative productive capacity of the soil.

The degree to which the soil degradation as defined above takes place on cultivated lands is influenced by a complex mixture of physical and chemical factors, such as the nature of the soil, cultivation practices, slope of the land and climate (also by economic and social factors but those will not be discussed in this study). These factors will be discussed in the following chapters and it will be examined how much influence each of them had on the degradation of the sites in the research area.

## 5. NATURE OF THE SOIL, RESULTS & DISCUSSION

Soils differ in characteristics depending on their parent materials and the extent to which they have developed under the influence of climate and natural vegetation, a process known as weathering. Some soils are inherently more susceptible to erosion than others or to put it in another way, some are more resistant to erosion than others. This factor, erodibility, is very difficult to measure quantitatively because of the many variables involved, not only when the soil is in its natural state, but particularly after it has been cultivated. There are however properties of soils which in combination affect erodibility, such as the physical quality texture, the chemical composition and the content of organic matter. These factors also indicate the degree of degradation already reached.

### 5.1 Texture

Texture refers to the relative proportion of primary particles of sand, silt and clay in a sample of soil. Due to intense rainfall, the soils can have been subject to a process of eluviation involving downward or lateral movement of clay and other suspended colloids. As a result the surface horizons of these highly leached soils can be of coarse texture, containing little clay and silt (Lal, 1979).

In regions of permanently dry subsoils with rainfall of high intensity and short duration, sandy soils give higher yields, while heavy soils do not yield so well (FAO, 1967).

Silt:clay ratio is an important criterion for classification of soils in the tropics and gives some indication as to whether the soil is weathered. The more weathered a soil is, the lower is its silt content, the silt will be weathered to clay. The older well weathered soils tend to be more resistant to erosion (Lal, 1979). This is acknowledged by Boels et.al.(1982) who states that erosion mainly affects soils with a low clay content, lacking cohesion.

Soils of coarse texture usually have lower levels of available nutrients than those of finer textures (FAO, 1967) and are therefore less fertile.

Table 2: Particle size distribution in % weight

	A Tagala	B Sian	C Fatin	A Tagala	B Sian	C Fatin
	Degraded			Non-degraded		
Clay (<2µm)	37.0	17.6	12.6	24.6	22.4	16.7
Silt (2-50µm)	34.1	26.3	33.1	27.0	20.1	48.6
Sand (50-2000µm)	28.9	56.1	54.3	48.5	57.5	35.7
Texture	CL	SL	SL	SCL	SCL	L

It can be seen in Table 2 that two of the three degraded soils have a low clay content (<20%). This in combination with a high sand content (>50%) makes that they are classified as 'sandy loam' soils. This low clay content can be a result of the degradation of the soil. The lighter parts are washed and blown away. The soils are now subject to erosion, lacking cohesion due to the low clay content. It is imaginable that the yield on this field was unremunerative; according to the FAO (1967) clayey soils give lower yields in these climatic regions. The third degraded soil, the one in Tagala, has a quite different texture. It has a high clay content and low sand content, a 'clay loam' soil.



Two of the three less/non-degraded soils have an equal high clay content as the two degraded soils, so here the silt:clay ratio is much lower (sandy clay loams). This indicates a less weathered and eroded soil, which it is. Here too, one soil is found to differ from the others, the soil in Fatin (site F) has a very low sand and clay content and very much silt. It consequently has the highest silt:clay ratio.

## 5.2 Organic matter

The organic matter content of the soil depends on the balance between supply of dead organic material and its removal. The removal is dependent on the surface runoff and the decomposition rate of the material (mineralisation). High temperatures cause a rapid mineralisation, with an optimum at 30°C, and high rainfall rates cause rapid leaching and thus less organic matter (Boerma, 1992). These circumstances are only the case in the wet season in the research area.

Soils with a high lutum content (sites A, D and E) often have high organic matter content due to the lower mineralisation rate. This is a result of the fact that the organic matter is protected against breakdown by the formation of stable clay-humus complexes (Locher and Bakker, 1990).

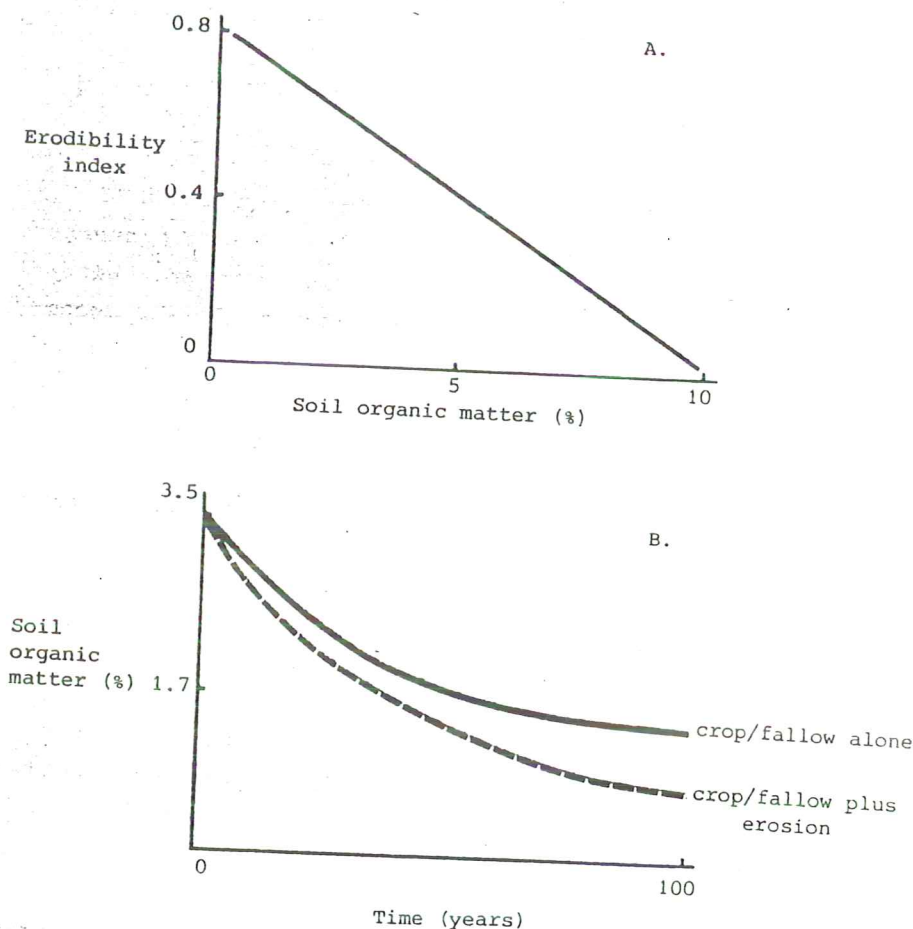


Fig. 1: The relationship between soil organic matter content (%) and erodibility index (A) and the effect of cultivation and cultivation with erosion on the soil organic matter content (B). (Voroney et al., 1980)



Organic matter is of great importance because of its ability to produce a soil with an open poreus, but water retentive structure; it acts like a sponge, taken in retaining water and releasing it as required by the plants. Soils with this kind of structure are very resistant to erosion (FAO, 1979) (fig. 1a). Conversely, nearly all soils with little or no organic matter are very susceptible to erosion. In addition, serious losses of organic matter and colloid friction, due to soil erosion, result in a rapid decline in fertility of sub-tropical soils (Greenland, 1981).

Table 3: Changes in soil organic matter under different systems of management on 15 percent slope of an Alfisol Ibadan, Nigeria (Lal, 1976) (0-10 cm)

Treatment	pH	Organic carbon (%)	Total nitrogen (%)
After clearing Feb. 1972			
Bare fallow	7.3	2.5	0.24
Maize-maize	7.1	2.2	0.19
Cowpea-maize	7.5	2.7	0.25
After 2 crop years Feb. 1974			
Bare fallow	4.2	1.1	0.11
Maize-maize	5.3	1.4	0.12
Cowpea- maize	5.8	1.9	0.16

Data in Table 3 and Figure 1b show that organic carbon declines rapidly under cultivation, particularly if the crop residue is either removed for other uses or is ploughed in. Organic carbon content and total nitrogen may decrease to less than fifty percent of the initial level over a short period of three years (Juo and Lal, 1977). Especially when the soil lies bare, leading to runoff down the bare slope and an increase in temperature and exposition and therefore a more rapid decomposition. It should be kept in mind however, that this decrease in organic matter probably is a result of the erosion of the top 10 cm and not only of cultivation.

Organic matter content of the sites (Table 4) varies from zero to 3.8%. According to a rating of organic matter by Landon (1984) the organic matter content of the sites can be classified as low to very low. An organic matter content of less than two percent as is the case at three sites is according to Barrow (1991) an indication for soil degradation, together with a high risk of soil erosion.

Table 4: Organic matter content of the sites

	A Tagala	B Sian	C Fatin	D Tagala	E Sian	F Fatin
	Degraded			Non-degraded		
Total (%)	3.8	0.0	0.9	2.7	3.8	1.8

Two of the three degraded sites have a very low organic matter content of less than one percent. This indicates severe erosion. The third (Tagala site A) has a higher organic matter content, 3.8%, which is still low according to Landon (1984). The non-degraded soils differ clearly from the degraded sites in organic matter content. They have an average higher organic matter content which is still low though.

All the sites have a low organic matter content due to cultivation and climate. The content of the degraded sites is even lower because they lie bare and are subject to additional organic matter losses through runoff over the bare surface. The former A-horizon, containing organic matter, is mostly eroded away. High temperatures

and exposition at the bare surface also result in mineralisation and therefore decline of organic matter.

### 5.3 Soil reaction (pH)

The pH of the soil greatly affects the nutrient elements and their uptake by the crops. Decline in soil pH may be as serious as decline in soil organic matter content (Greenland, 1981). It gives an idea of the more suitable crops to grow. Landon (1984) gives an idea about the pH requirements for crops to grow and gives a range of pH tolerance for satisfactory yield.

Millet: pH 5-6

Sorghum: optimum pH 6-8, possible pH 5-8.5

Maize: optimum pH 5-7, possible pH 5-8

Table 5: The pH H<sub>2</sub>O of the sites

	A Tagala	B Sian	C Fatin	D Tagala	E Sian	F Fatin
	Degraded			Non-degraded		
pH H <sub>2</sub> O	5.4	5.4	6.1	6.5	6.8	6.7

The three degraded sites A, B and C, all have a pH of lower than 6.1 (Table 5). The non-degraded sites have a pH of 6.5 to 6.8. Clearly the pH of the degraded sites has decreased to a level too low for optimum sorghum cultivation.

### 5.4 Cation-exchange capacity (CEC)

Measurements of the CEC, at a given pH, are related to the sum of the cations held by the permanent negative charge on the clay particles and the cations held by the organic matter. The measurements are commonly made as part of the overall assessment of the potential fertility of a soil. Measured CEC values often depend critically on pH, the lutum content and the organic matter content.

The FAO (1979) quote CEC values of 8 to 10 cmol/kg soil as indicative minimum values in the top 30 cm of the soil for satisfactory production, provided that other factors are favorable. Lower values than these should be highlighted in land suitability classifications. Any CEC values of <4 cmol/kg soil indicate a degree of infertility normally unsuitable for agriculture. According to Landon (1984) a CEC level of >20 cmol/kg in the topsoil is necessary to favor high fertility conditions. The less soils are degraded, the higher CEC they have and the more productive they are (Greenland, 1981).

Table 6: CEC (cmol/kg soil) of the sites

	A Tagala	B Sian	C Fatin	D Tagala	E Sian	F Fatin
	Degraded			Non-degraded		
CEC	9.9	7.1	5.0	14.7	10.9	22.4

The CEC clearly separates the degraded from the non-degraded soils. According to the rating of Landon (1984) the degraded soils all have a low CEC (Table 6). This can very well be a result of degradation. It means the soil has not much nutrient reserves and is



marginal for cultivation. If crops or other vegetation won't grow due to a low pH the risk of erosion also increases.

The non-degraded soils have a low to medium CEC. This is normally satisfactory for agriculture, especially when fertilizer is used. Only the non-degraded soil in Fatin has a CEC value higher than 20 cmol/kg. This soil can be quoted as fertile and is, especially with fertilizer, good for agriculture.

### 5.5 Base saturation

The base saturation is the percentage of bases on the soil absorbing complex; it is the proportion of the CEC accounted for by exchangeable bases (Ca, Mg, K and Na) and is frequently used as an indication of soil fertility. However, the base saturation percentage (BSP) does not distinguish between different bases, and imbalances in their relative proportions can cause severe plant nutrition problems.

Soils with a high base saturation are preferred for agriculture. Soils with a low value are deficient of major essential plant nutrients. Often aluminum is present at too high a proportion on the exchange complex, causing toxicity.

The BSP values are used in soil classification by FAO/Unesco (1974) as indications of soil fertility status:

>50%: more fertile soils (eutric)

<50%: less fertile soils (dystric)

A general interpretation of BSP values is as follows: low <20; medium 20 to 60; high >60.

The BSP values in the research area are medium to high (Table 7). Only the BSP of the non-degraded site in Fatin is low. This is caused by a low sum of bases and highest CEC. On the This is strange because the low BSP indicates a non-fertile soil around Fatin while actually the harvests are best at site F. Furthermore, it can be seen that two of the three degraded sites have relative low BSP values (of around 50%). This is in accordance with the degraded nature of these sites.

### 5.6 Individual exchangeable cations

The levels of exchangeable cations in a soil are usually of more immediate value than the CEC, because they not only indicate existing nutrient status, but can also be used to assess balances amongst cations. This is of great importance because many effects, for example on soil structure and on nutrient uptake by crops, are influenced by the relative concentrations of cations as well as by their absolute levels. According to Thomas (1994) the cations of Na and K disappear first by degradation, followed by Ca, Mg and Si.

#### *Interpretation of exchangeable calcium (Ca)*

Indices of plant-available Ca are of little value, since the availability varies enormously from soil to soil, and is highly dependent on a number of other factors. Normally Ca deficiency as a plant nutrient occurs only in soils of low CEC at pH values of 5.5 or less. Calcium may also be effectively deficient at high pH levels when there is an excessive Na content; this leads to less stable soil structures.

The exchangeable Ca values of the research sites are low (<4) to normal (4-10 cmol/ kg soil) (Table 7). The non-degraded sites, except site F, have higher values than the



degraded sites. The low values can be a result of the degradation, but as stated before indices of Ca are not very reliable as degradation indicator.

Table 7: Individual exchangeable cations, sum of bases and base saturation (cmol/kg soil) of the sites

	A Tagala	B Sian	C Fatin	D Tagala	E Sian	F Fatin
	Degraded			Non-degraded		
Calcium (Ca)	4.11	3.24	4.57	6.68	6.58	2.88
Magnesium (Mg)	1.17	0.66	0.66	1.64	2.49	0.88
Potassium (K)	0.10	0.10	0.14	0.25	1.11	0.27
Sodium (Na)	0.06	0.03	0.02	0.03	0.02	0.12
Ca : Mg	3.51	4.91	6.92	4.07	2.64	3.27
Sum of bases	5.45	4.03	5.39	8.60	10.11	4.15
Base saturation	45.62	56.84	100	58.31	92.85	18.50

#### *Interpretation of exchangeable magnesium (Mg)*

The presence of Mg deficiency in a crop may not only be associated with low Mg content in the soil, but also with the presence of large amounts of other cations, particularly Ca and K. With increasing Ca:Mg ratios above 5:1 the Mg may become progressively less available to plants, although soils can remain fertile over a very wide range of Ca:Mg ratios. When Mg is present in very much larger amounts than Ca, the latter may become somewhat less available, and the soil structure becomes weaker due to increased deflocculation of the clay (Landon, 1984). Both matters, however, are not the case on the sites in the research area (table 7), except for case C, the degraded site near Fatin. This site has a Ca:Mg ratio of 6.92 and might suffer from a Mg shortage, when one would start cultivating again. In none of the sites Mg is present in larger amounts than Ca, so the soil structure will not be weak due to a shortage of Ca.

Deficiency symptoms resulting from low absolute values of exchangeable Mg, rather than cation imbalance, have been reported in acid, coarse textured soils having exchangeable Mg levels of <0.2 cmol/kg soil (Heald, 1965), or <0.5 cmol/kg soil in sub-tropical environments. High levels of Mg may be taken as those above 4.0 cmol/ kg soil.

The Mg levels in the research area can not be classified as high but they are all above 0.5 cmol/kg soil and Mg will be sufficient in the soil (Table 7). Two of the degraded sites have the lowest levels of 0.66 cmol/kg soil. Two of the non-degraded sites have the highest levels, of 1.64 and 2.49 cmol/kg soil. The degraded sites thus have a lower average Mg level (perhaps due to more degradation).

#### *Interpretation of exchangeable potassium (K)*

Exchangeable potassium levels are of only limited value for predicting response since they give no direct indication of the capacity of the soil to release currently unavailable K over a period of time. Moreover, the K status in the well weathered soils in the sub-tropics varies considerably, according to soil mineralogy, parent material and degree of degradation. As all other factors are more or less constant in the research area the K status says something about the degree of degradation. According to Greenland (1981) the majority of soils would become deficient in plant available potassium if the soil organic matter level became depleted as a result of intensive cultivation, especially under improper soil management practices.

In the K levels in the research area there is a distinct difference between the degraded and non-degraded sites (Table 7). The degraded sites all have values lower than 0.14 cmol/kg soil, the non-degraded have values higher than 0.25 and in the case of site

E, Sian, even as high as 1.11 cmol/kg soil. It is clear that the degradation, possibly caused by improper soil management practices, has led to a lowering of the K level of the soil. And the other way round it holds that the K level of the degraded sites confirm that they are really more degraded than the other (cultivated) sites. This can also be seen in the potassium levels necessary for agriculture on sandy loam soils as interpreted in the Ministry of Agriculture Zimbabwe, where levels lowering 0.1 are deficient, 0.1-0.2 are marginal, levels of 0.2-0.3 are adequate and levels above 0.3 are very good for cultivation. In the research area the K level of the degraded sites is deficient to marginal for cultivation, while the non-degraded sites have an adequate to rich level.

#### *Interpretation of exchangeable sodium (Na)*

Although Na may, in particular circumstances, be utilized by some plants as a partial substitute for K, it is not an essential plant nutrient. Its absence, or presence in only very small quantities, is therefore not usually detrimental to plant nutrition. However, when sodium is present in the soil in significant quantities, particularly in proportion to the CEC, it can have an adverse effect on the physical conditions of the soil.

The Na levels of the sites in the research area are not very different from each other and are very low, absolute as well as in proportion to the CEC (Tables 6 and 7). Only site F near Fatin has a slightly higher level, which however is still not high enough to cause adverse physical response.



## 6. CULTIVATION PRACTICES, RESULTS & DISCUSSION

The influences of soil on the rate of erosion are modified by the cultivation or farming practices employed; the way in which the crops are grown, the livestock raised and the land treated by tillage and other means. All plants, animals, soils and tillage implements have characteristics which can be utilized in various ways, some leading to soil erosion and poor yields, others to soil conservation and high yields. Some important examples are mentioned in this chapter.

### 6.1 Crops

The rate of erosion is reduced to the minimum when the soil is completely covered by vegetation. Pasture plants grow so close together that the soil is very efficiently protected from both water and wind erosion. Well managed pasture thus exhibit some of the best anti-erosion measures which can be devised, and they are applicable over a wide range of soils, slope and climatic conditions, including the research area.

In the case of maize, sorghum and millet (the crops grown on the research sites) there is a considerable space between each plant which must be weeded. To obtain maximum yield it is necessary to maintain the optimum plant population and also an optimum spacing between and within rows. It has been found that the spacing within the row can be as close as 15 to 23 cm depending on variety, much closer than was at one time thought possible, without reduction in yield (FAO, 1976). This characteristic is very important from the soil conservation point of view. Crops closer together will prevent erosion to occur. If the rows be planted up and down sloping land, and the soil is erodible, serious erosion may occur from runoff water rushing down the strip of bare soil during heavy rainstorms. On the other hand, if the rows be planted on, or nearly on, the contour the rate of erosion will be greatly reduced because the relative closely spaced plants in the row will tend to check the velocity of runoff and allow more water to percolate into the soil. If the crops are grown on ridges along the contour the erosion hazard from runoff can be reduced still further. This illustrates that the crop itself is not the culprit if soil erosion occurs, but the way it is grown and managed.

In the research area almost all farmers know that it is better to grow the plants on the contour, and they act like it. Whether they knew in the past and when it was introduced is not known. It can be after the degraded sites became bare and in that case it can have been one of the reasons why they became bare. The crops in the research area are not grown on ridges along the contour.

### 6.2 Animals

All kinds of farm livestock, such as cows, sheep and goats can cause soil erosion. They can destroy good pasture by over grazing and trampling. Goats are much maligned because they not only eat and trample all the grass, but browse on shrubs and trees as well until there is not a green leaf or succulent branch left.

After the rainy season the crops are harvested the livestock is admitted on the fields to eat the harvest remnants and to, at the same time, fertilize the soil. The fields that lie fallow are grazed as well. From the interviews it became evident that some farmers weren't glad with the animals on their fields, but they are Peuhl animals and the farmers can't refuse them. Often it is a traditional agreement that the Peuhl can use the



fields after the harvest for the grazing of their animals (Ettema and Gielen, 1992). Many farmers, though, led their own livestock on the field after harvesting. A result can be erosion of the soil.

Soil erosion due to overgrazing results from technical and socio-economic factors, such as poor land management, uneven distribution of animals, too many animals for the carrying capacity of the vegetation; other social factors are that the animals are important in maintaining the social relationships and for festivities and ceremonies. In cases of emergencies selling some livestock can quickly give the farmer some cash (Ettema and Gielen, 1992). The continuous passage of herds of animals from one grazing area to another forms bare paths and tracks which can soon develop into gullies through erosion.

It may be clear, that these results are not the fault of the animals, but the way in which they and the land are managed.

From the interviews it appeared that all the farmers had animals on their fields after the harvest, in almost all the cases it concerned livestock of the Peuhl. One farmer even had his own livestock on the field now and then. Having animals on the field clearly is not a factor that discriminates between the different sites in the research area.

### 6.3 Tillage

Tillage practices and implements have been developed over the centuries to manipulate the soil with the intention of improving conditions for plant growth. The earliest implements are pointed sticks used by hand and that is the ploughing method most farmers in the research area still use, if they plough at all. Some have the later developed hand hoes (iron pointed) wooden ploughs pulled by animals (the *houe manga*). The use of these implements has tended to cause less damage to soil structure than the multi-furrowed ploughs and discs, harrows and cultivators more recently developed by industrial nations.

The importance of tillage from the soil conservation point of view is its effect on soil structure and moisture status. Modern high powered machines are capable of more intensive tillage than the hand and animal operated implements and can be a potent force for soil destruction and erosion, especially in the conditions of the semi-arid zones (FAO, 1976). There is little doubt that semi-arid and (sub-)tropical soils cannot stand up to intensive tillage and mismanagement to the same extent as soils of the temperate regions. Therefore, nowadays the concept of minimum tillage and mulching is gaining considerable support, especially for soils in the semi-arid zones.

Irrespective of the factors discussed above, when ploughing and other tillage operations are carried out up and down the slope of the land in high (seasonal) rainfall areas the result is serious soil and water loss. To reduce the risk of erosion, all tillage operations must be carried out along the contour or at least across the slope (and when necessary supported by conservation measures). In the interviews all farmers who did plough, said to plough along the contour to reduce the rate of runoff and so increase the infiltration and decrease the degree of erosion.

Ploughing means a better soil cultivation in less time than would be needed with the hand. Whether ploughing leads to a higher average yield is hard to say. The main effect seems to be that more ground can be cultivated in the same time (Ettema and Gielen, 1992).

From the interviews it appears that soil tillage reduces or prevents erosion. The fact is that on all the degraded sites there has never been ploughed and that all the non-degraded sites are being ploughed. This indicates that erosion only exists there where the



soil is not ploughed. However, before simply believing this, the following should be kept in mind. The degraded sites are not cultivated anymore and if they have never been ploughed, that might be so because in the time they were still cultivated ploughing wasn't applied yet at all, nowhere. So it is risky to say those sites have become degraded because they were not ploughed. In that case may be all sites should have become degraded. So, it has not been proved that ploughing prevents soil erosion and that the degraded sites have become bare because they weren't ploughed.

#### 6.4 Fertilizer

The major limiting factor in crop production is often available nutrients in soils. Without adding stable manure or fertilizers, crop production depends on the amounts of nutrients released by soil and added by rainwater and dust (Buringh, 1979). In older sub-tropical soils, the amount of weatherable minerals, which can supply necessary nutrients, is little, if any. The nutrient status of soils can be improved by adding natural fertilizers and chemical fertilizers. The advantages of organic fertilizers are increase in organic matter, biological activity and nutrient supply. The content of nutrients in organic fertilizers, however, is rather low. Various experiments have clearly shown that it is necessary for every farmer to collect and preserve as much manure and compost as possible and to add this to his soils. In combination with weeding, it can increase low crop yields by 50% or more. The next step might be application of chemical fertilizers, particularly N, P and K. The first applications of chemical fertilizers are not meant to get high yields, but to increase crop yields under local conditions by 25 or 50%. However, in the sub-tropics chemical fertilizers are fully effective only in combination with humus. This requires the use of organic manure on a large scale to maintain soil fertility. In this dry area there is very little animal manure available for this purpose because most of it has to be used for fuel and as binding material for the construction of dwellings. Composting crop residues or stubbles does not seem to offer much prospect because these have to be consumed by the animals.

The Burkinabé farmers have long believed that the success of the harvest was completely dependent on the amount of rainfall. This situation is changing. The farmers start to realize that a low soil fertility is also an important limiting factor for high yields. But for the farmer the usage of chemical fertilizer is only of use when the harvest increases so much as to give the costs of the fertilizer amply back. Usually this is not the case with millet and sorghum. It is with maize, but only with more rainfall (as in south-western Burkina) (Ettema and Gielen, 1992).

From the interviews it appeared that the farmers believe that fertilizer (chemical or organical) would increase their yield, some said it would double their yield, but have often not enough animals to produce it or money to buy (chemical) fertilizer. Besides, a cart or bicycle are needed to drive out the fertilizer on the field. When they use fertilizer, it is often only on a part of their land or not much, while a few ton's/ha every year are necessary to keep up the soil fertility.

On two research sites chemical fertilizer and compost is used together with manure. These two sites are non-degraded ones. On the degraded sites only one farmer used manure, together with mulch. It is difficult to say whether the use of manure has effect on the degree of degradation. It is likely that without the use of fertilizer the crop growth decreases and thus the chance of erosion increases.



In order to gain insight in the effect of fertilizer simple field trials can be set up, demonstration fields can be set out and within a few years farmers can be advised what to do (Buringh, 1979).

## 6.5 Mulching (paillage) and crop residues

Covering the soil with crop residues such as the straw and stubble of grain crops reduces soil losses very considerably. Systematic use of mulches for soil conservation control and moisture conservation is known as mulch farming. Under this system all or most of the residues from the previous crop are left on the surface of the soil. Mulching for erosion control is of particular value when the crop itself, like maize, sorghum and millet, due to its habit of growth or spacing, does not protect the soil adequately (FAO, 1977).

Crop residues protect the soil from erosion by reducing the impact of rain-drops thus reducing the danger of surface sealing. Residues hold considerable amounts of water at the soil surface, and tend to retard surface flow, which allows more time for water to infiltrate into the soil (FAO, 1977).

Mulches tend to lower the soil temperature and control heat gains during the day and heat losses during the night. This is generally an advantage in warm areas with a dry season as the research area. Mulch prevents surface sealing by preventing direct raindrop impact on the soil, and by encouraging enhanced biological activity, which leads to the development of macropores in the soil. An example of runoff and soil loss under different mulch rates is given in Table 8.

Table 8: Effect of mulch rate on runoff and soil loss on uncropped land at IITA, Ibadan, Nigeria (Greenland and Lal, 1977). Rainfall = 61.1mm

Mulch rate (ton/ha)	Runoff (%)	Soil loss (ton/ha)
0	50.0	4.83
2	19.7	2.48
4	8.0	0.52
6	1.2	0.05

The soil and water loss data shown are an average of four slopes of 1, 5, 10 and 15 per cent. The water runoff and soil loss decreased exponentially with increase in mulch rate:

$$\text{Soil loss: } C''M^k$$

where M is the mulch rate and  $C''$  and k are constants (Greenland and Lal, 1977).

Without machinery mulch farming with annual crops is somewhat laborious using only hand labour. It is very work intensive to cover the whole field with mulch and that is a reason why many farmers do not apply mulching. That is while some see clear advantages in mulching. The farmers say the mulch protects the soil against water erosion and that mulch is necessary to prevent manure from washing away down the slope. One farmer explained he didn't use mulch because the water runoff washed it away anyway. Almost all the farmers led the crop residues on the field. Often only partly because the crop residues are also used to feed the animals.

## 6.6 Weeding

According to Greenland and Lal (1977) clean weeding exposes the soil to erosion unless the crop canopy is thick and close enough to protect the soil adequately. Weed control

can also be obtained by mulching, by the use of herbicides and by close cropping, this is much more desirable than other systems of weeding. Weeding by cultivation, especially where the soil is more erodible and on sloping land, may cause serious erosion. However, according to Ettema and Gielen (1992), who wrote about the situation in Burkina Faso, the removal of weeds is an absolute condition for the success of the harvest. This last assertion seems more acceptable, since all the questioned farmers practice weeding. Probably it is even more effective to weed more times than only one. Some of the farmers weed two or even three times. There is not a relation between the number of times weeded and the degree of degradation of the field.

## **6.7 Soil conservation**

### *Stone dikes*

The construction of a dike of stone along the contour has many advantages. The force of the water runoff is decreased and the infiltration of the water in the soil increases. Secondly, soil is deposited against the stones with favorable consequences for crop growth. Thirdly, the (possible) applied manure washes away less quickly. So, the stone dikes make it interesting for the farmer to start using manure (Ettema and van Gielen, 1992).

The construction of the stone dikes is very laborious. It is typically something to do in the dry season. Even then the construction often takes place during several years. To transport the stones a cart is very important but not everyone has one to his disposal. From the interviews it appeared very clearly that on all the non-degraded sites dikes have been constructed. There aren't any and haven't been any on the degraded sites. It shows that stone dikes are very important to prevent erosion.

### *Hedges*

Another conservation measure is hedges around the fields. These reduce wind erosion but water erosion too. They are especially important in the dry season.

Many farmers have already planted (or constructed of dead material) hedges. In combination with stone dikes they can almost reduce the erosion to zero.



## 7. OTHER FACTORS

### 7.1 Climate

The main elements of climate which affects the rate of erosion are rainfall, wind and temperature. As the research area is one with a high seasonal rainfall it is as well vulnerable to water erosion during the rains as it is subject to wind erosion during the long dry season.

Wind and water are not the only problems in dry areas. Temperatures are usually high, and this means that evaporation is high. Unless adequate precautions are taken, salt toxics to plants are brought up from below and concentrated in the upper layers of the soil.

Semi-arid areas are (also) subject to erosion by water, particularly low lying plains which fan out from range of hills (as case A, Tagala is a good example). During a heavy seasonal rainfall the runoff suddenly rushes down the hillsides and the bare fan as flash floods. These floods can cause extensive damage to soil and, if any, crops and other vegetation. Especially when the fan is bare the water can reach high velocities and has a high potential erosivity.

This factor climate is a very important one. According to Greenland (1981) the erosion hazard in sub-tropical regions is due more to extreme climatic erosivity than to soil erodibility.

Case A, Tagala, is an alluvial fan and will obviously be formed by floods. They will take the fertile upper layer of the soil and prevent vegetation to grow. In order to cultivate this land soil conservation measures have to be taken to slow down the water and make it possible for plants to grow.

As all sites are situated in the same area with the same climate, the climate won't cause differences between them. It can though, be an additional erosion factor once the erosion has started and the soil is already becoming bare.

### 7.2 Slope of the land

The slope of the land, that is its gradient, is an important factor affecting the rate of erosion. Land which has any slope at all, sufficient to allow water to run down it, may be subject to erosion. If the slope is steep it can be expected that excess water from rainfall will run down at a higher velocity than a gentle one and cause more serious erosion. The length of the slope is also important, because it can be expected that the longer the slope, assuming the same rate of rainfall, the greater will be the volume of excess water accumulating upon it, all of which must run down the slope at ever increasing volume and velocity. According to Lal (1976) however, runoff is more dependent on soil hydrologic characteristics and less on the slope steepness.

Water runoff and soil loss observations under straw mulches have supported the belief that slope steepness is not the dominant factor when mulch-farming techniques are employed to prevent erosion. The data in Table 9 (Greenland and Lal, 1977) indicate that soil loss was not significantly increased when slope steepness increased from 1 to 15 percent with mulch rates of 4 to 6 ton's of straw/ha. Fortunately, therefore, soil management can be more important than slope gradient as a factor determining potential erosion hazard.

As all the research sites have approximately the same slope gradient it can not be a reason for a different degree of soil erosion. It can, though, like the climate, be an additional erosion factor once the erosion has started (maybe due to mismanagement) and the soil has already become partially bare.

Table 9: Effect of slope steepness on soil loss (ton's/ha) under continuous maize with mulch compared with the loss of bare soil, Ibadan, Nigeria. (Rainfall is 105.4 mm)

Slope %	Bare plot	Maize=Maize (mulched)
1	0.8	0.00
5	4.27	0.01
10	4.27	0.09
15	29.80	0.02



## 8. CONCLUSION

One factor alone can not be used to predict accurately what will happen on the land under field conditions. The cause of degradation and the degree to which it takes place on cultivated lands is influenced by a complex mixture of physical factors, such as the nature of the soil, slope of the land, land management practices and climate.

Soil management can be more important than the slope and the nature of the soil as a factor determining soil erosion. Proper management practices can reduce erosion to negligible levels. Thus, the erosion in the research area is not caused by the nature of the soil alone, moreover because the nature of the soil hardly varies within the research area. If the right management practices had been taken the degradation probably would not have started or would not have become so severe.

Because the nature of the soil does not vary considerable in the research area it can not give rise to the degraded areas. It does indicate though, something about the degree of degradation that has already taken place. It appeared from the soil texture, organic matter content, pH, CEC and sum of bases of the research sites that the in this research called "degraded areas" really are more degraded than the "non- or hardly degraded" ones.

The degradation can be a result of land management practices, though care has to be taken not to jump to conclusions based on the information from the interviews. That is, the degraded areas are not cultivated anymore. If some practices have never been applied there, that might be so because in the time these sites were still cultivated those practices were not yet applied anywhere. So it is risky to say those sites have become degraded as a result of poor management or of a lack of conservation measures, while that poor management and lack of conservation measures were applied everywhere, on the presently degraded sites as well as on the presently non-degraded sites.

There are however management practices that are presently put into practice on the cultivated sites that have never been applied on the degraded sites. They might presently prevent these sites from degradation and the lack of them might have caused the degradation of the other sites. These practices are tillage, chemical fertilizer and conservation measures as stone dikes and hedges around the fields.

Summarizing it appears that land management practices are the trigger of the soil degradation. In combination with a poor nature of the soil degradation will actually occur.

## LITERATURE

- Asten van, P.J.A. & M.J. van de Pol, 1996. Soil, vegetation, land use and erosion risk mapping in the northern part of Sanmatenga, A guide to the physiographic and erosion map. Antenne Sahelienne. PEDI-Kaya.
- Barrow, C.J., 1991. Land Degradation. pp. 295.
- Begeman, J., J.W. Nibbering, M. Slingerland, E. Munck, L. de Stroosnijder and W. Hoogmoed, 1995. Antenne Sahelienne UAW/UO: Rapport annuel 1994 et perspectives 1995, Amenagement et Gestion de l'Espace Sylvo-Pastoral au Sahel. Wageningen, The Netherlands.
- Boels, D., D.B. Davies & A.E. Johnston, 1982. Soil Degradation. Proceedings of the land use seminar on soil degradation/ Wageningen/ 1980. pp. 280.
- Boerma, J.A.K., 1992. Algemene Bodemkunde. Rijksuniversiteit Utrecht. Vakgroep Fysische Geografie. pp. 102.
- Boerma, J.A.K., P.F.M. van Gaans and C.J.M. Klawer, 1995. Handleiding bij het practicum PRM2-1995/1996 voor tweedejaars Fysisch Geografen. Faculteit Ruimtelijke Wetenschappen, Universiteit Utrecht.
- Buringh, P., 1979. Introduction to the study of soils in tropical and subtropical regions. Centre for Agricultural Publishing and Documentation, Wageningen.
- CILLS, 1992. Atlas agroclimatique des pays de la zone du cills, program agrhymet, Issa Béri, Niamey, Niger.
- Ettema, W. and G. Gielen, 1992. Burkina Faso. Landenreeks K.I.T., Novib NCOS.
- FAO, 1969. Soil Survey Interpretation and its use. Soils bulletin, Food and Agriculture Organisation of the United Nations. Rome.
- FAO, 1976. Soil conservation for developing countries. Soil resources development and conservation service, land and water development division. FAO of the U.N.. Rome.
- FAO, 1979. Soil survey investigations for irrigation. Soils bulletin no. 42. FAO, Rome.
- FAO & Unesco, 1974. Soil map of the world, Vol. 1. Legend - Dudal R. et al., Unesco, Paris.
- Greenland, D.J., 1981. Characterization of Soils, in relation to their classification and management for crop production: examples from some areas of the humid tropics. pp 446.



- Greenland, D.J. & R.Lal, 1977. Soil Conservation and Management in the humid Tropics. Based on the proceedings of the international conference on soil conservation and management in the humid tropics, Ibadan, Nigeria, 1975. Chichester. pp 283.
- Guinko, S., 1984. Vegetation de la Haute-Volta, University of Bordeaux, France.
- Heald, W.R., 1965. Calcium and Magnesium. In: Methods of soil analyses, Part 2, Agronomy No 9; Black C.A. Am. Soc. Of Agron., Madison, Wisconsin.
- Hoek, R. van der, A.Groot, F.Hottinga, J.J.Kessler and H.Peters, 1993. Perspectives pour le développement soutenu des systemes de production agrosylvopastorale au Sanmatenga, Burkina Faso, Documents sur la gestion des ressources tropicales, WAU Wageningen, The Netherlands.
- Hottin, G and O.F. Ouedraogo, 1975. Carte Geologique at 1:1000 000 de la Republique de Haute Volta, notice explicative Direction de la geologique et des mines, Ministere du commerce, du developpement industriel et des mines, Republique de Haute-Volta.
- Juo, A.S.R. & R.Lal, 1977. The effect of fallow and continious cultivation on the chemical and physical properties of an Alfisoil in Western Nigeria. Pl. Soil. 47, pp 567-84.
- Kroonenberg, S.B., 1985. Land forms on the earth in their tectonic and climatic context. Collegedictaat: Geomorfologie 1, Department of soil science, LUW, Wageningen.
- Lal, R., 1976. Soil erosion investigations on alfisoils in southern Nigeria. IITA Monograph No. 1.
- Lal, R., 1979. Soil physical properties and crop production in the tropics. Wiley & Sons. Chichester. pp 551.
- Landon, J.R., 1984. Booker Tropical Soil Manual. pp. 450.
- Locher, W.P. & H. de Bakker, 1990. Bodemkunde van Nederland. Algemene Bodemkunde. Malmberg. pp. 439.
- Sombroek, W.G. and I.S.Zonneveld, 1971. Ancient dune fields and fluviatile deposits in the rima-Sokoto river Basin (N.W. Nigeria), Soil Survey Papers No.5, Netherlands Soil Survey Institute, Wageningen.
- Thomas, M.F., 1994. Geomorphology in the tropics. A study of weathering and denudation in low latitudes. pp. 460.
- Voroney, R.P., J.A. van Veen & E.A. Paul, 1980. Organic carbon dynamics in grassland soils. II. Model verification of cultivation effects and prediction of long term erosion influences. Can. J. Soil Sci.

## ANNEX 1

### MAP OF SANMATENGA IN BURKINA FASO (WITH CLIMATIC ZONES)

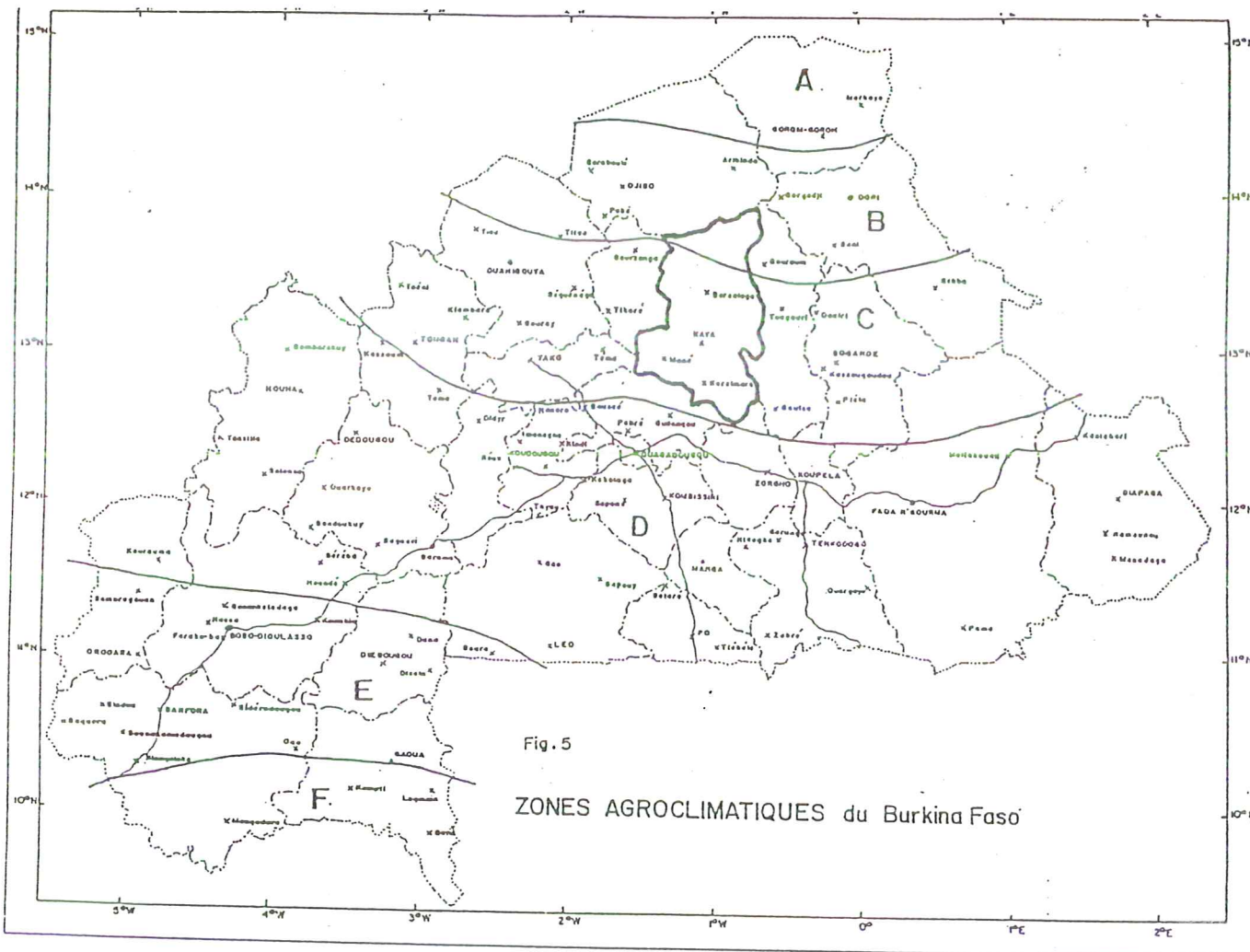


Fig. 5

ZONES AGROCLIMATIQUES du Burkina Faso

Encircled province: Sanmatenga  
 Zone C: Subsahélien Climatic Zone with Sahelo-Soudanien vegetation  
 Zone B: Sahel Climatic Zone with with Steppe vegetation



## ANNEX 2

The questions asked in the interview

### ENQUETE EN FRANCAIS

Numéro d'enquête:

Va ensemble avec unité:

Date:

Nom du paysan:

Age du paysan:

Village:

### GENERAL

1. Quand est ce que vous avez commencé à cultiver le champs ?
2. Est ce que le champs était cultivé en ce temps ?
3. En quel condition était le champs en ce temps (par exemple au sujet de végétation) ?
4. Est ce que vous utilisez le champs toujours ?
5. Si non, quand est ce que vous avez arrêté de l'utiliser et pourquoi ?
6. Quel est le grandeur du champs ?
7. Quel est le type de sol selon le classification traditionnelle ?

### L'AGRICULTURE

8. Quelle culture est semée et quand c'est cultivé (depuis le début de l'exploitation) ?
9. Il y a une rotation de culture, et si oui, de quoi ?
10. Quel est le rendement du champs (en sac/kg)
  - a. pour une année normale ?
  - b. pour une année humide ?
  - c. pour une année sèches ?
11. Est ce que le rendement est resté égal en ce temps, ou est-il augmenté ou diminué (En cas de augmentation ou décroissance: quel était le rendement autrefois) ?

### METHODE DE L'USAGE DU CHAMPS

12. Quand vous semez (en relation de la précipitation) ?
13. Est ce que vous labourez le champs ? Si oui:
  - a. Quel type du charrue vous utilisez ?
  - b. Jusqu'à quel profondeur vous labourez ?
  - c. Quand vous labourez ?
  - d. Combien de fois vous labourez ?

### MESURES POUR CONSERVATION

14. Il y a des mesures pour combattre l'érosion (bandes enherbées, les diguettes de pierre, troncs d'arbres, paillage, labourer au sens opposé de la pente, laisser les résidus des plantes dans le sol) ? Si oui:
  - a. Quelles mesures sont là ?
  - b. Pourquoi ces mesures ?
  - c. Depuis quand (quel temps) les mesures existent ?
15. Est-ce que vous utilisez du fumier. Si oui:
  - a. Quand vous utilisez du fumier ?
  - b. Combien de fumier ?
  - c. Quel type de fumier (paillage, fumier organique/compost, fumier pur, minéraux NPK/urée)?
16. Il y a-t-il de l'irrigation ?
17. Est-ce que vous utilisez des pesticides ?
18. Est-ce que vous éloignez les mauvaises herbes, et si oui de quelle façon ?
19. Est-ce que vous êtes incommodé par le striga ? Si oui:
  - a. Depuis quand ?

## CHANGEMENTS DE CARACTERISTIQUES DU SOL

20. Est-ce que vous avez observé des changements de:
  - a. Végétation
  - b. Striga
  - c. Erosion
  - d. Structure
  - e. Profondeur du sol
  - f. Infiltration d'eau
  - g. Rétention d'eau
  - h. Incrustation
  - i. Fertilité du sol
  - j. Rétention du fumier
  - k. Qualité agronomique

## L'ELEVAGE

21. Il y a-t-il de l'élevage dans le champ ? Si oui:
  - a. Quels et combien des animaux broutent sur le champ ?
  - b. Quelle partie de l'année sont-ils là ?
22. Il y avait un parc d'animaux ?
  - a. Il y a/avait un accord avec les Peuls ?



# ANNEX 3

## SUMMARY OF THE RESULTS OF THE INTERVIEWS

		A Tagala	D Tagala	B Sian	E Sian	C Fatin	F Fatin
		degraded	non-degraded	degraded	non-degraded	degraded	non-degraded
based on interview		5	1	2, 13	8, 12	9	4
hectare		3	2.5	3	2	2	1.5
traditional soil type		Zimidi (=zegdega ?)	Zimidi (=zegdega ?)	Baftanga (Zipélé)	Baftanga	Zegdega	Zegdega
cultivation since ...		ancestors	ancestors	ancestors	ancestors	ancestors	ancestors (15yr himself)
still cultivated ?		not since 10 yrs.	yes	not since 7/15 yrs.	Yes	not since 1 yr.	Yes
landuse	past	sorghum	sorghum	sorghum, millet	rotation: 3 yrs sorgh, 1 yr cot.	sorghum	sorghum maize peanuts cabbas
	present	-	sorghum	-	rotation: 3 yrs sorghum, 1 yr peanuts	-	+ rize maniok potato pima tomatoes etc.
yield	past	2 carts/ha	more	2 carts/ha	?	2 carts/ha	less
	present	-	2 carts/ha	-	8 carts/ha	-	5 carts/ha
ploughing ?		no	yes (a part)	no	yes	no	yes
fertilizer ?		no	yes	no	yes	yes	yes
pesticides ?		no	yes	no	yes	sometimes	yes, since 6 yr
weeding ?		yes	yes	yes, 2 times	yes, 3 times	yes, 2 times	yes
conservation measures ? which?		Hedges, crop residues	stone lines, hedges, crop residues	no	stone lines, crop residues	crop residues, pailage (wants: hedges + stone lines)	pailage, stone lines, hedges, crop residues
striga ?		not much	yes	much/no	yes, every 3th year	yes, not much	no, not since 3 yrs
cattle-breeding ?		after the harvest	after the harvest	after the harvest	after the harvest	now and then	only in sorghum after harvest
changes of the land ?		less vegetation, crust formation less fertile less quality		less vegetation. now erosion less infiltration less fertile	less vegetation. same quality but less rain	less vegetation now erosion less fertile	no erosion more fertile better quantity
reason degradation		less rainfall	less rainfall erosion	shortage of rain	little rainfall since 7/8 yrs bad conservation	less rainfall	-

# ANNEX 4

## RESULTS OF THE SOIL ANALYSES

	A Tagala	B Sian	C Fatin	D Tagala	E Sian	F Fatin
Degraded				Non-degraded		
Particle size distribution in % weight						
Clay (<2µm)	37.0	17.6	12.6	24.6	22.4	16.7
Silt (2-50µm)	34.1	26.3	33.1	27.0	20.1	48.6
Sand (50-2000µm)	28.9	56.1	54.3	48.5	57.5	35.7
Texture	cl	sl	sl	scl	scl	l
Organic matter content						
Total (%)	3.8	0.0	0.9	2.7	3.8	1.8
Exchangeable bases (cmol/kg soil)						
Calcium (Ca)	4.11	3.24	4.57	6.68	6.58	2.88
Magnesium (Mg)	1.17	0.66	0.66	1.64	2.49	0.88
Potassium (K)	0.10	0.10	0.14	0.25	1.11	0.27
Sodium (Na)	0.06	0.03	0.02	0.03	0.02	0.12
Sum of bases	5.45	4.03	5.39	8.60	10.11	4.15
CEC	9.9	7.1	5.0	14.7	10.9	22.4
Base saturation %	45.6	56.8	100	58.3	92.9	18.5
Elec. Cond. (ms/cm)	0.06	0.14	0.07	0.06	0.14	0.6
pH H <sub>2</sub> O	5.4	5.4	6.1	6.5	6.8	6.7