# Minimum tillage for soil and water management with animal traction in the West-African region



by

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***Abstract***

*The paper reviews the utilization levels of animal traction for better soil and water management, through conservation tillage in the West Africa region. Various tools and techniques used by farmers are reported. Recommendations in order to improve farmers' environmental conditions for better agricultural productivity and sustainability have been proposed.*

## 1. Introduction

Farmers in the West-Afiican region are mainly smallholders who must contend with increasing population pressure on available land, low level of mechanisation, short fallow, permanent cropping and risky rainy, seasons. The existing farming systems seem to be vulnerable with regard to continuous degradation of the farmers' environmental conditions. Current practices have led to advanced soil erosion which has compromised productivity on both land and crops.

Farmers depend greatly on animal traction for energy supply to meet their agricultural production objectivés. The energy provided represents more than 90% of the mechanical energy used in agriculture in the area of study. The use of animal traction is viewed by Jaeger (1984) as an important step in creating more production opportunities and increasing retums through better land preparation and jmproved timeliness of field operations. However, the intensity of animal traction utilisation in relation to the level of farmers' experience is highly variable from country to country.

Animal traction was introduced in Senegal, Guinea and Mali in the late 1920s and early 1930s. The most significant impact of animal traction in today's farming systems has been the increase in cultivated area per active household member rising from 30 to 40% in Senegal and 40 to 70% in Mali.

For the last two decades, agriculhual production throughout the Sahel has been mainly bound by the shortage of rainfall along with its uneven distribution during the rainy season. The amount of rainfall has decreased by an average of 33 to 45%, inducing new farmers' production strategies towards meeting food security requirements (Posner *et al.*, 1988). The coping strategies translate the farmers' concern to reach sustainable cropping systems through decisions to be made on when and how to conduct field activities in relation to available resources (Jouve, 1986). However, there is a number of limiting factors on farmers' performance which can help explain their response to the situation.

A number of research studies, conducted both on-station and on-farm throughout the region, have shown that sustainability of cropping systems is better achieved when agricultural practices are aimed at improving plant-soil-water relations.

### 1.1 Objective

The objectives of this paper are:

(i) to review the use of animal traction in the region towards better soil-water management through conservation tillage,

(ii) to identify the most suitable tools and techniques available to farmers and

(iii) to formulate recommendations in order to improve farm environmental conditions for enhanced sustainability.

To do so, major research findings in relation to major constraints to soil-water management, tillage and crop growth are discussed. Most of the researches on animal traction have been conducted in Senegal, Mali, Guinea, Togo, Sierra Leone, Burkina Faso, Niger, Nigeria and Tchad. However, there is emphasis on research activities conduced in Senegal.

## 2. Climate and soils description

### 2.1 Climates

The climatic transition in West Africa takes place across a short distance between humid and dry weather. In this short distance away from the equator, the occurrence of two rainy seasons is observed. The dry spell between the two rain seasons is short and can vary in length in relation to the duration of the sun cycles. Vegetation in the area corresponds to the humid forest. The high amount of rainfall has the tendency to create more soil nutrients and leaching problems leading to fragile and infertile soils. Soil protection is a must.

As pointed out by Beets (1990), the weather around the 15$^0$ latitude is divided into two distinct seasons in relation to occurrence of rains: dry season and rainy season. The area where this climate prevails is becoming narrower with the global pejoration of the weather. The rainfall is still significant and relatively reliable. It stretches from moist to forest Savannah with an average annual rainfall of 1000 mm. Water runoff is a serious problem as are forest tires during the dry season. Fires are frequent and can burn completely the grass covering and protecting the soil, leaving bare soil surfaces to receive the first tropical rain events at the beginning of the rainy season.

Northward, the semi-arid to arid types of climate prevail in the central and northern part of Sahel countries from Senegal to Tchad. The weather is dry and hot with one short rainy season. Rainfall is unreliable as drought situations are always reported from year to year in terms of mid-season droughts or dry spells during the rainy season. Many studies have showed difficulties encountered in finding solution to the drought situations.

Dupont (1986) and Sivakumur (1988) developed techniques to predict the level of probability of dry spells from the onset of rains to the end of the final development stage of the crops grown at the farm.

### 2.2 Soils of West Africa

The soils in the West-Afiican region have been surveyed for more than twenty years by teams of African and European soil scientists. Charreau (1974) published the first most exhaustive soil classification for the Sub-Saharan Africa. This was made possible by a team of IRAT and ORSTOM (France) soil scientists. The West-African soil map was made of 12 classes subdivided into sub-classes, groups and sub-groups, families, series and types of soil. The family was composed of soils originating from the same kind of parent material. The series related to the position of the soil on the toposequence and the types to the texture of the surface horizon. Sub-Saharan Africa was divided into five large zones (Charreau, 1974):

- In the northern part of Senegal, Mali and Niger and Tchad: sand and dunes.
- In the Niger River's arc and in a great part of the Tchad basin: alluvial deposits ranging Çom pure sand to fine clay.
- West, South-West, and East'of the Niger River's arc in Burkina Faso, in two-thirds of Senegal, and in Southem Tchad were found the Terminal Continental formations. The materials generally went through a strong ferralitic alteration.
- In the Southern part of Niger River's arc, in the central part of Mali, and in the Western part of Burkina Faso is a vast area of Combro-Ordovician sandstones overlanded by an ancient "lateritic" iron pan.
- In the southem part of Mali, in Burkina Faso, in the central part of Tchad: crystalline shield made up of plutonic rocks, metamorphic rocks and volcanic rock"

The soil map showed that large areas of the West-African region are occupied by grey and yellow-to-beige ferragenous soils (Alfisol), and by red ferralitic soils (Oxisol). These soils are mainly characterised by a field capacity of 15 to 20% v/v and a wilting point of 7 to 9% v/v. The oxic horizon of the ferragenous and ferralitic soils are mainly made of a mixture of three elements: kaolin, amorphous hydrated oxides (iron and aluminium), and quartz. They are desaturated and characterised by a low cation exchange capacities (CEC) due to the presence of kaolinite, and by having almost reached the end of weathering in their evolution.

The ferragenous soils ("sol beige") present a sandy to course loamy texture in the upper horizon with a sub-angular blocky structure and a fine loam to fine clayey texture in the deeper horizon with angular blocky structure. The ferralitic soils ("sol rouge" or red soils) present some alfic characteristics with sub-surface horizons made of clay accumulation. Their texture and structure are similar to the grey type. Other important types of soils are those located in dryer areas, mainly made of sandy texture and these soils represent a transition between ferragenous and vertisol types (Ducreux, 1984).

The characteristics of these soils are important for two main reasons:

- the wetting and drying cycles in relation to the aggregates and structure stability, and
- the hardening process ("prise en masse") taking place during the dry season and after intermittent rainfalls followed by dry spells during the rainy season.

For these reasons, the management of soil moisture regime appears to be a critical issue for plant growth in this part of Africa, especially at the beginning of the rainy season.

Nicou (1975) had studied these two combined characteristics which tend to confer to thesoils specific physical and mechanical behaviour. A major finding, confirmed by Ducreux (1984) was the fact that the low clay content in the upper horizon (8 to 12%) and the presence of kaolinite are responsible for the tendency of the aggregates to harden through cementation during the drying phase of the cycle.

A textural index called 'Hardening Index", defined as the ratio of the clay content over the coarse fraction of the soil (coarse silt + coarse sand), was introduced to describe the physical behaviour of the tropical soils. They found that there was a linear relationship between the hardening of the soil upper horizons and the HI index for soils studied in Senegal and Niger. The higher the HI index, the higher the tendency of the soils to harden during the drying phase of the cycle.

The phenomenon just discussed was found to be important in relation to crop production, in tillage and in root penetration. If the hardening process took place during land preparation, the draft required (averaging 250 kN) on these ferrogenous and ferralitic soils was too high for draft animals found in West-Africa. For better utilisation of existing animal-drawn farm implements and optimisation of available animal energy, more studies need to be oriented towards determining the soil specifio resistance to traction at different soil moisture level.

After the occurrence of the first usefùl rain, farmers in their majority do not carry out field operations at optimal soil water content as the window in terms of working days is usually too short to allow the completion of the task on time (Fall, 1985; Lee *et al.*,1993). In relation to other limiting factors, farmers need to be aware of the different techniques used in conservation tillage in order to take full advantage of the available soil water content.

The key success to environmental and farming system sustainability is to train smallholders to become soil moisture managers by giving them more insight on subjects like:

- Animal-drawn implements selection with suitable working components.
- Physical and mechanical characteristics of their soil types.
- Soil moisture regime (infiltration, holding capacity).
- Consumption rate and vegetative development of grown crops.

## 3. Conservation tillage with animal traction

Research activities on no-till, minimum tillage, and later on conservation tillage with animal traction started in the early 1960s in many West African countries. These activities were mainly conducted on station until 1979 when the shortage of rainfall and the drought situation induced significant changes in farmers' production systems. However, conservation tillage could not be isolated from the broader practices of soil conservation. The baseline was to develop techniques that:

(i) reduced the number of mechanised field operations,

(ii) improved timeliness of field operations,

(iii) reduced energy requirements,

(iv) reduced wind and water erosion,

(v) improved soil-water availability to plants,

(vi) maintained soil fertility,

(vii) reduced capital investment for farm implements.

The combination of two or more conservation practices must contribute to the implementation of a sustainable farming system to preserve the enviromnent. Sustainability is complex concept as shown by the many definitions encountered in literature. Jodha (1990) cited by the FAO ( 1994) gave a comprehensive and sufficient definition:

*"the ability of the agricultural system to maintain a certain well-defined output level ofperformance over time, and if required, to enhance that output without damaging the essential ecological integrity of the system".*

In the dry and semi-humid West-Africa, the onset of the rainy season has been investigated by Sivakumar (1988) who stipulated that it corresponds to:

*"the date after May 1st when rainfall accumulated over 3 consecutive days is at least 20 mm and when no dry spell within the next 30 days exceeds 7 days".*

Because ofthe hardening process phenomenon discussed earlier *("prise en musse")*, **most** of the tropical soils can be worked only if the soil is wet enough to allow the working component of the implement to penetrate the soil surface. When dry, the amount of draft required is just too high for the species of draft animals used by farmers. The moisture of status of these soils (ferralitic and ferragenous) is such that the plastic phase is non-existent as the soil goes from solid (11 to 13% v/v) to liquid (14 to 17% v/v) state (Ducreux, 1 984; Fall, 1992). Seedbed preparation with animal traction is only possible in the friable state of the soil.

Field'operations monitoring and experiences have showed that a 20 cm mouldboard plough (working at an average depth of 10 cm gave the be$t results in terms of draft requirements and weed control. Two techniques are applicable: ploughing and ridging. To prevent soil erosion, the field must not be ploughed to the edge, a narrow band of grassed unploughed land needed to be left to prevent lose soil particles to follow waterways (Fall, 1985). From the onset of rains, the number of working days is the most limiting factor for farmers to achieve their production objectives in terms of amount of land to seed on time and energy requirements. Le Moigne (198 1) found that on one hand, ploughing and ridging were not advisable for rainfall between 30 mm/day and 50 mm/day. On the other hand, the operation was difficult to perform after a 10-day dry spell. If performed correctly, these seedbed preparation techniques gave the best results with regard to yield, plant roots development and soil protection.

### 3.3 Post-trop development cycle tillage in wet soil

This technique has shown its merits in many experiences conducted on-station, The target farmers are the same as the above, in areas with annual rainfall greater than 800'mm. The best results were obtained in rice growing areas where soils stayed wet longer than in upland areas after the rains had stopped. The main objectives of this end-of-season-tillage was to take full advantage of the level of current status of soil moisture and to bury the crop residues, after harvest, in order to protect the soil from wind erosion and to increase soil organic matter. The techniques are yet to be accepted by farmers who are still using crop residues for animal feed or as input for other off-season activities.

More investigations and research are needed to design adequate implements and working components to carry out this type of tillage with animal traction. The main constraints are: effrciency of crops residues burial, level of draft required, and alternatives for animal feed.

### 3.4 Seedbed preparation in dry soil

Farmers located in areas with rainfall less than 600 mm are subject to drastic year-to-year weather variation as drought is more frequent and severe. It is crucial for farmers to take advantage of all the soil moisture provided by unpredictable rain events. For this reason, the soil water management techniques must go beyond tillage to include landscape improvement (live fences, windbreaks). There is no need to wait for the onset of the raih season to start field activities. The seedbed preparation in dry soil gives more timeliness in terms of weeding performed as early as possible to allow adequate crop germination and development as the rain season is short. Three techniques with specific implements are available to farmers:

1) tillage in dry soil conditions,
2) scarification with tines and different sizes of sweeps, and
3) direct seeding with no-till.

#### 3.4.1 Ploughing in dry soil

Ploughing in light soil is hard to perform. The difficulties reside in the lack of stability of the implement as the furrow is cut but not overturned. This technique of ploughing leaves an heterogenous soil surface (Ducreux, 1984) to be subjected to wind and first rain event erosion. The practice is not sustainable over time and should not be advocated to fat-mers. In heavier soil, it is not only the quality of the tillage which is a problem but the draft requirements are just too high. Implements are subject to damages and to rapid wear. Field tests have reported the wear of 1 share per day in ferragenous soils.

### 3.5 Scarification of soil surface

The seedbed preparation with implements (generally toolbars) equipped with a set of sweeps (3 or 5) of different shapes (full, half and sizes (200 mm to 350 mm). The technique consists of allowing the sweeps to till the soil subsurface and to undercut any standing stubble and weeds. The

The dynamic characteristic of sustainability, as time is involved, required farmers to adapt their practices according to the changing environment (meteorological, economical, etc.). In these conditions the use of animal traction has a significant role to play towards helping farmers achieve more durable reproductive farming systems. Seedbed preparation represents the most critical field operation for which to find adequate solutions in relation to better soil-water management, soil protection and energy savings.

The energy savings aspects are viewed by many policy makers as a real dilemma as many experiences around the world have showed the positive correlation between energy input and crop yields per ha. It must be emphasised at this point that the energy involved in this study is more mechanical than commercial.

### 3.1 Energy savings and soil protection

Conservation tillage aims to maintain and enhance soil productivity by preventing land degradation. The reduction of the number of field operations is achieved with animal traction in comparison if compared with conventional tillage. The level of investment on farm implements is lower with minimum tillage compared to conventional.

An important and undesirable side effect of tillage is soil compaction as energy from farm equipment traffic is directly transmitted to the soil. Ducreux (1984) and Fall (1992) tried to evaluate the effects of this energy by using the Proctor method which compared the variation of soil bulk density at different soil water contents under simulated charges: The results were as follow:

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|---|---|
| Animal traction | 65 $J/dm^3$ of soil |
| Small to medium tractors | 104 $J/dm^3$ of soil |
| Heavy machinery | 350 $J/dm^3$ of soil |

These levels show that the use of animal traction can improve soil aeration and water infiltration as levels of compaction are less. For the tropical soils, especially for ferralitic and ferragenous, the water retention is higher in non-compacted soil, with an exception of silty soils. The beneficial effects provided by animal traction can be further improved by adding organic matter to the soil, such as manure and crop residues. These help increase water holding capacity. Experiences conducted in Ghana showed that the decrease of organic matter in sandy soils from 5 to 3% reduced soil water retention from 57% to 37% (Beets, 1990). In the same study, Beets (1990) mentioned the other beneficial effects of soil organic matter towards protection of soil from degradation including:

- supply of CEG to weathered soils,
- contribution to soil aggregation,
- reduction of the soil susceptibility to erosion
- decrease of the concentration of Aluminium and Manganese
- increase in flora and fauna activities by creating channels for better soil aeration.

The question that remains now has to do with what is the current status on the techniques available to farmers or tested by research, especially for seedbed preparation and cultivation, to optimise these benefits.

### 3.2 Seedbed preparation in wet soil at the beginning of the rainy season

These seedbed preparation techniques concem mainly farming systems located in areas with rainfall more than 800 mm. The advanced soil degradation observed today in many farming systems in the Humid Tropical West-African region is mainly due to ploughing in relation to the precipitation profile during the rainy season and to soil erosion. Deep ploughing in these conditions can result in disastrous effects on soil resources as the energy from tropical raindrops will literally explode soil aggregates and destroy their structure. Experiences conducted in sandy clay soils showed that, if the soil surface is not protected enough, soil erosion (in t/ha) and nutrient loss (in kg/ha) increased respectively by 27 and 15 times as runoff (in % of rainfall) increased by more than 1 000 times (Khatibu *et al.*, 1984).

For thecrop development aspects, Nicou *et al.* (1970) had showed that on average, roots development in ferragenous type of soil (Beige soil) was far better under tillage executed with a mouldboard plough than under soil surface scarification.

The responses given by animal traction users to these environmental conditions were mainly oriented towards better choice of implements and types of soil protection practices to be applied as animals got more and more integrated in the crapping system. Nevertheless, farmers are generally confronted with three major problems:

1) the unpredictable onset of the rainy season,
2) the narrow range of soil rnoisture for seedbed preparation and
3) the rapid growth of weed after the onset of rains

main advantage of this practice resides in the fact that crop residues are left mixed in the soil surface for effective protection against erosion and water runoff. This is the most widely used technique today in the dry semi-arid Sahel, from Senegal to Tchad). The purpose of this scarification is to allow the first rains to infiltrate and water to be stored in the sub-surface horizon for better seed germination. The draft requirements are moderate. as the depth range of cultivation is around 6 to 9 cm. It must be noted that the positive effects of this technique on yield have not been demonstrated.

### 3.6 Shallow sub-soiling

Special $60^0$ angle-chisels, named Gouvy have been tested lately on farmers' fields of the Groundnut Basin of Senegal aiming to improve soil water status in dry soil after the first rains (Pirot and Paris, 1980; Garin and Sene, 1988). Le Thiec and Bordet (1988) had also tested a similar steel-made chisel built by CEEMAT/CIRAD and called RS in Botswana and in Burkina Faso. It consisted of a single rigid standard frame toolbar equipped with an adjustable $60^0$ angle-chisel. At an average depth of 8- 10 cm, the chisel shatters and loosens the soil especially in dry conditions. It requires less draft compared to mouldboard plough and also has the advantage of leaving crop residues on the surface. The chisel is ineffective when the soil is already wet, depending on the importance of water stress and the types of crops (groundnut, millet, maize). The distance between two single subsoil rows can vary from 30 to 100 cm. Water from rain will enter rapidly in the shattered rows to improve water lateral redistribution in the soil profile.

In general on one hand, the chisels had improved the soil surface rugosity by 20 to 60% to cut down significantly the water runoff during the first rains of the season. Groundnut yield was increased by 20% the first year. From the present status of research on animal traction towards water control, the seedbed preparation in dry soils needs further studies and investigations towards the development of better tools to enhançe the soil moisture regime.

### 3.7 Direct seeding in dry soil

This is widely used in the Senegalese groundnut basin in the Gambia. The technique consists of using a one-row-weeder (Super Eco seeder from SISMAR) pulled by a donkey or a horse. It produces minimum of soil disturbance (Metcalfe and Elkins, 1980). After the seed is placed in dry soil, farmers pray for the rain to be at the *rendez-vous*. In this situation, timeliness is not a problem. However, it is important to mention that the way this practice is carried out by farmers is more oriented towards meeting their production objectives rather than protecting the soil from hazards.

One main reason is the fact that none of the seeders used at present time by farmers is really designed to plant crops in sod or stubble, meaning that more investigations are needed to irnprove farmers' practices.

Globally, the advantages of this technique are the following aspects:

- reduction of production costs,
- improvement of soil retention and less runoff,
- decrease in level of soil compaction,
- better timeliness in seeding,
- reduction in some weather related risks.

## 4. Implements selection discussion and recommendations

The same types of implements are encountered in all the West-African countries except for Guinea where a significant part of the implements were introduced from China in 1968 at the earlier stage of animal traction implementation. Even ifthe implements are more less the same across the countries, most of them have been adapted to fit the local situation, with regard to draft animals, soil types, farmers height etc. The Ciwara and Houe Asine (Mali) were adapted from the Sine 9 cultivator and the Occidental Hoe respectively. The main local manufacturers are SISMAR and URPATA in Guinea.

Implements are still imported from developed countries (EMCOT, BAJAC. EBRA, etc.) and parts of the implements used today are built by local blacksmiths.

The most used implement types are moulboard ploughs, ridger ploughs, spring and rigid tine cultivators, harrows, seeders and groundnut diggers. These implements have not changed since the 1960s except for some minor adaptations. In the selection and utilisation process, farmers are generally confronted with the challenge of fitting the energy requirements for different field activities to the draft animal without degrading the environment. Each implement has its own utilization requirements in terms of when and how to use it.

To slow down the process of soil degradation currently observed in farmers conditions, it is crucial that animal drawn implements be operated by skilled operators. Training farmers to new techniques is one way to limit the unwanted effects of tbe technology on the direct environment. It is also important to keep in mind that the learning process of farmers can be very slow and can take years (Fall, 1997).

The best practice towards environmental sustainability with animal traction starts first of all with increasing the range of implement selection with new types to take into account thk changing environmental conditions. Mechanised farming must be conducted from a holistic perspective within agroforestry-based farming systems in order to improve land use. Beets (1989) defined agroforestry as a land-use in which tries are grown in such spatial arrangement to foster both ecological and economic interactions between the tree and the other component of the farming system: soil conservation by the rootihg systems, dune fixation, fertility improvement, fodder trees for animals, windbreaks, etc.

## 5. Conclusion

The sustainability of the environment is a major concem to policy makers and to farmers willing to adopt new practices without jeopardising agricultural productivity. The introduction of animal traction in smallholders farming systems in West Africa has brought about significant positive changes in the production systems but on the other hand, has induced advanced soil degradation processes. It is possible to reverse the situation by introducing new farming practices that go beyond simple animal traction utilisation.

At this stage of development, animal traction has proven its positive impact in raising cropping systems productivity. However, the technology needs to be adjusted to the rapid changes taking place in the environment. Efforts must be oriented towards designing tools and introducing new practices to take full advantage of the scarce amount of rains falling in different parts of West Africa today. This will help mitigate the effects of droughts on crop production. The techniques will vary from one agro-ecosystem to another mainly characterised by the level of wetness. To this perspective, agroforestry practices need to be investigated to complement any activity around the use of animal traction.

Emphasis will be placed on a good ex *ante* farmers' understanding of the potential contributiorn of the new techniques towards solving the sustainability and soil protection constraints. For these reasons, animal traction projects in the future must be apprehended from a multidisciplinary perspective. A number of questions need to be addressed when implementing fùture animal traction projects:

- Is it possible to explain to farmers what environmental sustainability is about?
- How can farmers manage the knowledge generated so far under the conceptual framework of sustainability as interpreted by WCED (1987).

Because the level of animal traction utilization is still low in most parts of West Afiica, the room left for improvement can cover different aspects:

(i) design of better implements ta include post-tillage operations like weeding and harvesting,

(ii) optimization of draft animal utilisation to take full advantage of the available energy by planning field operations during the most suitable hours of the day,

(iii) meeting the feeding requirements of the working animals from better integration of different farming system components,

*(iv)* emphasising farmers' training sessions as part of any animal-traction-based projects to reduce the learning period.

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