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Effect of discs harrow use on lixisol roughness and clods sizes in Burkina Faso

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***Abstract*— *Soil tillage allows a good establishment of crops in Burkina Faso. The aim of the study conducted in Saria is evaluation of the disc harrow used for tillage in order to find ways of mitigating these negative effects. The discs harrow evaluation is done at three speeds on a lixisol in Saria. The operation is carried out at two moisture levels, 9 and 12%. Measurements are made on labor time, tillage depth and width, surface roughness and clod sizes. The results indicate that labor time per hectare decreases with speed. Between 2.2 and 10.4 km.h^{-1}, the time goes from 4.00 h.ha^{-1} to 1.25 h.ha^{-1}. Under these conditions, the soil surface roughness index varies from 1.27 at low speed to 1.06 for high speed. The size of clods increases from 1550 cm^3 2.2 km.h^{-1} to 81 cm^3 for 10.4 km.h^{-1}. The reduction of the clods sizes makes the plots sensitive to runoff and soil erosion. Soil tillage at an average speed of 6 to 7 km.h^{-1} maintain the roughness and the clods sizes and makes it possible to achieve a time of 1.6 h.ha^{-1}. The traction force is 315 DaN for 7 cm deep and 210 cm wide. It is possible to reduce labor time by increasing the tillage width and maintaining a speed of 6 km.h^{-1}.*

***Keywords*— Clod sizes, labor time, roughness, speed, tillage.**

I. INTRODUCTION

In the Sahel, the issue of environmental preservation involves integrated soil management. The resolution of the challenge of food and nutritional security in Burkina Faso must be done with a sustainable production system for the benefit of the populations [1]. In order to increase cereal production, producers are increasingly using the disc harrow for tillage [2]. This tool is used in more than 80% of farms in the western cotton zone of the country. It is appreciated by these users because of its speed and its earliness in carrying out the tillage. Indeed, for a soil wetting depth of 10 cm as for scarification with a manga hoe, the tillage operation with a disc harrow can begin well before plowing [3]. The use of this tool despite these advantages can lead to significant water erosion in poor conditions of use. Recommended speeds vary from 5 to 7 km.h^{-1}for ride-on discs harrow [4, 5]. The speed varies according to the soil conditions (physical state of the soil, quantity of organic matter to be buried, quality of the grinding of the organic matter, first or second pass, presence of stones or roots, etc.). In the climatic conditions of Burkina Faso where the rains are of high intensity especially at the beginning of the season, the soil surface state has an important role on runoff and erosion [6, 7, 8].

This study is intended to evaluate the effect of tillage speed with the disc harrow on the soil surface condition at the Saria research station.

II. MATERIAL AND METHOD

2.1 Study site

The study was carried out in Burkina Faso at the Saria station (12° 16' N and 2° 9' W), located at 80 km west of Ouagadougou. The climate is north-Sudanian type [9]. It includes a dry season of 7 months (November – May) and a rainy season which lasts 5 months (June-October). The annual average rainfall is 800 mm. The rains are irregular in space and time, inducing periods of drought that are very often harmful to crops. Crops are planted at the start of the rainy season during the period of high evaporation with 5 mm per day of potential evapotranspiration (ETP) [10].

The vegetation is wooded savanna type, with the main woody species: *Khaya senegalensis, Annogeissus leiocarpus*, *Acacia penata*, *Mitragyna inermis*, *Tamarindus indica*, *Ficus sp.*, *Accacia ssp.*, *Combretum ssp.*, *Vitellaria paradoxa, Guiera senegalensis, Boscia senegalensis, Zizyphus mauritiana and Piliostigma ssp*. The herbaceous cover is composed by *Pennisetum pedicellatum, Schoenfeldia gracilis*, *Loudecia togoensis* and *Andropogon Sp*. [9].

The soil is leached lixisol type [11], with an average depth varying from 80 to 100 cm. This depth is limited by the presence of petroplinthite layers [3, 12]. The slopes are on average low (≤ 1%), but the rains are often high intensity (50 to 80 $mm.h^{-1}$). The texture of the tilled horizon is sandy-clayey (on average 55% sand, 31% silt and 14% clay). The soils are poor in organic matter (< 1% on average), in nitrogen (≈ 0.7 $g.kg^{-1}$) and in assimilable phosphorus (≈15 $mg.kg^{-1}$). Their water storage capacity (WRC) is low (80 to 100 $mm.m^{-1}$) [13, 8].

2.2 Tillage equipment

Tillage was carried out by the 16 discs harrow tool. Eight are crenelated at the front and 8 other normal at the back. The disc diameter is 50 cm. The tillage width is 210 cm.

The Mahindra model 605 DI two wheels drive tractor has been used. It has a power of 57.00 CV or 42.50 kW.

Fig. 1: Discs harrow hitched to the Mahindra 605 DI tractor during experiments.

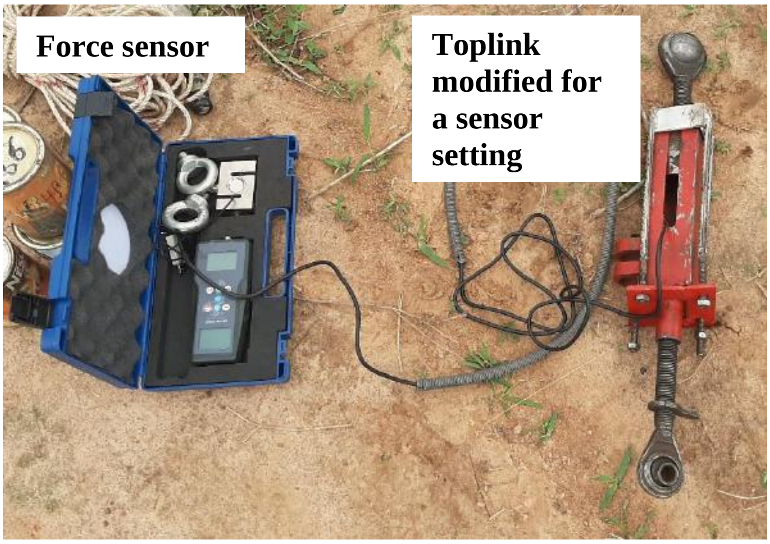

Fig. 2: MF 207 1000 kg traction and compression dynamometer on third point arm modified for insertion of the force sensor.

2.3 Experimental Design

The study device has three main plots of 51.0 x 15.8 m. On plot P1, tillage with the disc harrow was done at a speed of 2.19 and 3.82 km.h^{-1}. On plot P2, it was carried out with the same tool at a speed of 5.13 and 5.67 km.h^{-1} , and on plot P3 at a speed of 10.40 and 9.81 km.h^{-1}. The average tillage depth was measured as well as the tillage width.

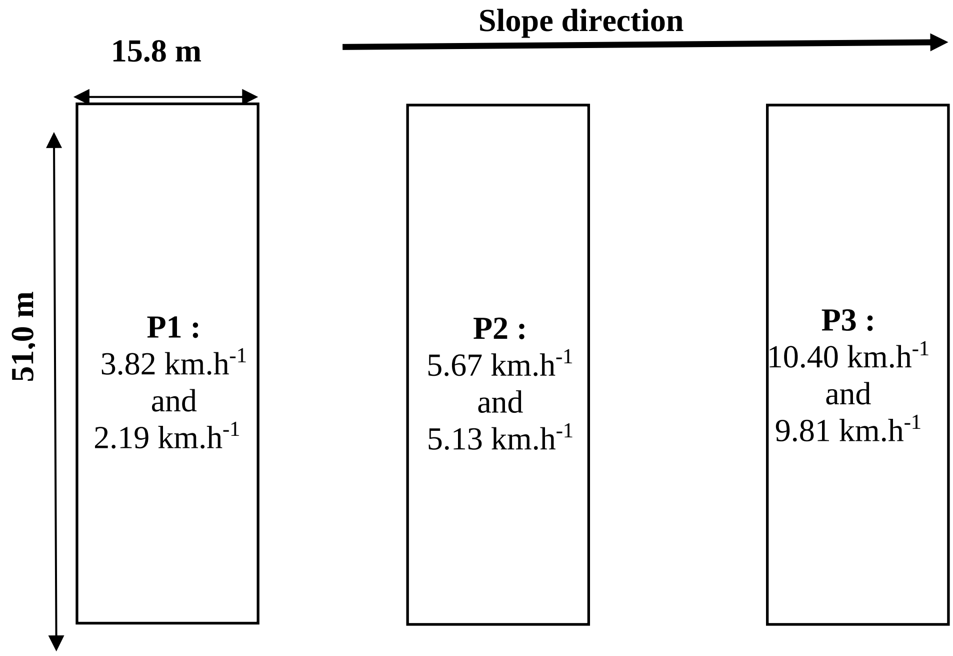

Fig. 3: Experimental device

2.4 Measurements and observations

- The sizes of the clods have been measured in 1 m² surface in 4 repetitions on each plot. The longest side is the length, the next side is the width, and the shortest side is the thickness.

- The labor time has been measured. Tractive force was measured by placing a traction and compression dynamometer on the tractor's TopLink modify (Fig. 2).

- The soil roughness was measured by the chain method [14]. The chain, 1.0 m long (L) is placed on the surface of the soil so that it hugs the surface micro-modeling. The vertical projection of the chain (lo) is then measured with a tape measure (10 repetitions).

2.5 Data processing

The data is processed by the XLSTAT Version 2021 2.2.1141 software. The variance analysis module is used and the comparison of means is made by Newman-Keuls test. The regression module has also been used.

III. RESULTS

3.1 Traction force and tillage depth

The traction force average is 314.7 daN. The standard deviation is 157 daN (Table 1). The presence of stumps on the plot caused peaks reaching of 550 daN.

The analysis of variance carried out on the tillage depth indicated its slight decrease when the speed of the tool increases (Fig. 1). The probability is 0.042. Speeds of 2.19 and 5.13 km.h^{-1} have an average depth from 7.0 to 6.6 cm. The depth of the greatest speed has been 6 cm on average.

Table 1: "V" Disc Harrow Traction Force

Parameters	Traction Force (daN)
Mean	314.7
Standard error	157.1

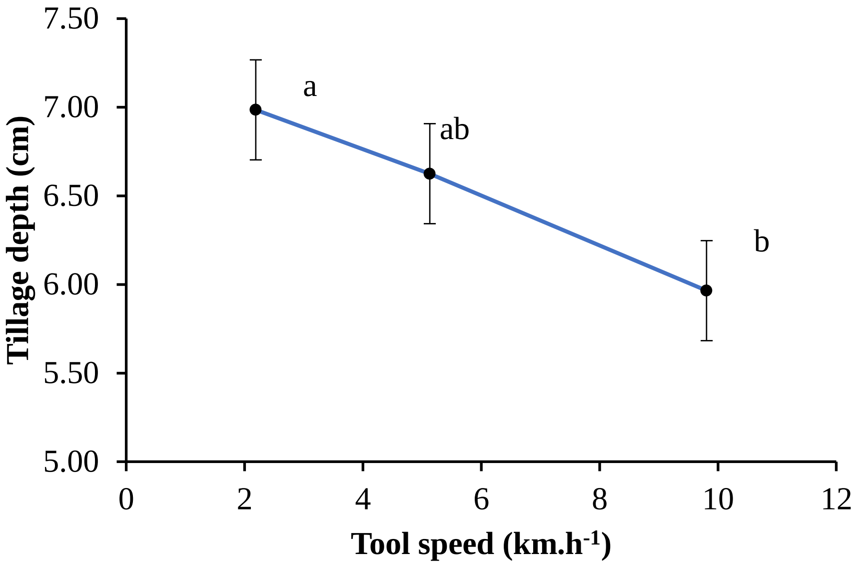

Fig. 4: Variation of tillage depth according to the tool speed

Note: a, ab and b denote different groups of means

3.2 Labor time

The variation in labor time per hectare is shown in Fig. 5. The labor time reduction was a function of the speed (Fig. 5). With n=6 the coefficient of determination of 0.97 is very highly significant.

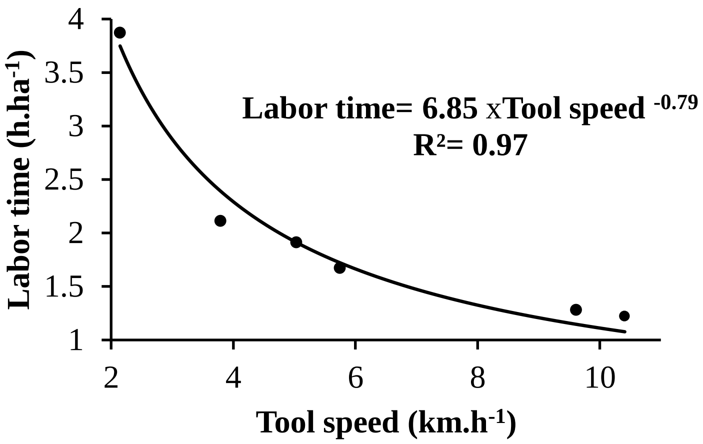

Fig. 5: Variation of labor time per hectare according the tool speed

3.3 Soil roughness index

The graphs in Fig. 6 below show the variation of the soil surface roughness index in two tillage conditions (at 9 and 12% moisture). In both situations the analysis of variance shown a very highly significant difference between the means of the roughness index on the three plots. The probability is less than 0.0001. At the high speed of passage around 10 $km.h^{-1}$, the roughness index is close to that of the initial state of the soil before the tillage. The analysis of the roughness after a rain of 8.5 mm shown a very highly significant difference between the roughness index on the plot at high speed (10 $km.h^{-1}$) and the two other plots. On the plot treated at 10 $km.h^{-1}$ there is no index reduction after this rain.

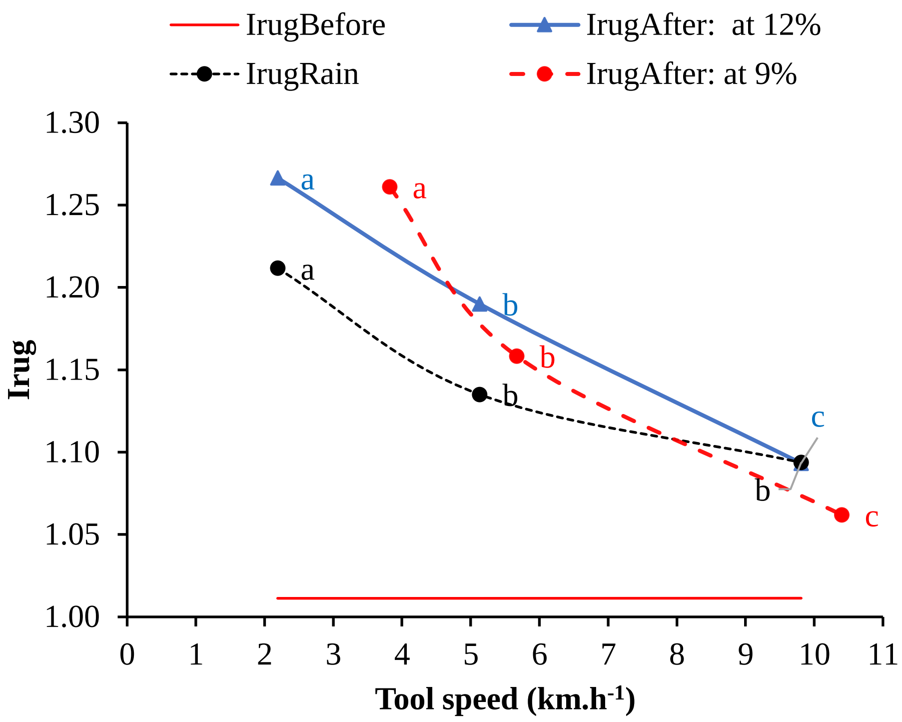

Fig. 6: Variation of the roughness index on two soil moisture

3.4 Clods volume

The analysis of variance carried out on the volumes of clods on the plots indicates a very highly significant difference between the first two speeds (2.2 and 5.1 km.h^{-1}) and the fastest (10.0 km.h^{-1}) with tillage carried out at 12% moisture (Fig. 7). For tillage at 9% moisture, there is a very highly significant difference between the size of the clods on the slow speed plot (3.8 km.h^{-1}) and those of the clods on the other plots (5.1 and 9.9 km.h^{-1}).

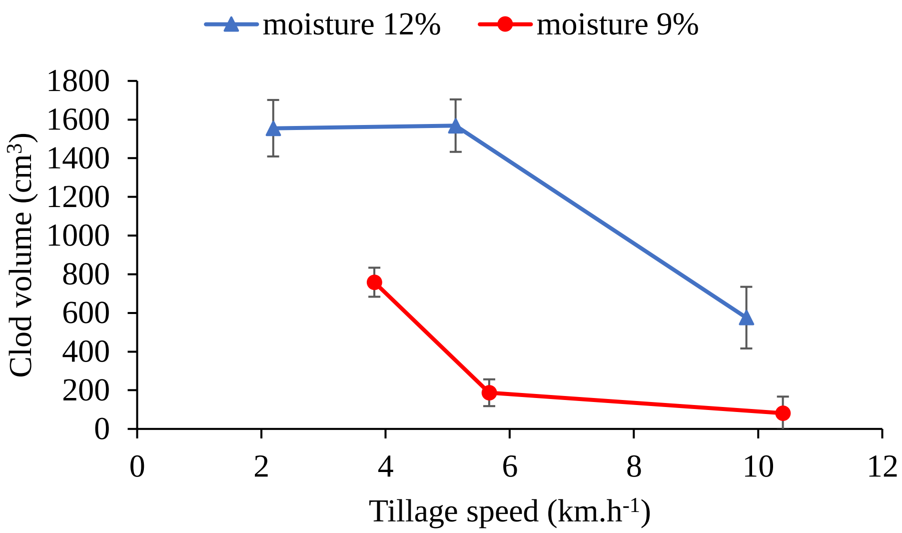

Fig. 7: Variation of clods volume at two soil moisture levels and tillage with a disc harrow

IV. DISCUSSION

4.1 Optimization of the use of the tool

The measurement of the traction force made it possible to have the average at a traction effort of 315 daN with the harrow with 16 discs of 550 kg. At 12% soil moisture the average tillage depth is 6.52 cm. With a tillage width of 210 cm, the soil cutting section is 6.52 cm x 210 cm i.e., 1369 cm². The soil cutting force is 0.23 daN by cm². It is then possible to increase the labor width by 90 cm to reach 300 cm. This will provide a traction force of 449.9 daN. The weight of the tool will increase but would still be within the lifting capacity of the tractor, which is 2200 kg. Labor time per hectare would then be reduced.

4.2 Labor time

The labor time per hectare goes from 3.9 h at 2.2 km.h^{-1} to 1.1 h at 10 km.h^{-1}. Faster the tool passes, the lower is the time spent per hectare. Service providers using the discs harrow have their contract carried out per hectare [15, 2]. Faster is the tillage speed, larger are the tillage surfaces and higher is the gain for the operator. But the high speed does not seem favorable to maintaining the surface roughness in the climatic conditions of the central region where the rains are often high intensity [8]. The solution of increasing the tillage width considering the traction force makes it possible to reduce the labor time per hectare even the tillage is done at moderate speeds. A tillage speed at around 6 km.h^{-1} makes it possible to do 1.6 h.ha^{-1} with the width of the tool of 210 cm. With a width for the tool of 300 cm, the labor time at the same speed would be 0.44 h.ha^{-1} or approximately 30 min.ha^{-1}.

4.3 Variation of soil surface roughness

The variation of the roughness index is a function of the speed. It is also a function of the moisture of the soil at the date of the tool passage. At the favorable moisture limit for wet tillage on this soil (12%) [10], roughness indexes varied from 1.19 to 1.27. This value is close to that obtained by [3] on the mechanized zaï plot in Saria, which was 1.28. With the tillage on the soil at 9% moisture, the roughness index at a speed of 3.8 km.h^{-1} is high (1.26), but with the tillage at 5.8 km.h^{-1} the roughness index is lower (1.16) and it reaches 1.06 at 10.40 km.h^{-1}. The moisture of 9% is close to that of the state of friable consistency soil [10]. The action of the discs on the soil at this state of consistency favorable to the bursting of the clods, gives small particles of soil [16]. This makes the plot more vulnerable to water erosion. After the rain of 8.5 mm, the roughness index reduction was 4.26% and 4.62% respectively on the plot treated at slow speed (2.2 km.h^{-1}) and that treated at medium speed (5.1 km.h^{-1}). Despite this reduction, the index is still higher than that of the high-speed tillage. The large size of the clods on these plots allows them to retain some of the roughness after the rain. The graphs in Fig. 4 show the variation of the sizes of the clods with the two soil tillage's moisture levels. The clods are large with low and medium speeds at 12% moisture (1550 cm^3). But with high speeds around 10 km.h^{-1} they are reduced (550 cm^3). For moisture of 9% the sizes of the clods are smaller. These results are conformed to the observations made by [17] on the reduction of clods sizes. It varies from 760 cm^3 for the lowest speed to 81 cm^3 for the high speed. There are very small clods. This confirms the fact that speeds from 10 km.h^{-1} destroy more clods, especially on soils with low moisture. This makes them susceptible to runoff and erosion [18].

V. CONCLUSION AND PERSPECTIVES

The discs harrow's speed of 10 km.h^{-1}destroys the clods. The roughness index is low on the plots treated under these conditions. The increase in speed is more harmful for the surface roughness when the soil moisture is low, i.e., close to that of the state of friable consistency. Labor time is reduced by rapid tool passage. Given the fact that the disc tool has a relatively low traction effort regarding the width the pass, it is possible to reduce the labor time per hectare by increasing the tillage width of the tool while remaining within the average speed of 6 to 7 km.h^{-1}. Increase discs axes length could save time by carrying out the tillage of a hectare in a short time even at 6 km.h^{-1}. Training users is important in order to explain to them the impact of the misuse of the tool on the environment in the short term and also on their economic activity in the medium term.

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