Dry soil tillage tines RS8 and IR12: two efficient tools for *zaï* technique mechanisation in the Sahel

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Abstract

In the semiarid and arid sahelian zone, the *zaï* practice is a well-known efficient method for the rehabilitation of degraded bare and crusted soils. It consists in digging pits (20-40 cm width, 10-15 cm depth) in which organic amendments are added. The realisation of this traditional practice requires for a man about 300 hours ha^{-1}. For many smallholders, this time labour remains a big constraint to the large diffusion of the technique. The alternative local solution consists in using animal traction force (cattle drawn) with the tine set on a frame, to create pits in the crossing points of perpendicular furrows. The experiment was conducted in two sites: Saria village (12° 16′ N and 2° 9′ W) in the North soudanian climate (800 mm), and Pougyango village (12° 59′ N and 2° 9′ W) in the sahelian climate (600 mm). The experimental design consisted in 5 treatments with 3 repetitions. Two treatments of mechanised *zaï* were compared to traditional *zaï*, scarifying, and zero tillage. Soil texture was sandy-clay type at Saria and sandy loamy type at Pougyango. RS8 tine was used for Saria soils and IR12 for Pougyango soils.

The tractive effort with RS8 tine at Saria was 115 kg. Pit sizes obtained with RS8 tine was 9 ± 2 cm depth and 28 ± 2 cm in diameter. At Pougyango village, with the IR12 tine, tractive effort was 100 kg and the pits sizes was 10 ± 1 cm depth and 39 ± 3 cm in diameter. Soil resistance to penetration at Pougyango, was better in mechanised *zaï* treatments than in traditional *zaï* ones, mostly between the pits. Plant gathering reached 80% in mechanised *zaï* plots without earth extirpation from the pit (MZ), 40% in mechanised *zaï* plots with earth extirpation from the pit (MZE) and 30% in manual *zaï* plots (MnZ). At Pougyango site, sorghum grain yield in treatment MZE was 35% greater that obtained with the two other treatments. Labour time was 66 hours ha^{-1} per man for MZ and 132 hours ha^{-1} per man for MZE. Cost analysis showed that the total cost for MZ was 39.258 f cfa ha^{-1}, 51.158 f cfa for MZE and 55.000 f cfa ha^{-1} for MnZ. Mechanised *zaï* has improved soil physical characteristics and hence, soil moistening. *Zaï* mechanisation appeared less costly. Moreover, it induced a better sorghum crop production and could be well spread if the animal tractive force available to farmers wasn't limited by factors like low alimentation, bad health and bad harnessing of animals.

Keywords: dry soil tillage, zaï mechanisation, crusted soil, rehabilitation, Sahel

Introduction

The North of Burkina Faso a sahelian land of West Africa has low rainfall moving from 400 to 700 mm y^{-1}. In this region farmers are confronted with rainfall irregularity and topsoil encrusting inducting the sterile areas which are not permeable to water (Casenave and Valentin, 1992; Ambouta *et al.,* 1999). Those sterile areas locally called "zipellé" are traditionally tilled by manual *zaï* technique (Ouedraogo and Kaboré, 1996). This soil regeneration and water conservation method is manually used with picks and mattocks. Manual labour time is to long (300 h man^{-1} ha^{-1}) and tillage in the hot and dry season is arduous for farmers. Despite soil rehabilitation and interesting sorghum grain yield (600 to 800 kg ha^{-1}) and straw yield (2600 kg ha^{-1}); the practice diffusion to farmers is slowed by those factors:

-the tillage is painful for farmers during the hot and dry season,

-the high labour time makes required a lot of person for the manual *zaï* practice (Wedum *et al.,* 1996).

To perfect this practice which can be assimilated to the farmers production intensification, and to make easier his application to large areas, dry soil tillage tines RS8 and IR12 was used with cow traction force to make *zaï* holes (Sédogo *et al.,* 1998).

This research purpose is to evaluate the mechanisation of *zaï* holes making and labour time reduction, the efficiency of the tools for mechanised *zaï* practice, the comparative cost of mechanised and manual *zaï*, and the effect of this method on sorghum grain and straw yield production.

Materials and Methods

Plots locations

The research is done in 2000, on tow villages located in Sudanian regions: Saria (12° 16′ N, 2° 9′ W) and Pougyango (12° 59′ N, 2° 16′ W). The annual rainfall average is 800 mm at Saria and 600 mm at Pougyango. It is not regular, little periods of draught often occurred.

The majority of soils are a Ferric lixisol (FAO-UNESCO, 1989). The topsoil texture is sandy-loamy type in Saria and loamy type in Pougyango. Soil depth varied from 30 to 50 cm. The most important difference in the tow types of location, is the crusty topsoil at Pougyango reducing water infiltration and plants growing. Topsoil is not crusty in Saria but the soil is more compact than Pougyango soil because of clay. The experimentations are done in both cases on sterile plots called "zipellé".

Experimental design

Tow techniques of mechanised *zaï* practice (mechanised *zaï* with earth extirpation: MZE, and mechanised *zaï* without earth extirpation: MZ) were compared with manual *zaï*: MnZ and usual tillage practice of scarifying with animal traction force and manual soil preparation with dig or zero tillage. The effect of plots is evaluated with the principal crop of this zone. The experimental design is a Fisher bloc with 5 treatments and 3 replications. The treatments were those:

(1)Control plot: Manual tillage with dig (GRT) has done by farmers in Saria zone. In Pougyango zone the control plot is a zero tillage plot.

(2)Scarifying plot with cow traction force with "houe manga" (SCA). This tillage is useful in the major area in the Central and North region of the country because of the lowest of the traction force, the swiftness, and the earliness of is application.

(3) Manual *zaï* plot (MnZ). The *zaï* pits are making by manual picks like farmers done.

(4) Mechanised *zaï* with earth extirpation (MZE). *Zaï* pits are making by dry soil tillage tine RS8 in Saria or IR12 in Pougyango. After mechanised tillage, earth extirpation is realised manually by men at the cross of tines tillage. The earth is putting backside pits like moon crescent.

(5) Mechanised *zaï* without earth extirpation (MZ). It is only realised by dry soil tillage tools RS8 or IR12.

Cow manure is used at the level of 160 g pits^{-1} with correspond to 5 t ha^{-1}

The crop

The crop used is local sorghum ecotype (Nongomsoba) in Saria and (Sariasso 12) which have a short vegetative stage at Pougyango.

Observations and measurements

Soil resistance measurement is realised on the horizon (0-20 cm). This factor is useful to appreciate the traction force of soil tillage. It is done with a percussion penetrometer describe by ORSTOM (1993). Tools effect is evaluated by deep and larger measurement by a meter and a graduate bar. The traction force is measured by mechanical dynamometer. Labour time has been measure by a chronometer. After soil tillage the moisture deep progression is evaluated at the end of important rainfall. Sorghum rising is measured by counting pits in each plot. Sorghum grains and straw production are wetting after dry period of 14 days at the end of growth period.

Results and Discussion

Tine RS8 and IR12 efficiency for mechanised *zaï* pits realisation

Table 1 presented dry soil tillage factors (labour time, holes dimensions, and traction force) for mechanised and manual *zaï* application in Saria and Pougyango. MZ is the most rapid technique. It's need only 64 h man^{-1} ha^{-1}. Doing MZE increase the labour time to 132 h man^{-1} ha^{-1}. The tow-mechanised techniques are better than the manual one which takes 300 h man^{-1} ha^{-1}.

Table 1 Comparison between tools effect in mechanised and manual *zaï*.

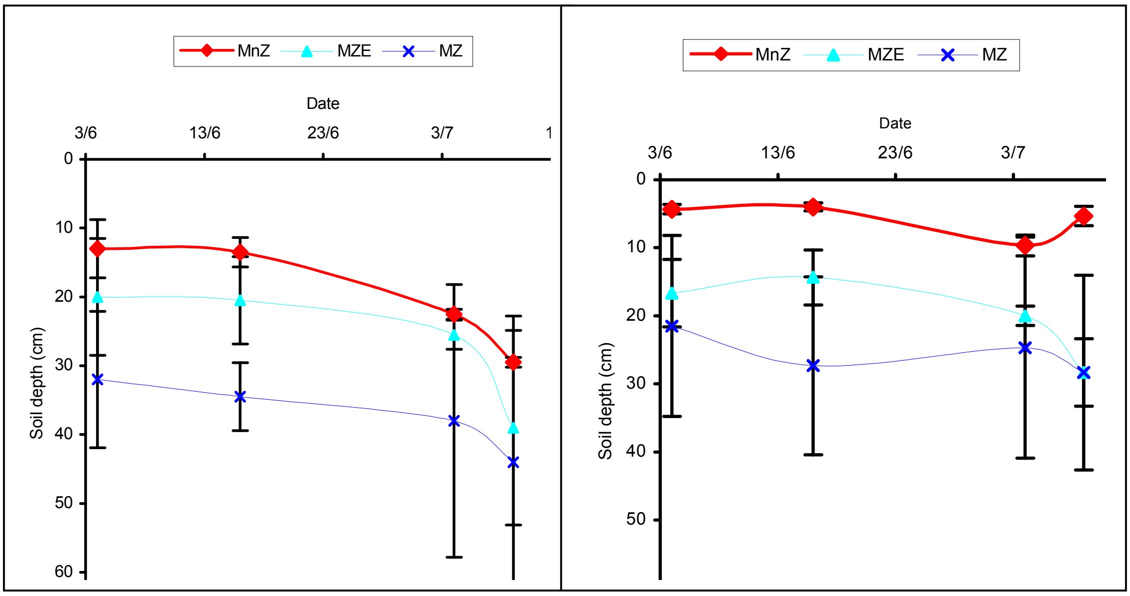
	MZ		MZE			MnZ		
	Deep (cm)	Larger (cm)	Deep (cm)	Larger (cm)	Effort (kgf)	Deep (cm)	Larger (cm)	Effort (kgf)
				Saria				
Mean	7.3	25.4	29.5	9.5	115	11.9	31.7	#
SD	1.8	1.0	2.4	0.9	5	1.1	3.0	#
				Pougyango				
Mean	10.6	39.4	39.3	10.3	101	11.3	40.9	#
SD	0.5	2.7	3.9	0.1	7	0.6	0.8	#
Labour time	64 h ha^{-1}		132 h ha^{-1}			300 h man^{-1} ha^{-1}		

: No data have been measured

MZE: mechanised zaï plots with earth extirpation; MnZ: manual zaï plots; MZ: mechanised zaï plots without earth extirpation; SCA: scarifying with cow traction; GRT: manual tillage

Dry soil tillage tine RS8 and IR12 used is based fundamentally on Herblot (1984) then Barro (1988) research, witch exposed that in the Central area of the country broking dry soil increase soil permeability and water storage. Dry soil tillage must be done when the soil has a hard consistency. Broken hard consistency soil induced cracks in soil and clods in the topsoil. Clods protect on topsoil from crusting. So we can easily imagine that the effect of the tines on soil will depend on its type in the way of traction force and holes dimensions (Table 1). Saria soil is compact and sandy clay. Nicou (1975) explains that in the dry season this kind of soil become hard. The moisture is less at Saria (1.05 %) than Pougyango (2.92 %). Pougyango soil is clay loamy. That explains difference of traction force and dimension of holes in the two regions.

Moisture deep evolution after tillage is shown on graphics A) and B) of Figure 1. In *zaï* holes (manual or mechanised), moisture deep is about (15 to 35 cm) and (5 to 17 cm) on the odder plots.

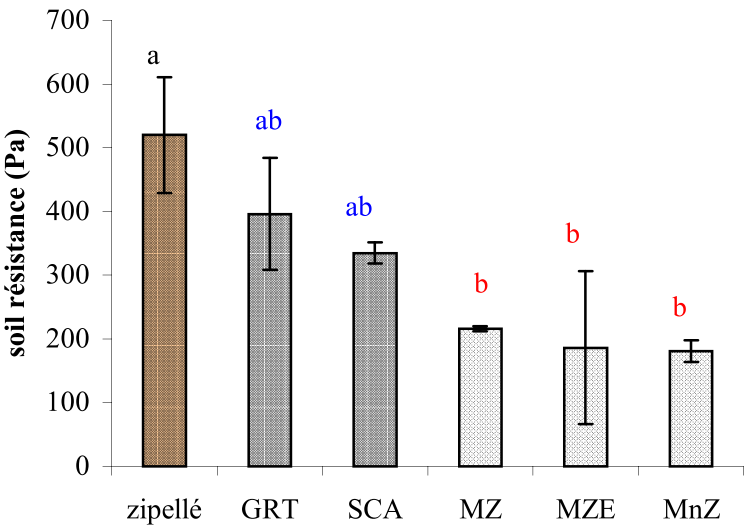


MZE: mechanised zaï plots with earth extirpation; MnZ: manual zaï plots; MZ: mechanised zaï plots without earth extirpation

Figure 1 Moisture deep variation in *zaï* hole (A) and out of *zaï* hole (B).

Manual *zaï*, broke crusty topsoil from place to place and water infiltration is located. The using of dry soil tillage tine RS8 and IR12 broke soil on all the area over tillage deep. Water infiltration and storage is better (Lethiec, 1990; Barro, 1997; Sédogo *et al.,* 1998). The hole creating by the crossing of tillage can be used for *zaï*. It can receive manure and runoff water. This hole is the future pits of the crop. Sorghum gets there in hydrous and mineral food. More than water storage which is an important factor in Sahel, other interesting points of *zaï* must be considered.

We observe that *zaï* practice decrease topsoil resistance (Figure 2) comparatively to scarifying or zero tillage on “zipellé”. This is a favourite factor for the soil rehabilitation. The low soil resistance have been observed on “zipellé” in the North of Burkina Faso (Zombré *et al.,* 1999).



a, b : mean that those plots are in the same group (Newman and Keuls classification)

MZE: mechanised zaï plots with earth extirpation; MnZ: manual zaï plots; MZ: mechanised zaï plots without earth extirpation; SCA: scarifying with cow traction; GRT: manual tillage

Figure 2 Topsoil resistance in horizon (0-5 cm).

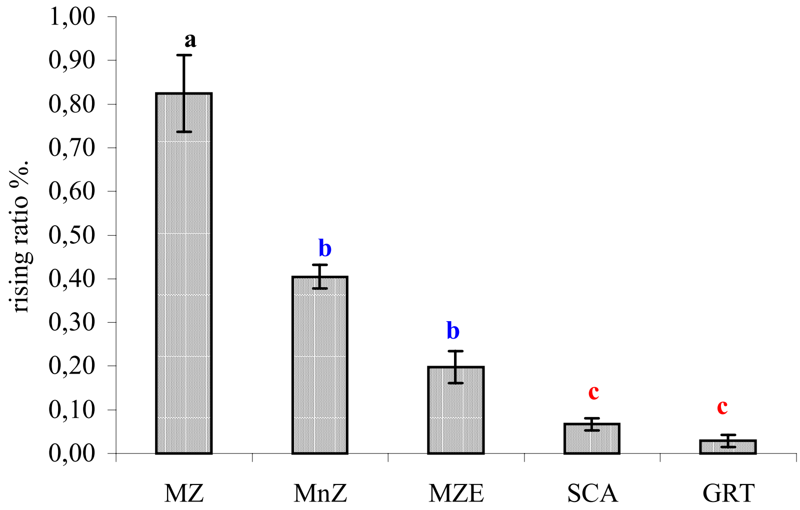
The difference of the traction force depends of soil cohesion (Caquot and Kérisel, 1966) and moisture. The traction force is low (101 kgf) at Pougyango and height at Saria (115 kgf). Despite difference, hole deep at Saria is lower than Pougyango's (Table 1). The raison is the difference of soil texture and moisture in those two regions.

For mechanised *zaï* it is only necessary for man to drive harnessing. Roose *et al.* (1993); Ouedraogo and Kaboré (1996), measured 300 h man^{-1} ha^{-1} for manual *zaï* labour time. Or results confirm it. Mechanisation of *zaï* allow farmer to work 80 % more quickly than manual *zaï*. The cost analysis showed that manual *zaï* (MnZ) need 55000 Fcfa ha^{-1}. Mechanised *zaï* with earth extirpation (MZE) is evaluated to 51158 Fcfa ha^{-1}. It is not really different of the manual one. This high cost is related to by the manual extirpation witch is so long (68 h man^{-1} ha^{-1}). Mechanised *zaï* is 30 % lowest than the manual *zaï* (39258 Fcfa ha^{-1}).

Considering the positive results of tillage factors and holes dimensions, the trail show that *zaï* practice can be mechanised. This mechanisation makes the practice easer. Tools actions on soil depend on soil type. It is more important in sandy loamy-soil. Research pursuit will give more precisions on *zaï* mechanisation.

Sorghum rising and production

Observations were done on sorghum rising and results are presented on Figure 3. Manual *zaï* (MZ) get the better rising. It is low on the odder plots. Soil moisture is the essential reason. Sowing are done on 25th June. At this period the moisture is important in the pits of *zaï* (20 to 30 cm deep) (Figure 1 A) and very low on no-tillage and scarifying plots (5 cm deep) (Figure 1 B). In low rainfall conditions all pits of manual *zaï* can't be humid because water is not sufficient for going over upwards slope pits. So, down slope pits can't be moist. Statistical analysis and Newman–Keuls classification gave tree categorizes (Figure 3). Photo 1 present scarifying plot and beside a mechanised *zaï* plot at the rising stage. Mechanised *zaï* plot has clods and moisture; scarifying plots stay crusty and dry.



a, b, c: mean that those plots are in the same group (Newman and Keuls classification)

MZE : mechanised zaï plots with earth extirpation; MnZ: manual zaï plots; MZ: mechanised zaï plots without earth extirpation; SCA: scarifying with cow traction; GRT: manual tillage

Figure 3 sorghum rising ratio fluctuation in Pougyango plots.

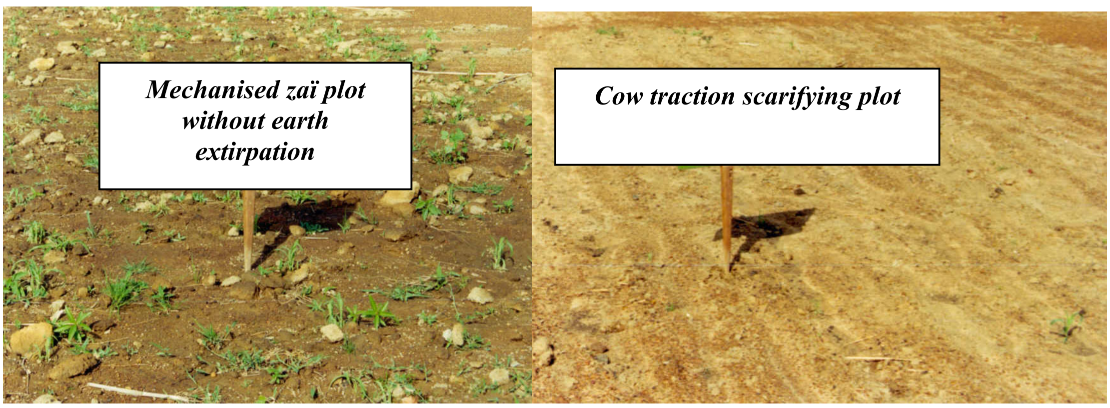


Photo 1 Mechanised *zaï* plot compared with a scarifying plot at sorghum rising stage in Pougyango zone.

Results of grains and straw production are presented in Table 2. At Saria we don't find significant difference between the treatments for grain yield production. «Grattage» plots have the lowest straw production in this region. *Zaï* and scarifying plots get the same level of production. Water infiltration hasn't be a limiting factor in this soil if there is tillage by *zaï* (manual or mechanical) or scarifying. Soil is not crusty and rainfall level is important (800 mm y^{-1}).

Table 2 Sorghum grains and straw yield at Saria and Pougyango in 2000 (kg ha^{-1}).

	SARIA		POUGYANGO	
Plots	Grain yields	Straw yields	Grain yield	Straw yields
MZE	1198 a	3125 a	607 a	2626 a
MnZ	1520 a	3272 a	433 a b	2015 a b
MZ	1250 a	3081 a	404 a b	2085 a b
SCA	1367 a	3168 a	211 b	644 b
GRT	1176 a	2300 b	167 b	867 b
Probability	0.1839	0.0260	0.0325	0.0086
Significance level	NS	*	*	**
CV (%)	16.1	13.0	39.7	32.7

NS: Not Significant; *: Significant; ** Highly Significant.
CV (%): Coefficient of variation
a, b: mean that those plots are in the same group (Newman and Keuls classification).
MZE: mechanised zaï plots with earth extirpation; MnZ: manual zaï plots; MZ: mechanised zaï plots without earth extirpation; SCA: scarifying with cow traction; GRT: manual tillage or no tillage

At Pougyango significant difference between plots for grain yield production and highly significant difference for straw yield production. *Zaï* plots are the better for the production (grains and straw). The worst plots are scarifying and no tillage (GRT). Those practices are not efficient for crop production on crusty soil with low rainfall. The important production on *zaï* plots is caused by water storage inducted by those techniques. The Photo 2 present scarifying plot beside a mechanised *zaï* plot at the flower stage. The lower of Pougyango production comparatively to Saria is explain by lowest of rainfall and the shortest of plant growing cycle.

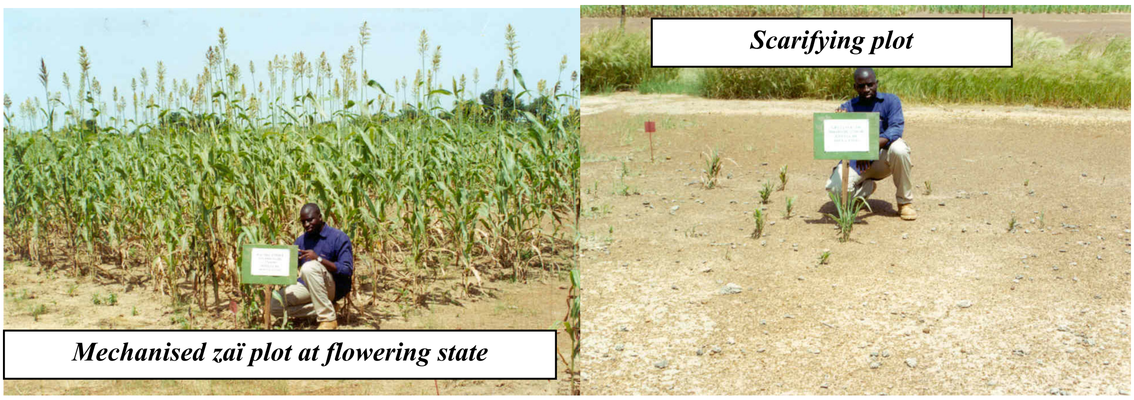


Photo 2 Mechanised *zaï* plot compared to scarifying plot at sorghum flower stage at Pougyango zone.

Conclusion

Those results show that soil rehabilitation by mechanical *zaï* practice is possible by using dry soil tillage by tine RS8 or IR12. The mechanical *zaï* can by used by farmers who have tillage tools (plough, tiller) and animal harnessing (cow or donkey). Labour time is 64 h ha^{-1}. Mechanised *zaï* is more efficient for soil moisture and 30% lest expensive than manual *zaï* (39,258 opposed to 55,000 f cfa). *Zaï* practice (mechanised or manual) reduces topsoil resistance. His effect is more important in sandy-loamy soil type than sandy-clay soil type. In the two localities, *zaï* is more productive than tillage usually used by farmers (scarifying and "grattage" or no tillage). We expect that it can be useful for farmers to have the labour time evaluation during mechanical *zaï* practice with and single cow or donkey. Mechanical *zaï*, a rapid water conservation and efficient fertilisation technique, will allow Sahelian farmers to enhance the standard living level of people.

Acknowledgement

We say thank so lot to "Special Program CES/AGF" which financed this research. The results will contribute to enhance the standard living of Sahel farmers. We congratulate INERA/GRN-SP centre fellow workers for their hardiest and their tenacity, which gave those results.

References

Ambouta, K.J.M., B.I. Moussa and D.S. Ousmane. 1999. Réhabilitation de la jachère dé gradée par les techniques de paillage et de *zaï* au Sahel. Edt. John Libbey Eurotext. La Jachère en Afrique Tropicale, Rôles, Aménagement, Alternatives. Dakar. Avril 13-16 1999. p. 751-759.

Barro, A. 1997. Effet du travail du sol en sec à la dent RS8 sur l'amélioration de la production du sorgho au Burkina Faso. Dans Le travail du sol dans les systèmes mé canisés. Actes Colloque septembre 1996 Cirad Montpellier. p 61-63.

Barro, A. 1988. Contribution à l'étude des relations eau-sol-plante-machine. Mémoire de diplôme d'ingénieur d'agronomie tropicale Option recherche. ESAT-2 Montpellier 50 p.

Caquot A. et J. Kérisel. 1966. Traiter de mécanique des sols. Edition Gauthier-Villars, Paris.

Casenave, A. and C. Valentin. 1992. A run-off capability classification system based on surface features criteria in the arid and semi-arid areas of West Africa. J. Hydrol. 130:231-249.

FAO-UNESCO. 1989. Carte mondiale des sols. Légende révisée. Rapport sur les ressources en sols du monde. 60 FAO. Rome. 125 p.

Herblot, G. 1984. Une expérimentation de travail du sol en sec au Burkina Faso. Machinisme agricole Tropicale 88:18-28.

Lethièc, G. 1990. Le coutrier à traction animale: recherche alternative au labour en ré gion sèche. Les cahiers de la recherche-développement 28:83-86.

Nicou, R. 1974. Le problème de prise en masse à la dessiccation des sols sablo-argileux de la zone tropicale sèche. Agr. Trop. XXX No. 4–Oct. –Déc. 1975.

ORSTOM. 1993. Bulletin du groupe de travail sur la dynamique actuelle des sols. 2:122-135.

Sédogo, P.M., A. Barro and M. Bonzi. 1998. La dent RS8 de travail de sol en sec, une alternative à la charrue. Science et technique 23:44-48.

Sédogo, P.M. 1993. Evolution des sols ferrugineux lessivés sous culture: incidence des modes de gestion sur la fertilité. Thèse de doctorat es sciences, Université Nationale de Côte d'Ivoire. 285 p.

Wedum, J., Y. Doumbia, B. Sanogho, G. Dicko and O. Cissé. 1996. Réhabilitation des terres dégradées. Le *zaï*, dans le cercle de Djenné (au Mali). in Techniques traditionnelles de conservation de l'eau et des sols en Afrique. edt. Karthala. Paris, Amsterdam, Wageningen, Reij Ch., Scoones I., Toulmin C. p. 95-102.

Zombré, N.P., A. Mando and J.B. Ilboudo. 1999. Impact des techniques de conservation des eaux et des sols sur la restauration des jachères très dégradées au Burkina Faso. In La Jachère en Afrique Tropicale, Rôles, Aménagement, Alternatives. Volume I. Dakar, Avril 13-16,1999. p. 751-759.