a86

Determinants of the Availability of Adequate Millet Stover for Mulching in the Sahel

J. Baidu-Forson

ABSTRACT. Millet and sorghum stover protect intensively cultivated soils from rapid degradation and promote sustained productivity. Quantities of stover found on farms in the Sahel are mostly inadequate for effective mulching. Surveys conducted in western Niger revealed that the inadequacy of stover for mulching is principally due to the low millet stover yields, particularly in drier areas of the Sahel. The application of P fertilizer represents a feasible option for increasing stover yields. Also, evidence of historical relationships between yearly amounts of stover remaining on farms suggests the possibility of gradual build-up of stover for mulching on farms. Other important determinants of observed level of millet stover are: distance of farms from household compounds, differences in crop production potentials, cropping practice, and interactions between amounts of previous stover, cropping practice and crop production potentials.

INTRODUCTION

Demographic and economic factors have contributed to changes in the ecological balance that supported extensive crop production

J. Baidu-Forson is Principal Scientist (Economics), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), ICRISAT Sahelian Center, B.P 12404, Niamey, Niger.

The author gratefully acknowledges the pertinent comments and suggestions of William Payne, Elias Ayuk, Joost Brouwer, Roger Stern and the journal's anonymous reviewers.

Submitted as JA number 1384 by ICRISAT.

Journal of Sustainable Agriculture, Vol. 5(1/2) 1995
© 1995 by The Haworth Press, Inc. All rights reserved.

systems in West Africa (Matlon and Spencer, 1984). In particular, increased population pressure on arable land has resulted in decreased lengths of fallow periods which previously guaranteed low-level but stable crop production. But, research has shown that continuous cropping of arable land results in reduced soil organic matter, increased Fe and Al (Bationo and Mukwonye, 1991), leaching of bases, subsequent increases of soil acidity and declines in yields (ICRISAT Sahelian Center, 1992 p. 81). Therefore, there is a need to adopt practices that protect the agricultural production environment and permit long-term exploitation of arable land resources. The recycling of millet and sorghum stover represents an important option for achieving these goals. But, the diversion of stover to other economic ends by households is assumed to be a constraint to the availability of adequate stover for mulching (Matlon, 1983). Surveys were conducted in western Niger to verify this assumption and identify factors that influence the availability of stover for mulching on farms.

Role of Stover in Soil Nutrient Replenishment

Recycled crop residues, including millet stover, replenish soil P and N (Charreau and Nicou, 1971; Tourte, 1971; Pichot et al., 1974; Ganry et al., 1978). Levels of Ca, Mg, and K in the 0-20 cm topsoil also increase significantly due to the release of basic cations after decomposition or the capture of dust of different nutrient composition by the residues (Geiger et al., 1988).

Protection of Agricultural Environment with Stover

The total sand content of surface soils in most parts of the Sahel is around 90%, of which 85% fall within soil textural ranges of very high (0.1-0.15 mm) to high (0.05-0.1 mm and 0.15-0.5 mm) erosion risks (Sivakumar et al., 1990). These soils are similar to those surveyed at the ICRISAT Sahelian Center and classified as psammentic paleustalf, siliceous and isohypermic (West et al., 1984), according to USDA classification.

Susceptibility of sandy soils to wind erosion is a major problem in the Sahelian region of West Africa because moving sand affects crop establishment by damaging seedlings (Sivakumar et al., 1990). Stover mulch reduces sand losses (ICRISAT Sahelian Center, 1991), controls surface runoff (Mietton, 1986) and reduces extreme soil temperatures. Therefore, the addition of stover conserves soil and arrests soil degradation (Pichot et al., 1981).

Impact of Stover Recycling on Crop Production

Millet, *Pennisetum glaucum* (L.) R. Br., grain yields were substantially improved at the ICRISAT Sahelian Center research station when millet stover was used as mulch in combination with P fertilizer (Fussell et al., 1987). The application of inorganic fertilizers alone resulted in yield declines over time where stover was removed (Pichot et al., 1981). Therefore, stover amendments are important for the stability of crop production (Pieri, 1985).

MATERIAL, SURVEY AREA DESCRIPTION AND METHODS

Material

Millet is the predominant crop grown in the Sahelian regions of Niger, Burkina Faso, Mali and Senegal (Figure 1). Cowpea, groundnut and small amounts of sorghum are cultivated either in intercrops with millet or alone. However, the residues of crops other than millet are always harvested due to their higher feed and commercial values. Therefore, the study was limited to an examination of factors that influence on-farm availability of millet stover for mulching.

Description of Study Areas

Surveys were conducted in 11 villages selected along a north-south transect in three districts of western Niger (Figure 2): Hamdallaye [2°25'E, 13°33'N], Dantiandou [2°46'E, 13°24'N] and Kirtachi [2°28'E, 12°45'N]. The agroecology of the study areas is the typical Sahelian environment, namely sandy soils with sparse

FIGURE 1. Geographical Map Showing the Sahelian Region of West Africa.

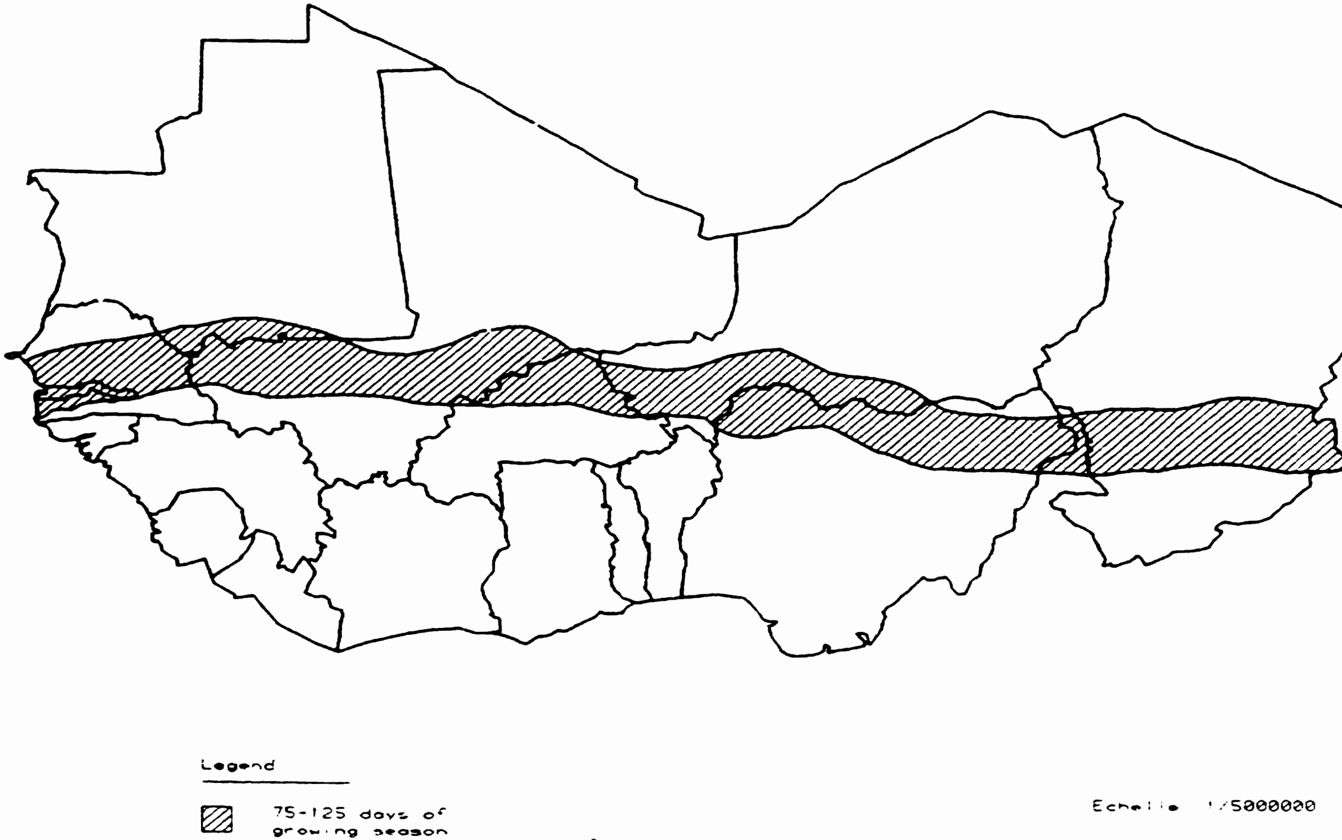
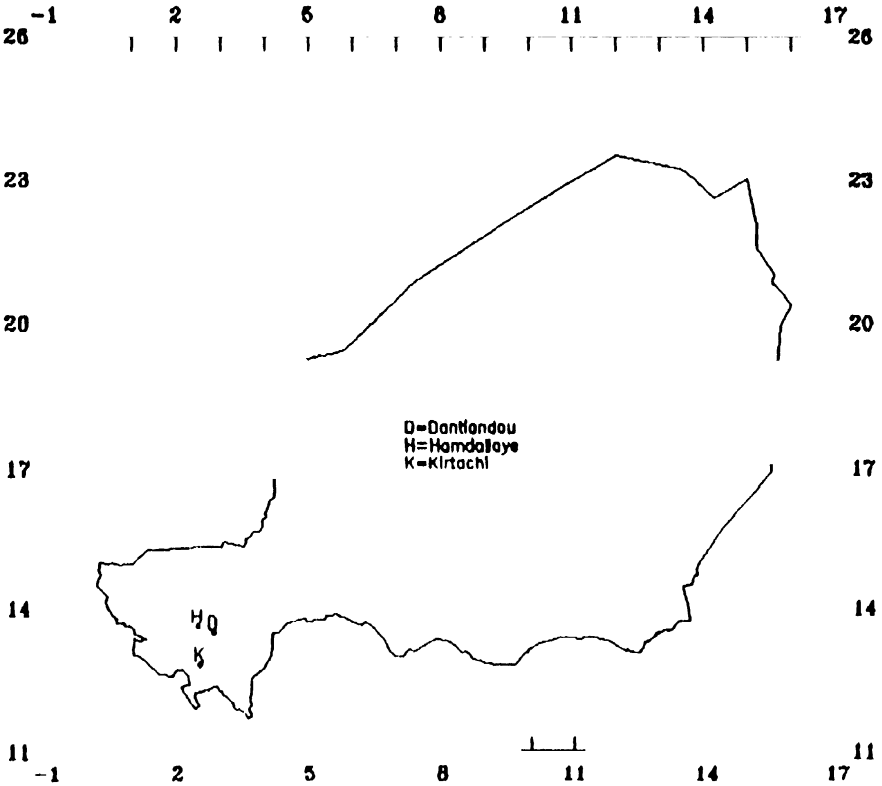


FIGURE 2. Map Showing the Study Sites in Niger.



vegetational cover, found in northern arable areas of Niger, Burkina Faso, Mali and Senegal. Kirtachi is the southernmost district, close to the transition zone between the Sahelian and Sudanian zones. It therefore has a higher rainfall (650-700 mm annual mean) than the other two northern districts which have similar dry (450-500 mm annual mean rainfall) conditions. Soils in the two northern districts are similar and more sandy than soils in the Kirtachi district.

The three districts are mostly populated by two ethnic groups, "Djerma" and "Peul." Djerma households are sedentary crop farmers who in addition may raise some small and large ruminants. The predominant occupation of the Peul is livestock herding. However, sedentary Peuls now cultivate millet and other crops in addition to raising livestock.

Livestock managed by transitory herders and from sedentary households graze millet stover left on farmlands. Access to stover by livestock of transitory herders are sometimes secured through formal exchanges of grazing rights for overnight paddocking of animals on farms. More commonly, access to farmland after grain harvests is poorly regulated.

Survey Methods

In each district, study villages were chosen on the basis of the representativeness of millet stover management practices. The number of sample households that were randomly chosen from enumerated household lists and analyzed are: 22 in Hamdallaye district; 24 in Dantiandou district; and 18 in Kirtachi district. The quantity of millet stover collected and directly used by each household was intensively monitored between October 1989 and July 1992. After the grain harvest of 1991, the air dry weight of stover produced on each farm was estimated from representative stratified samples. Each field was roughly divided into high, low and average stover production areas. Based on the relative areas, samples of stover yields were taken proportionally from the three categories, at the rate of three 10 m^2 plots per hectare. In April 1991 and March 1992, millet stover remaining on each farm was similarly estimated. The sampling covered 128 farms. Since millet stover yields could be affected by cropping practice, millet planted as a sole crop was distinguished from millet planted in intercrops. Also, farm size and the distance of each farm from the household's compound were measured.

Analytical Methods

Summary statistics were computed for millet stover requirements of farm households, estimated stover yields, farm size and amounts of stover found on farms.

A regression procedure was used to fit independent variables that best explained variation in the levels of stover available on farms in March 1992 (RMAR92, kg ha^{-1}). Potential explanatory variables were selected on the basis of results of previous research and observations. In West Africa, stover disappearance from farmlands is attributed to the activities of termites and grazing by livestock (Quilfen and Milleville, 1983; Allard et al., 1983). Since stover disappearance (DISP) is likely to influence levels of millet stover available for mulching, the difference between levels of stover mulch observed on farms in March 1992 (RMAR92) and estimated stover production on each farm in October 1991 was used as an explanatory variable. Farming systems literature in West Africa shows the occurrence of declining fertility from household compounds outward (Charreau, 1974; Prudencio, 1987). This formed the basis for the inclusion of a variable on distance (DIST, km) of farms from household compounds in the list of explanatory variables. Intercrops in the Sahel most frequently include millet and cowpea. Cultivar types, relative planting dates and plant densities are likely to affect millet yields in the Sahel (Ntare, 1990; Ntare and Williams, 1992). Therefore, a dummy variable (MIX) that distinguished sole millet (MIX = 0) from intercropped millet (MIX = 1) was considered. Level of previous stover mulch found on-farm in April 1991 (RAPR91, kg ha^{-1}) was used as an explanatory variable because research suggests that crop residues used as mulch increased seedling dry mass when compared with similar dry mass obtained from unmulched plots (ICRISAT Sahelian Center, 1989 p. 76). Based on farm level observations, other variables considered were: farm size (SIZE, ha); a dummy variable to represent differences in crop production potentials (NK), between the more favorable crop production environment in Kirtachi district (NK = 0) and the less favorable production environments in the two similarly dry districts (NK = 1); and interactions between crop production potentials and DIST, MIX and RAPR91. Data collected from 128 farms were pooled in the regression analysis, using SAS (SAS Institute).

RESULTS AND DISCUSSION

Millet Stover Yields

Millet stover yields of 2000 kg ha^{-1} or more were recorded on about 5% of farms in the drier districts (Hamdallaye and Dantiandou) and nearly a quarter of sampled farms in the wetter Kirtachi district (Table 1). On the other hand, stover yields of less than 1000

TABLE 1. Millet stover production levels in three districts of Niger, October 1991.

Range of millet stover production (SP, kg ha^{-1})	Percentage farms within SP range		
	Hamdallaye district	Dantiandou district	Kirtachi district
$SP \geq 2000$	4	5	24
$1500 \leq SP < 2000$	12	41	26
$1000 \leq SP < 1500$	37	18	33
$SP < 1000$	47	36	17

Number of farms sampled were: 51 in Hamdallaye district; 61 in Dantiandou district; and 54 in Kirtachi district.

Note: Moisture content of air-dried millet stover is less than 10% (S. Fernandez, personal cornunication).

kg ha^{-1} were obtained on 36-47% of farms in the drier areas but on only 17% of farms in the wetter district. The results show that millet stover yields are dependent on crop production potentials. More importantly, substantial improvements in yields would be needed to ensure the availability of adequate levels of stover for mulching on most farms in the Sahel, particularly in the drier areas. Options for increasing the availability of stover for mulching of farmlands include application of inorganic fertilizer to increase biomass production (Bationo and Mokwunye, 1991); and investment of post grain-harvest labor in the harvesting and storage of millet stover.

The application of P fertilizer permitted farmers to increase millet plant density from the traditional level of 0.4 hills/m^{-2} to 0.8 hills/m^{-2}. The consequent substantial increases in millet biomass (ICRISAT Sahelian Center, 1988 p. 84) resulted in increased availability of residual stover to protect soils from erosion (ICRISAT, 1989 p. 181). More importantly, millet grain yield increments of up to 250% were obtained with the use of inorganic fertilizer under farmers' management (ICRISAT Sahelian Center, 1988 p. 84). Economic analysis of grain yield increases of 44%-130% observed at the farmer level showed that the application of P fertilizers to millet is economical even in the severest drought years (ICRISAT, 1985). Financial returns were highest when 24 kg ha^{-1} of 50% acidulated rock phosphate were applied (Fussell et al., 1987 p. 258). Since the millet grains produced make it profitable to apply modest amounts of P, farmers are likely to accept recommendations to apply P. However, fertilizer supply constraints could limit the option of using P fertilizer to increase biomass production.

Another option for increasing millet stover availability for mulching requires the use of post-grain harvest labor for harvesting, storing and the spreading of stover on farmland immediately prior to the commencement of the next rainy season. But opportunity costs to off-season migratory labor, possible conflict of stover spreading with sowing, the desire of farmers to rest after grain harvest and farmer perception of possible externality gains from grazing livestock are factors that could prevent farmers from exercising this option. Also, soils from which millet stover is removed for storage will be exposed to wind erosion during the dry season that precedes the spreading of stored stover.

Millet Stover Requirements of Sample Households

With the exception of the 1991/92 monitoring period in the Kirtachi district, more than 80% of the sample farm households collected millet stover (Table 2). Millet stalks were used for the construction of fences, sheds, granaries and the fabrication of beds. But, on the average, not more than of 33 kg ha^{-1} of millet stover were required by households in the Hamdallaye and Dantiandou districts. Therefore, average stover requirements constituted less than 2.5% of average stover yields in the drier districts. Even the largest quantities collected by a household accounted for only 15% or less of the average millet stover production. Millet stover requirements of households in the wetter district were slightly higher than those in the two drier districts. Even then, the average and largest quantities of millet stover collected by households in the wetter district accounted for 3.5% and 32% of the mean production. The results suggest that millet stover requirements of Sahelian households are generally low. Therefore, the assumption that households divert stover to economic ends (Matlon 1983) cannot be generalized for all types of stover, locations and households.

TABLE 2. Summary statistics of millet stover requirements of sample households and area cultivated, 1989/90 to 1991/92.

Survey period Oct-Jul	Summary statistic	Hamdallaye district	Dantiandou district	Kirtachi district
1989/90				
	Percent stover users[1]	*	92	89
	Mean weight[2] (kg ha^{-1})	*	29	91
	Maximum weight[3] (kg ha^{-1})	*	151	254
	Average farm size (ha)	*	8.7	4.6
1990/91				
	Percent stover users	82	96	89
	Mean weight (kg ha^{-1})	33	23	92
	Maximum weight (kg ha^{-1})	92	92	279
	Average farm size (ha)	6.5	11.3	4.8
1991/92				
	Percent stover users	96	83	33
	Mean weight (kg ha^{-1})	27	18	51
	Maximum weight (kg ha^{-1})	184	121	521
	Average farm size (ha)	7.8	8.4	4.3

[1] Number of sample households: 22 in Hamdallaye district; 24 in Dantiandou district; and 18 in the Kirtachi district.

[2] Average weight of stover collected per hectare, for households collecting millet stover.

[3] Maximum weight of millet stover per hectare, collected by a member of the sample households.

Notes: * No summary statistics available.

Average area corresponds to the average number of hectares cultivated by sample households to sole millet and millet-based mixtures.

Millet Stover on Farms Prior to Cropping Season

In March 1992, average amounts of millet stover found on farms in the drier districts accounted for 21% of the mean of stover production for October 1991 (Table 3). Even in the Kirtachi district, where comparatively larger amounts of stover were observed, only 39% of the total stover production remained on farms by March

TABLE 3. Summary statistics on millet stover on farms, in three districts of Niger.

Year/Month of sampling	District	Quantities of stover on farms (kg ha^{-1})				Number of farms sampled[1]
		Min	Max	Mean	SD	
1991/April						
	Hamdallaye	130	550	283	104	40
	Dantiandou	110	790	325	149	52
	Kirtachi	430	1190	755	209	43
1991/October						
	Hamdallaye	570	2730	1090	385	51
	Dantiandou	340	3790	1198	554	61
	Kirtachi	700	3560	1618	636	54
1992/March						
	Hamdallaye	90	600	231	96	46
	Dantiandou	90	690	251	85	58
	Kirtachi	250	1520	631	249	54

[1] The differences in number of farms sampled reflect changes that resulted from the cultivation of new farms or the abandon of old farms by sample households.

1992. Generally, millet stover found on farms averaged less than 800 kg ha$-^{1}$ (Table 3). However, as much as 2000 kg ha$-^{1}$ of millet stover may be required for soil conservation and crop protection against sandblasts.

Regression Results

The development of a strategy for increasing the availability of millet stover for mulching requires the identification of variables that explain observed variation in amounts of stover found on farms. Regression results show that variables that explained 73% of the variation in amounts of millet stover on farms in March 1992 (current level of stover) were: distance of farms to household compounds, changes from sole millet crop to millet-based intercrops, differences in crop production potentials and previous amounts of stover (Table 4). Interactions of location with intercrops and previous levels of stover were also found to be significant in explaining variation in current levels of millet stover.

Millet stover yields respond to improvements in soil fertility. Therefore, the sign and significance of the distance of farms to household compounds confirm the existence of a fertility gradient (Charreau, 1974; Prudencio, 1987). According to the regression results, a decline of 14.2 kg of stover remaining on farms occurs for each additional kilometer distance from household compound. Also, the sign and significance of previous stover mulch variable

TABLE 4. Results of estimated regression.

Independent variables	Estimated regression	
	Parameter Estimate	Standard Error
Intercept	517.4*	88.7
Location dummy[1] (NK)	−294.4*	96.2
Intercrop (MIX)	−192.6*	55.5
Distance of farm (DIST)	−14.2**	5.8
Previous stover (RAPR91)	0.39*	0.09
Intercrop*Location (MIXNK)	206.7*	62.6
Previous stover*Location (RAPRNK)	−0.25**	0.13
Model F-value = 58.9 Total DF = 127		
Adjusted R^2 = 0.7323		
Dependent variable = Current stover (RMAR92)		

* Significant at 1%.

** Significant at 5%.

[1] Location dummy denotes differences between wetter and drier areas in terms of the crop production potentials.

(RAPR91) confirm the effect of increased stover mulch on biomass yield of the subsequent millet crop (ICRISAT Sahelian Center, 1989 p. 77).

The parameter for differences in production potentials suggests that lower millet stover yield occurs in areas with lower crop production potential. The negative influence of intercropping on millet stover yields reflects the occurrence of competition between crops and/or reduced millet plant populations particularly in the wetter areas where intercropping is much more effective.

Termite activity was prevalent on most farms and millet stover represents an important source of livestock feed in the Sahel. Yet, the amounts of stover that disappeared from farmlands (DISP) did not significantly explain variation in the observed level of current stover available for mulching. This suggests the disappearance of relatively constant proportions of total millet stover production. Since the bulk of millet stover is consumed by livestock, the disappearance of constant proportions of stover from farmlands may be due to selectivity of different parts of millet stover during grazing and/or the lapse of time after which livestock found remaining stover to be less palatable. Also, although large farms generally occurred on marginal lands, farm size did not significantly influence variation in the level of millet stover available for mulching.

SUMMARY

The recycling of stover represents a feasible and necessary option for preventing soil degradation and assuring long-term crop production in the Sahel of West Africa. Millet stover requirements of Sahelian households were generally low and therefore important quantities of millet stover are not diverted to economic ends. Previous levels of stover mulch, distance of farms from household compounds, cropping practice and differences in crop production potentials were found to be important determinants of variations in amounts of stover observed on farms shortly before the onset of a cropping season. More importantly, stover production on most farms were found to be very low, particularly in the drier areas. The application of modest amounts of P fertilizer represents a feasible and necessary option for improving millet stover yields and increasing the availability of adequate amounts of stover for mulching in the Sahel. In areas where imported fertilizers are unavailable, composted rock phosphates or other types of compost could provide adequate fertility. Biomass production is even more spectacularly improved when fertility and local water harvesting are combined in techniques such as "zai" in Burkina Faso and "tassa" in Niger.

Due to the importance of livestock herding in the Sahel and the need to satisfy the feed requirements, the cultivation of alternative types of feed represents an option for relieving grazing pressure on stover left in the field. However, the formulation and enforcement of laws governing access to farmlands by free-grazing livestock may be needed in many parts of the Sahel if stover availability for mulching is to improve substantially. The laws should regulate grazing and prevent free access to farmlands, especially in areas of high livestock density. It is also important that livestock herds are maintained at levels consistent with the carrying capacity of grazing land.

REFERENCES

Allard, J.-L., Y. Bertheau, J.-J. Drevon, O. Seze, and F. Ganry. 1983. Resources èn résidus de récolte et potentialités pour le biogaz au Senegal. Agron. Trop. 38: 213-221.

Bationo, A., and A.U. Mokwonye. 1991. Role of manures and crop residue in alleviating soil fertility constraints to crop production: with special reference to the Sahelian and Sudanian zones of West Africa. p. 217-225. In: A.U. Mokwunye (ed.) Alleviating Soil Fertility Constraints to Increased Crop Production in West Africa. Kluwer academic publishers, Dordrecht/Boston/London.

Charreau, C. 1974. Soils of tropical dry and wet climatic areas of West Africa and their management. Agron. Mimeo No. 74-26. Dept. of Agron., Cornell Univ. Ithaca, New York.

Charreau, C., and R. Nicou. 1971. L'amélioration du profil cultural dans les sols sableux et sable-argileux de la zone agronomiques. Agron. Trop. 26: 209-255, 565-631, 903-978, 1183-1237.

Fussell, L.K., P.G. Serafini, A. Bationo, and M.C. Klaij. 1987. Management practices to increase yield and yield stability of pearl millet in Africa. p. 255-268 In: Proc. of Int. Pearl Millet Workshop, April 7-11, 1986. ICRISAT, Patancheru, AP, India.

Ganry, F., G. Guiraud, and Y. Dommergues. 1978. Effect of straw incorporation on the yield and nitrogen balance in the sandy soil/pearl millet cropping system of Senegal. Plant and Soil 50: 647-662.

Geiger, S.C., A. Manu, and A. Bationo. 1988. Changes in the chemistry of a sandy Nigerian soil following long-term residue and fertilizer additions. p. 52. In: Agron. Abstr. Amer. Soc. Agron. Madison, Wisconsin.

International Crops Research Institute for the Semi-Arid tropics (ICRISAT). 1985. Annual report 1984. ICRISAT, Patancheru, A.P. India. 376p.

International Crops Research Institute for the Semi-Arid tropics (ICRISAT). 1989. Annual report 1988. ICRISAT, Patancheru, A.P. India. 279p.

International Crops Research Institute for the Semi-Arid tropics (ICRISAT) Sahelian Center. 1988. ICRISAT West African programs annual report 1987. ICRISAT Sahelian Center, Niamey, Niger. 147p.

International Crops Research Institute for the Semi-Arid tropics (ICRISAT) Sahelian Center. 1989. ICRISAT West African programs annual report 1988. ICRISAT Sahelian Center, Niamey, Niger. 125p.

International Crops Research Institute for the Semi-Arid tropics (ICRISAT) Sahelian Center. 1991. ICRISAT West African programs annual report 1990. ICRISAT Sahelian Center, Niamey, Niger. 132p.

International Crops Research Institute for the Semi-Arid tropics (ICRISAT) Sahelian Center. 1992. ICRISAT West African programs annual report 1991. ICRISAT Sahelian Center, Niamey, Niger, 144p.

Matlon, P.J. 1983. The Technical Potential for Increased Food Production in the West African Semi-Arid Tropics. Paper presented at the conference on Accelerating Agricultural Growth in sub-Saharan Africa. University of Zimbabwe/IFPRI, Aug. 29-Sept. 1, Zimbabwe. 54p.

Matlon, P.J., and D.S. Spencer. 1984. Increasing food production in sub-Saharan Africa: environmental problems and inadequate technological solutions. Amer. J. Agric. Econ. 66: 671-676.

Mietton, M. 1986. Méthodes et efficacité de la lutte contre l'érosion hydrique au Burkina Faso. Cahiers ORSTOM Série Pédologie 22: 181-196.

Ntare, B. 1990. Intercropping morphologically different cowpeas with pearl millet in a short season environment in the Sahel. Exp. Agric. 26: 41-47.

Ntare, B., and J.H. Williams. 1992. Response of cowpea cultivars to planting pattern and date of sowing in intercrops with pearl millet in Niger. Exp. Agric. 28: 41-48.

Pichot, J., S. Burdin, J. Charoy, and J. Nabos. 1974. L'enfouissement des pailles de mil Pennisetum dans les sols sableux dunaires. Son influence sur les rendements et la nutrition minérale du mil. Son action sur les caratéristiques chimiques du sol et la dynamique de l'azote minérale. Agron. Trop. 29: 995-1005.

Pichot, J., M.P. Sedogo, J.F. Poulain, and J. Arrivets. 1981. Evolution de la fertilité d'un sol ferrugineux tropical sous l'influence des fumures minérales et organiques. Agron. Trop. 36: 122-133.

Pieri, C. 1985. Fertilisation des cultures vivrières et fertilité des sols en agriculture paysanne sub-Saharienne: l'experience de l'IRAT. p. 254-278. In H.W. Ohm et J.G. Nagy (ed.) Technologies Appropriés pour les Paysans des Zones Semi-Arid. Purdue University, West Lafayette, Indiana.

Prudencio, Y.C. 1987. Soil and Crop Management in Selected Farming Systems of Burkina Faso. SAFGRAD, Ouagadougou. 152p.
Quilfen, J.-P., and P. Milleville. 1983. Résidus de cultures et fumure animale: un aspect des relations agriculture-élévage dans le nord de la Haute-Volta. Agron. Trop. 38: 206-212.
Sivakumar, M.V.K., C. Renard, M.C. Klaij, B.R. Ntare, L.K. Fussell, and A. Bationo. 1990. Natural resource management for sustainable agriculture in the Sudano-Sahelian zone. p. 129-158. In: R.P. Singh (ed.) Sustainable Agriculture: Issues, Perspectives and Prospects in the Semi-Arid Tropics. Vol. 1. Indian Society of Agronomy, New Delhi, India.
Tourte, R. 1971. Thèmes lègers thèmes lourds systèmes intensifs. Voies différents ouvertes au developpement agricole du Senegal. Agron. Trop. 19: 1034-1072.
West, L.T., L.P. Wilding, J.K. Landeck, and F.G. Calhoun. 1984. Soil Survey of ICRISAT Sahelian Center. Soil and Crop Science Department. Texas A & M, College Station: Tropsoils.

RECEIVED: 08/17/93
REVISED: 12/07/93
ACCEPTED: 12/15/93