Study of Organic Matter Flows on Farms in the Western Cotton Zone of Burkina Faso

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Summary

In the sub-Sahelian zone, it has become necessary to use organic manure as a means of maintaining or improving cultivated soil fertility. The expertise developed by the farms, in terms of how various organic matters can be used by rural populations, plays an essential role when it comes to promoting the use of organic manure. In this way, organic matter inflows and outflows were quantified at farms in a village in the western cotton zone of Burkina Faso over the period of one year. Results show that the average plant biomass production was estimated at 38.1 tonnes per farm, 33.8% of which were harvested products, 65.2% crop residues (mainly cereal straw) and 1% shrub shoots. This is in addition to an average manure production estimated at 8.6 tonnes, based on average livestock numbers on each farm. However, only 30% of the organic residues produced were used on the farms, 14% of which were returned to the soil as manure. This low return ratio can lead to the depletion of organic matter in the soil, which makes it necessary to identify other methods for crop residue management on the farms.

Résumé

Etude des flux de matières organiques dans les fermes agricoles en zone cotonnière Ouest du Burkina Faso

La connaissance des matières organiques disponibles au niveau des exploitations agricoles et de leur utilisation, est indispensable pour le renforcement de la fumure organique qui est devenue nécessaire pour le maintien de la fertilité des sols cultivés en zone soudano-sahélienne. Les flux d'entrée et de sortie des matières organiques au sein des exploitations agricoles dans la zone cotonnière ouest du Burkina Faso, ont été quantifiés au cours d'une année. La production moyenne de plantes de biomasse par ferme a été évaluée à 38,1 tonnes constitués par 33,8% de produits récoltés; 65,2% de résidus de plantes composés en très grande partie par les pailles de céréales et; 1% de rejets d'arbustes. A cela s'ajoute la production de fumier estimée à 8,6 tonnes de fèces en moyenne compte tenu du nombre moyen de ruminants par ferme. Mais seulement 30% des résidus organiques produits ont été utilisés dans l'exploitation agricole dont 14% ont été restitués aux sols essentiellement sous forme de fumier. Face à ce faible taux de restitution pouvant conduire à terme à un appauvrissement des sols en matières organiques, il est indispensable de trouver des modes de gestion permettant de mieux valoriser les fortes quantités de matières organiques disponibles sur les fermes pour l'entretien de la fertilité des sols.

Introduction

As a substrate, which can provide nutritional elements, increase water storage capacity and mineral elements, maintain microbial life and stabilise the structure, organic matter plays a central role in increasing soil productivity (2, 9, 11, 14). Improving organic matter stocks has therefore proven vital for maintaining cultivated soil fertility (2, 4, 9, 12).

The main methods of increasing organic matter stocks in cultivated soils essentially involve fallowing and organic amendments (1, 8, 11, 12). But long-term fallowing, which is the traditional method previously used to restore soil fertility, in particular its organic status after cultivation, tends to cause the disappearance of cropping systems. In addition, for most growers, increasing organic stocks in soils has to involve reinforcing the use of organic matters available on the farms and, if possible, making use of external sources. This requires sound knowledge of the stocks available on the farms and how they are used by rural populations.

This study subscribes to this approach and aims to quantify organic matter flows on the soil surface at field and farm level in the western cotton zone of Burkina Faso.

Materials and methods

1. Physical environment

The study was conducted in the Kadomba region, which is located between 11°23 and 11°41 north latitude and, 3°45 and 4°8 west longitude. The

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climate is South Sudanese (*6*) and characterised by a rainy season lasting from April/May-October, with an average annual rainfall of 1062 mm for 1990-2000.

2. Description of farms
The farms were studied based on surveys, observations and field measures focusing on a sample of 23 farms.

3. Evaluation of organic matter production on the farms
Biomass production has been estimated on the basis of field surface areas and crop yields (grains, fibres or husks and harvest residues) and that of shrub shoots. Crop and shrub shoot production was assessed on square areas measuring 25 m^2 and 100 m^2 respectively and expressed in kg/ha of dry matter. For fallow land, only herbaceous biomass was evaluated using 9 m^2 plots.
Theoretical manure production was quantified according to the number of cattle and small ruminants, assuming average annual manure production of 750 kg per cow (3) and 125 kg per small ruminant (13).

4. Evaluation of organic matter flows in the fields
Organic matter flows entering the fields correspond to harvest residue and/or manure/compost applications. Harvest residue applications, which correspond to residues remaining in the soil after field preparation, were evaluated using 100 m^2 plots and quantities expressed in kg/ha of dry matter. For manure/compost applications, the quantities applied were evaluated according to the number of cart loads, which was converted into kg, based on the figure of 200 kg per load (15).
Harvest residue exports, which correspond to organic matter outflows, were evaluated by quantifying samples taken during harvesting and the dry season. The former were assessed by direct measurement after picking, while the latter were estimated by measuring the difference between the initial yield and samples taken during harvesting, plus residues remaining at field preparation stage. Quantities of burnt biomass correspond to the remaining crop and shrub shoot residue quantities for fields that were burnt at preparation stage.

Results

1. Farm characteristics
The farms are family-run, with a workforce ranging from 4 - 45 people, one third of whom are under 10 years old. The cultivated areas, including fallow land, range from 2.5-22.5 hectares, with an average size of 10.9 hectares. Figure 1 shows that maize covers the largest area (32.8%), followed by cotton, which covers 26.5% of the land. Sorghum comes next with 16.3%. Other crops, such as millet, peanuts, cowpeas and rice come next, each of which occupies less than 0.5 hectare. The average amount of fallow land on each farm represents 15.4% of its total surface area.

Livestock are kept with, on average, 9.6 cattle and 11.1 small ruminants. At least one third of cattle are draught oxen. The farming method adopted is the intensive type. Most of the animals are kept in natural pastures during the rainy season. During the dry season, residues remaining in the fields represent the main food source for the animals, which are also provided with additional harvest residue feed stocks. This is especially true of draught oxen.

2. Organic matter production on the farms
2.1. Plant biomass quantities
Data concerning plant biomass quantities produced in cultivated fields is shown in table 1 for crops and shrub shoots.
- Crop biomass
The total quantity of biomass harvested in the form of grains, husks or fibres has been estimated at an average of 12.90 tonnes for each farm. The distribution per crop type shows that cereals represent 76%, which includes 58% for maize alone; the share of cotton grain is 23% and remainder (1%) consists of pulses.
Harvest residue biomass has been estimated at 24.85 tonnes on average for each farm. Cereal straw represents 81%, cotton stalks 18% and pulse stalks 1%.
- Shrub shoot biomass
The main shrub species identified are: *Piliostigma* sp*., Lannea microcarpa, Diospyros mespiliformis, Detarium microcarpum*. The shoots develop in the form of clumps with a height of between 0.20 and 0.80 m. Average quantities of shoot biomass are small. When all fields are considered, they range from 29.3-67.1 kg/ha, with an average yield of 369.9 kg for each farm.
- Fallow biomass
Land is left fallow for 1-15 years on 70% of the farms studied. The main herbaceous species found on fallow land are: *Pennisetum subanguustum; Pseudapricus pseudodrella; Andropogon* sp*.; Imperata cylindrica.*

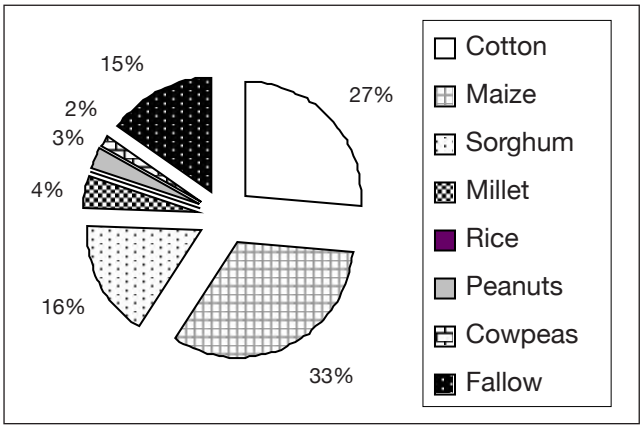


Figure 1: Average crop rotation per farm in 2000.

Table 1
Mean amount of dry matter produced by crops per farm

	Crops						
	Cotton	Maize	Sorghum	Millet	Rice	Peanuts	Cowpeas
a Average area (in ha)	2.87	3.55	1.76	0 .46	0.03	0.30	0.17
b Yield: grains, husks and fibres (in kg/ha)	1039.6 ± 474	2046.0 ± 496	1059.1 ± 475	1002.6 ± 431	935.4 ± 946	291.8 ± 89	424.4 ± 124
c Harvest residues (in kg/ha)	1613.2 ± 666	3160.8 ± 733	4045.4 ± 1360	3332.4 ± 1296	1154.1 ± 436	554.7 ± 138	674.4 ± 198
d Shrub shoots (in kg/ha)	29.3 ± 24	43.5 ± 42	46.1 ± 25	44.0 ± 41	62.1 ± 12	53.8 ± 18	67.1 ± 43
e Total plant biomass (in kg/ha) e = b+c+d	2682.1	5250.3	5150.6	4379.0	2151.6	900.3	1165.9
f Total average yield (in kg) f = e x a	7697.6	18638.6	9065.1	2058.1	64.5	270.1	198.2

Table 2
Number of livestock and theoretical manure production per farm

	Number of cattle			Theoretical manure production (kg/year)		
	Cows	Small ruminants	Total	Cows	Small ruminants	Total
Mean values	9.6	11.1	20.8	7206.5	1391.3	8597.8
Extreme values	0-46	0-46	2-80	0-34500	0-5750	1125-37000

Herbaceous biomass from fallow land was estimated at 6.79 tonnes/ha on average with values ranging from 1.91-15.19 tonnes/ha, with an average total yield of 11.34 tonnes per farm.

2.2. Converted organic matter production

Theoretical annual manure production was calculated according to cattle numbers at each farm (Table 2), based on 750 kg dung per cow and 125 kg per small ruminant. The number of animals distributed between cattle and small ruminants ranges from 2 - 80 on average per farm. Estimated manure quantities range from 1.13 - 37 tonnes, with an average manure production of 8.60 tonnes per farm.

For converted organic matters applied in the form of compost and manure, quantities range from 0 - 20 tonnes with an average of 6.55 tonnes per farm.

3. Use of organic matters

3.1. Harvest samples taken from crop residues in the fields

The results (Table 3) refer to crop residue samples. Samples collected during harvesting are larger for pulse stalks and rice straw than for major cereals. Other exports take place throughout the dry season, between November-April, and focus on all remaining pulse residues, 58.7-80.4% of cereal straw and 24.3% of cotton residues. For the entire farm, out of a total average yield of 24.85 tonnes of crop residues, 76.7% is exported from the fields, including 14.3% during harvesting and 62.4% during the dry season. This means that, at the end of the dry season, there is still an average of 5.75 tonnes of residues, 60.4% of which consists of cotton stalks.

3.2. Manure and/or compost applications in the fields

Manure and/or compost applications are applied mainly to maize, cotton and sorghum fields. The average quantity applied per farm was estimated at 6.55 tonnes, of which 73.9% for maize fields, 39.1% for cotton fields and 8.7% for sorghum fields (Figure 2).

4. Figures for quantities of organic matters used by farms

Figures for the use of various sources of organic matters (Figure 3) show that, out of a total average organic residue yield of 33.82 tonnes per farm (not including fallow land), only 10.10 tonnes were used, which includes 3.55 tonnes in the form of crop residues collected during harvesting and 6.55 tonnes as manure or compost applied in the fields, with a usage rate of 29.9%. The majority of organic matter produced (70.1%) is more or less lost to the farm – either due to burning or consumption by animals from outside the farm.

Table 3
Use of crop residues on farms

	Crops						
	Cotton	Maize	Sorghum	Millet	Rice	Peanuts	Cowpeas
1 Residue production (kg)	4629.9	11220.8	7119.9	1566.2	34.6	166.4	114.6
2 Quantity of residues collected during harvesting (kg)	0	1030.4	2113.0	228.3	34.6	97.3	49.3
3 Quantity of residues remaining at the end of the dry season (kg)	3472.4	1469.3	536.8	271.2	0	0	0
4 Quantity of residues lost during the dry season (kg) 4 = 1-2-3	1123.5	8721.1	4470.1	1066.7	0	69.1	65.3
Export rate for harvest residues (%)	24.3	86.9	92.5	82.7	100	100	100

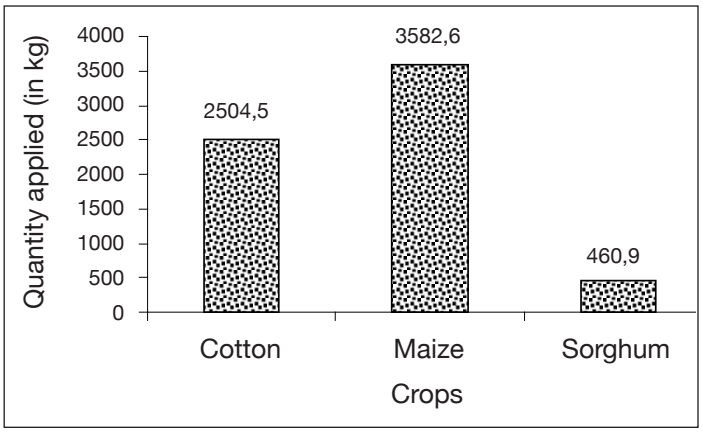
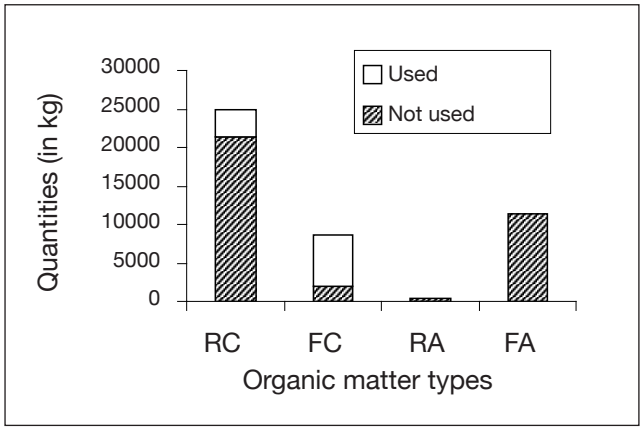


Figure 2: Average amounts of manure or compost applied per crop (kg).



RC: Crop residues FC: Manure and/or compost RA: Shrub shoots Fa: Fallow

Figure 3: Total quantities of organic matters used per farm.

Discussion

The farms studied are of the family-run agro-pastoral type and focus chiefly on crop production. The area cultivated by each farm (10.9 hectares on average) is quite high compared to the national figure, which is 3.7 hectares (7). The crop system is of the cotton-based cereal type (10).

The harvest residues assessed represent the majority of plant biomass available on the farms, with average quantities estimated at close to 25 tonnes per farm. These residues can be categorised according to crop type: cereal straw (maize, sorghum, millet and rice), which form the largest group with 81%, pulse stalks (peanuts and cowpeas), which account for only 1% and cotton stalks, which represent 18%. Shrub shoot biomass can be used to increase quantities of organic matter produced in the fields. It has been estimated at around 370 kg per farm. The average quantities harvested per field are quite small. This can be explained not only by the duration of continuous cultivation in the fields (5-20 years) but also by the intensive work required for annual tillage. All of these factors are detrimental to shrub regeneration.

The management of these organic matters is open throughout the region. This could lead to losses for the farm. For example, 72% of cereal residues or an average of about 14.5 tonnes per farm were removed during the dry season. This organic matter is consumed mainly by livestock on the land or under transhumance. This is explained by the major pressure caused by animals on cultivated land during the dry season, after natural pastures have been burnt during bush fires (5). However, part of the problem can be put down to the removal of organic matters by other parties for domestic use.

In addition to plant biomass, the farms use converted organic matters created from manure and compost. Due to the relatively high number of ruminants per farm (an average of 9.6 cattle and 11.1 small ruminants), the farms can produce enough manure, which can be used for external applications of organic matters from natural pastures and/or cultivation areas (2, 5, 9). But manure production is relatively low. In fact, keeping livestock, which means allowing animals to graze in pastures and fields during the day

and bringing them into enclosures or parks at night, enables an average theoretical manure production estimated at 8.60 tonnes. With a single pair of adult draught oxen fed in the stable, it possible to produce 4-6 tonnes of manure per year by feeding them 2.5-4.5 tonnes of straw per year (3). With 9.6 oxen and 25 tonnes of harvest residues, each farm should therefore produce an average of 19.2 tonnes of manure, if the animals are fed in the stable. In addition to low manure production linked with the current livestock farming system, some of the manure is ultimately spread on the land, due to the extensive nature of this farming method (9).

The composting conducted in the region can enable all harvest product residues to be recovered, which are produced close to living accommodation (11) and not included in the study. Unfortunately, quantities of manure and compost effectively recovered are significantly below the real potential of the farms.

The various results indicate low use of organic matters as additives on farms. In fact, out of an average yield estimated at 46.7 tonnes, only about 14% is applied to the soil in the form of manure or compost. This may result in reduced soil fertility on the farms (2, 8, 9, 14).

Cereal residues remaining in the fields and shrub shoots are mostly collected into piles before being burned during soil preparation. The same applies to cotton stalks, most of which are burned. As a result, the total amount of material lost to the farms due to burning in the fields can be estimated at 20% of plant residues.

Conclusion

In Burkina Faso, soil organic matter plays a central part in soil productivity and the application of organic matters onto soils is considered crucial for the development of sustainable agricultural systems. This makes it vital to encourage the use of any organic matters produced in order to increase soil organic stocks.

The presence of ruminants (especially draught oxen) on most farms in the cotton-growing region represents a major asset for more effective use of organic matters. Crop residues should therefore be used to feed the animals, which will convert them into manure to be used as a fertiliser. Most farms therefore have the resources to produce enough manure, because of the large quantity of crop residues that they produce. The problem to be solved is how cereal residues should be collected and stored and how animals should be kept. This makes it necessary to develop the technique of integrating agriculture and breeding on farms.

Cotton stalks, which are very rarely consumed by the animals, can be used as compost in the fields. The current burning system is wasteful and prevents the soil from gaining nutritional elements. However, it will be necessary to identify appropriate composting techniques for this type of wood residue.

In addition to livestock farming and composting, the identification of solutions for the promotion of organic manure could also focus on techniques for direct use that are appropriate for conditions on the farms.

Literature

1. Bacyé B., Feller C. & Moreau R., 1998, Décomposition d'une poudrette de fumier incorporée dans un sol sableux de versant et un sol argilo-limoneux de bas-fond en milieu soudano-sahélien (Burkina Faso). AFES, Etudes et Gestion des Sols, pp. 109-121.
2. Bationo A., Buerkert A., Sedogo M.P., Christianson B.C. & Mokwunye A., 1993, A critical review of crop-residues use as soil amendment in West African semi-tropics. *In:* Livestock and sustainable nutrient cycling in mixed farming systems of sub-Sahara-Africa. Volume II Technical papers. Proceeding of an internal Conference International Livestock Center for Africa (ILCA). Addis Ababa, Ethiopia 22-26 November 1993. pp. 305-322.
3. Berger M., 1996, L'amélioration de la fumure organique en Afrique Soudano-sahélienne. Agriculture et Développement N° hors-série. 35 pages.
4. Bielders C.L., Michels K., Schlecht E. & Mahler F., 1998, Le potentiel de la fumure organique et du paillage pour l'intensification de la production agricole sur terres dégradées du sahel. *In*: Breman H. & Sissoko K./ Karthala Ed. L'intensification agricole au sahel. Pp. 747-758.
5. Dugué P., 1998, Les transferts de fertilité dus à l'élevage en zone de savane. Agriculture et Développement N° 18 juin 1998. pp. 102-106.
6. Fontes J. & Guinko S., 1995, Carte de la végétation et de l'occupation du sol du Burkina Faso: notice explicative. Ministère de la coopération Française. 67 pages.
7. Gbikpi P., 1995, Agriculture Burkinabè. Session d'accueil des nouveaux coopérants. Ouagadougou 6-8 décembre. 50 pages.
8. Latham M., 1997, Crop residues as strategic resources in mixed farming systems. *In*: Crop residues in sustainable mixed crop/livestock farming systems. Pp. 181-190.
9. Manlay R., 2000, Dynamique de la matière organique à l'échelle d'un terroir agro-pastoral de savane ouest-africaine (Sud-Sénégal). Thèse de Doctorat, ENGREF, Montpellier, France. 185 pages.
10. MARA, 1997, Etude sur la typologie des exploitations agricoles familiales et adoption d'une nouvelle stratégie agricole. Rapport provisoire, Ouagadougou, Burkina Faso. 230 pages.
11. Ouédraogo E., Mando A. & Zombré N.P., 2001, Use of compost to improve soil properties and crop productivity under low input agricultural system in West Africa. Agriculture, Ecosystems and Environnement *84* (2001) 259-266.
12. Roose E. & Barthès B., 2001, Organic matter management for soil conservation and productivity restoration in Africa: a contribution from Francophone research. Nutrient Cycling in Agroecosystems *61*: 159-170, 2001.
13. Sanfo R., 1983, Connaissance et amélioration de l'embouche traditionnelle. Eléments d'analyse et propositions de développement de l'embouche intensive ovine dans le milieu rural. Province du Yatenga Burkina Faso. Mémoire de fin d'études d'Ingénieur du développement rural, Université de Ouagadougou. 86 pages.
14. Sédogo M.P., 1993, Evolution des sols ferrugineux lessivés sous culture: incidence des modes de gestion sur la fertilité. Thèse d'Etat, FAST/ Université Nationale de Côte-d'Ivoire, 285 pages.
15. Waneukem V., 1996, Appréciation de la fourniture d'azote par le sol. Cas des sols en maize de la zone sud-soudanienne du Burkina Faso. Thèse de doctorat en sciences agronomiques. ENSA de Montpellier (France). Pp. 45-46.

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