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Valorization of shea caterpillar droppings *(Cirina butyrospermi* Vuillet) in the ecological management of soil fertility in Burkina Faso

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Abstract

Works on park lands show that shea tree is a widespread species in the fields in Burkina Faso. There are caterpillars which are rich in proteins and throw out important quantity of dejection on the soil surface. The aim of this study was to determine the amount of droppings produced by caterpillars and their chemical quality in Koumbia area. The amount of dejection was determined on small plots and expressed as amount of dry matter (DM). Chemical analyzes have focused on the major elements (C, N, P and K). Our results show an average production of 19.34 kg for an average area of 68.47 m^2 under a shea tree. We also observe that the production of caterpillar droppings is a function of the shea trees density and fluctuate between 440 and 3 775 kg ha^{-1}. The data of chemical analyzes show that caterpillar droppings have high content of carbon (477.7 g kg^{-1}) and nitrogen (10.8 g kg^{-1}) and low content of phosphorus (0.3 g kg^{-1}) and potassium (0.9 g kg^{-1}). The amounts of C and N that caterpillar droppings are likely to bring, show that they can cover between 56 and 484 % of annual loss of soil C and fully compensate exports N of major crops (cotton, maize, sorghum) of the study area. The valorization of caterpillar droppings is therefore a way of ecological management of soil fertility of shea parks. However, the C/N (44) of caterpillar droppings suggests further agronomic investigations.

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Introduction

Cropping systems in Burkina Faso are characterized by intensive tillage, a common grazing and burning of crop residues. With population growth and the rapid spread of cotton field, there is an increasing of cultivated territory and continuous use of land. The consequence of these practices is the rapid deterioration of soil fertility (Traoré *et al.*, 2007; Coulibaly *et al.*, 2012.). To restore the soil production capacity, research has proposed various technologies like the use of manure, compost and litter (Sédogo 1993; Berger, 1996; Bacyé *et al.*, 1998).

The recycling of the biomass produced by components of traditional agroforestry systems have been the subject of research (Bayala *et al.*, 2003; Saïdou *et al.*, 2012). The research conducted by Bayala *et al.* (2003) showed that the soil carbon increases significantly when the amount of *Parkia biglobosa* mulch increases in soil. In shea parks (*Vitellaria paradoxa* c.f. Gaertn), the work of Saïdou *et al.* (2012) show that the soil carbon, nitrogen and phosphorus were higher under the shea tree compared to soil which is not under the shea tree.

In Burkina Faso, shea tree is a widespread species in agro-systems. The products of this species are mainly butter and caterpillars. Shea caterpillars, rich in proteins, play an important role in the lives of rural households and the economy of the country. In their larval stage, the caterpillars consume shea leaves and release significant amounts of manure to the soil surface. These droppings, from the digestion of shea leaves, are a source of soil organic matter. This study was initiated to determine (i) the amount of caterpillar droppings, (ii) chemical properties of these droppings and (iii) the quantities of nutrients that can be recycled into the soil *via* shea caterpillars.

Materials and methods

Study area

The study was conducted in 2014 in the village of Koumbia (4°24'01'' longitude, 12°42'20'' of north latitude and altitude 290 m) located in the province of Tuy in the West of Burkina Faso (Fig.1). This village is the administrative center of the municipality of Koumbia which is subject to a Sudanese climate with rainfall between 800 and 1100 mm per year. Koumbia is characterized by relatively plane terrain, very high agricultural impact (52 % of land is under cultivation), high animal density (22 UBT km^{-2}) and human heavy pressure (38 persons km^{-2}). Thirty percent (30%) of the land are occupied by protected forests (Diallo et Vall, 2010). Cotton is the main crop in the area, followed by corn. Livestock is one of the main activities of the area and represents, after agriculture, the second source of income for farmers.

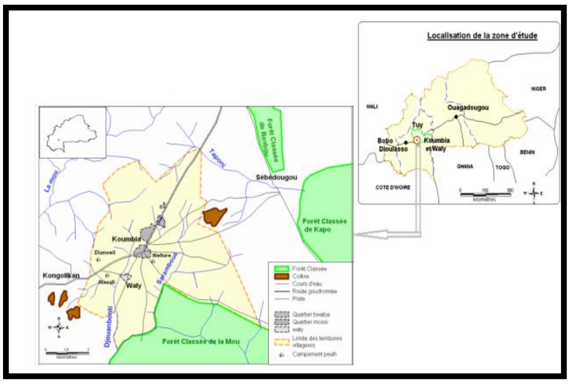


Fig. 1. Map of study area (Blanchard, 2008).

Determination of the amount of caterpillar droppings

To determine the amount of caterpillar droppings, we chose 6 shea trees (Picture 1) spaced 30 to 50 m of each other in fields. The height and the level of attack of trees by caterpillars were not identical. The area covered by the droppings under each shea was determined by measuring crown's diameters North-South (d1) and East-West (d2). The surface was obtained according to the formula used by Nouvellet *et al.* (2006): $S = [\pi(d1.d2)]/4$. The amount of dropping was measured on three plots of 1 m^2 each under each shea. The plots were arranged on the diameter with one near the foot of shea and the other 2 on the extremities. The determination of the amount of manure was conducted in August, a period that corresponds to the coming down of the majority of the caterpillars (Picture 2) and their collection for human consumption.

Pic. 1. Shea trees (leaves consumed by caterpillars).

Pic. 2. Shea caterpillar *(Cirina butyrospermi*).

Pic. 3. Caterpillar manure.

The amounts of dry matter (DM) of manure (Picture 3) were estimated per hectare (ha). We consider shea densities obtained by Kaboré *et al.* (2012). These authors determined shea densities per hectare following 6 types of plots: Young fields (cultivation for 2 years), middle age fields (cultivation for 6 years), old fields (cultivation for over 15 years), young fallow (abandoned for 2-3 years), fallow intermediate age (abandoned for 6-8 years) and old fallow (abandoned for over 15 years). Shea densities obtained according to the type of plot, are reported in Table 1.

Table 1. Shea tree density depending of the type of field (Kaboré *et al.*, 2012).

Type of field	Young field	IA field	Old field	Young fallow	IA fallow	Old fallow
Shea density (plant ha^{-1})	33.3	36	22.7	28	70	194.7

IA = Intermediate age.

Analysis of chemical parameters of caterpillar droppings

Analyses were realized on a composite sample made up from the sampling droppings. These analyzes were made in the laboratory of environmental and agricultural research of Farako-Ba station (Burkina Faso). The parameters analyzed are total carbon (C) (Walkley et Black, 1934), total nitrogen (N) (Hillebrand *et al.*, 1953), total phosphorus (P) (Novozansky *et al.*, 1983), and total potassium (K) (Walinga *et al.*, 1989).

Chemical parameters of caterpillar droppings were compared to those of shea leaves obtained by Bayala *et al.* (2005).

Assessment of C, N, P and K amounts bring by the droppings according to the type of plot

From the chemical characteristics we estimated the quantity (kg ha^{-1}) of the different chemical elements (C, N, P and K) that droppings can bring according to the type of plot. They were obtained as the product of the content of each element and the amount of dry matter of manure by type of plot.

Assessment of coverage of annual needs of soil C by the caterpillar droppings

We considered 372 kg.C ha^{-1} $year^{-1}$ as the amount of C mineralized annually (Berger *et al.*, 1987). The coverage of soil C need (%) was obtained as the ratio between the quantity of C droppings by type of field, and the amount of mineralized C annually.

Assessment of the economic value of manure following a valorization to urea

Obtaining caterpillar droppings in sufficient quantities corresponding to their coming down to trees their collect for consumption and especially the period of application of urea on crops. This leads us to make the hypothesis that the application of caterpillar manure on crops could substitute urea. To do this, we used the following formula to estimate the amount of urea: Urea Quantity (kg ha^{-1}) = N Quantity * (100/46), N quantity corresponding to that provided by the caterpillar droppings according to the type of plot and 100 kg of urea contains 46 kg of N.

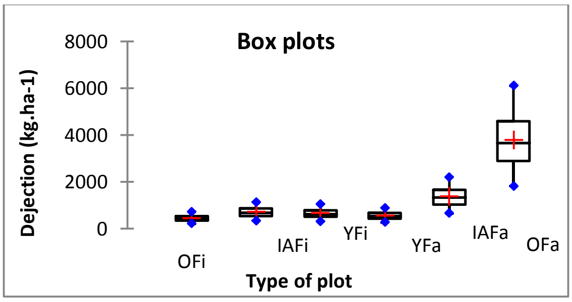
The economic equivalent was obtained by multiplying the amount of urea obtained by op that the amount of droppings produced under shea trees varies between 9.21 and 31.26 kg with an average amount per tree of 19.39±7.85 kg (Table 2).This production does not move in the same order as the area under of the shea tree. We note that for 53.69 m^2 area, the production is 21.60 kg against 14.55 kg for 100.56 m^2 area.

Fig. 2 shows that the highest production of dejection is obtained in old fallows (3 774.95 kg ha^{-1}), followed by middle age fallow (1357.20 kg ha^{-1}). Production of dejection in the 3 types of fields and young fallow is below 1000 kg ha^{-1} with the lowest obtained in old fields (440.12 kg ha^{-1}).

Table 2. Quantity of droppings produced by caterpillars per shea tree.

	Shea 1	Shea 2	Shea 3	Shea 4	Shea 5	Shea 6	Average
Crown ground surface (m^2)	46.91	79.88	68.53	53.69	61.25	100.56	68.47 (19.47)
Druppings (Kg DM $plant^{-1}$)	9.21	31.26	24.03	21.60	15.68	14.55	19.39 (7.85)

DM=Dry matter.



OFi = Old field, IAFi = intermediate age of field, YFi = young field, YFa = young fallow, IAFa = intermediate age fallow, OFa = Old fallow

Fig. 2. Caterpillar droppings production per type of plot.

Chemical properties of caterpillar droppings

The results show that the caterpillar droppings are rich in carbon with 477.7 g kg^{-1} (Table 3). The carbon is followed by nitrogen content (10.8 g kg^{-1}). Phosphorus and potassium contents are less than 1 g kg^{-1}.

We observe that there is a decrease in the content of the elements in the caterpillar manure compared with shea leaves. The ratio C/N (44) in caterpillar droppings remains high by the leaves (31).

Table 3. Chemical characteristics of caterpillar droppings compared with shea leaves.

	C	N	P	K	C/N
	g kg^{-1}				
Caterpillar droppings	477.7	10.8	0.3	0.9	44
Shea leaves (Bayala *et al.*, 2005)	484.4	15.6	1.8	4.3	31

Assessment of C amounts produced by caterpillar droppings and soil C cover requirements according to the type of plot

It is observed that the amount of C in the fields varies from 209 to 332 kg ha^{-1} with the lowest amount recorded in old fields (209.94 kg ha^{-1}). In fallow, the amount varies between 258.95 kg ha^{-1} for young fallow and 1 800.65 kg ha^{-1} for the old fallow. In the middle years fallow, the amount of C is 647.38 kg ha^{-1} (Table 4).

Although the amounts of C produced in the fields are small compared to fallow, they may be able to cover more than 50% of the annual loss of soil C with 82.79%, 89.50% and 56.43% respectively for young fields, intermediate age fields and old fields. For fallow, the amounts of C produced can cover more than 100% of the annual loss soil C except the young fallows whose C quantities cover only 69.61% of the soil needs.

Table 4. Amount of C and annual coverage in soil C needs depending of the type of plot.

	YFi	*IAFi*	*OFi*	*YFa*	*IAFa*	*OFa*
C Quantity (kg ha^{-1})	307.97	332.94	209.94	258.95	647.38	1800.65
Coverage in soil C needs (%)	82.79	89.50	56.43	69.61	174.03	484.05

OFi = Old field, IAFi = intermediate age of field, YFi = young field, YFa = young fallow, IAFa = intermediate age fallow, OFa = Old fallow

Assessment of N, P and K amounts produced by caterpillar droppings according to the type of plot

The results show that the amount of nitrogen in fields ranging from 4.74 kg ha^{-1} for old fields and 7.52 kg ha^{-1} for the intermediate age fields (Table 5). In fallow, the amounts vary between 5.85 kg ha^{-1} (young fallow) and 40.69 kg ha^{-1} for the old fallows. Phosphorus amounts are less than 1 kg ha^{-1} in all types of plot except old fallow which get 1.06 kg ha^{-1}. The amounts of potassium are also below 1 kg ha^{-1} in all types of fields and young fallows. In intermediate age fallow and old fallow, the amounts of K are respectively 1.21 and 3.37 kg ha^{-1}.

Table 5. Quantity of NPK produces by caterpillar droppings depending the type of plot (kg ha^{-1}).

	YFi	*IAFi*	*OFi*	*YFa*	*IAFa*	*OFa*
N quantity	6.96	7.52	4.74	5.85	14.63	40.69
P quantity	0.18	0.20	0.12	0.15	0.38	1.06
K quantity	0.58	0.62	0.39	0.49	1.21	3.37

OFi = Old field, IAFi = intermediate age of field, YFi = young field, YFa = young fallow, IAFa = intermediate age fallow, OFa = Old fallow

Assessment of the economic value of manure following a valorization to urea

The results show that the caterpillar droppings can make between 10.31 kg ha^{-1} of urea for old field and 88.47 kg ha^{-1} of urea for old fallow. The potential economic gain recorded is 3362, 4933 and 5332 FCFA ha^{-1} respectively for the old fields, young and intermediate age fields (Table 6). For fallow, it reaches 28 840 and 10 369 FCFA ha^{-1}, for old fallow and intermediate age fallow, respectively. For young fallow, the economic value is 4147 FCFA ha^{-1}.

Table 6. Economic valorization of N quantity in the caterpillar droppings by the type of plot**.**

	Urea quantity (kg ha^{-1})	Economic profit (FCFA ha^{-1})
YFi	15.13	4 933
IAFi	16.36	5 332
OFi	10.31	3 362
YFa	12.72	4 147
IAFa	31.81	10 369
OFa	88.47	28 840

OFi = Old field, IAFi = intermediate age of field, YFi = young field, YFa = young fallow, IAFa = intermediate age fallow, OFa = Old fallow.

Discussion

Results show diversity in the amount of caterpillar droppings per Shea tree. The amount of droppings is not connected with tree size. This could be explained by the level of caterpillar population per shea tree. We can however remember that for 68.47 m² area, we can obtain 19.39 kg of caterpillar droppings.

According to shea density per type of plot, we could get 440 to 3 775 kg ha^{-1}.The data indicate that production in the fields and young fallows are low compared to intermediate age fallow and old fallow. We could say that if shea density is more important in the plot, caterpillar droppings are so important. These results suggest the importance to promote shea protection in the fields, because lack of space the farmers do not practice fallow (Kaboré *et al.*, 2012).

The analysis of chemical properties of caterpillar manure show that their contents of C, N, P and K respectively decreased by 98.6%, 69.1%, 15.6% and 20.8% compared with those of the shea leaves. We could explain these results by the using of the different chemical elements by caterpillars for their growth and development. The decrease of the levels could be explained also by no consumption of the petioles and central ribs of the leaves by caterpillars. However, chemical analysis of the leaves takes into account these parts of the leaves. The investigation of Blanchard *et al.* (2014) carried out in the same area as this study shows that the farmers produce and use 4 types of organic manure (average quality manure, dung high value amendment, medium quality compost and compost high value amendment). The results obtained by these authors indicate C contents varying between 91 and 204 g kg^{-1}, N contents varying between 4 and 11 g kg^{-1} and P levels ranging between 2 and 5 g kg^{-1}. Carbon and nitrogen are the main factors limiting tropical soils, the data on organic manure produced and used by farmers respectively show that they are poorer than caterpillar droppings for carbon. For nitrogen, manure has a similar quality as the caterpillar droppings. The C/N ratio of the caterpillars manure is higher than shea leaves. Recent works on other feces in western Burkina Faso indicate C/N 17.85; 16.37; 57.04 and 25.91 respectively for the poultry droppings, cattle, pigs and sheep manure (Ouattara, 2013). Blanchard *et al.* (2014) obtained for manure produced by farmers a C/N ratio of between 18.4 and 23.2. It notes that except manure of pigs, other manures have a C/N lower than the caterpillar droppings. Given the high value of this C/N ratio of caterpillars manure, we can make hypothesis that their mineralization would be slow and may cause the immobilization of soil nitrogen by microorganisms.

The results show that more than 50% of annual loss of soil C can be covered by caterpillar droppings regardless of the shea tree density. For old fallow and intermediate age fallow, coverage of soil C needs is greater than 100%. For the main crops of the study area (cotton, maize and sorghum), the work of Cretenet *et al.* (1994) show that they export between 2.5 and 2.99 kg ha^{-1} of nitrogen, between 1.19 and 2.19 kg ha^{-1} of phosphorus and between 2.1 and 5.27 kg ha^{-1} of potassium. Our results on the quantities of these mineral elements producer by caterpillar droppings show that they can fully compensate the exports of N by crops and partially offset the export of P and K by crops. These results suggest maximize the valorization of caterpillar droppings in carbon and nitrogen management in the shea parks characterize by soils which are poor for these chemical parameters.

Economic assessment of caterpillar droppings indicates that they may allow farmers to make gains of 10 to 88 kg.ha^{-1} urea or 3 362 à 28 840 FCFA ha^{-1} according to the type of plot. In a context of rising prices of chemical fertilizers, the valorization of these droppings would be an important contribution to the environmental management of soil fertility.

Additional to the contribution of soil fertility management, consumption of shea leaves by caterpillars has the advantage of reducing the effect of shea trees shading on crop and soil productivity. The work of Gbemavo *et al.* (2010) show that shea shade has a negative influence on the number of plants per m^2, the number of branches loaded capsules per plant and the number of capsules per plant.

Conclusion

The results of this study highlight the importance of strengthening of shea parks for a significant production of caterpillar droppings. Data on the chemical characteristics of caterpillar droppings show that they are rich in carbon and nitrogen and can contribute strongly to the environmental management of soil fertility as well as the manure produced and used by farmers in the area study. Caterpillar droppings have the advantage of being produced on the plots during the vegetative phase of crops. They could therefore be valued without transforming labor. We can conclude that in addition to the Shea caterpillars are a source of protein for human consumption; their droppings are a way of ecological management of soil fertility. This preliminary work suggests research perspectives like the study of the mineralization of manure into the soil looking-out the C/N ratio and the effects of droppings on crop yields and their organoleptic quality.

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