

Crop production in the village territories of a southern Sahelian agropastoral district: fraction exported and fraction recycled by livestock

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Abstract:

Collecting crop by products and bush straw has become a common practice in the rural Dantchandou district, particularly for social use and livestock feed. However, these withdrawals lead to a decline in soil fertility and, by the same token, a drop in soil carbon sequestration potential. The objectives of this study are to quantify annual removals of crop by products and bush straw, to identify annual removals recycled by the district's livestock and finally to determine annual removals exported from the district. To do this, a survey was carried out among 307 heads of household in 10 villages in the district, and 100 sellers of crop by products and bush straw were surveyed at markets and sales outlets. The results revealed the various agricultural by products harvested in the area: legume haulms (*Vigna unguiculata*, *Arachis hypogaea*, *Vigna subterranea*), *Pennisetum glaucum* stubble and sorrel and *Sesamum indicum* residues, as well as the different types of bush straw used in the area: straw for fodder and those used as materials (*Andropogon gayanus* and *Ctenium elegans*). These withdrawals amount to 6325.93t per year for the district as a whole. However, more than half of this harvest, i.e., 3641.26t, is used to feed the livestock of local households. The remainder is either used for social purposes, or sold by farmers locally in the villages, at markets or outlets, in order to increase their income. Sales outside the district, corresponding to exports, are estimated at 711.66t per year. The overall finding was that, on the whole, harvests for livestock feed in local households exceeded those for sale

Key Word: Bush straw, by products, Dantchandou district, export of plant biomass, legumes haulms, stubble.

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I. Introduction

In Niger, natural pastures form the basis of the diet of herbivores. The country has nearly 62 million hectares of rangeland, or 45% of its territory (DS/MAGEL, 2019). However, the expansion of cultivated areas under the combined effects of population growth, climate change and climatic variability, is restricting the availability of natural forage resources, and at the same time creating increased competition around forage resources, exacerbating the vulnerability of production systems (Boubacar et al., 2021). Among the coping strategies used by livestock farmers to deal with the various climatic and social hazards are the collection of bush straw and the use of crop by products and residues. Indeed, the reduction in grazing areas and the ever-increasing need for animal products (meat, milk, hides, skins, etc.) are driving livestock farmers to exploit as far as possible all the food resources offered by crops in terms of crop by products (FAO, 2014), and natural pastures (bush straw). However, while on-site grazing of animals on fields, fallow land and rangelands enables better carbon storage, via the contribution of organic matter through deject and the direct recycling of carbon from residual grass and litter, the exclusive and frequent harvesting of crop residues and bush straw from these areas can lead to excessive harvesting levels (repeated exports of carbon and mineral elements including N, P and K) and reduce the carbon storage capacity of these environments (Gac et al., 2010). The environmental changes caused, also have significant repercussions on rainfed crop production, forcing farming households to diversify their sources of income (FAO, 2015). Selling crop byproducts and bush straw is one of many practices enabling households to improve their resilience to food insecurity. But in a situation of resource degradation (declining soil fertility

following the removal of materials from fields and rangelands), it is important to determine how much is exported from the district in relation to total removals from the district. This gives an idea of the quantities that are not recycled locally and are considered lost by the district. The aim of this study is to quantify the harvesting of crop by products and bush straw at district level, and to identify the quantities recycled by livestock and those exported from the district.

II. Material And Methods

2.1. Presentation of the study area

The study took place in the Dantchandou district, located 75 km east of Niamey in the agro-pastoral zone of Niger. Formerly the canton of Dantchandou, then the Dantchandou district since 2005, the study area is located in the Tillabéri state, between latitudes 13° 30' and 13° 45' North and longitudes 2° 35' and 2° 50' East. It covers an area of around 919 Km² (Figure 1) with a semi-arid tropical climate (Hiernaux and Ayantunde, 2004; Dutordoir, 2006), characterized by average daily temperatures with a minimum of 15°C in December and January and a maximum of over 45°C in April, and an annual average of 30°C (Bodo, 2019). Two main seasons characterize the area: a relatively short rainy season of 3 to 4 months and a long dry season of 8 to 9, with a mean annual rainfall at the Banizoumbou site of 482.6 mm (standard deviation 103.7) from 1990 to 2022. The distribution of the various natural plant formations in the study area is based on their topographical location and hydro-pedological affinity (Massuel, 2005). This makes it possible to distinguish three types of plant formations: tiger bush (plant formations on armored plateaus), shrub savannah (on sandy skirts and glacis) and lowland vegetation. Agriculture, the main activity practiced by the entire population, is largely selfsubsistence-oriented, and techniques remain traditional (Hiernaux and Ayantunde, 2004). Livestock farming is highly developed in the area, and herds are subject to seasonal movements.

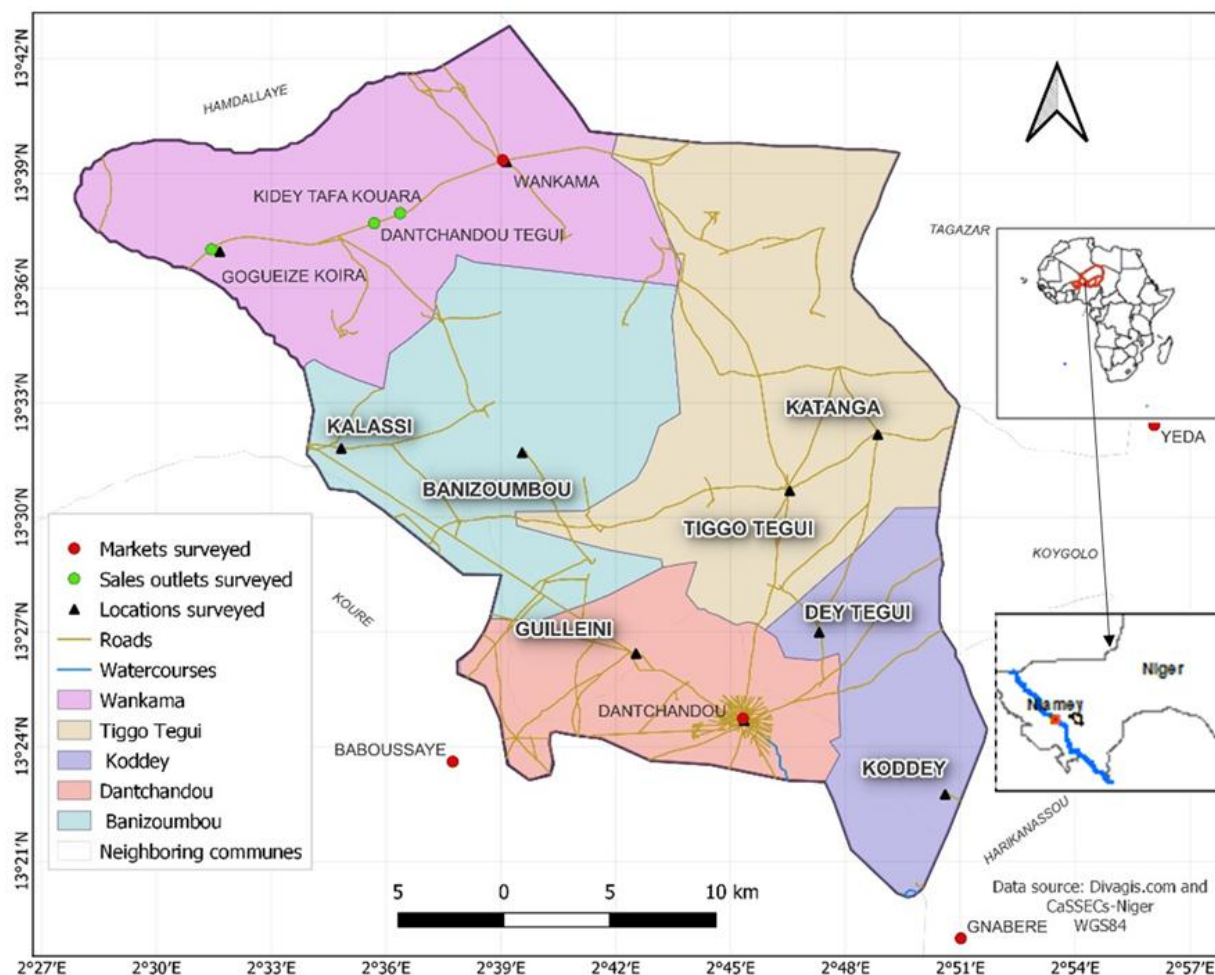


Figure 1: Map of villages, markets and sales outlets surveyed

Collecting data

Quantification of crop by product and bush straw removals and identification of the quantities allocated to livestock in the district were based on household surveys using individual interviews. The villages and households to be surveyed were sampled beforehand. As the Dantchandou district is divided into five (05) terroirs, two villages were selected in each terroir to ensure that each was representative (Fig.1). The villages were chosen to include small, medium, large and very large villages. The number of households to be surveyed is determined by Slovin's (1960) formula:

$$n = \frac{N}{(1 + Ne^2)}$$

With: n = Sample size; N = Parent population (cumulative number of farm households in the ten (10) villages selected); e: Margin of error set at 5%.

On this basis, the sample size to be surveyed in the district was 307 farm households. The weight of each village was determined by dividing the number of farm households in it by the total number of farm households in the ten villages selected (Table I). To obtain the proportion of households to be surveyed per village, these weights were multiplied by the sample (n).

$$\text{Village weight} = \frac{\text{number of agricultural households per village}}{\text{total number of agricultural households in selected villages}}$$

A survey sheet on the type of by products and bush straw harvested, the quantities taken and those allocated to livestock, was administered to them. The survey sheet was sent to both sedentary Zarma and sedentary Fulani and Tuareg agro-pastoralists in the district. The latter are surveyed when they visit the villages, or at their camps, which are usually located close to the villages.

Table I: Sample characteristics

Territories	Villages	Village size	Number of agricultural households GRPH/2012	Weight	Number surveyed
Banizoumbou	Banizoumbou	Large	157	0,11	33
	Kalassi	Medium	134	0,09	28
Tiggo Tegui	Tiggo Tegui	Medium	127	0,09	26
	Katanga	Small	54	0,04	11
Koddey	Koddey	Small	102	0,07	21
	Deytegui	Large	147	0,1	31
Dantchandou	Guilleyni	Small	96	0,07	20
	Dantchandou	Very large	413	0,28	86
Wankama	Wankama	Medium	123	0,08	26
	Goguézé Koira	Small	119	0,08	25
Totals			1321	1	307

As the sale of crop by products and bush straw is fairly widespread in the area, in addition to the household survey, a survey was carried out among one hundred (100) sellers of crop by products and bush straw from the district, distributed at sales outlets and weekly markets in the Dantchandou district and neighboring districts (Table II), with the aim of gaining an idea of the proportions of each type of product sold according to the origin of the buyers, and the variation in product prices according to the time of year. Indeed, environmental changes caused by a combination of climatic factors (Droughts, floods...), and societal factors (population growth leading to land fragmentation and the proliferation of family farms with very small cultivated areas), have significant repercussions on rainfed crop production, thus forcing farming households to diversify their sources of income in order to improve their resilience to food insecurity (FAO, 2015; Maman et al., 2015).

Table II: Number at market level and sales outlets surveyed

	Markets/sales outlets	Number surveyed
Dantchandou district	Wankama	24
	Dantchandou	30
Neighboring towns	Babousaye	10
	Yeda	7
	Gnaberé	5
Sales outlets	Dantchandou tagui	9
	Tchida tafa koira	8
	Goguézé	7

Determining the weight of different products

Locally, products are presented in bunches *Vingna unguiculata* haulms, *Pennisetum glaucum* stubble, bush straw, etc. or in 100 kg bags (haulms of *Arachis hypogaea*, *Vigna subterranea*). In order to convert them into the same internationally recognized unit, the various products were weighed in the villages surveyed, according to their availability. To obtain representative weights, the various products were also weighed at the markets and sales outlets surveyed.

Data processing and analysis

The data collected were subjected to descriptive statistics and an analysis of variance (ANOVA) was performed to detect any differences in mean between groups, using SPSS.25 software. Groups were formed according to village size in terms of number of households: small (1 to 119), medium (120 to 139), large (140 to 412), and the exceptional case of Dantchandou, the district's main town, considered very large (413 farm households). Groups were also made according to territories, proximity of villages to roads (near or far) and status of sales outlet (market or point of sale). Differences were considered significant at the 5% level. The results were then grouped into tables and figures.

Scale up of crop by products and bush straw collection

To extrapolate harvests to the district level, the average quantities harvested for each product and the number of farm households surveyed collecting that product were brought down to the district level simply by applying the elementary rule of proportionality or rule of three. In the event of significant differences ($p \leq 0.05$) between group averages for certain products, extrapolation was based on group averages. Villages were thus divided into groups, and the group values were then summed to give a single value for each product concerned at district level.

III. Result

Socio-economic characteristics of respondents

The results of the household and sales outlet surveys enabled us to identify the main respondents involved in the collection and sale of crop by products and bush straw. Of the 307 people surveyed at household level, 90.2% were men and 9.8% women (Fig. 2). In terms of sales outlets, whether markets or sales points, the respondents were mainly men, with 92.1% and 91.7% respectively. The women surveyed at market level (7.9%) were sellers of traditional items, most often made from *Pennisetum glaucum* stubble (traditional bunks). At sales outlets, they are mainly *Arachis hypogaea* haulm sellers (8.3%).



Figure 2: Proportion of men and women surveyed

Collecting crop by products and bush straw

All respondents collect crop by products. The crop by products collected are legume haulms: *Vingna unguiculata*, *Arachis hypogaea*, *Vigna subterranea*, with 89.6% (N=275), 60.6% (N=186), and 17.3% (N=53) respectively. *Pennisetum glaucum* stubble is the main cereal by product collected after harvest in the area, with 93.2% (N=286), and only 16% (N=49) of respondents are involved in the collection of *Hibiscus sabdariffa* Aand *Sesamum indicum* residues. Bush straw collection is a fairly widespread practice in the study area (73.6%). Two main types of bush straw are collected, depending on their specific use: fodder bush straw for livestock and building material bush straw (Fig.3). Fodder straw is the most widely collected type of straw (52.8%). It is most often a mixture of several spontaneous annual grasses and perennials (Table III). The material straw species collected were: *Andropogon gayanus* Kunth (47.9%) and *Ctenium elegans* Kunth (15.6%). It should also be noted that most of these collections took place within the district, in crop fields (*Andropogon gayanus* and *Ctenium elegans*), fallow land and pastoral enclaves.

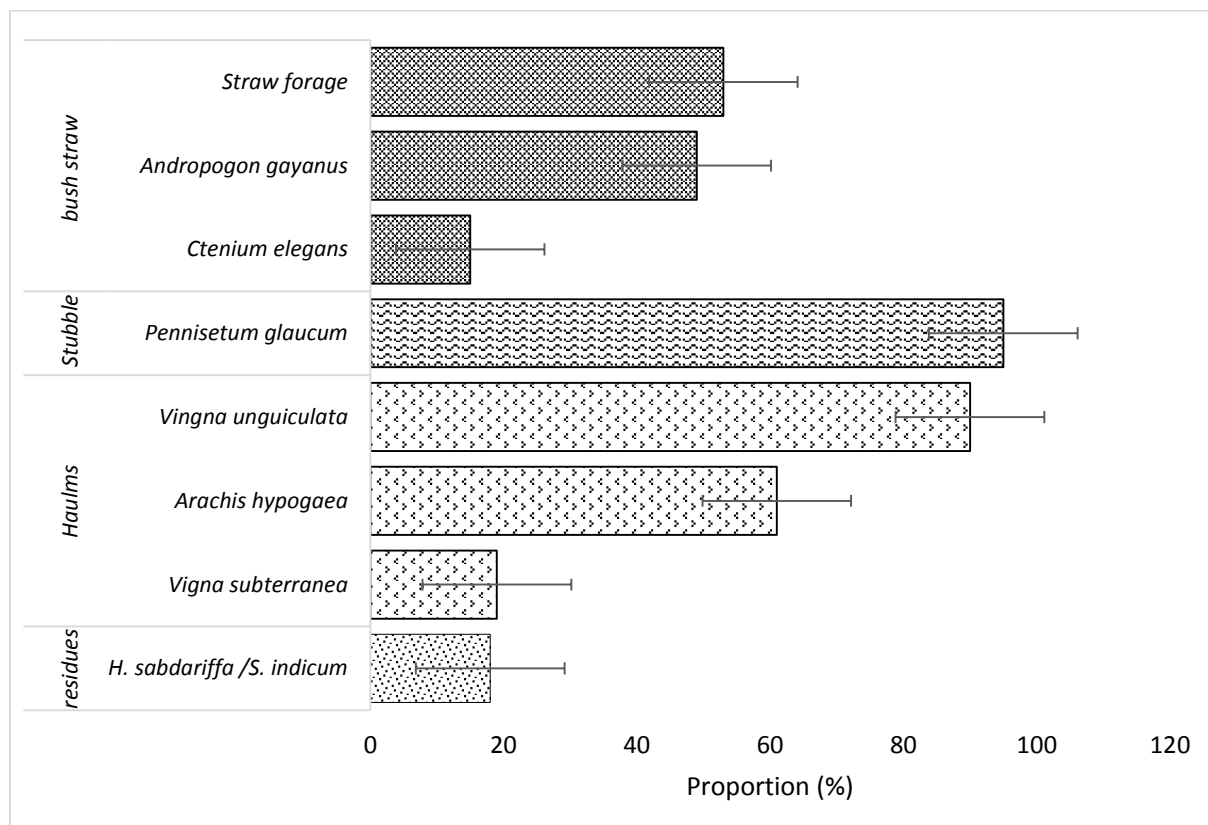


Figure 3: Different types of crops by products collected, bush straw and proportion (%) of respondents who collect them

Different uses of crop by products and bush straw collected by surveyed households

The household survey revealed that crop by products and bush straw are used for a variety of purposes, and the proportions allocated to each type of use depend on the nature of the product and household needs. The survey revealed that almost all the legume haulms collected from *Vigna unguiculata*, *Arachis hypogaea* and *Vigna subterranea* were used to supplement livestock, with 82.7%, 58% and 17.3% respectively. The majority of respondents use millet, *Andropogon gayanus* and *Ctenium elegans* stubble for social purposes (83.4%, 44.6% and 15.6% respectively). As far as sale is concerned, it appears that only a small proportion of respondents collecting crop by products and bush straw sell these products. Nevertheless, bush straw fodder and *Vigna unguiculata* haulms are the products most marketed by the households surveyed, at 18.2% and 17.6% respectively.

Table III: Proportions (%) of the different uses of by products and bush straw in the households surveyed

Use	legume haulms		Stubble	Bush straw			Other	
	V. <i>unguiculata</i>	A. <i>hypogaea</i>	V. <i>subterranea</i>	P. <i>glaucum</i>	Forage straw	A. <i>gayanus</i>	C. <i>elegans</i>	H. <i>sabdariffa</i> / S. <i>indicum</i>
Supplements	82,7 N=254	58 N=178	17,3 N=53	49,2 N=151	41,7 N=128	-	-	13,1 N=40
Social uses	-	-	-	83,4 N=256	-	15,6 N=48	44,6 N=137	-
Left in the field	-	-	-	-	-	-	-	2,9 N=9
Sales	17,6 N=54	6,5 N=20	-	2 N=6	18,2 N=56	3,6 N=11	6,5 N=20	-

Destination of products sold

Buyers of crops by products and bush straw come from three main sources: the Dantchandou district, neighbouring districts and urban area (Niamey). Surveys at markets and sales outlets revealed that for most of the products marketed, a large proportion is sold to buyers from urban areas and neighboring districts (Table IV). These proportions range from 42% to 80% of sales for urban area, and from 10 to 30% of sales for neighboring districts.

Table IV: Proportions (%) sold by buyer origin

Product types	Dantchandou district	Neighboring districts	Urban area (Niamey)
<i>Vigna unguiculata</i> haulms	16	20	64
<i>Arachis hypogaea</i> haulms	10	10	80
Stubble	24	18	58
Forage straw	20	30	50
<i>Andropogon gayanus</i>	33	25	42
<i>Ctenium elegans</i>	18	28	54

Scaling up observations of crop by product and bush straw collection

Annual withdrawals of crops by products (4,254.55t) and bush straw (2,071.38t) are very high, representing 6,325.93t for the zone as a whole. In terms of quantity, the products harvested most in the district are bush straw fodder (1767.66t), followed by *Pennisetum glaucum* stubble for domestic use (1701.95t) and fodder (1646.04t). *Vigna unguiculata* haulms are the most widely harvested legume haulms (788.27t), and *Andropogon gayanus* is the most widely used straw material (201.7t) in the area. Extrapolation of the results for crops by products and bush straw withdrawals for livestock feed shows that households in the Dantchandou district allocate a large proportion of their withdrawals to feeding their animals. *Pennisetum glaucum* stubble is the most widely stored fodder for livestock (1573.22t), followed by bush straw fodder (1,242.38t). *Vigna unguiculata* haulms are the leguminous haulms most used for livestock feed (639.54t), while *Vigna subterranea* haulms are the least used for supplementation (8.18t) (Table V).

Table V: the fractions exported and recycled by livestock from crop by products and bush straw withdrawals

Product types	Quantity withdrawn	Quantity recycled	Quantity exported
<i>Vigna unguiculata</i> haulms	788.27	639.54	148.73
<i>Arachis hypogaea</i> haulms	93.74	78.84	14.9
<i>Vigna subterranea</i> haulms	8.18	0	8.18
Stubble for social use	1701.95	1701.95	0
Forage stubble	1646.04	1573.22	72.82
<i>H.sabdariffa/S.indicum</i>	16.37	16.37	0
Bush straw fodder	1767.66	1376.98	390.68
<i>Andropogon gayanus</i>	201.7	158.1	43.6
<i>Ctenium elegans</i>	102.02	61.09	40.93

Communal sale of crop by products and bush straw

Extrapolating sales of crop by products and bush straw to the district as a whole, sales totaled 892.77t. The proportion exported outside the district corresponds to the sum of the proportions sold to buyers in neighboring districts and urban area. It was found that 80% of these sales, 711.66t, were exported to neighboring districts and urban area (Table VI). By product type, 83.3% or 236.45t of crops by products sold were exported from the district, and 76.3% or 475.21t of bush straw sold was exported from the Dantchandou district.

Table VI: Export of crop by products and bush straw in the rural commune of Dantchandou

Product types	Local sales (t)	Export (t)	Proportion exported %	Export in FCFA (post-Harvest)	Export in FCFA (shortage)
<i>Vigna unguiculata</i>	177,06	148,73	84	20119018	32236363
<i>Arachis hypogaea</i>	16,56	14,9	90	2051455	2712772
<i>Pennisetum glaucum</i>	95,81	72,82	76	1128197	2115370
Total crop by product	289,43	236,45	83,3	23298670	37064504
Forage straw	488,35	390,68	80	28380584	48682701
<i>Andropogon gayanus</i>	65,08	43,6	67	3923116	6391524
<i>Ctenium elegans</i>	49,91	40,93	82	3801984	5471477
Total bush straw	603,34	475,21	76,3	36105685	60545703
Total	892,77	711,66	80	59404355	97610207

IV. Discussion

Characterization of samples of crop by products and bush straw

The main crops grown by households in the study area are *Pennisetum glaucum* and *Vigna unguiculata*, which are cultivated in association or as a pure crop by the whole family under the direction of the head of household (usually a man). *Arachis hypogaea* and *Vigna subterranea* haulms are not very well developed in the area, and are mainly grown by women. This explains the low yields of *Arachis hypogaea* (93.74t) and *Vigna subterranea* (8.18t) compared with *Vigna unguiculata* (788.27t) and *Pennisetum glaucum* stubble (1701.95t and 1646.04t). *Hibiscus sabdariffa* and *Sesamum indicum* are also only secondary crops, and the level of soil fertility means that *Sorghum bicolor* can only be grown in a few places. These various by products are harvested for a variety of purposes. In addition to their use as livestock feed (legume haulms, straw and *Pennisetum glaucum* fodder stubble), some of them play an important role in the well-being of households, starting with the various possible social uses. The same observation was made by Garba (2007), in a study carried out in the Fakara region (Niger). *Pennisetum glaucum* stubble and *Andropogon gayanus* and *Ctenium elegans* bush straw are used to varying degrees for various domestic purposes in all the villages surveyed. These include construction (fencing and roofing of concessions, garden hedges, huts, granaries, poultry sheds...), and various other comfort uses (handmade beds, handmade soap...). We also note that the quantities used for each type of use are fairly heterogeneous and depend on the nature of the product, but also on the locality. This explains the high standard deviations and coefficients of variation. For example, in villages where offseason crops are grown, households use larger quantities of *Pennisetum glaucum* stubble for garden hedge construction, in addition to other social uses. Also, in villages with clay-rich soils, households are less likely to rely on plants for construction (use of mud bricks).

Bush straw is mainly collected from crop fields, fallow land and wasteland. However, many of those interviewed mentioned the disappearance of certain popular species from the area. This can be explained by the harvesting stage. Indeed, early harvesting (before maturity) by uprooting and cutting spontaneous forage species, causes the loss of plant biodiversity of the harvesting sites (Dan Gomma et al., 2017). Finally, these various products are mostly stored on sheds and house roofs, but also in pens, on the *Arachis hypogaea*, in the field or on

trees. This corroborates the findings of Salissou (2020), in a study carried out in Maradi, Niger, on agricultural byproducts.

Impacts of harvesting crop by products and bush straw on the soil

Extrapolation of the results to the scale of the district highlighted the importance of harvesting crop by products and bush straw in the study area. Plant matter remaining on the soil represents a significant proportion of soil organic matter (OM) and is an essential factor in soil carbon storage. Consequently, large-scale removal of OM from the soil also leads to a reduction in soil carbon. The same observation is made in a study by Guerin and Roose (2017) in semiarid West Africa, who assert that the diversity and intensity of plant biomass uses at farm and terroir scales limit forage availability and, consequently, the restitution of organic matter (OM) and carbon to the soil. We also note that, in addition to its role in increasing productivity, the expected effects of soil OM are: a reduction in the risk of drought and an increase in the nutritional value of cereals, nitrogen fixation by legumes, and plant resistance to disease (Ganry and Thuriès, 2017; Sitou *et al.*, 2019).

Characterization of fodder allocations of crop by products and bush straw to household livestock

A significant proportion of crop by products (2398.88t) and bush straw (1242.38t) is used to feed household livestock. We note that large quantities of millet stubble (1646.04t), once little used for livestock feed, are now stored for livestock feed due to the shortage of fodder. The same observation was made by Garba (2007). This highlights the importance of livestock farming in the area and the low forage availability of natural rangelands. Agro-pastoralists use almost all of these products to feed their animals, and rarely sell them. Those who are not stockbreeders sell them to stockbreeders or to intermediaries who transport them to the towns. These results are comparable to those of Salissou (2020), who asserts that on the whole, a significant fraction of crop residues is used in animal feed and the rest is sold. We also note that these different products are not managed in the same way by agro-pastoralists. Each type of fodder is intended for a particular animal production. Legume tops are mainly used to feed small ruminants, while stubble and some bush straws are often destined for large ruminants. A similar finding was made by Lawal *et al.* (2017), in a study of fodder in Niamey (Niger). The conservation period corresponds to the cold dry season, and fodder is stored in the form of stacks on the *Arachis hypogaea*, on the trees and roofs of houses, on the shed, or in enclosures (Garba, 2007; Salissou, 2020; Bodé, 2004).

Return of organic matter to the soil

The heavy use of crop by products and bush straw in livestock feed in the area means that some of the organic matter removed by animals is returned to the soil. This return of matter is made possible by the transport of manure to the fields by farm households (stable manure, household waste), by the parking of animals in the fields or by the grazing of livestock on natural rangelands. In fact, the restitution of nutrients by the animal is the result of the ingestion of fodder, its digestion and the excretion of faeces, as well as urine and emitted gases. According to a study conducted by Guerin and Roose (2017) in semi-arid regions of West Africa, on extensive rangelands, faeces contain 40-60% of the biomass consumed, i.e., carbon, including a large proportion of lignin-rich fibres. Together with urine, faeces contain 75 to 90% of the nitrogen and minerals (P, Ca, K, Mg) ingested by livestock, with minimum levels corresponding to young growing animals or dairy cows, and maximum levels to adult animals undergoing maintenance, which therefore retain few nutrients. But in rapidly changing contexts of agricultural densification of terroirs, the disappearance of fallow land and land reserves, fertility transfers by animals from uncultivated rangelands are becoming less and less important, while exports by animal and plant products in response to urban demand are growing (Guerin and Roose, 2017; Sitou *et al.*, 2019). We also note that products used for domestic purposes (*Pennisetum glaucum stubble*, *Andropogon gayanus* and *Ctenium elegans*) can also contribute to this return of organic matter to the soil. In fact, once used, these products, when not used as fuel, are often transported to the fields to fertilize them.

Destination of various products marketed and exported within the municipality

Most sales of crop byproducts (83.3%) and bush straw (76.3%) are directed to urban area. This can be explained by the proximity of the Dantchandou district to the Niamey and the strong demand from urban and peri-urban livestock farms. The department of Kollo, in which the rural Dantchandou district is located, is a major source of fodder for Niamey. It is said to contribute 38.7% of the Niamey livestock fodder supply (Maman, 2014). These products are transported to urban centers via wholesalers, semi wholesalers (carters and camel drivers) or resellers (Lawal, 2014; Sitou *et al.*, 2020). This once again confirms the heavy dependence of Niamey's livestock on fodder from Fakara. This dependence on fodder for urban and peri-urban livestock is linked to the expansion of housing as a result of urbanization, and to the monopolization of rangelands by crops. These findings corroborate those of Dan Gomma *et al.* (2017).

However, the increasing commercialization of crop by products, bush straw and animal by products is accentuating the export of organic and mineral matter from the area. This limits the restitution of organic matter to the soil by animals on a terroir and ecosystem scale.

V. Conclusion

Crop by products and bush straw play an important role not only in livestock feed, but also in the well-being of the population of the Dantchandou district, for whom they provide various social services and contribute to household income through sales. For the district as a whole, these annual withdrawals amount to 4254.55t of agricultural by products. The area under cultivation in 2021 covered 33.9% of the territory (91809 ha), 31121ha, which amounts to an average of 136.7kg/ha of byproducts. The annual harvest of bush straw for the whole district amounts to 2071.38t, or 36kg/ha, combining fallow and rangeland (corresponding to 57527.8ha of the area). Thus, a total of 6325.93t of crop by products and bush straw are harvested throughout the district. These withdrawals are by no means negligible, and their scale can have a significant impact on the physical and chemical composition of soils, by limiting soil carbon sequestration, among other things, and risk accentuating the degradation of the area's natural resources, with significant consequences for the environment. The quantities of by products allocated to livestock amount to 2398.88t, and bush straw 1242.38t, making a total of 3641.26t of crop by products and bush straw for livestock feed. The type of residue used varies from one animal to another. Thus, for the 20625 cattle reared in the district, the stubble allocated represents 80kg/year/animal, the straw 60kg/year/animal. For the 3,8857 sheep and goats, tops represent 19.4kg/year/animal. The valorization of these products by the district's livestock constitutes a means of restoring organic matter taken from the soil, through animal defecation. Annual exports amount to 236.45t for by products and 475.21t for bush straw, for a total of 711.66t for the whole district.

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