Evaluation of Feed Resources in Mixed Crop-Livestock Systems in Sudano-Sahelian Zone of Mali in West Africa

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Abstract
Livestock are important assets to the rural poor in developing countries but are faced with the major challenge of marked seasonal feed availability. A study was carried out to assess existing and potential feed resources and constraints to livestock production in Southern part of Mali. A feed assessment tool was used to collect necessary data. The assessment included focus group discussions and individual interviews. Results showed that seasonal shortage in feed supply, absence of livestock route and lack of watering points were the major constraints facing livestock production in the study areas. Pastures and green forage were the main feed for animal during the wet season while crop residues, fodder trees and shrubs were the main source of feed in the dry season. Results further showed that almost all types of crop residues were used for livestock feeding compared to other uses. The highest dry matter contents of ruminant total diet came from grazing.

Key words: Feed Resources, Crop Residues, Feed Quality, Pasture, Farmers, Perceptions

Introduction

The common feed resources for livestock production in Mali as in other sub-Saharan Africa countries are pastures, crop residues, and agro-industrial byproducts. Common problems associated with these resources are marked variation in availability and quality, and seasonal shortage which have been consistently reported as the major constraint to ruminant production (Devendra and Leng 2011) in the developing countries. Feed resources are generally abundant in the wet season and the quality is good. Nevertheless, feed scarcity is a big problem in the late dry season (March to May) and at the start of rainy season (late May/June). Hence, addressing feed problem can significantly increase livestock productivity in West Africa. Despite the continued reduction in the size of pasture and cultivable areas for crop production in Mali, ruminants will continue to depend primarily on fodder from natural pastures and crop residues. Livestock feed supply from natural pastures is characterized by seasonal fluctuation in total dry matter (DM) production and nutritional quality because of the distinct seasonal variation in plant growth

in relation to the annual rainfall pattern (Hassen *et al.*, 2010). In mixed farming system of southern region of Mali, crop residues such as groundnut haulm, maize stover, millet straw, sorghum straw, cotton hay, rice straw, etc. are important feed sources for ruminant livestock (Dembélé 1995). These crop residues form the main feed resources for livestock in the region from November to March which is quite important both for the maintenance of the animals and production but the contribution of crop residues to animal nutrition declines from March to May when there is acute feed scarcity. This seasonal feed shortage was pointed out as the major constraints to increase ruminant productivity in developing countries (Kebreab *et al*., 2005). As a consequence, livestock are generally undernourished and thus become more susceptible to diseases.This study was conducted to assess the existing and potential feed resources with respect to ruminant production at farm household level in Koutiala and Bougouni districts of southern Mali in West Africa. This evaluation is to guide the development of effective strategies to improve nutrition and livestock productivity based on locally available feed resources. The feed evaluation is also important to develop strategies for efficient use of these resources. In addition to evaluation of feed resources, the study also entailed characterization of constraints to livestock production in the study sites.

Materials and Methods

Study Sites

The study sites included six villages in Southern Mali: Namposséla (-5.34º long; 12.33º lat), Sirakelé (-5.48 long; 12.51º lat) and Zanzoni (-5.57º long; 12.61º lat) in Koutiala district and Diéba (-8º long; 10.91º lat), Sibilira (-7.76º long; 11.44º lat) and Yorobougoula (-7.91º long; 11.52º lat) in Bougouni district located in Sikasso region of Mali. Crop farming and livestock husbandry are the main sources of household income in these areas. Both districts also offer more opportunities in terms of available feed resources for better livestock productivity. The two study sites were selected in terms of different opportunities for intensification of the farming systems. These different opportunities include market access which is better for communities in Koutiala than for Bougouni and current status of natural resource base. The level of natural resource degradation in Koutiala is higher than in Bougouni due to greater cropping intensity. The two study sites provide a good contrast in terms of market access and status of natural resources, which are two factors essential to intensification of the farming systems in the region.

Methodology

Feed Assessment Tool (FEAST) developed by International Livestock Research Institute (ILRI) was used to evaluate the existing and potential feed resources in the study sites (Duncan *et al*. 2010). FEAST is a systematic method to assess local feed resource availability and use. It helps in the design of intervention

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strategies aiming to optimize feed utilization and animal production. FEAST consists of two components namely Participatory Rural Appraisal (PRA) and individual farmer's survey. The surveys were conducted between October and November, 2013. For the PRA, 15 farmers including men (2/3) and women (1/3) in each study village were involved in a group discussion to assess the constraints and opportunities for improving livestock feeding systems, participatory diagnosis of livestock production systems and availability of feed resources. In total, the group discussions involved 112 farmers in all the six communities in the two districts. The goal of the individual survey was to gather specific information from farmers about feed resources and feeding practices. A semi-structured questionnaire was used for data collection. Twelve farmers in each study village were selected for the individual interview. The twelve farmers selected were representative of 3 wealth categories in the community, namely farmers with small, medium and large land holdings. Based on the focus group discussion, the average land holding was determined in each community which was used to categorize the farmers into three wealth groups. Four farmers from each wealth category were interviewed in each community. In total, 72 farmers were interviewed in the two districts.

Laboratory Analysis

Samples of feed resources in the study sites were collected in December, 2013 and were air dried and prepared for laboratory analyses. Samples of feeds collected were analyzed for dry matter (DM), ash content, nitrogen, fiber components [neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL)] and *in vitro* organic matter digestibility (IVOMD) using near infrared reflectance spectroscopy (NIRS) technique. The sample fineness for NIRS analysis was 2mm. The wave length range to estimate the chemical composition was 1100 to 2500 nanometer. NIRS is an indirect analytical method based on the development of empirical models in which the concentration of a feed constituent is predicted from complex spectral data (De Boever *et al.*,1995). Crude protein was estimated from nitrogen content (nitrogen x 6.25). Metabolizable energy (Mcal/kg DM) was derived from IVOMD.

Statistical Analysis

Data analysis was carried out using Excel™ spread sheet and SAS (SAS, 1987).

Results and Discussion

Feed Availability and Chemical Composition

The main feed resources for livestock in Bougouni and Koutiala districts and their chemical composition are presented in Table 1. It could be highlighted that these feed resources are common in most livestock farming systems in sub-Saharan Africa (Powell *et al.* 2004, Yami *et al.* 2013). Among the feed resources, natural pastures and crop residues accounted for the largest proportions of livestock feed in the study areas in terms of DM content, CP and ME (Table 2). Results presented in Figures 1a and 1b showed that

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grazing and green forage contributed more than 80% of animal diet during the wet season. Most part of cereal residues were grazed on crop field. However, some farmers do store their crop residues in an open shade for later use as animal feed.

Table 1: Chemical Composition of Main Feed Resources for Livestock in Bougouni and Koutiala Districts (% on a dry matter basis)

Feed category	Feed type	OM	CP	NDF	ADF	ADL	IVOMD
Crop residues	Maize stover (stem)	97.31	2.45	80.83	57.98	8.09	56.44
	Maize stover (leaves)	92.63	4.31	73.44	48.57	6.05	74.45
	Millet stover (stem)	96.79	1.62	90.29	72.29	9.65	53.60
	Millet stover (leaves)	92.00	7.67	66.88	45.19	3.34	53.09
	Sorghum stover (stem)	96.55	3.80	70.89	46.29	3.54	42.41
	Sorghum stover (leaves)	88.53	11.83	56.24	38.26	2.90	51.67
	Rice straw (both leaves and stem)	85.53	5.59	70.33	50.30	3.92	54.72
Legume hay	Groundnut haulm	89.25	9.06	51.88	44.70	8.00	61.47
	Cowpea hay	90.34	9.43	54.10	43.15	6.62	67.92
Cultivated forage	Callinadra	91.56	10.25	45.68	39.84	10.09	52.42
	Cowpea forage	88.39	14.57	40.51	32.23	4.01	78.85
	Sorghum forage	89.91	8.29	55.84	44.15	8.81	60.10
Browse(leaves)	*Afzelia africana*	93.22	12.37	42.07	44.69	13.71	52.29
	Pterocarpus erinaceus	90.76	15.03	51.96	49.99	14.68	56.78
	Parkia biglobosa	96.96	5.38	62.60	45.00	8.75	50.84
	Calotropis procera	79.58	21.48	27.55	26.58	9.28	89.02
	Landoephia heudoletii	94.40	10.96	33.70	29.62	16.25	54.52
	Vitex doniana	90.81	6.76	53.66	44.71	9.73	52.58
	Ziziphus mauritiana	93.59	12.00	51.02	38.35	10.01	56.28
	Bohinia reticulatum	93.28	4.74	47.38	40.08	12.21	51.95
	Lannea microcarpa	92.53	5.89	34.07	25.99	14.46	67.70
Herbage	*Pennissetum pedicellatum*	94.57	3.11	82.34	57.72	7.82	27.36
	Andropogon gayanus	98.15	2.31	84.14	57.25	8.96	15.46
	Digitaria horizontalis	92.90	5.85	74.52	52.20	5.78	39.58
	Pacicum miliaceum	90.91	12.39	45.67	40.10	10.63	59.25
	Olea europeae	88.44	12.78	52.04	39.56	7.61	65.93
	P.purpureum	93.97	5.71	75.13	52.97	6.23	46.32
	Stylosanthes hamata	94.11	7.74	68.65	55.37	10.26	46.69
	Echinochloa pyramidalis	87.95	3.23	76.07	53.03	7.96	38.32

***ADF**: acid detergent fiber; **ADL**: acid detergent lignin; **CP**: crude protein content; **IVOMD**: in vitro organic matter digestibility; **NDF**: neutral detergent fiber; **OM**: organic matter.*

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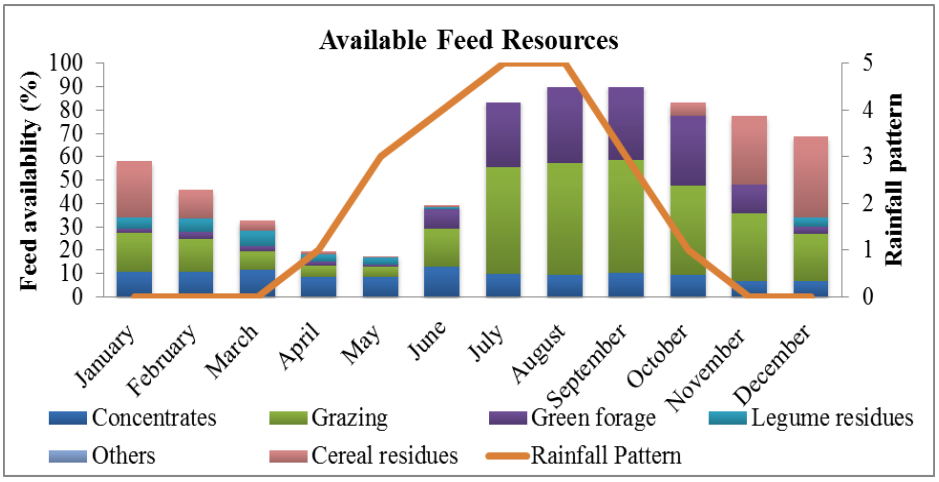
Fig 1: Feed resources availability in Koutiala (A) and Bougouni (B). Rainfall pattern is on a scale of 0-5, where 5 = heavy rainfall and 0 = no rainfall

A



B

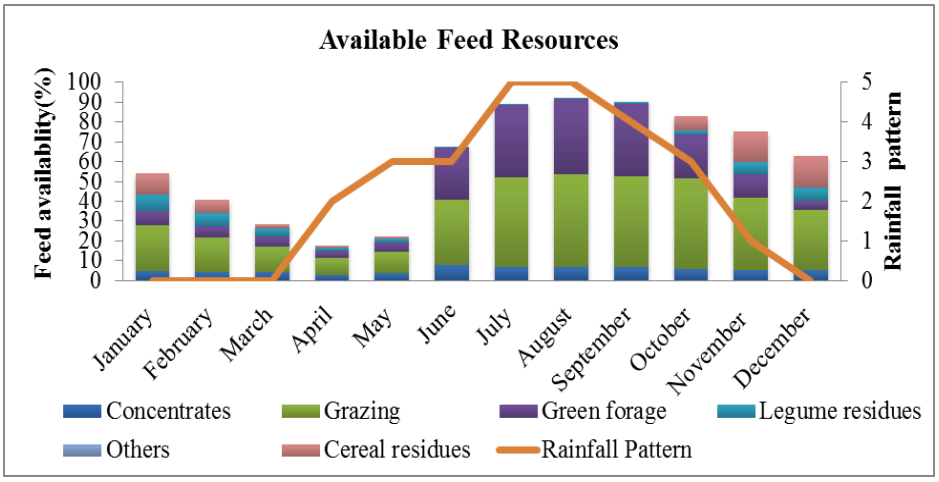


Table 2: Contribution of Different Feed Sources to Dry Matter (Dm), Crude Protein (Cp) and Metabolizable Energy (Me) Of Total Diet of Ruminants in the Study Sites (expressed in %)

Feed source	Bougouni			Koutiala		
	DM	CP	ME	DM	CP	ME
Grazing	59	54	58	50	39	49
Crop residues	25	23	24	30	23	26
Cultivated fodder	1	2	1	1	2	2
Naturally occurring and collected fodder	14	16	16	13	14	14
Purchased feed	1	5	1	6	22	9

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Cowpea hay like residues of other leguminous crops were collected and stored, and used to feed animal later in the dry season or sometimes sold. The quantity and quality of feed resources available decreased as the dry season progressed. Also, the importance of crop residues decreased as the dry season progressed while that of browse increased. In this period of the year, fodder trees and shrubs play an important role for ruminant nutrition (Ickowicz and Mbaye 2001, Ouédraogo-Koné 2008). The preference for browse species varied according to season and animal species. However, regardless of animal species and zone, browse species are more frequently used as animal feed in the dry season (Zampaligré *et al*. 2013). To cope with the problem of feed scarcity towards the end of the dry season and at the start of the rains, most farmers had to purchase feed (Table 3).

Table 3: Purchased Feeds by the Farmers Interviewed (means ± standard error of means)

	Bougouni			Koutiala		
Feed type	n	Quantity bought(kg)	Price (FCFA)	n	Quantity bought(kg)	Price (FCFA)
Cereal bran	13	191.5±42.3	7495±1410	26	848.1±276.4	41163±13858
Cotton grain	2	80.00±0	7000±0	3	316.7±33.3	40500±5628
Cotton seed	9	175.6±45.5	25888±8011	28	803.6±183.6	100696±20706
Parkia biglobosa powder	1	200±0	5000±0	20	38150±84.4	28565±6316
Cowpea hay				4	550.0±144.3	63125±15390

FCFA, Francophone West African currency; as at the time of the study 1 USD = 490 FCFA

The quantity of feed purchased by Koutiala's farmers was significantly higher than in Bougouni ($P<0.05$) for all feed types. The presence of natural pasture and shrubs/trees allow better access to feed resources in Bougouni which explained the reduced quantity of feed purchased in this site compared to Koutiala. Livestock feed production using cultivated forage species is not widely practiced in the study areas. In fact, only 21 (29%) farmers in both study sites out of 72 interviewed grow some fodders for the sole purpose of feeding livestock. The forage species grown in the study areas were cowpea (Sangaranka variety), *Brachiaria ramosa sp*., *Stylosanthes hamata* and forage sorghum (Segetana variety) in a small area. Land areas for the cultivated forage were 0.32 ha and 0.64 ha for cowpea (Sangaranka variety) in Bougouni and Koutiala district respectively. And for *Stylosanthes hamata*, the areas were 0.25 ha in both study sites. The land areas for the remaining cultivated forages ranged between 0.25 and 0.75 ha. According to the group discussions, the main reasons for the low practice of cultivated forage were lack of forage seed and lack of awareness of the importance of the improved forage species. In addition, farmers in Koutiala also attributed the low practice of cultivated forage to shortage of land. These reasons for the low level of cultivated forage are similar to reasons reported by Hassen *et al.* (2010). Generally, the adoption of introduced forage in tropical developing countries has been limited. For example, Elbasha

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et al. (1999) cited by Kebreab *et al*. (2005) and Toutain *et al*. (2000) noticed that although the value of fodder banks in West Africa was recognized by agro-pastoralists, its adoption was slow.

Results of the laboratory analysis of common feed resources showed that cultivated forages such as cowpea and sorghum forage and legumes hay had higher nutritional value in terms of CP content and IVOMD compared to other feed types (Table 1). The leaves part of cereal (maize, millet and sorghum) stovers had higher crude protein content (CP) and digestibility than the stems fraction. The nutritional values of browses varied markedly from about 5 to 21% CP and 50 to 89% digestibility. The major constraint to the consumption of browses by ruminants is the presence of anti-nutritional factor, particularly tannin. The cereal residues and some herbage had a high ADF which is an indicator of low quality of feed. The nutritional values of herbages varied from about 2 to 13% CP and 15 to 66% digestibility. These results on chemical composition of main feed resources are largely consistent with the range of reported values by Savadogo (2000), Ben Salem and Smith (2008) and Ayantunde *et al*. (2014). However, the CP values in our study for cowpea hay and groundnut haulm were low compared to those reported by Ayantunde *et al*. (2014). The difference could be explained by the location and period we collected feed samples at which time most leaves have fallen remaining mainly the stems. The nutritional quality of browse species such as *Afzelia africana*, *Pterocarpus erinaceus*, *Calotropis procera*, *Landoephia heudoletii* and *Ziziphus mauritiana* were good in terms of CP. These results agree with values reported for browse species by Zampaligre *et al.* (2013) and Ayantunde *et al.* (2014).

Utilization of Crop Residues

As shown in Table 4, between 40 and 90% of the crop residue for all types of crops were used for livestock feeding compared to other uses, according to the respondents. Crop residues accounted for at least 20% of the total ruminant diet in both study sites (Table 2) which demonstrated the increasing importance of crop residues as animal feed in mixed crop-livestock systems. The importance of crop residues as livestock feed in the study sites conform with reports by FAO (2014) that crop residues are one of the most important feed for ruminant in smallholder crop-livestock production systems of sub-Saharan. Sandford (1988) observed that crop residues are vital livestock feeds, especially in the drier parts of West Africa. Moreover, crop residues that remained in the fields were used for mulching and for protection against erosion. In addition, cereal crop residues remaining on the soil surface at the onset of planting were gathered and burned. The proportions of crop residues sold in both study areas were practically low. Only residues of leguminous crops (cowpea hay and groundnut haulms) are normally sold.

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Table 4: Use of Crop Residues in the Study Sites as Reported by the Respondents (% of total use)

Crop residue	Site	Feeding	Fumigation	Burnt	Sold	Construction
Cotton	Bougouni	39.1	15.7	45.2	0	0
	Koutiala	44.1	51.8	4.1	0	0
Maize	Bougouni	78.6	12.1	9.3	0	0
	Koutiala	52.9	43.9	3.23	0	0
Sorghum	Bougouni	66.2	7.7	26.	0	0
	Koutiala	60.8	34.9	41.7	0.3	0
Millet	Bougouni	66.0	0	34	0	0
	Koutiala	39.1	47.4	13.5	0	0
Rice	Bougouni	88.1	7.5	0	0	4.4
	Koutiala	71.1	28.9	-	-	
Groundnut	Bougouni	91.3	7.9	0.8	0	0
	Koutiala	80.0	20.0			
Cowpea	Bougouni	96.2	0	0	3.8	0
	Koutiala	71.8	28.2			

Major Constraints to Livestock Production in the Study Sites

Major constraints to livestock production in the study sites were feed scarcity particularly in late dry season, unavailability of water in the dry season, animal disease and low productive capacity of local livestock breeds (Table 5). The problem of feed scarcity as one of the major constraints to livestock production in the study sites has been reported in many others countries in West Africa.

Table 5: Major Problems Facing Livestock Production and Suggested Solutions

Major problem	Suggested solution
Feed scarcity	Support for cultivated forage, training on improved feed conservation, training of farmers on efficient feed practices, treatment of straws and feed processing, information and sensibilization on bush fire
Unavailability of water especially in the dry season	Education on water harvesting techniques, creation of pastoral wells, development of standing pools
Animal disease	Strengthening the capacity of community animal health workers and farmers in diagnosis of common animal diseases, their prevention and treatment
Lack of animal housing	Providing the community with technical and financial support for construction of animal house and fencing materials.
Absence of stock routes and conflict between herders and farmers	Creation of livestock corridors, development of local conventions on natural resource management, conflict management and transhumance through community consultations.
Low productive capacity and poor reproductive performance of local breeds	Improving quality of local breeds, introduction of improved breeds, training of farmers in animal breeding and reproduction

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In the review of under-nutrition in smallholder ruminant production systems by Kebreab *et al.* (2005), seasonal feed shortages particularly in the dry season were pointed out as the major constraints to increase ruminant productivity in developing countries. As a consequence, livestock are generally undernourished during this time and thus become more susceptible to diseases. Other constraints reported by the farmers included poor reproductive performance, conflict between herders and farmers and lack of housing for the animals. These constraints are symptomatic of the extensive livestock production system which is dominant in the study sites.

Conclusion

The results of this study suggest that the availability of feed resources depends partly on season and type of crop grown in the study areas. Thus, crop residues constitute a major source of livestock feed after pastures and are vital livestock feed during the dry season. The study revealed that livestock feed production using cultivated forage species is not widely practiced in the study areas. Hence, to address the main problem of feed scarcity, technical and institutional interventions are necessary to help farmers to make a more efficient use of their crop residues and to promote fodder cultivation to improve livestock nutrition and consequently the productivity.

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