Evaluation of feed resources in mixed crop-livestock systems in the Sudano-Sahelian zone of Mali

Produced by: Clarisse Umutoni and Augustine A. Ayantunde

Published by: International Livestock Research Institute

May 2014

www.africa-rising.net

The Africa Research In Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-for-development projects supported by the United States Agency for International Development as part of the U.S. government's Feed the Future initiative.

Through action research and development partnerships, Africa RISING will create opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children, and conserve or enhance the natural resource base.

The three projects are led by the International Institute of Tropical Agriculture (in West Africa and East and Southern Africa) and the International Livestock Research Institute (in the Ethiopian Highlands). The International Food Policy Research Institute leads an associated project on monitoring, evaluation and impact assessment.

This document was made possible with support from the American people delivered through the United States Agency for International Development (USAID) as part of the US Government's Feed the Future Initiative. The contents are the responsibility of the producing organization and do not necessarily reflect the opinion of USAID or the U.S. Government.

Contents

Summary

A study was carried out to assess existing and potential feed resources and constraints to livestock production in Koutiala and Bougouni districts in Southern part of Mali. A Feed Assessment Tool (FEAST) which was developed by International Livestock Research Institute (ILRI) was used to collect necessary data on the livestock production systems and feed resources. FEAST is a rapid systematic method to assess local feed resource availability and use. The assessment included focus group discussions and individual interviews.

The results of the feed assessments showed that the main crops grown in the mixed crop-livestock systems of Koutiala and Bougouni were cotton, maize, sorghum, millet, groundnut, and cowpea. The largest proportion of almost all types of crop residues were used for livestock feeding rather than any other uses (about 75% and 60% for Bougouni and Koutiala districts, respectively). Livestock owned per household was almost the same in both study areas (Bougouni = 12.00±0.6 TLU; Koutiala = 11.99±0.67 TLU Ninety percent and 86.6% of the households interviewed in Koutiala and Bougouni, respectively kept at least one draught cattle primarily to support cropping operations.

The main feed resources for livestock in the study sites were natural pasture, crop residues, shrub/tree leaves and agro-industrial byproducts especially cereal bran and cottonseed cake. The feed availability depends on season. Pastures and green forage (herbage) were the main feed for animal during the wet season (June to October), contributing more than 80% of animal diet during this period. The quantity and quality of pasture declined as the season advanced from wet to dry. Feeding of crop residues mostly begins soon after crop harvest in October/early November and extending up to February or early March. In both study areas, especially in Bougouni, as the dry season progressed the importance of crop residues as animal feed decreased while that of browse increased. Browses tended to form a significant part of the ruminant diet between February and May.

The highest dry matter content of ruminants' total diet came from grazing (50 and 59 % respectively in Koutiala and Bougouni Yanfolila districts). The animals' protein and Metabolizable Energy (ME) requirements were also met largely from the grazing. Crop residue is second to grazing in the provision of the animal's dietary nutrient requirement. Although crop residues were produced in large amounts, their full and efficient utilization for livestock has been hindered by inadequate knowledge of farmers on feed processing and treatment, and lack of improved technologies for feed storage. Seasonal shortage in feed supply, stock route and lack of watering point were the major constraints facing livestock production in the study area. Training of farmers on effective feed resources utilization, and production of cultivated forage could be very important to raise the capacity of farmers to address these constraints.

Introduction

Livestock are important assets to the rural poor in developing countries and approximately 70% of the world's ruminant populations are located in developing countries, where they play multiple roles **(**ILRI, 2002**).** It is estimated that livestock contribute to the livelihoods of more than two-thirds of the world's rural poor and to a significant minority of the peri-urban poor (ILRI, 2002). For these populations, livestock play a critical role in both the sustainability and intensification of agriculture productivity in most farming systems. They provide nutritious food products for human consumption and income-generation opportunities. Their manure helps maintain soil fertility contributing to the overall sustainability of the farming enterprise **(**Sere et al., 2008**).** Livestock provide also traction to cultivate fields. For many, livestock provide livelihood options available as they exploit common resources for private gain. In addition, in many rural societies poor women derive their income from livestock keeping.

The common feed resources in sub-Saharan Africa for livestock production are pastures (herbaceous plant, fodder trees/ shrubs), crop residues, cultivated forage, and concentrate feeds (agro-industrial by products, grains, feed supplements etc.). The common problems with these resources are marked variation in availability and quality, and seasonal shortage, which have have been consistently reported as the major constraint to ruminant production (Leng and Devendra, 2011, Souvant, 2004; FAO, 2012) in the developing countries. Addressing feed problem can significantly increase livestock productivity.

Due to growing population in Mali in general, the natural resource base for livestock production is under increasing threat and this can lead to natural resource degradation. Apart from demographic pressure, the other major causes of natural resource degradation are expansion of cropping fields into grazing areas, shortening of fallow period, continuous cultivation of crop fields with low addition of external inputs such as fertilizer, deforestation to grow crop particularly cotton in Sikasso region, and probably climate variability and change. Then, degradation of natural resources affects availability of feed resources.

Feed resources are generally abundant in the wet season and the quality is good. Feed scarcity is a big problem in the late dry season (March to May). Despite the continued reduction in the size of pasture and cultivable areas for crop production, ruminants will continue to depend primarily on fodder from natural pastures and crop residues. Livestock feed supply from natural pasture 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 and 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). 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. Animals usually lose weight during this period (late dry season: March to May) despite significant consumption of browse (Leloup et al., 1996).

In addressing this problem of feed shortage, it is necessary to assess the existing and potential feed resources, use, costs and gaps with respect to ruminant production to meet the requirements of livestock. These evaluations will guide the development of effective strategies to improve nutrition and livestock productivity based on locally available feed resources. Evaluation of the existing and potential feed resources is also important to develop strategies for efficient use of these resources by reducing waste. In addition, it is also necessary to promote proper management of natural resources, and the adaptation of livestock systems to available feed resources (Corniaux et al., 2005; Griffin, 2009; CIRAD, 2010 and Doré et al., 2011).

The main reason for selecting the administrative district ("cercles") of Koutiala and Bougouni in the Sikasso region was the potential and the opportunities they present for the development of animal production. In addition, the study area has the highest production of cotton and cereal in Mali. Both districts also offer more opportunities in terms of available feed resources for better livestock productivity. Strategies for the development of livestock feed that consider the use of local resources already adapted to the local environment must be explored in this area.

The result of this study will contribute to identification of improved feeding strategies for livestock. Besides, this study will help to define future interventions in developing livestock feeding systems to enhance productivity and viable integration of the crop and livestock sectors in southern region of Mali. Accordingly, this study was conducted with the objective to assess existing and potential feed resources and gaps at farm household level in order to enhance optimal use for improved farm productivity in Koutiala and Bougouni districts. The specific objectives of this study were to characterize the existing farming systems and livestock management in the study sites, and to assess locally available feed resources for livestock production.

In this study, we are testing the hypothesis that the assessment of feed resources will promote the identification of innovative strategies to improve feed for livestock and therefore contribute to the improvement of livestock productivity and consequently the livelihood of smallholder farmers.

Material and methods

Description of the study sites

The study sites included the following villages: 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-Yanfolila district located in Saikasso, a southern region of Mali. These study sites are in the region with the highest agricultural production in Mali. Based on agricultural production statistics for 1984 to 2000, Sikasso region accounted for 37% of national millet and sorghum production, 63% of maize production, 13% of groundnut production and 95% of cotton production (Cellule de Planification et de Statistique, 2001). Koutiala zone is the cotton production capital of Mali followed by Bougouni. Annual precipitations in the two study sites range from 700 – 1000 mm and 900 – 1200 mm for Koutiala and Bougouni, respectively. Crop farming and livestock husbandry are the main sources of household income in Koutiala and Bougouni. As a result, there is a close interdependence between crop and livestock sub-systems in the study area. Figures 1 and 2 illustrate clearly the study area.

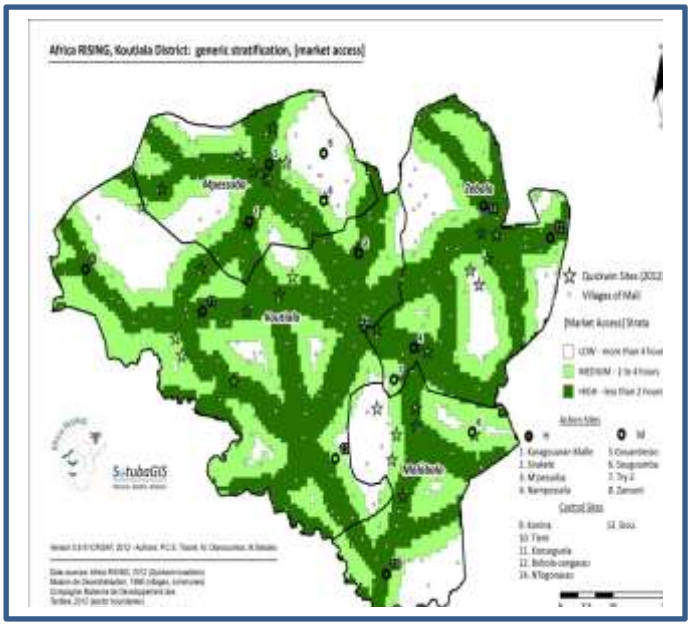


Figure 1. Koutiala district (cercles)

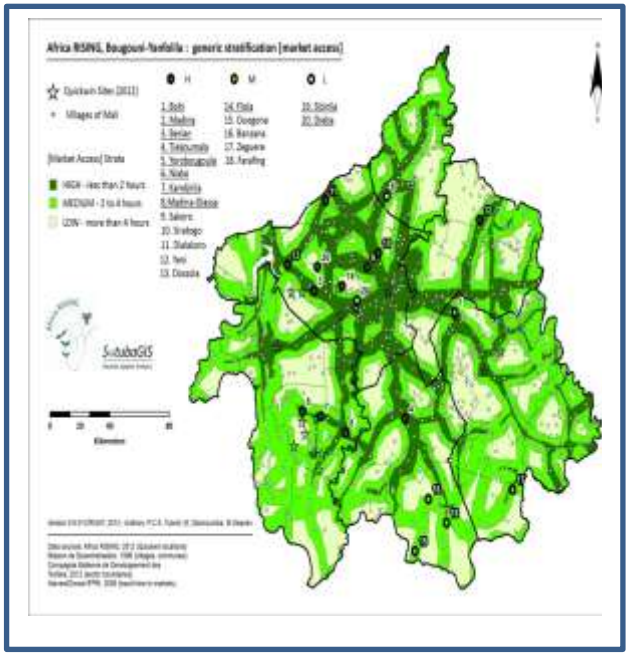


Figure 2. Bougouni district

Methodologies

The 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 strategies aiming to optimize feed utilization and animal production. FEAST consists of two components namely Participatory Rural Appraisal (PRA) and individual farmer's survey. PRA exercise aims at capturing an overview of the farming system with particular emphasis on livestock feeds and description of major problems facing livestock production. The individual interview of the farmers aims at collecting quantitative information on crop-livestock production, feed availability and quality.

Implementation of the survey

The survey was conducted between October and November 2013 in three communities (Dieba, Sibirila and Yorobougoula) in Bougouni-Yanfolila district and three communities in Koutiala district (Nampossela, Sirakele and Zanzoni). For the PRA, 15 farmers including men (2/3) and women (1/3) in each study village were invited to a meeting of about half-a-day to assess the constraints and opportunities for improving livestock feeding systems. This meeting consisted of participatory diagnosis of livestock production systems, feed resources and availability and livelihood strategies. In total, group discussion was conducted with 112 farmers in all the six communities in the two study sites.

The goal of the individual survey was to gather specific information from individual farmers about their farming practices. A semi-structured questionnaire was used for data collection. Twelve farmers in each study village were selected for the individual interview relating to their farming systems and feeding practices. The twelve farmers selected were representative of 3 wealth categories in the community namely farmers with small, medium and large land holdings. Four farmers from each wealth category were interviewed in each community. In total, 72 farmers were interviewed in the six communities in the two study sites.

Table 1. Average land size in each study community

	Bougouni			Koutialla		
	Diéba	Sibilira	Yorobougoula	Namposséla	Sirakelé	Zanzoni
Average land holding in ha	13	15	9	11	20	12

Data analysis

The statistical analysis was carried out using SAS (1987) using Means procedure. T test was used to test if there is any significant difference between the two study sites for the dependent variables.

Results and discussion

Rainfall distribution

Two distinct seasons occur in both study areas Koutiala and Bougouni-Yanfolila namely the dry season which occurs from early November till April and rainy season which occurs from May to the end of October. The peak period for rainfall is in July and August. However, in these last years, rainfall patterns are becoming unpredictable and unreliable (Table 2). Figure 3 showed the general distribution of rainfall in Koutiala and Bougouni-Yanfolila according to farmer's perceptions and meteorology service data. The trends are the same with both sources of information. According to the meteorology data, Bougouni-Yanfolila district receives more precipitation than Koutiala district.

Table 2. Rainfall distribution in different study villages according to farmers' perceptions

Sites	Villages	January	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Koutiala	Nampossél a	0	0	0	1	3	5	5	5	3	1	0	0
	Sirakelé	0	0	0	0	3	3	4	5	4	2	0	0
	Zanzoni	0	0	0	1	3	5	5	5	3	1	0	0
Bougouni-Yanfolila	Diéba	0	0	0	2	3	3	5	5	4	3	1	0
	Sibilira	0	0	0	2	3	3	5	5	4	3	1	0
	Yorobougo ula	0	0	0	2	3	3	5	5	4	3	1	0

The shaded portion indicates the rainy season and the numbers show the magnitude of rainfall in each month on the scale of 0 (none) to 5 (highest) according to those interviewed.

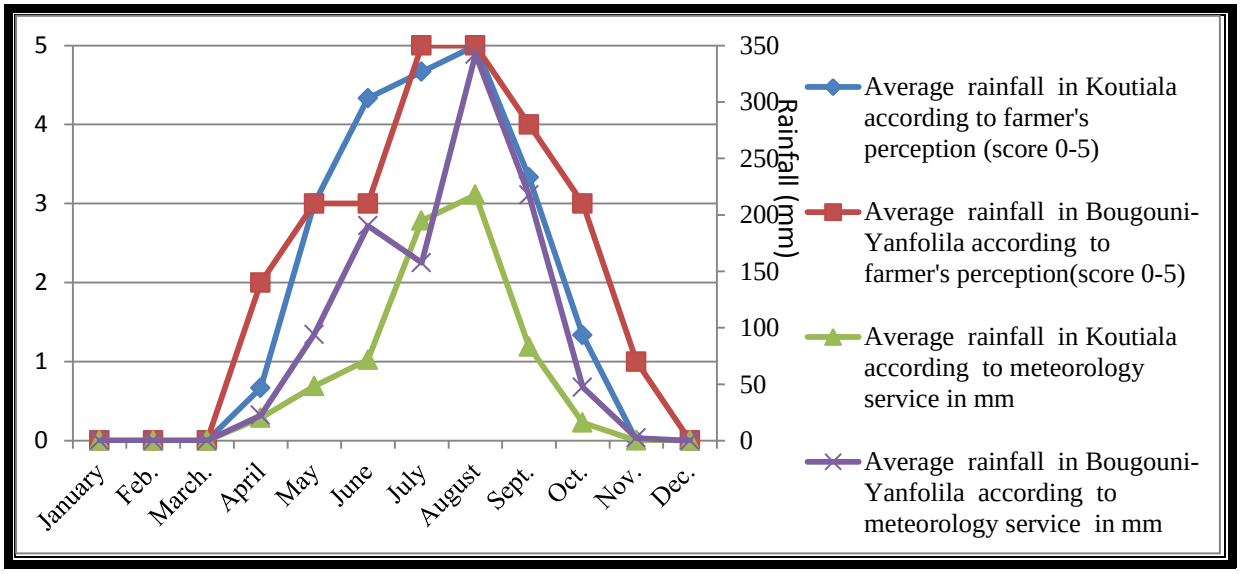


Figure 1. Rainfall distribution in Koutiala and Bougouni –Yanfolila districts according to farmers perceptions and meteorology service data

Cereal crops, cotton, groundnut, cowpea, okra, peas and potatoes were the main crops grown in the wet season. During the dry season leguminous crops (e.g. cowpea) are usually grown by irrigation.

Small-scale irrigation is practiced in all the communities as presented in Table III. The number of household with access to irrigation was relatively high in Diéba, Zanzoni and Yorobougoula (100%, 90% and 80% respectively) villages while this was modest in Nampossélа village (60%). Access to irrigation was minimal in Sibilira (15%) and Sirakéle (2%) villages due to the lack of water bodies for irrigation.

Table 3. Percentage of household that have access to irrigation in the community study

Cercle	Village	Access to irrigation (%)
Koutiala	Nampossélа	60
	Sirakelé	2
	Zanzoni	90
Bougouni-Yanfolila	Diéba	100
	Sibilira	15
	Yorobougoula	80

Household characteristics, land holdings and use pattern

Mixed crop-livestock systems are dominant in the study areas. Sere and Steinfeld (1996) define mixed crop–livestock systems as those in which at least 10% of the feed comes from crops and/or crop by-products or more than 10% of the total agricultural production comes from non-livestock farming activities. As population densities increase, there is pressure to intensify agricultural production, which leads to an increase in the interactions between crop and livestock production (McIntire et al., 1992). Average household size was 17.33±11.88 (Diéba= 19±15; Yorobougoula=16±11.15; Sibilira=18±17.5; Nampossélа= 19±13.28; Sirakéle= 19±14.80; Zanzoni=13±8). Average land areas cultivated were 8.81 and 15.83 ha for Bougouni Yanfolila and Koutiala districts, respectively (Table 4). The land cultivated in Bougouni –Yanfolila was significantly lower than in Koutiala ($p<0.05$).

This difference could be attributed to the diversification of livelihood activities in Bougouni-Yanfolila than in Koutiala. The other explanation that can be given for these results was the higher population in Koutiala than Bougouni which necessitate expansion of cropping area to meet the demand for food. This expansion of cropping area is often associated with an increased risk of degrading natural resources and increased incidence of conflict among users (Kebreab et al., 2005).

Table 4. Cultivated land area in the study sites

Area	N	Mean	Std Error	Minimum	Maximum
Bougouni	36	8.81	0.95	1.00	26.76
Koutiala	36	15.83	1.67	2.75	40.5

From the 3 classes of resources endowment identified (small, medium and large) based on the amount of land utilized for farming, farmers with small land area was dominant class in all study area. Table 5 shows the percentage of farmers in each category of farmers.

Table 5. Categories of farmers according to land owned from the farmers interviewed

	Bougouni –Yanfolila		Koutiala	
Category of farmers	Range of land size in ha	%of household that fall into the category	Range of land size in ha	%of household that fall into the category
Landless	0	0	0	0
Small farmer	< 8	44.44	<12	41.67
Medium farmer	8-13	30.56	12-27	36.11
Larger farmer	> 13	25	> 27	22.22

From household survey, agriculture is the main economic activity in both study areas. As presented by Traore (1998), the Southern Mali's economy is largely dependent on the production from the primary sector with 80% of agricultural production from rainfed agriculture. Study led by Dury et al., 2012 showed that cereal production in the Sikasso region is higher than in most other parts of Mali and the region of Sikasso is also renowned for rainfed cotton. The results showed that the main food crops grown in Koutiala and Bougouni-Yanfolila area are pearl millet, maize, sorghum, groundnut, cowpea and rice which are generally cultivated as monoculture. However, for many farmers cowpea is often intercropped with cereal. The intercropping consists of various spatial arrangements of maize/millet/sorghum and cowpea. Some other intercropping is practiced such as groundnut with Dah and cowpea with sesame.

The main cash crop, known in the study area as "white gold" is cotton and its production is currently increasing compare to 1990s. Specifically, as shown in Table 6, maize, cotton and groundnut were the most dominant crop in Bougouni-Yanfolila with a mean cultivated area per household of 3.61±0.51 ha, 3.52±0.36 ha, and 2.08±0.27 ha, respectively. The main crops in Koutiala were pearl millet, sorghum and cotton with the overall mean cultivated area of 4.09±0.50ha, 4.03±0.44 ha, and 3.68±0.48 ha, respectively.

Table 6. Average area of land utilized for the various crops grown in Bougouni - Yanfolila and Koutiala districts

Dominant crop	Bougouni-Yanfolila				Koutiala			
		Mean ±s.e.				Mean±s.e.		
	n	Total	Male	Female	n	Total	Male	Female
Cotton	22	3.52±0.36[a]	3.75±0.36 n=20	1.25±0.25 n=2	34	3.68±0.48[b]	3.99±0.62 n=24	2.91±0.69 n=10
Cowpea	13	0.53±0.08[a]	0.56±0.08 n=12	0.25 n=1	28	0.83±0.11[b]	0.93±0.13 n=21	0.54±0.09 n=7
Groundnut	36	2.08±0.27[a]	2.55±0.32 n=26	0.87±0.19 n=10	34	1.03±0.12[b]	1.14±0.17 n=24	0.78±0.09 n=10
Maize	28	3.61±0.51[a]	3.80±0.56 n=25	2.0±0.58 n=3	31	2.39±0.3[b]	2.50±0.34 n=22	2.11±0.68 n=9
Millet	5	1.38±0.24[a]	1.38±0.24 n=4	0.02 n=1	34	4.09±0.50[b]	4.30±0.61 n=24	3.60±0.91 n=10
Rice	17	0.78±0.12[a]	0.92±0.20 n=9	0.63±0.13 n=8	9	0.61±0.10[a]	0.56±0.10 n=8	1.0, n=1
Sorghum	14	1.30±0.24[a]	1.42±0.26 n=12	0.63±0.38 n=2	36	4.03±0.44[b]	4.32±0.55 n=25	3.36±0.69 n=11

N.B: Mean with different letter for each crop across the two sites are significantly different at P<0.05

The difference in cultivated area for each crop in Bougouni-Yanfolila and Koutiala is significant ($p<0.05$) except for rice.

Ninety percent and 86.6% of the households interviewed in Koutiala and Bougouni-Yanfolila, respectively kept at least one draught cattle. Small ruminant (sheep and goat) are kept by all the households in Koutiala while there are a remarkable difference in number of household which kept small ruminant in Bougouni -Yanfolila. Sheep were kept by 54% while goats were kept by 83.3% of the households interviewed. The higher proportion of households which kept goats compared to those who kept sheep can be explained by the availability of shrubs and trees in Bougouni-Yanfolila district which is easily exploitable by goat as feed

In many dryland agroecosystems of West Africa, poor soil fertility and low and erratic rainfall are major limitations to crop production (Breman and de Wit, 1983). For many households, diversification into livestock reduces risk by providing insurance in the case of crop failure. In these systems, livestock are also a source of liquidity and investment capital in the absence of savings and credit institutions.

As can been seen in figure 4, groundnut is cultivated by nearly all the households (100% in Bougouni -Yanfolila, 94% in Koutila) in both study sites. All the households interviewed in Koutiala cultivated sorghum whereas only a few number of households cultivated the crop in Bougouni-Yanfolila. In Bougouni-Yanfolila, women were more involved in groundnut and rice cropping than men. For example, the entire female farmers interviewed grown groundnut while eight out of ten farmers grown rice.

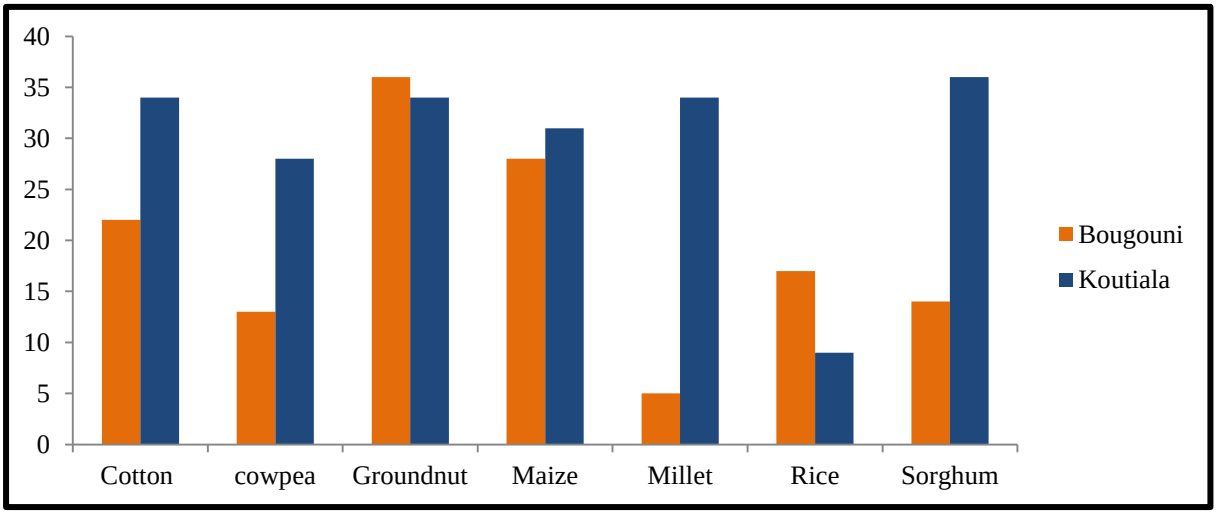


Figure 2: Percentage of respondents who grown different crops

Crop residues

As shown in Table 7, between 40 and 90% of the crop residue biomass for all types of crops were used for livestock feeding compared to other uses Crop residues are already the most important feed for ruminant in smallholder crop-livestock production systems of Africa and contribute substantially to the supply of nutrients animals in mixed farms of Latin America (Williams and al.1997). Crop residues are vital livestock feeds, especially in the drier parts of West Africa (Sandford, 1990). In addition to use as livestock feed, crop residues are also used as fuel and construction material, and are sold to provide income to meet household needs (Sandford, 1989; McIntire et al., 1992). Residues that remain in the fields are used for mulching and for erosion protection.

Table 7. Residue use in the study sites

Crop residues	Area					
		Feeding	Fumigation	Burnt	Sold	construction
Cotton	Bougouni-Yanfolila	39.09	15.68	45.22	0	0
	Koutiala	44.12	51.76	4.12	0	0
Maize	Bougouni-Yanfolila	78.57	12.14	9.29	0	0
	Koutiala	52.90	43.87	3.23	0	0
Sorghum	Bougouni-Yanfolila	66.15	7.69	26.15	0	0
	Koutiala	60.83	34.87	41.67	0.33	0
Millet	Bougouni-Yanfolila	66	0	34	0	0
	Koutiala	39.12	47.35	13.53	0	0
Rice	Bougouni-Yanfolila	88.125	7.5	0	0	4.375
	Koutiala	71.11	28.89	-	-	
Groundnut	Bougouni-Yanfolila	91.25	7.92	0.833	0	0
	Koutiala	80	20	-	-	
Cowpea	Bougouni-Yanfolila	96.15	0	0	3.85	0
	Koutiala	71.79	28.21	-	-	

The proportion of crop residues sold in both study area was practically nil. This could be due to feed shortage in the area which necessitates using the crop residues for feeding household animals and the remaining part is generally used for fumigation or to make potash which is used in farmer's nutrition. According to the findings of Powell and al. (2004), feeding crop residues and using manure to fertilize cropland is perhaps a rational strategy. In many areas of West Africa, cereal crop residues remaining on the soil surface at the onset of planting are usually gathered and burned.

Cultivated forage

Livestock feed production using cultivated forage species is not widely practiced in the study areas. Only 21 (29%.) farmers out of 72 interviewed grown some fodder for the sole purpose of feeding livestock (Bougouni –Yanfolila: 25%; Koutiala: 33%). The forage species grown in the study areas were cowpea (Sangaranka variety), Bracharia, Stylosanthes and forage sorghum. As shown in Table 8 below, the practice of cultivated forage is more developed in Koutiala than in Bougouni-Yanfolila area. The main reasons for the low level 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 this low practice of cultivated forage to shortage of land. Hassen et al. (2010) argued that the low practice of cultivated forage in smallholders' farmers is more due to the lack of awareness about the importance of improved forage species. Generally, the adoption of introduced forage in tropical developing countries has been limited. For example, although the value of fodder banks in West Africa was recognized by agro-pastoralists, its adoption was slow (Elibash and al., 1999 cited by Kebreab et al., 2005). Kebreab et al. (2005) conclude that the reasons for poor adoption appear to be the lack of evidence of economic profitability and the inadequate technical support.

Table 8. Number of respondents who planted improved forage in the study areas

	Bougouni-Yanfolila		Koutiala	
Cultivated forage	n	Area	n	Area
Cowpea forage	7	0.32	7	0.64
Stylosanthes	2	0.25	1	0.25
Bracharia	-	0	1	0.25
Sorghum	-	0	3	0.75

Livestock assets, their role and management

The livestock species reared in the community are given in Table IX. Livestock number per household was almost the same in both study areas (Bougouni-Yanfolila = 12.00±0.60 TLU; Koutiala = 11.99±0.67 TLU). A generally high number of livestock in the study sites could be attributed to the settlement of Fulani herdsmen in the areas and investment of farm incomes in livestock (Bosma et al, 1996. Coulibaly, 2008). Cattle was the dominant species in the study sites (Bougouni-Yanfolila=11.46±3.48 TLU; Koutiala=8.64±2.93). Approximately 77% and 99% of the households interviewed in Bougouni-Yanfolila and Koutiala, respectively kept at least one pair of draught cattle for farm operations. Households that do not own any draught cattle normally hire it when required.

Table 9. Livestock ownership in Tropical Livestock Unit (mean±s.e.) in the study areas

Species	Category	Bougouni-Yanfolila	Koutiala
Cattle	Lactating cow	2.59±0.69[a]	1.26±0.33[b]
	Non lactating cow	3.91±1.21[a]	2.78±1.38[a]
	Bulls	0.89±0.27[a]	1.17±0.60[b]
	Draught oxen	1.81±0.31[a]	2.35±0.29[a]
	Calves	1.26±0.68[a]	1.08±0.33[b]
Sheep	Sheep	0.27±0.06[a]	0.72±0.16[b]
Goat	Goat	0.67±0.15[a]	0.84±0.13[a]
Donkey	Donkey	0.50±0.08[a]	1.36±0.16[b]
Poultry	Poultry	0.13±0.02[a]	0.22±0.03[b]
Pig	Pig	0.01±0.01[a]	0.21±0.13[b]
	Overall mean	12.00±0.6	11.99±0.67

Mean in the same row with different superscript letter are statistically different at P<0.05

As presented in Table 9, the high proportion of cattle in both study areas demonstrates the significance of cattle in the farming systems, particularly the draught animals. In the cotton zone of Southern Mali, 90% of family production units have cattle, and 60% have reproductive animals, in addition to draught oxen (Poccard-Chapuis et al., 2007**).**

In some West African dryland areas, draft animals, most commonly cattle, but also donkeys, horses, mules, and even camels contribute to crop production through the provision of power to assist farmers in the production, harvesting, processing, and marketing of crops (Powell, 2004). In addition, cattle are kept to provide milk for household nutrition (Stangel, 1995). The average number of sheep kept in Koutiala was significantly higher than that in Bougouni-Yanfolila but the average number of goat per household was almost the same in both study areas. The main purpose of keeping sheep and goat is to generate cash income to meet household needs and as a source of meat especially for festivity. In time of insufficient crop harvest, sheep and goats are also sold to purchase grain and meet other family needs. Sheep and goats are also kept for manure and for sacrifice. Donkey are mainly used for transporting people and agricultural products to and from the homestead , drinking water for animal and human being, wood, crop residues and charcoal to market place. Poultry are kept as immediate sources of cash for family needs, and as meat, gift for strangers, and for sacrifice.

Livestock can help cement social networks and for many poor households, livestock is the primary form of savings.

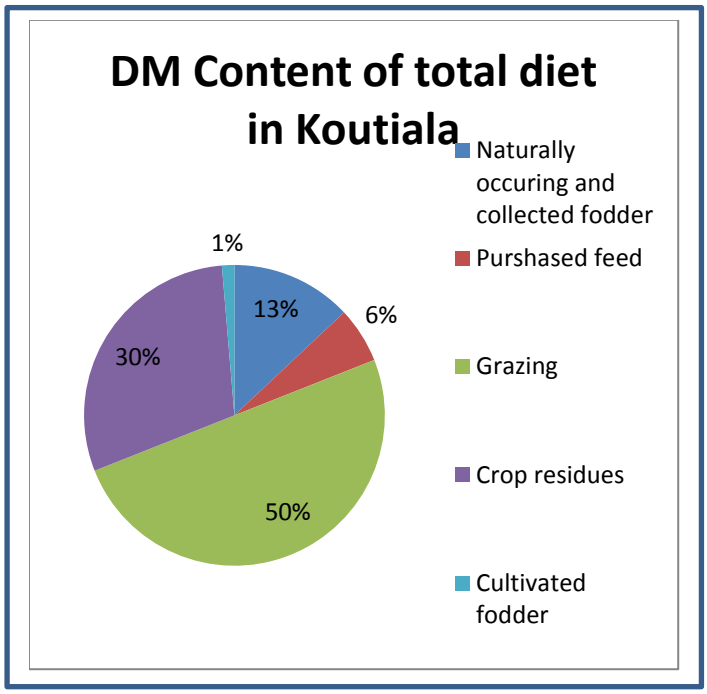
All animal breeds kept in study areas are indigenous types (local breed). Ba (2011) shows in the study conducted in Southern region of Mali that cattle breeds present in the cotton zone in Southern Mali are mainly zebu, taurine trypanotolerant breed (N'Dama) and crossbred between Zebu and N'Dama locally called Méré. In both study areas, the management of livestock depends on the availability of feed resources and it varies with season. In general, cattle were herded during the day in the wet season and tethered at night without any supplementary feeding.

During the dry season, herding and tethering of all cattle were still practiced in Koutiala but only by few herders in Bougouni-Yanfolila. In addition, some farmers do send their cattle on transhumance. Sheep and goats are normally tethered at homesteads and along the road side for grazing during the wet season and during the dry season they are allowed to free-range or sent on transhumance with cattle. During the dry season, all animals which were not sent on transhumance were supplemented (cereal bran, cottonseed cake, crop residues especially cowpea hay). The common feeding strategies in the area included grazing natural pastures and feeding crop residues. These results agree with report by Coulibaly et al. (2007) on feeding strategies for cattle around the town of Sikasso, located in the heart of the cotton area in southern Mali.

Major livestock feed resources and seasonal feed availability

The main feed resources for livestock in Bougouni-Yanfolila and Koutiala districts were natural pasture, crop residues, shrub/tree leaves and agro-industrial byproducts especially cereal bran and cottonseed cake as shown in Figure 5 and Table 10. The same feed resources were reported by Ba (2006) , Dembele (1995) and Susan et al. (1996) for the same region (Southern region) where we conducted our study. These feed resources are common in most livestock farming system in sub-Saharan Africa (Lukuyu et al. 2011, Hassen et al., 2010, Zingg, 2011 and Powell et al., 2004).

Among the feed resources, natural pasture and crop residues contributed the largest source of livestock feed in the study areas in terms of dry matter content, crude protein and metabolizable energy. Grazing, crop residues, naturally occurring and collected fodder, purchased feeds and cultivated fodder contributed 50, 30, 13, 6, and 1% of the total ruminant diet, respectively in Koutiala, and 59, 25,14,1 and 1% of the total ruminant diet, respectively in Bougouni-Yanfolila



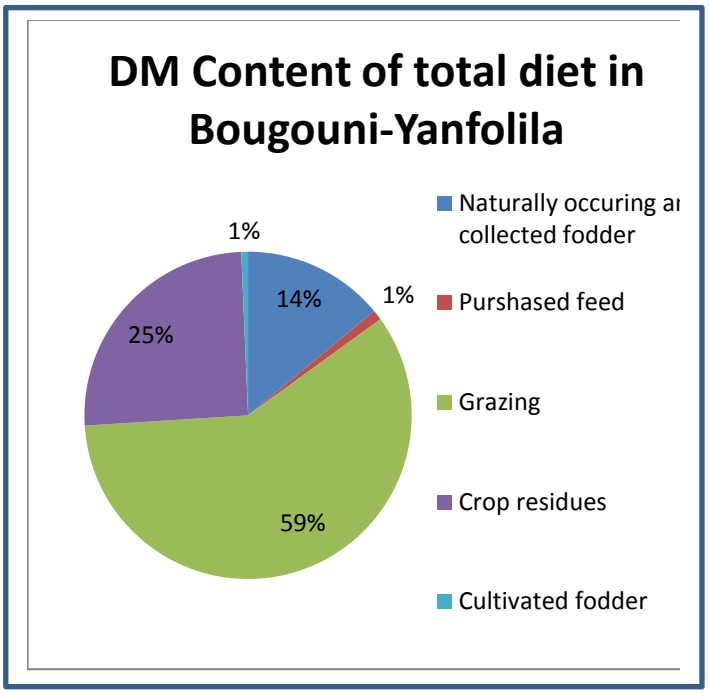
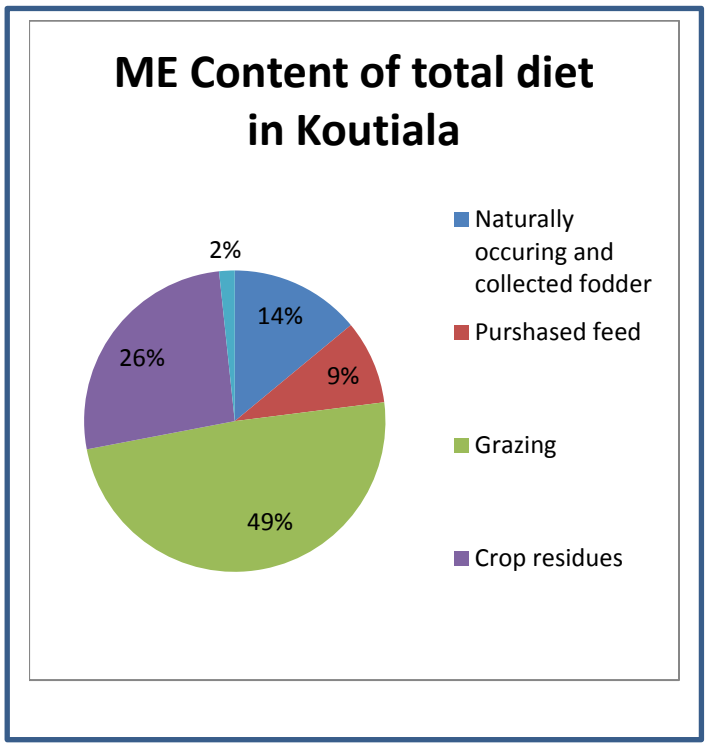


Figure 5. The contribution of different feed sources to dietary dry matter (DM) of ruminant diet in the study sites



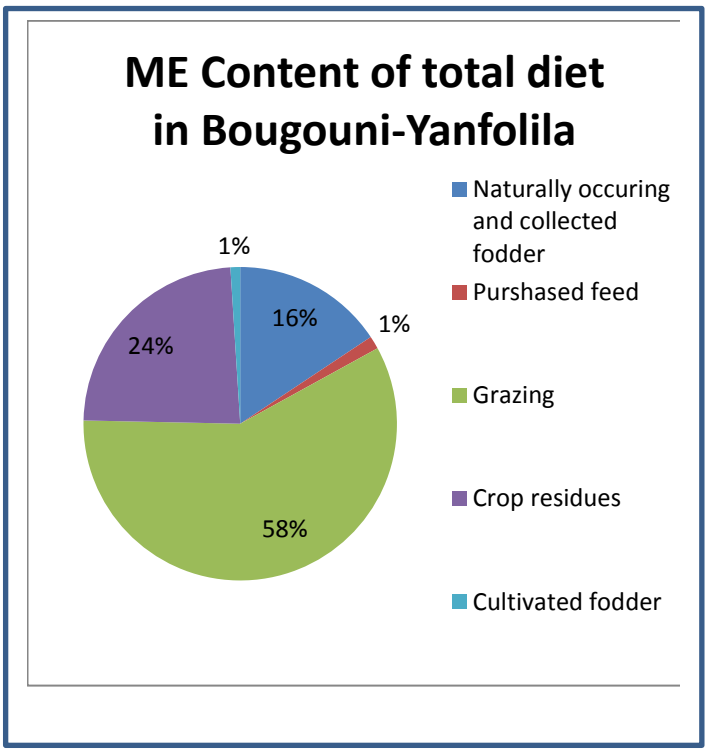
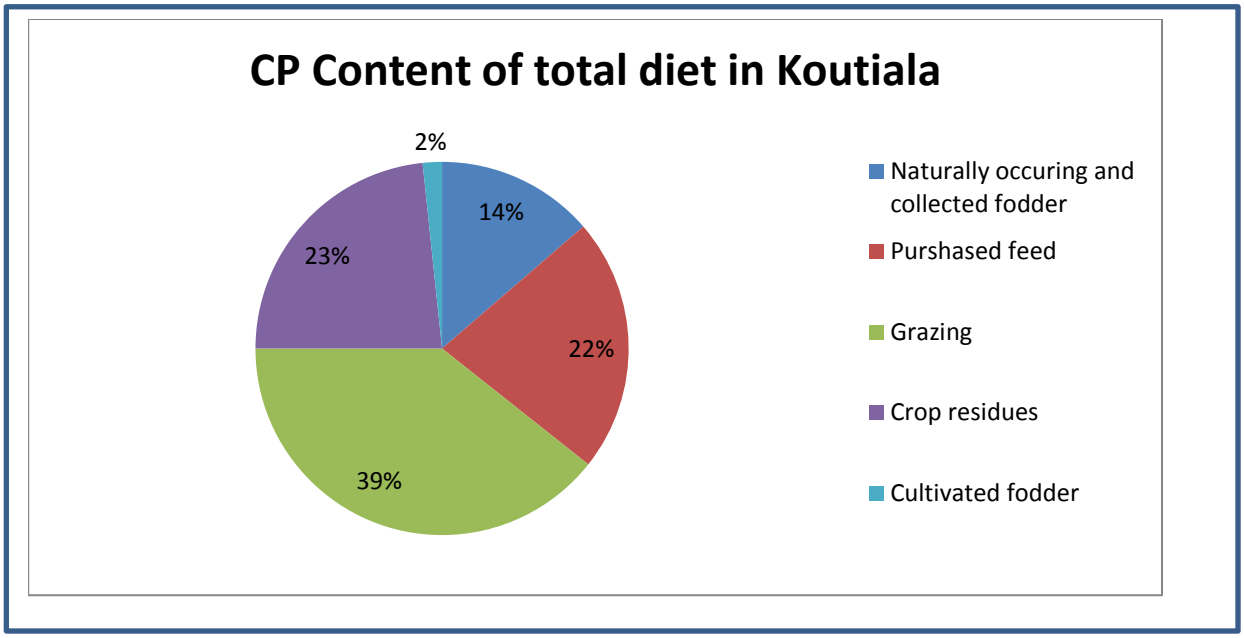


Figure 6. The contribution of different feed sources to dietary metabolizable energy (ME, MJ/kg) of ruminant diet in the study sites



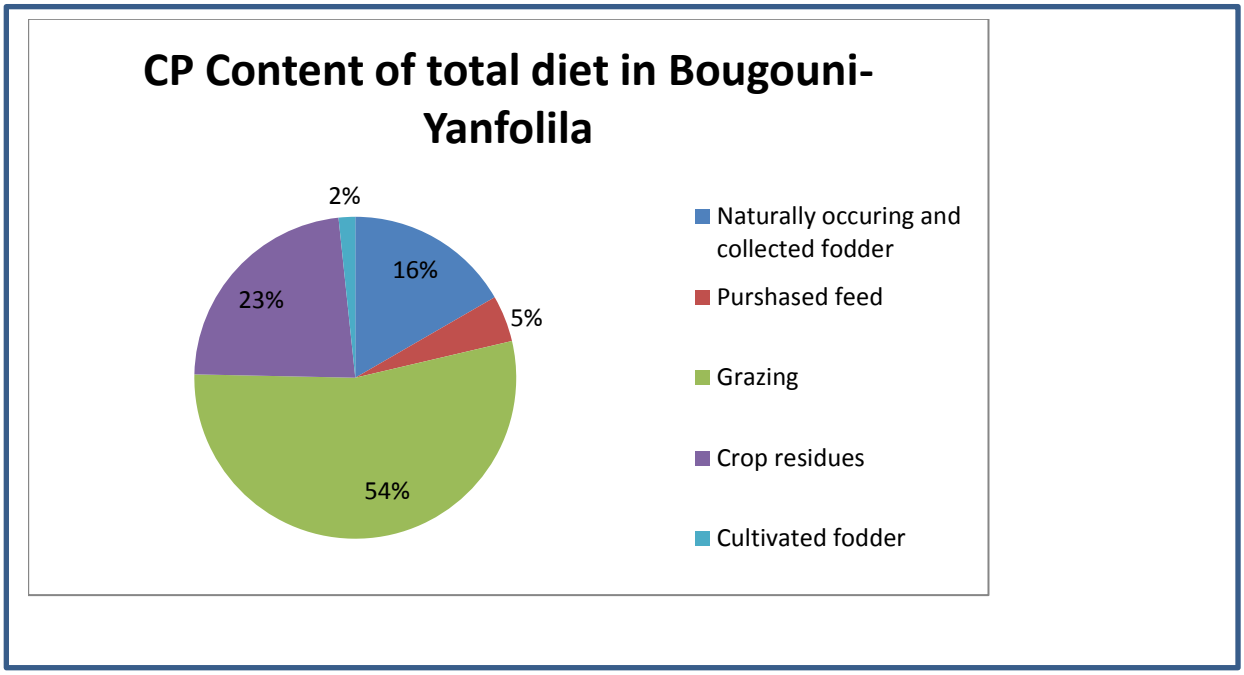


Figure 7. The contribution of different feed sources to crude protein content of ruminant diet in the study sites

Table 10. Feed resources as reported by respondents in Koutiala and Bougouni –Yanfolila districts

Feed category	Feed type	Feeds nutritional quality
Crop residues	Stover maize	
	Maize straw	
	Millet stover	
	Millet straw	
	Sorghum stover	
	Sorghum straw	
	Rice straw	
Cereal bran	Maize bran	
	Millet bran	
	Sorghum bran	
	Rice bran	
Legume hay	Groundnut haulm	
	Cowpea hay	
Mineral supplement	Néré powder	
Cotton	Cotton grain	
	Cotton seed cake	
	Cotton straw	
Cultivated forage	Callinadra (Djala)	
	Brachiaria	
	Cowpea forage (Sangaranka)	
	Sorghum forage (Segetana)	
Browse	Afzelia africana (Linguin)	
	Pterocarpus erinaceus (N'guenou)	
	Parkia biglobosa(Nérémugou)	
	Browser (Fougou-Fougou)	
	Landoephia heudoletii(Nofonbulu= Nonfon2)	
	Vitex doniana(Koronifing)	
	Ziziphus mauritiana (Tonmôlon)	
	Cola nitida(Worôboulou)	
	Bohinia reticulatum(Gnana)	
	Combretum velutinum(Nguangnaga)	
	Vetiveria nigritana(Bakôgo)	
	Lannea microcarpa (N'Pékou : raisin sauvage)	
Green forage	Herbage (Ngolo)	
	Herbage (Wagan)	
	Herbage (N'narkata)	
	Herbage (Korokorokunba)	
	Herbage (Nanfoboulou)	
	Herbage (Nonchitoma)	
	Herbage (Sylo Xantex)	
	Herbage (Bourgou)	

Results presented in figures 8 and 9 showed that in the study sites, grazing and green forage were the main feed sources for animal during the wet season (June to October), contributing more than 80% of animal diet. The quantity and quality of pasture declines as the season advances from wet to dry. The end of wet season coincides with the harvest period which implies that crop residues are available as animal feed.

Crop residues feeding mostly begins soon after the crop harvest in October/early November and extending up to February or early March. During the cool dry season (October to December), cattle feed is based on crop residues from the household crop production. Cereal residues are grazed on crop field because due to the problem of labour to collect and transport crop residues. The problem of transportation of crop residues was mainly reported in Bougouni-Yanfolila. Cowpea hay is often collected and stored, and used to feed animal later in the dry season. For efficient utilization of crop residues, physical treatment of the straws should be promoted in the study areas. However, some farmers do store their crop residues in an open shade for later use as animal feed as shown in pictures 1 and 2. The distribution of stored crop residues and concentrates (cereal bran, cottonseed meal, etc.) is usually done in January according to the location and the available and is in addition to natural pastures and postharvest. They are given periodically and selectively.

In both study areas especially in Bougouni-Yanfolila , the importance of crop residues decreases as the dry season progressed while that of browse increases. In this period of the year, fodder trees and shrubs play an important role for ruminant nutrition, providing proteins, minerals, vitamins and energy (Ickowicz and Mbaye, 2001; Ouédraogo-Koné, 2008). In Bougouni-Yanfolila, browses tended to form a significant part of the ruminant diet between February and May. The preference for browse species varied according to season and animal species. The preference for browse is high for goats than others 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, most farmers had to purchase feed. The purchased quantity in both study areas were presented in table 11.

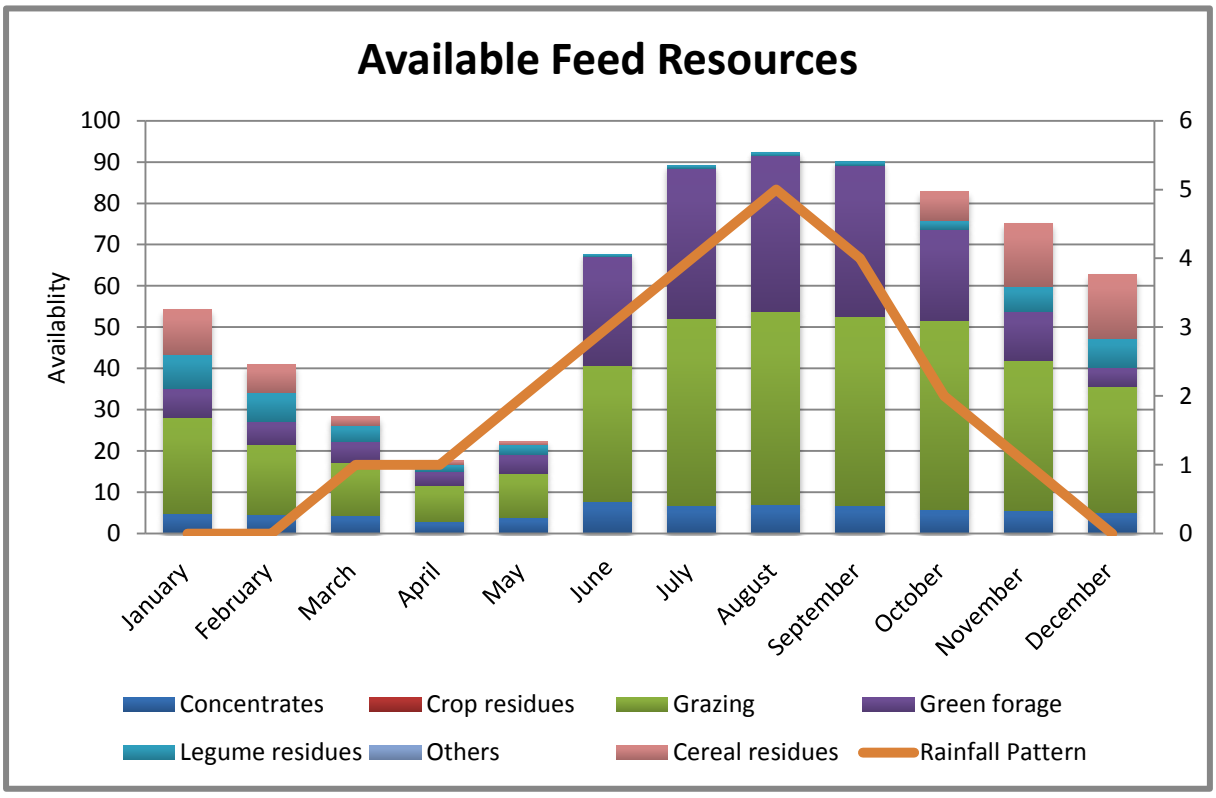


Figure 8. Feed resources availability in Bougouni - Yanfolila

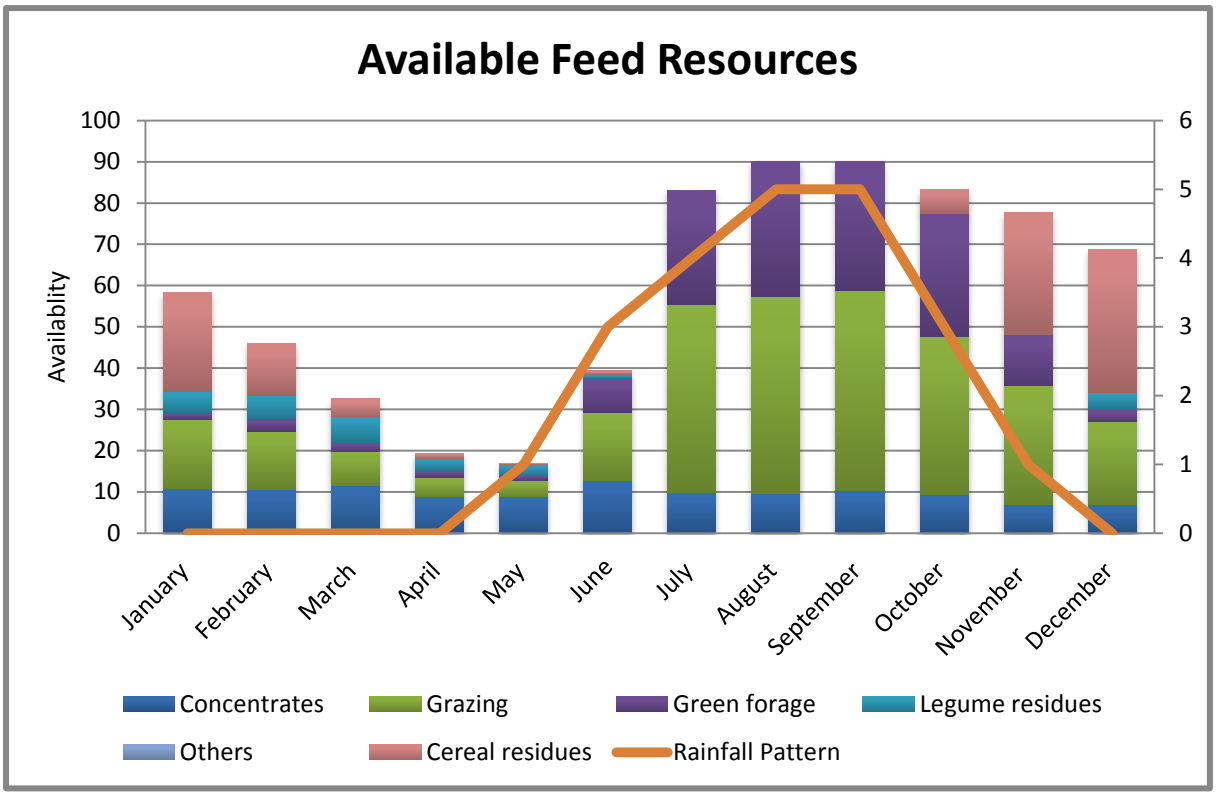


Figure 9. Feed resources availability in Koutiala

Picture 1. Open shed conserved maize residues by a household

Picture 2. Open shed conserved groundnut residues by a household

From table 11, the quantity of feed purchased by Koutiala's farmers was significantly higher than in Bougouni -Yanfolila ($p<0.05$) for all feeds except for mineral supplement. The presence of natural pasture and shrubs/trees allow better access to feed resources in Bougouni –Yanfolila which explained the reduced quantity of feed purchased in this site compared to Koutiala.

Table 11. Purchased feeds (mean ±standard error) and ingredients by those interviewed in the study sites

	Bougouni-Yanfolila			Koutiala		
Feed type	n	Quantity sold (kg)	Price (FCFA)	n	Quantity sold (kg)	Price (FCFA)
Cereal bran	13	191.54±42.26	7495±1410	26	848.08±276.42	41163±13858
Cotton grain	2	80.00±0	7000±0	3	316.67±33.33	40500±5628
Cotton seed	9	175.56±45.49	25888±8011	28	803.57±183.57	100696±20706
Néré powder	1	200±0	5000±0	20	38150±84.39	28565±6316
Salt	29	110.17±19.44	11385±20148	33	104.55±17.53	9962±1399
Cowpea hay	-	-	-	4	550.0±144.34	63125±15390
	Bougouni-Yanfolila			Koutiala		
Feed type	n	Quantity sold (kg)	Price (FCFA)	n	Quantity sold (kg)	Price (FCFA)
Cereal bran	13	191.54±42.26	7495±1410	26	848.08±276.42	41163±13858
Cotton grain	2	80.00±0	7000±0	3	316.67±33.33	40500±5628
Cotton seed	9	175.56±45.49	25888±8011	28	803.57±183.57	100696±20706
Néré powder	1	200±0	5000±0	20	38150±84.39	28565±6316
Salt	29	110.17±19.44	11385±20148	33	104.55±17.53	9962±1399
Cowpea hay	-	-	-	4	550.0±144.34	63125±15390

Major sources of income

Diversification of income sources has been put forward as one of the strategies households employ to minimize household income variability and to ensure a minimum level of income (Alderman and Paxson, 1992). In this study, the main sources of household income as shown in table 12 were agriculture (crop farming) especially cotton and cereal crops, and livestock (sale of cattle, sheep and goat) in both study areas. Agriculture contributed 59% and 67% to the total income whereas livestock contributed 25% and 16% respectively, in Bougouni-Yanfolila and Koutiala. These results may be due to the suitability of the southern region of Mali to agriculture and livestock production. The results are close to the values reported by Abdulai and CroleRees (2001). The same authors observed that much of household's non-crop income comes from livestock, mainly cattle. The contributions of other livelihood activities to the household income were generally low.

Table 12. Major sources of household income in the study sites

Income source	Bougouni-Yanfolila	Koutiala
Agriculture	58.83^{a}	67.2^{a}
Livestock	25.44^{b}	16.44^{b}
Remittance	6.47^{c}	8.00^{c}
Labour (non-farm)	3.75^{c}	1.36^{de}
Business	3.14^{c}	6.94^{dc}
Arboriculture	2.36^{c}	0^{e}

Mean in the same column with different superscript letter are significantly different at $p<0.05$ and mean in the same row with different superscript letter are significantly different at $p<0.05$.

Constraints to livestock production and potential solutions in the study areas

Farmers in the study areas face a number of constraints regarding livestock production as shown in Table 13. The importance of these constraints is different from one village to another, but in general Bougouni-Yanfolila's farmers were mainly faced with problem of lack of water especially during the dry season, animal disease, and feed scarcity at the end of the dry season. In the case of Koutiala feed scarcity, problem of livestock passage and disease are the major constraints.

The problem of lack of water especially during the dry season is due insufficient and depletion of standing pools and well, and lack of water infrastructure in the areas such as water pump.

Farmers in both study area reported that disease and poor access to veterinary services are also major constraints limiting livestock production. Farmers suggested that this situation can be addressed by strengthening the capacities of community animal health workers and training of farmers in diagnosis of common animal diseases, how to prevent them and provide basic treatments.

Feed scarcity is the other most important problem identified by farmers. Feed availability is only considered to be a problem towards the end of the dry season (March - May), when all crop residues have been consumed. During this time, the livestock are generally undernourished and thus become more susceptible to diseases.

In the review of under-nutrition in smallholder ruminant production done by Kebreab et al. (2005), seasonal feed shortages were pointed out as the major constraints to increase ruminant productivity in developing country.

The other problem listed by farmers was livestock stock routes and the associated conflicts. In the study area, farmers reported that they are no clear stock routes or where they existed, the livestock passage has been blocked by the through the encroachment by the expansion of field crops. Kebreab and al. (2005) reported that the expansion of cropping land and use of land for other activities lead to the decline in availability of grazing resources.

The only solution the farmers see is the establishment of stock routes to reduce the conflict between farmers and herders during the cropping season.

Table 13. Major problem facing livestock production in the study areas

Site	Community	Major problem for livestock production in the study area	Score	Rank
BOUGOUNI	DIEBA	Animal disease - Treatment of disease	3	2
		Feed issue	2	3
		Unavailability of water – especially in the dry season	4	1
		Stock route-Conflict with crops farmers	0	5
		Lack of housing provision - Theft	1	4
	YOROBOUGOULA	Animal Disease - Treatment of disease	3	2
		Stock route-Conflict with crops farmers	0	5
		Animal housing	2	3
		Animal watering	4	1
		The low quality of animal semen for reproduction	1	4
	SIBILIRA	Unavailability of water – especially in the dry season	3	1
		Feed issue	2	2
		Disease - Treatment of disease	1	3
		Conflit lies between herders and farmers	0	4
KOUTIALA	NAMPOSSELA	Lack housing provision	0	5
		Feed issue	4	1
		Disease - Treatment of disease	3	2
		Stock route	2	3
		Watering	1	4
	SIRAKELE	Stock route	0	5
		Feed issues	4	1
		Disease - Treatment of disease	3	2
		Watering	2	3
		Lack housing provision	1	4
	ZANZONI	Feed issue	4	1
		Watering	1	5
		Stock route	3	2
		Disease - Treatment of disease	1^{+}	4
		Reproduction contraints- low productivity	2	3

Table 14. Suggested solutions to constraints to livestock production in the study areas

Site	Constraints in livestock production	Suggested solutions
BOUGOUNI-YANFOLILA	Unavailability of water-especially in the dry season	- Education on water harvesting technologies - Development of water point - Creation of pastoral wells - Development of standing pools
	Disease-Treatment of disease	-Provide the community with sufficient and competent local agent in animal health - Strengthen the capacity of local agents in animal health -Farmers training on the knowledge of basic animal disease, their prevention and treatment
	Stock route-conflict with crop farmers	-Creation of pastoral tracks -Development of local convention on Natural resources management (NRM) and conflict management through community consultations -Development of local conventions on transhumance -Opening of pastoral route
	Lack housing provision-theft	-Assist the community , technical and financial for the housing construction, housing package and to arrange fences for animals
	Quality of local animal semen	-Improving quality of Local breed semen
KOUTIALA	Feed issue	- Supports for cultivated forage -Help farmers to start community seed production of forage -Training on feed conservation technical and supports to construct storage rooms - Farmers training on animal nutrition - Supports for feed treatment and feed processing equipment
	Disease - Treatment of disease	- Training of farmers on the prevention and treatment of common diseases - Increase farmers knowledge on animal diseases - Supports training on local veterinary agent
	Watering	-Construction of wells specifically for watering animals Education on water harvesting technologies - Development standing pools and retaining water
	Stock route	- Dialogue between communities to reach agreements on natural resource management -Information and sensitization of communities on convention governing pastoral tracks - Opening of pastoral tracks
	Lack housing provision	-Assist the community , technical and financial for the housing construction, housing package and to arrange fences for animals
	Disease - Treatment of disease	- Increase farmers knowledge on animal diseases - Supports training on local veterinary agent
	Reproduction constraints - low productivity	-Training needed in animal reproduction -Support to improve the productivity of local animal

Conclusions

The dominant farming systems in the study sites are mixed crop-livestock systems which are critical to the household food security and /or income generation. The results of our study demonstrate the high degree of integration of livestock in the farming systems in both study sites. However, livestock production is seriously constrained by a combination of feed shortage, poor nutritional management, absence of stock routes for livestock, and poor adoption of appropriate technologies.

Acknowledgements

We wish to thank the AMEDD (Association Malienne d'Eveil pour le Developpement Durable) for its strong support for this work. We are also indebted to thank the farmers who participated in this research.

References

ABDULAI A., CROLEREES A., 2001. Determinants of income diversification amongst rural households in Southern Mali. *Food Policy* 26: 437–452.

ALDERMAN, H., PAXSON, C.H., 1992. Do the poor insure? A synthesis of the literature on risk and consumption in developing countries. Policy Research Working Papers, WPS 1008. The World Bank.

BA A., 2006. Analyse des stratégies de gestion de la matière organique dans les unités de production de la zone cotonnière au Mali-Sud. Etude de cas dans les villages de Dentiola, Nankorola, Pala et Zoumana Diassa. Mémoire de fin de cycle, Master Agronomie et Agro-alimentaire, Productions Animales en Régions Chaudes, Agro Montpellier, France.

BA A., LESNOFF M., POCCARD-CHAPUIS R., MOULIN C.H., 2011. Demographic dynamics and off-take of cattle herds in southern Mali. Tropical Animal Health and Production, 43: 1101-1109.

BA, 2011. Exploitation du cheptel bovin dans la zone cotonnière au Mali-sud. Thèse de doctorat. Montpellier Sup Agr. Montpellier- France.-170p.

BANDA J.W. and KAZEMBE J.A., 2008. Livestock sector training needs assessment report for Southern Africa. ILRI, Addis Ababa.

LUKUYU B., KUGONZA J., WABWIRE R. AND BALTENWECK I., 2011. Characterisation of the livestock production system and potential for enhancing productivity through improved feeding at Namayumba, Wakiso district of Uganda.

BOSMA R H., BENGALY M., DEFOER T., 1993. Pour un système de production durable : plus de bétail. Le rôle des ruminants au Mali-Sud, dans le maintien du taux de matière organique dans les sols''. In : Powell J.M., Fernandez- Rivera S., Williams T.O., Renard C. Livestock and sustainable nutrients cycling in mixed farming system of Sub-Saharan Africa. vol. II. Actes de conférence, 22-26 novembre. ILCA, Addis Ababa, 1995.

BREMAN,H., AND C.T. DEWIT. 1983. Rangeland productivity and exploitation in the Sahel. *Science* 221: 1341–1347.

CIRAD, 2010. La nature comme modèle. Pour une intensification écologique de l'agriculture. Montpellier, France, CIRAD.

CORNIAUX C., FALL T.S. ET RIPPSTEIN G., 2005. La production et la transformation des produits: les fourrages et les aliments du bétail (277): Bilan de la recherche agricole et agroalimentaire au Sénégal. Dakar: ISRA; ITA ; Montpellier : CIRAD.

COULIBALY D., 2008. Changements socio-techniques dans les systèmes de production laitière et commercialisation du lait en zone péri-urbaine de Sikasso, Mali. Thèse de doctorat, AgroParisTech, Paris, France.

DEMBELE B., 2008. Utilisation des pailles et des fanes dans huit villages de la zone cotonnière du Mali dans les systèmes agriculture – élevage. Mémoire de fin cycle Master, SupAgro, Montpellier, France.

DEMBELE N'F., 1995. Etude Economique de la disponibilité et l'utilisation des suppléments dans l'alimentation des bovins au Mali. Etude de cas des éleveurs du cercle de Koutiala. Thèse de Doctorat de Spécialité Agroéconomie, Institut supérieur de Formation et de Recherche Appliquée (ISFRA), Bamako, Mali. Rapport PSS n° 14, AB-DLO, Wageningen.

DEVENDRA C. et LENG R.A., 2011. Feed Resources for Animals in Asia: Issues, Strategies for Use, Intensification and Integration for Increased Productivity. *Asian-Aust. J. Anim. Sci*. 24(3): 303-321.

DORE T., MAKOWSKI D., MALEZIEUX E., MUNIER JOLAIN N., TCHAMICHIAN M., TITTONELL P., 2011. Facing up to the paradigm of ecological intensification in agronomy: Revisited methods, concept and knowledge. *European Journal of Agronomy*, 34: 197-210.

FAO, 2012. Balanced feeding for improving livestock productivity – Increase in milk production and nutrient use efficiency and decrease in methane emission, by M.R. Garg. FAO Animal Production and Health Paper No. 173. Rome, Italy.

TARAWALI G. AND HIERNAUX P., 1998. Improving Crop–livestockSystems in the Dry Savannas of West and Central Africa. Reports from the Workshop on Crop–Livestock Systems in the Dry Savannas of West and Central Africa held at IITA, Ibadan.

GRIFFON M., 2009. Pour des agricultures écologiquement intensives. Cotes d'Armor, France, Editions de l'Aube.

HASSEN A., EBRO A., KURTU M. and TREYDTE A.C., 2010. Livestock feed resources utilization and management as influenced by altitude in the Central Highlands of Ethiopia. *Livestock Research For Rural Development* 22(12).

ICKOWICZ, A., MBAYE, M., 2001. Forêts soudaniennes et alimentation des bovins au Sénégal. CIRAD.

IFAD, 2004. Livestock and the poor. Rome, taly.

KEBREAB E., Smith T., Tanner J., and Osuji P., 2005. Review of under nutrition in smallholder ruminant production systems in the tropics. In coping with feed scarcity in Smallholder livestock systems in developing countries.

LUND, P. (2002). The Bangladesh Semi-Scavenging Poultry Model; Study on the Impact, Structure and Function of the Poultry Model in the DANIDA Funded Agricultural Sector Programme Support with Special Reference to the Participatory Livestock Development Component. DANIDA, Copenhagen.

MCINTIRE, J., BOURZAT D., AND PINGALI P., 1992. Crop–livestock interactions in Sub-Saharan Africa. World Bank, Washington, DC.

NIELSEN, H. (1996). 'The Socio-Economic Impact of a Smallholder Livestock Development Project, Bangladesh'. Proceedings of the workshop, 'Integrated Farming in Human Development', Danish Agricultural and Rural Development Advisers Forum, 25-29 March, Tune Landboskole, Denmark.

OUÉDRAOGO-KONÉ, S., 2008. The Potential of Some Sub-humid Zone Browse Species. Doctoral Thesis, Swedish University of Agricultural Sciences, Uppsala.

POCCARD-CHAPUIS R., COULIBALY D., BA A., SISSOKO S., BENGALY M. AND COULIBALY J., 2007. Analyse affinée des pratiques et des stratégies paysannes. Rapport technique final, Projet PASE, IER, Sikasso, Mali.

POWELL M.J., PEARSON A.R., AND HIERNAUX H.P., 2004. Crop–Livestock Interactions in the West African Drylands. *Agronomy Journal* 96:469–483.

PRESTON T. R., 1998. Le développement des systèmes de production laitière sous les tropiques. CTA.

PRESTON T.R., 1987. Adaptation des systèmes d'élevage aux ressources alimentaires disponibles dans les pays tropicaux. CTA, Ede, Pays-Bas.

RPCA, 2010. Rapport annuelle : Rôle et place de l'élevage dans l'espace Ouest Africain. Réseau de Prévention des Crises Alimentaires, Accra.

SANDFORD S. 1990. Integrated cropping–livestock systems for dryland farming in Africa. p. 861–872. In P.W. Unger et al. (ed.) Challenges in dryland agriculture—a global perspective. Proc. Int. Conf. on Dryland Farming, Armarillo/Bushland, TX. 15–19 Aug. 1998. Texas Agric. Exp. Station., College Station.

SANDFORD, S. 1989. Crop residue–livestock relationships. p. 43–56. In Soil, crop, and water management systems for rainfed agriculture in the Sudano-Sahelian Zone. Proc. Int. Workshop, ICRISAT Sahelian Centre, Niamey, Niger. 7–11 Jan. 1987. ICRISAT, Patancheru, India.

Sénégal: potentiel et limites. *Bois et forêts des tropiques* 270, 47e61.

SERE C., AYANTUNDE A., DUNCAN A., FREEMAN A., HERRERO M., TARAWALI S. and WRIGHT I., 2008. Livestock production and poverty alleviation-challenges and opportunities in arid and semi-arid tropical rangeland based systems. In: the proceedings of multi-functional grasslands in a changing world. XXI International Grassland Congress and VII International Rangeland Congress, China. 19-29.

SERE´ C., AND H. STEINFELD. 1996. World livestock production systems— current status, issues and trends. Anim. Prod and Health Paper 127. FAO, Rome.

SOUVENT D., 2004-2005. Principes généraux de l'alimentation animale. Paris : INA.

STANGEL, P.J. 1995. Nutrient cycling and its importance in sustaining crop–livestock systems in Sub-Saharan Africa. p. 37–59. In J.M. Powell et al. (ed.) Livestock and sustainable nutrient cycles in mixed-farming systems of Sub-SaharaAfrica.Volume II: Technical papers. Proc. Int. Conf., Addis Ababa, Ethiopia. 22–26 Nov. 1993. International Livestock Centre for Africa (ILCA), Addis Ababa Ethiopia.

STATISTICAL ANALYSIS SYSTEM INSTITUTE, 1987. SAS/STAT for Personal Computers, SAS Institute, Inc., Cary, NC

SUSAN J.L.E., LELOUP, MANNETJE L't and MEURS C.B.H, 1996. Seasonal fodder consumption and liveweight changes of sedentary cattle in southern Mali. *Tropical Grasslands*. (30).229-236

ZAMPALIGRE N, DOSSA H.L, SCHLECHT E., 2013. Contribution of browse to ruminant nutrition across three agro-ecological zones of Burkina Faso. *Journal of Arid Environments* 95 (2013) 55-64.

ZING F., 2011. Characterisation of the livestock production system and potential for enhancing productivity through improved feeding in Boneya Village, Diga District, East Wollega Province, Western Ethiopia.