Improving small ruminant production in mixed crop-livestock systems through feed and health interventions in southern Mali

Augustine Ayantunde[1], Clarisse Umutoni[1], Theophile Dembele[2], Koita Seydou[2], Oumar Samake[2]

Produced by [1]International Livestock Research Institute (ILRI), [2]Malienne d'Eveil au Développement Durable (AMEDD)

Published by International Institute of Tropical Agriculture

April 2018

www.africa-rising.net

The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) program comprises three research-in-development projects supported by the United States Agency for International Development (USAID) as part of the US 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 regional 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 the program's monitoring, evaluation and impact assessment. http://africa-rising.net/

This document was made possible with support from the American people delivered through the 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 US government.

Contents

Acknowledgements

We are grateful to the farmers in Sirakele and Zanzoni in Koutiala District for their kind participation in this study. Furthermore, we thank the Association Malienne d'Eveil pour le Développement Durable (AMEDD) for their strong support in the data collection. This study was conducted under the Feed the Future Africa RISING project in West Africa funded by the United States Agency for International Development (USAID). The authors are solely responsible for the opinions expressed in this paper.

Summary

Small ruminants are an integral part of mixed crop and livestock systems in Mali and they fulfil various roles in household food security as source of meat and milk, and means of additional income to meet food and cash needs. Besides, small ruminants also produce manure which is an invaluable source of organic matter for improving soil fertility. However, small ruminant production in Mali is challenged by the poor performance of animals largely due to inadequate nutrition and diseases. Given the low inputs into sheep and goats production by the smallholder farmers, their animals are rarely vaccinated or treated regularly against diseases and supplementary feeding is often on an ad hoc basis. Combining health and feed interventions can lead to a better animal performance than a single technology.

Based on our experience and promising results from feed and health interventions for improved small ruminant production in Ghana under the Africa RISING project, a pilot study was initiated in Mali involving combined feed and health interventions in two communities namely Sirakele and Zanzoni in Koutiala District in the southern region of Mali. The objective of this study was to assess the effects of combined feed and health interventions on small ruminant production in mixed crop and livestock systems in southern Mali. Zanzoni village served as the control group while Sirakele received feed and health intervention. Twenty households were randomly selected in each community for a year-long study spanning the period August 2016 to August 2017. Results from the study showed that the average household flock size for sheep and goats in the feed and intervention group doubled within a year (August 2016–sheep: 5.30±0.81; goats: 6.75±1.24; July 2017–sheep: 11.90±1.56; goats: 12.70±2.04) whereas average flock size in control group (Zanzoni) remained largely the same within the same period. The average number of birth per household for both sheep and goats were 5.72±2.10 and 15.20±3.41 for control and treatment groups, respectively. The mortality rate was significantly lower in Sirakele with the intervention than in the control site. Results on weight development showed that the goats and sheep under treatment gained 42.98±3.28 and 47.12±2.73 g/day, respectively compared to 22.59±2.29 and 16.58±2.74 g/day for goats and sheep, respectively under control. Significantly more manure was collected from the animals under the feed and health intervention compared to those in the control group. Partial cost benefit analysis showed the annual net return of 95,349±25,388 Franc CFA (FCFA) per household for the feed and health intervention in Sirakele compared to 88,575±8,693 FCFA per household for the control group in Zanzoni. The results confirm that feed and health intervention lead to significant and profitable improvement in small ruminant production.

Introduction

Small ruminants are an integral part of mixed crop and livestock systems in Mali and they fulfil various roles in household food security as source of meat and milk and means of additional income to meet food and cash needs (Wilson 1986; Ba et al. 1996). In the West African Sahel, majority of farmers raise small ruminants for immediate source of income, as insurance against emergencies and as mitigating measures in case of crop failures (Wilson 1991). Besides, small ruminants also produce manure which is an invaluable source of organic matter for improving soil fertility. In Mali, about 90% of households own sheep and goats as they are important for the livelihood strategies of many resource poor rural households (Ba et al. 1996). Small ruminant rearing provides employment opportunities for rural women and youth as they are heavily involved in the management of sheep and goats (Wilson 1991; Lebbie 2004). The short generation intervals of small ruminants compared to cattle allows for rapid flock growth within a short provided there is adequate nutrition and veterinary care. Compared to cattle, small ruminants tend to withstand drought much better (Lebbie 2004). For example, Wilson (1991) reported that the during the drought of the early 1980s in the Sahel, cattle losses were over 80% while those of small ruminants were not more than 50% of the flocks.

In view of the potential for rapid flock growth and the varied functions small ruminants fulfil in mixed crop and livestock systems, they could be a means of improving household food security and poverty alleviation among smallholder farmers. However, small ruminant production in Mali is challenged by the poor performance of animals largely due to inadequate nutrition and diseases (Wilson 1986; Ba et al. 1996). Given the low inputs into sheep and goats production by the smallholder farmers, their animals are rarely vaccinated or treated regularly against diseases (Ba et al. 1996) and supplementary feeding is often on an ad hoc basis (Ayantunde et al. 2014). Consequently, high mortality rate is common in small ruminant flocks in Mali (Ba et al. 1996) as well as in other Sahelian countries. One way in which mortality could be reduced is by vaccinating small ruminants against main diseases such as pasteurellosis, peste des petits ruminants (PPR) and deworming them. In addition to healthcare, strategic supplementation of the small ruminants is also essential to improve their performance (Ben Salem and Smith 2008; Nantoume et al. 2011; Konlan et al. 2017). Combining health and feed interventions will lead to a better animal performance than a single technology. Based on our experience and promising results from feed and health interventions for improved small ruminant production in Ghana under the Africa RISING project (Avornyo et al. 2015; Konlan et al. 2017), a pilot study was initiated in Mali involving combined feed and health interventions in two Africa RISING intervention communities in Koutiala District in the southern region of Mali.

The underlying hypothesis for this study was that combinations of improved management practices results in higher animal productivity, income, and household food security than single technologies. In this study, the interventions focused mainly on provision of healthcare and supplementary feeding. The objective of the study was to assess the effects of combined feed and health interventions on small ruminant production in mixed crop and livestock systems in southern Mali. The specific objectives were: (1) to assess the effects of feed and health package on sheep and goats live weight changes, flock dynamics (birth, death, offtake) and manure production, and (2) to quantify the costs and benefits of feed and health package in smallholder small ruminant production.

Methodology

Study sites

The study was undertaken in Sirakelé (-5.48° long; 12.51° lat) and Zanzoni (-5.57° long; 12.61° lat) villages in Koutiala District in southern region of Mali. Sirakélé is a village in the rural commune of Songoua that is situated about 15 km north of Koutiala town, while Zanzoni is located in commune Fakolo about 35 km from Koutiala town. Koutiala District is the cotton production capital of Mali. Both study communities are in a region with a high concentration of smallholder crop and livestock farmers which implies that the mixed crop and livestock farming system is dominant. The two study sites have a Sudanian climate characterized by an alternation of dry and rainy seasons that last about six months each. The dry season is normally between November and April while the rainy season is between May and October. Annual precipitation varies between 750–1,100 mm. Crop farming and livestock husbandry are the main sources of household foods and income in the study areas. The feed resources in both study sites are similar as reported by Umutoni et al. (2015) from the study on the evaluation of feed resources in Koutiala and Bougoni districts in southern Mali. The main feed resources are natural pastures, crop residues and agro-industrial by-products. This report was based on a one-year monitoring of sheep and goat flocks belonging to 40 households in two communities between August 2016 and August 2017.

Household selection for the study and animal management

The study involved 20 households in each community. The households were selected randomly based on ownership of sheep and or goats and willingness to participate in the study which entails monitoring of their animals for about one year. Both communities are intervention communities in the 'Zones of Influence' of the USAID-funded Africa RISING program in Mali. The goal of Africa RISING is to 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. At the beginning of the study in August 2016, the two communities were randomly allocated to either control or treatment groups. The control group consists of the 20 selected households in Zanzoni village while the treatment group comprises of the 20 selected households in Sirakelé.

The sheep and goat flocks in the treatment group received vaccination against pasteurellosis, PPR and trypanosomiasis, deworming and regular health care in case of any sickness, and supplementary feed (300 g of cotton seed cake per animal per day) throughout the 12 months of the study. Cotton seed cake was used as supplement in this study as it is readily available in the study sites due to widespread cultivation of cotton. The quantity of cotton seed cake offered was based on similar studies in Ghana where between 200 and 300 g of supplement was offered per animal (Konlan et al. 2017). Given that the experiment was undertaken on farm, physiological status was not considered while deciding the amount of supplement to be distributed to animals as it is difficult to adjust quantity offered to animal physiological status in rural farm conditions. The treatment package is referred to as 'Feed-health (FH) intervention' in this report. Vaccines produced by the Malian Central Veterinary Laboratory (Laboratoire Central Vétérinaire de Bamako) named 'Ovipeste' and 'Pastovin' were used for vaccination against PPR and pasteurellosis, respectively. Sheep and goats under FH intervention were vaccinated once per year against PPR at the dosage of 1 ml per animal and twice per year against pasteurellosis at the dosage of 2 ml per animal. The treatment animals were also vaccinated against trypanosomosis with Verben B12 and Kelamidum. Prophylaxis in the form of antibiotic and multivitamin injections, and deworming were given to treatment animals. Deworming was done twice in a year, at the beginning of the study in August and at the end of the rainy season in October using SYNANTHIC (oxfendazole). Treatment animals were also provided with the curative treatment when necessary.

The flocks in the control group did not receive any feed and or health intervention from the project. However, farmers in the control group treated their sick animals irregularly and offered crop residues particularly sorghum straw, cotton straw and groundnut haulms after the crop harvest, and browses in the late dry season on an ad hoc basis. In both study sites, daily management of sheep and goats involved grazing of natural pastures during the rainy season and crop residues in the dry season by most of the animals. Animals that were being fattened, lactating does and ewes, and sick animals were normally left around the homesteads, and fed there. The young animals (lambs and kids) were not allowed to graze until they were 3–4 months old. On returning from grazing, the animals in the FH intervention were each offered cotton seed cake as a supplement, which was often consumed immediately. At night, the animals in both control and treatments groups were tethered to pickets or penned in enclosures or shelters around the homesteads. About 94% of the sheep the study areas was Djallonke breed with the remaining belonging to Sahelian long-legged breeds. The Sahelian long-legged sheep were mainly male for fattening. The West African dwarf (about 96%) was the dominant goat breed with a few Sahelian long-legged goats.


Rams being fattened tethered at the homestead (photo credit: Clarisse Umutoni/ILRI).

Flock monitoring and data collection

All the sheep and goats in the selected 20 households each in Zanzoni (control) and Sirakelé (feed-health intervention) were ear-tagged at the beginning of the study in August 2016 for identification and weighed (see the Picture 2 of animal weighing). At the beginning of the study, the total flock of the 20 households consisted of 78 sheep and 84 goats in Zanzoni making a total of 162 animals while in Sirakelé the total flock consisted of 106 sheep and 135 goats making 241 animals in total. All animals in both the control and treatment groups were weighed every month for 3 days consecutively.

The two field technicians responsible for the monitoring of the experimental animals visited each household every month to collect data of any change in the household flock (demographic event) including birth, death, sale, animal slaughtered, giving out animal as gift or on caretaking, receipt of animal as gift or on caretaking arrangement, and loss through theft. The data on occurrence of death in the flocks was used to calculate mortality rate which is the number of death recorded as a percentage of the total flock at the beginning of the study. Offtake rate was calculated as the number of animal sold, slaughtered and given out as a percentage of the total flock at the beginning of the study. The manure deposited at the enclosures or shelters by the animals was collected each morning after removal of the sheep and goats from the pens by each household in both control and treatment groups. It was air dried and stored in a bag for weighing every month by the AMEDD field technicians.

Animal weighing (photo credit: Clarisse Umutoni/ILRI).

Collection of feed and faecal samples

Two samples of feed resources fed to the experimental animals were collected in the early and late dry seasons. The feed resources were mainly crop residues, browses and agro-industrial by-products. In total, 46 feed samples were collected and ground to pass through a 2 mm sieve for laboratory analysis of their chemical composition. Two faecal (manure) samples of 0.5 kg fresh weight were collected monthly from each household and these were air dried. Collected samples for each household were combined per season (wet/rainy, early dry and late dry) and ground for laboratory analysis. In total, 120 faecal samples were prepared for the laboratory analysis.

Laboratory analysis of feed and faecal samples

Samples of feed resources in the study sites were collected mainly in the early and late dry seasons (October 2016 to May 2017),air dried and prepared for laboratory analyses. They were analysed for dry matter (DM), ash content, nitrogen, fibre components [neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL)] and in vitro organic matter digestibility (IVOMD) using the near infrared reflectance spectroscopy (NIRS) technique. The sample fineness for NIRS analysis was 2mm. The wave length range to estimate the chemical composition was 1,100 to 2,500 nanometres. 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. The faecal samples were analysed for DM, OM, N and phosphorus (P) concentration.

Statistical analysis

Data analysis was performed with SAS (SAS, 1987) using means procedures for descriptive statics while T-Test was used to compare the means of demographic events (birth rate, mortality rate, offtake rate etc.), average daily gains, quantity of manure collected per household and cost and benefit between the control group and the group with feed-health intervention. Unless otherwise specified, the level of significance was set at $P < 0.05$.

Results and discussion

Flock structure and dynamic

The average flock size per household at the beginning of the study in August 2016 for sheep was 3.90±0.82 and 5.30±0.81 for the control and feed-health intervention groups, respectively (Table 1). For goats, the average flock size was 4.20±0.97 and 6.75±1.24 for the control and FH intervention groups, respectively. The results showed that the both sheep and goat flocks were dominated by females irrespective of the treatment. At least 80% of the sheep flock was female at the beginning of the study while at least 75% of the goat flock was female at the same period. These results agreed with the results on small ruminant production in the agro-pastoral systems in Central Mali by Wilson (1986) where it was reported that the females accounted for at least 75% of the sheep and goat flocks. Generally, the flock is dominated by female animals for reproduction and for flock growth, whereas the male sheep and goats are often sold to meet household cash needs as reported by Ba et al. (1996) that the offtake rate of male animals is often high compared to the female animals. The average flock size per household of sheep and goats at the beginning in our study sites in Koutiala district was lower than for the agro-pastoral sheep and goat flock in Central Mali reported by Wilson (1986) which were on average 9.48 and 23.57 for sheep and goats, respectively. The higher flock size of agro-pastoral flock than those of mixed crop-livestock farmers in southern Mali is expected as the farmers in the south are more oriented towards cropping than raising livestock whereas the agro-pastoralists are livestock keepers by tradition though they have settled down to grow crops (Ayantunde et al. 2011).

After a year, the flock size of the control group remained largely the same as at the beginning of the study (sheep–male 0.65±0.22; female: 2.95±0.73; goats–male: 1.15±0.33; female: 3.45±0.72) whereas the flock size of sheep and goats per household under FH intervention doubled within the same period (Table 1). The total number of the flock for the FH group increased from 106 sheep at the beginning of the study (August 2016) to 236 at the end of July 2017 while the number of goats increasing from 135 to 252 (Figure 1). These results demonstrate that feed and health interventions led to significant increase in flock size of sheep and goats within a short period through better reproductive and growth performance. Similar results were reported by Ba et al. (1996) in Mali with introduction of health treatment alone. Konlan et al. (2017) also reported synergistic benefits of the combined effect of providing concentrate feed and healthcare to small ruminants kept by smallholder farmers in northern Ghana. A similar trend of significant increase in small ruminant number with feed and health intervention was reported by Avornyo et al. (2015) also in northern Ghana.

Table 1: Household flock composition (mean ± standard error) at the beginning (August 2016) and at the end of the study (July 2017) in Zanzoni (control) and Sirakelé (feed-health intervention) in Koutiala District

Variable	**Control (n=20)**	**Feed–health (n=20)**
Beginning of the study (August 2016)		
Sheep		
Average number of male	0.75±0.33[a]	1.10±0.25[a]
Average number of female	3.15±0.69[a]	4.20±0.70[a]
Average total flock	3.90±0.82[a]	5.30±0.81[a]
Goat		
Average number of male	0.50±0.20[a]	1.60±0.42[b]
Average number of female	3.70±0.81[a]	5.15±0.97[a]
Average total flock	4.20±0.97[a]	6.75±1.24[a]
End of the study (July 2017)		
Sheep		
Average number of male	0.65±0.22[a]	5.20±0.93[b]
Average number of female	2.95±0.73[a]	6.70±0.93[b]
Average total flock	3.60±0.84[a]	11.90±1.56[b]
Goat		
Average number of male	1.15±0.33[a]	3.90±0.89[b]
Average number of female	3.45±0.72[a]	8.80±1.35[b]
Average total flock	4.60±0.99[a]	12.70±2.04[b]

Note: Values for each variable with different superscript are statistically significant (P<0.05)

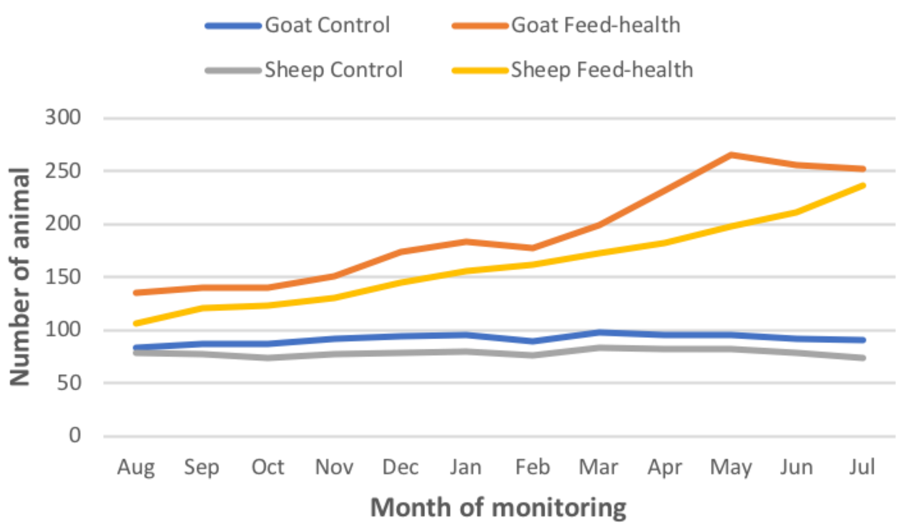

Figure 1: Flock growth of households under control and feed-health intervention in Zanzoni and Sirakelé, in Koutiala District during one year of monitoring.

Results on flock dynamics (Table 2) showed significant differences in birth rate, mortality rate and offtake rate between the control and feed-health intervention group. The mortality rate of the control group was 30.4% during one year of the study while that of the FH group was 13.3%, which was significantly lower than of the control group.

The results confirmed that mortality rate is always high in a small ruminant flock without adequate healthcare and nutrition (Konlan et al. 2017). According to Wilson (1986), the mortality rate can be up to 30% in sheep and goat flock in extensive livestock systems where healthcare is inadequate and nutrition can be poor, particularly in the dry season. Ejlertsen et al. (2012) reported mortality rates of 25–32% for sheep flock and of 13–23% for goat flock in southern Mali based on a recall survey. The major causes of death in the flocks in our study were diseases such as respiratory problems, diarrhoea and fever, losses due to predator and injuries. Similar causes of death were reported by Ba et al. (1996) for small ruminant flock in semi-arid areas of Mali. The results on repartition of birth and death in the control and FH groups between September 2016 and August 2017 are presented in Figure 2 and Figure 3. Most births tended to occur between March and September (Figure 2) while deaths tended to occur throughout the year though the lowest recorded cases of death were in January and February.

Table 2: Flock dynamic of sheep and goats under control (Zanzoni village) and feed-health intervention (Sirakelé village) between August 2016 and August 2017

Variable	**Control (n=20)**	**Feed–health (n=20)**
Average number of birth per household	5.72±2.10[a]	15.20±3.41[b]
Birth rate (%)	69.9±3.4[a]	126.7±4.9[b]
Mortality rate (%)	30.4±2.7[a]	13.3±3.1[b]
Offtake rate (%)	30.4±2.9[a]	38.8±3.1[b]
Average price per animal sold (FCFA)	19,777±841[a]	24,887±964[b]
Average income from animal sale per household (FCFA)	38,537±7,560[a]	169,125±26,545[b]
Average number of animal purchased per household	0.02±0.01[a]	0.34±0.04[a]
Average number of animal slaughtered for consumption per household	0.04±0.02[a]	0.09±0.02[a]
Average number of animal given out as gift/caretaking per household	0.04±0.01[a]	0.03±0.01[a]
Average number of animal received for caretaking per household	0.01±0.01[a]	0.08±0.03[a]
Average number of animal lost to theft per household	0.03±0.01[a]	0.04±0.02[a]

Note: Initial animal number was 241 sheep and goats in Sirakelé, and 162 sheep and goats in Zanzoni

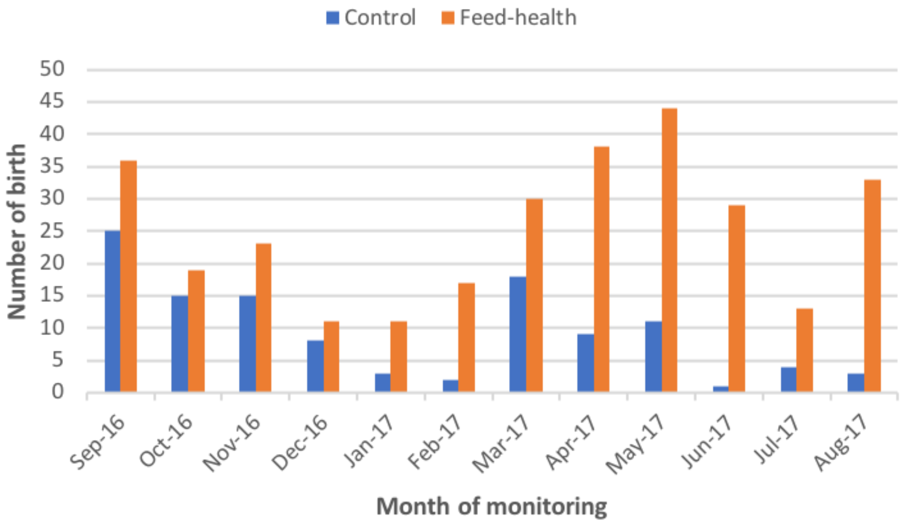

Figure 2: Number of birth in household flock under control and feed-health intervention in Zanzoni and Sirakelé, in Koutiala District.

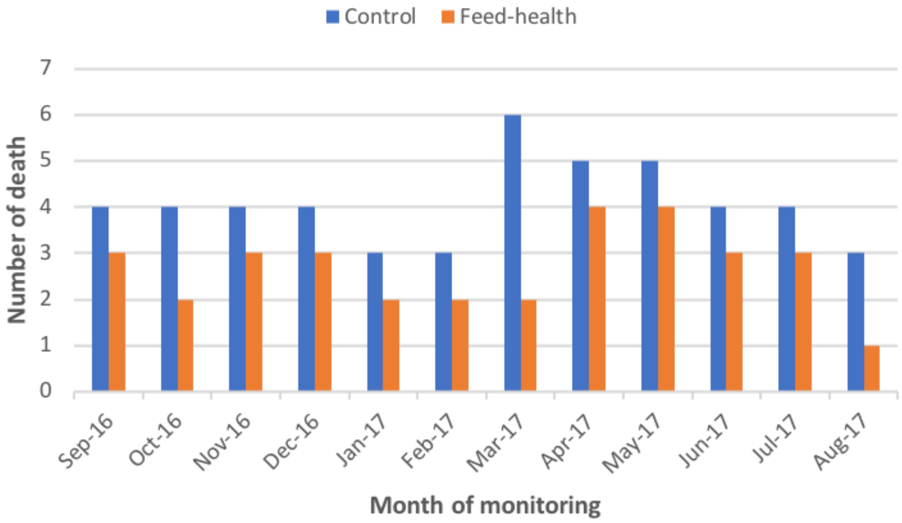

Figure 3: Number of death in household flock under control and feed-health intervention in Zanzoni and Sirakelé, in Koutiala District.

The annual offtake rates for sheep and goat flocks found in our study are similar to those reported by Ejlertsen et al. (2012) of around 29.5% in southern Mali. Lower offtake rates of 19–26% were reported by Wilson (1986) for small ruminants in agro-pastoral systems in central Mali. Offtake generally tended to be much higher in males than in females as the major reason for offtake is sale to meet immediate cash needs of the households and the males are often targeted for this (Ba et al. 1996). In our study, we did not collect sex-disaggregated data for the offtake but the anecdotal evidence from the participating households supports the claim that offtake is higher in males than in females. Generally, offtake is influenced by the number of animals available, immediate cash needs, prevailing market prices and animal's age and condition. Interventions that lead to significant increases in flock size like supplementary feeding and healthcare will tend to increase offtake as shown by the significant difference between the offtake rate of the control group and the feed-health group in our study. In Mali and other Sahelian countries in West Africa, sale of small ruminants is one of the key strategies for coping with crop failures (Lebbie 2004).

Body weight development and change

The results of this study showed that feed and health intervention had significant effect on body weight development and the average daily gain (ADG) of sheep and goats (Table 3). The average daily gains of sheep and goats in the control group were 16.58±2.74 and 22.59±2.29 g/day while the ADG for the animals that received feed and health intervention was almost double (sheep: 47.12±2.73; goats: 42.98±3.28). For the few lambs and kids that were weighed at birth, the birth weights were similar for both control and treatment groups.

Table 3: Weight changes of goats and sheep over a one-year period under control and feed-health intervention in Zanzoni and Sirakelé, Koutiala District

Variable	**Control**		**Feed–health**	
Goats				
	n	Mean ± se	n	Mean ± se
Weight at 1 month (kg)	10	2.45±0.16[a]	36	2.62±0.09[a]
Weight at 3 months (kg)	36	5.65±0.17[a]	101	5.71±0.13[a]
Weight at 1 year (kg)	14	12.89±0.80[a]	36	16.78±0.34[b]
Average daily gain (g/day)	131	22.59±2.29[a]	311	42.98±3.28[b]
Sheep				
	n	Mean ± se	n	Mean ± se
Weight at 1 month (kg)	6	2.92±0.27[a]	10	3.00±0.13[a]
Weight at 3 months (kg)	15	7.23±0.39[a]	34	6.75±0.22[a]
Weight at 1 year (kg)	3	18.5±0.76[a]	17	22.34±0.88[b]
Average daily gain (g/day)	117	16.58±2.74[a]	225	47.12±2.73[b]

Note: Values for each variable with different superscript are statistically significant ($P<0.05$).

The body weight development trend was similar until the fourth month for sheep (Figure 4a) and until the fifth month for goats (Figure 4b) under both control and treatment groups. Afterward, there was significant difference in the weight development of both groups. At one year of age, sheep and goats under the FH group weighed significantly higher than those under the control (Table 3).

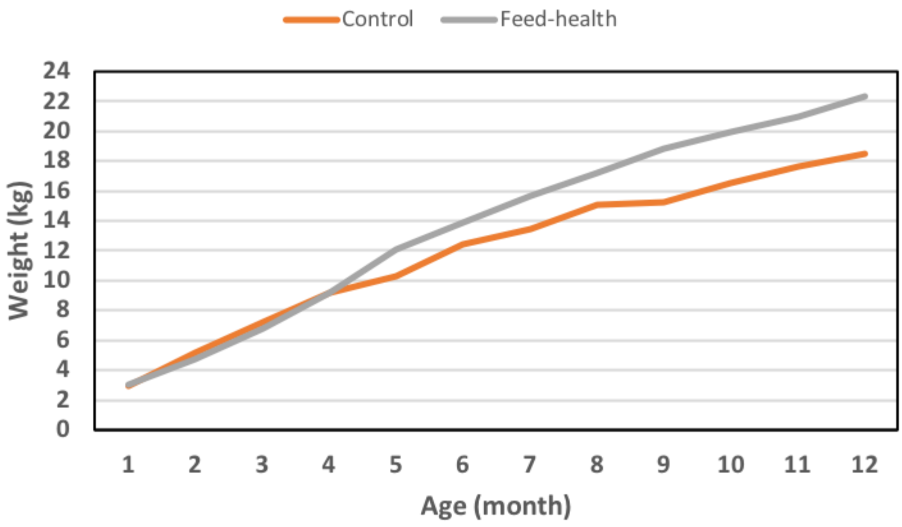

Figure 4a: Weight development of sheep under control and feed-health intervention from 1 to 12 months in Zanzoni and Sirakelé, Koutiala District.

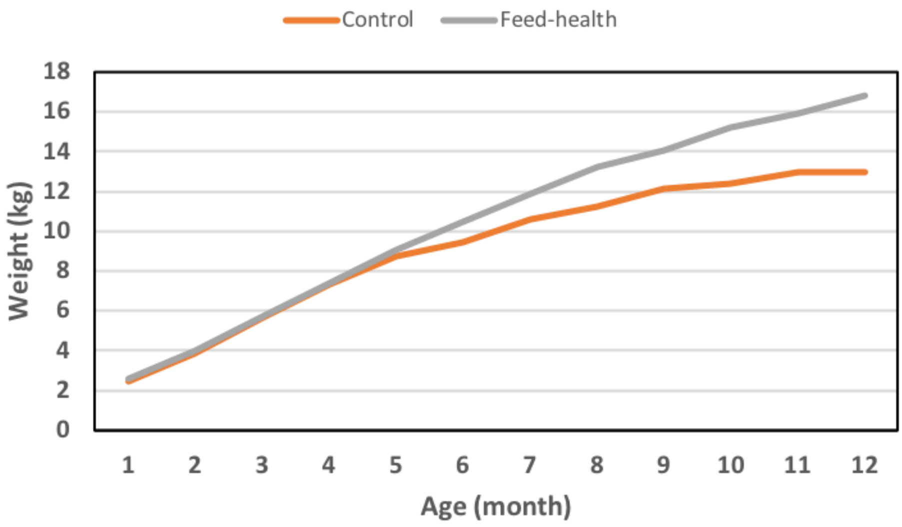

Figure 4b: Weight development of goats under control and feed-health intervention from 1 to 12 months in Zanzoni and Sirakele, Koutiala Districts.

The ADG values for sheep and goats for the control and treatment groups were similar to those reported by Avornyo et al. (2015) for sheep and goats, and by Konlan et al. (2017) for sheep in studies that involved feed supplementation and provision of healthcare. Konlan et al. (2017) reported ADG of 17.8 and 45.4 g/day for sheep under control and healthcare, respectively. The average daily gain values for the treatment animals were approximately the same as the 48.98 g/day and 49.19 g/day reported by Obese (1998) and Issaka (2006) from feeding trials where Djallonke sheep were supplemented with groundnut haulms, and cotton seed and cowpea vines, respectively. The live weights of sheep and goats at 3 months and 12 months in this study were lower than those reported by Wilson (1986) of 7 kg for goats and 9 kg for sheep at 3 months, and 18 kg for goats and 24 kg for sheep at 12 months of age. This could be attributed to differences in breed as the sheep and goat breeds in agro-pastoral systems in central Mali are mainly Sahelian long-legged sheep and goat breeds and are heavier than the West Africa dwarf breeds which are dominant in southern Mali where our study was conducted. The higher body weight of sheep and goats as from 4 months of age showed that the effect of supplementary feeding and healthcare on body weight development is cumulative.

Manure production and nutrient content

Results of manure collected from sheep and goats by households under control and feed-health intervention are presented in Table 4. More manure was collected by the households that received feed-health intervention than by those under control across all seasons (early dry, late dry and wet seasons). This suggests that feed and health intervention is also beneficial for soil fertility improvement as the farmers could collect more manure to apply to their crop fields. The main challenge of manure collected at homesteads is transportation to the crop field, particularly if the farm is far from the village. The manure collected per animal per day was highest for both groups (control: 102±4.06 g DM/animal/day; feed-health: 121.52±4.52 g DM/animal/day) in the late dry season while it was lowest in the wet season. This could be attributed to longer time spent around the homestead by the animals in the late dry season as there was virtually no feed in the grazing areas at this period which allowed for more manure to be collected. In the wet season, it is generally more difficult to collect manure as the water content in faeces is high. The quantities of manure collected from animals in both groups when expressed in g DM/kg live weight/day (Table 4) were much lower than the quantities of 10 to 13 g DM/kg live weight/day reported by Ayantunde et al. (2007) for sheep under feeding trials using faecal collection bags. This shows that there were losses in the collection of the manure by the farmers in this study. Besides, the manure deposited by the animals during grazing could not be collected which also explains the lower quantities of collected manure in this study. Manure nitrogen and phosphorus contents were similar for both control and treatment groups except in the wet season when the nitrogen content was higher for the feed-health group than the control.

Table 4. Collected manure by households under control and feed-health intervention from experimental sheep and goats between September 2016 and August 2017 in Zanzoni and Sirakele in Koutiala District.

Variable	**Control**	**Feed-health**
Early dry season (Oct–Jan)		
Collected manure–g DM/day/household	815±46[a]	1729±65[b]
Collected manure–g DM/animal/day	96.12±3.78[a]	119.72±4.55[b]
Collected manure–g DM/day/animal/kg live weight	5.14±0.19[a]	5.88±0.24[a]
Nitrogen concentration (g/kg DM)	20.95±0.31[a]	21.35±0.29[a]
Phosphorus concentration (g/kg DM)	3.76±0.13[a]	4.96±0.14[b]
Manure nitrogen output (g/day)	16.48±0.81[a]	37.03±1.47[b]
Manure phosphorus output (g/day)	2.81±0.14[a]	8.64±0.43[b]
Manure nitrogen output (g/animal/day)	1.98±0.07[a]	2.57±0.10[a]
Manure phosphorus output (g/animal/day)	0.35±0.02[a]	0.60±0.03[a]
Late dry season (Feb–May)		
Collected manure–g DM/day/household	891±49[a]	2392±104[b]
Collected manure–g DM/animal/day	102±4.06[a]	121.52±4.52[b]
Collected manure–g DM/day/animal/kg live weight	5.67±0.20[a]	5.68±0.21[a]
Nitrogen concentration (g/kg DM)	21.15±0.39[a]	20.89±±0.34[a]
Phosphorus concentration (g/kg DM)	3.89±0.15[a]	3.74±0.19[a]
Manure nitrogen output (g/day)	18.74±1.04[a]	50.51±2.60[b]

Manure phosphorus output (g/day)	3.29±0.20[a]	9.04±0.64[b]
Manure nitrogen output (g/animal/day)	2.14±0.09[a]	2.52±0.10[a]
Manure phosphorus output (g/animal/day)	0.38±0.02[a]	0.45±0.03[a]
Wet season (June–Sept)		
Collected manure–g DM/day/household	774±41[a]	2234±104[b]
Collected manure–g DM/animal/day	95.54±4.27[a]	112.27±4.64[b]
Collected manure–g DM/day/animal/kg live weight	5.29±0.24[a]	5.62±0.24[a]
Nitrogen concentration (g/kg DM)	18.83±0.36[a]	22.73±0.49[b]
Phosphorus concentration (g/kg DM)	7.21±0.15[a]	6.73±0.11[a]
Manure nitrogen output (g/day)	14.53±0.81[a]	51.30±2.78[b]
Manure phosphorus output (g/day)	5.54±0.32[a]	15.31±0.82[b]
Manure nitrogen output (g/animal/day)	1.78±0.09[a]	2.52±0.11[a]
Manure phosphorus output (g/animal/day)	0.69±0.04[a]	0.75±0.03[a]

Note: Values for each variable with different superscript are statistically significant (P<0.05).

The values of nitrogen and phosphorus concentration in the manure found in this study were much higher than those reported by Ayantunde et al. (2007) from feeding trials with sheep fed on groundnut haulms as supplement in the early dry season in Niger. In their study, the nitrogen concentration ranged from 10.7–12.8 g/kg DM and the phosphorus concentration ranged from 1.9–2.8 g/kg DM. The higher values could be partly attributed to better quality feed in southern Mali than the millet straw as basal feed and groundnut haulms as supplement used in the feeding trials by Ayantunde et al. (2007) as high nutrient feed will generally result in higher nutrient content of the manure (Ayantunde et al. 2018). In addition, the higher values obtained in this study could be attributed to contamination as manure collected might have been contaminated by urine, feedstuffs offered to the animals and dust. Given that manure collected by the households for application to the crop field is often a mixture of faeces and urine, our results give an indication of nutrients that may return to the soil. Higher manure nitrogen and phosphorus outputs were observed for manure collected by the households under the feed-health intervention than those in the control group which again confirms that better nutrition results in better manure quality.

The results on repartition of manure collected per household flock and per animal are presented in Figure 5 and Figure 6. The results showed that the quantity of manure collected per household per day tended to increase linearly from September 2016 to August 2017 for the feed-health group while it remained almost the same for the households in the control group (Figure 5). When expressed as quantity collected per animal per day, the quantity collected was between 100–120 g DM/animal/day for the feed-health group while the values for the control group were between 80–100 g DM/animal/day (Figure 6). In view of the importance of animal manure for soil fertility in West African Sahel, the more manure that could be collected, the better for the smallholder farmers as manuring leads to increased crop yield (Ayantunde et al. 2018). The main challenge is maintaining the appropriate number of animals to provide adequate manure.

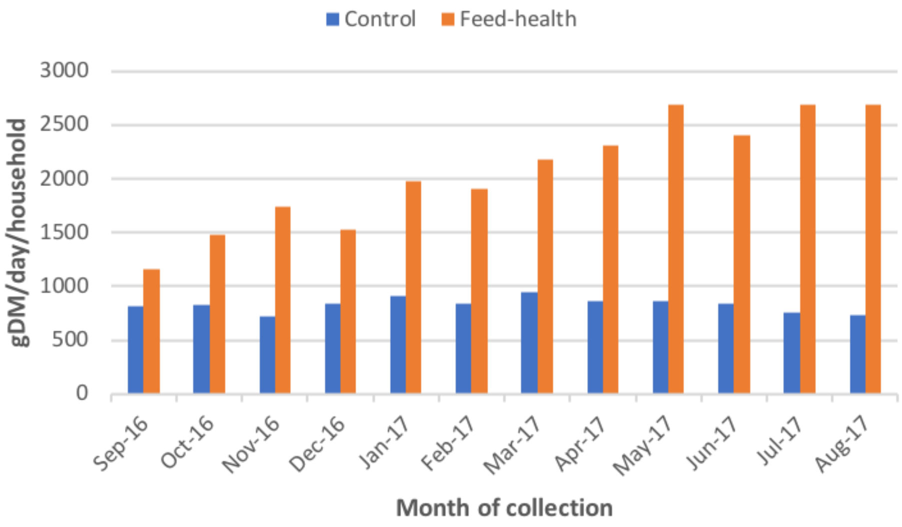

Figure 5: Manure collected per day per household (g DM/day/household) by farmers from sheep and goats under control and feed-health intervention groups.

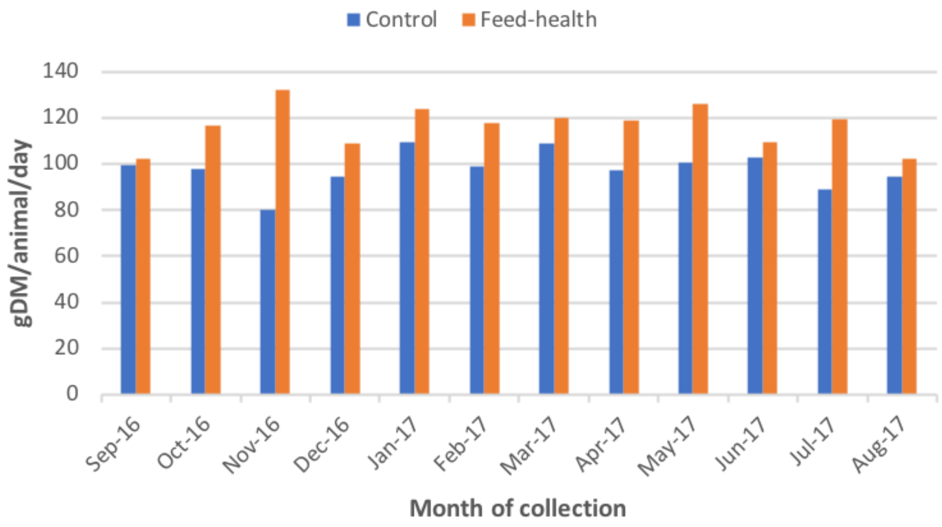

Figure 6: Manure collected per animal per day (g DM/animal/day) by farmers from sheep and goats under control and feed-health intervention groups.

A farmer spreading manure collected from his flock on the crop field (photo credit: Clarisse Umutoni/ILRI).

Nutritional quality of the available feed resources

Apart from the natural pastures, the other major feed resources found in the study sites were crop residues, agro-industrial by-products and browses. The common crop residues included sorghum stover, cotton straw, cowpea hay and groundnut haulms (Table 5) while the agro-industrial by-products were cotton seed cake and maize bran. Cotton seed cake had the highest crude protein among the feed resources offered to sheep and goats by the farmers in the two treatments.

The legume residues (cowpea hay and groundnut haulm) were also high in crude protein and in vitro organic matter digestibility. The browses (leaves of shrubs and trees) are important feed resources in the late dry season when there is feed scarcity (Umutoni et al. 2015) and they generally have high crude protein content, but they are high in lignin content (Table 5). The values of crude protein content of the cowpea hay and groundnut haulm in this study were higher than those reported by Umutoni et al. (2015) which could be attributed to period of collection of the feed samples and the associated differences in the leaf: stem ratio.

Table 5: Chemical composition of the main feed resources for ruminants in Zanzoni and Sirakele in Koutiala District (% on a dry matter basis).

Feed type	**OM**	**CP**	**NDF**	**ADF**	**ADL**	**IVOMD**	**ME(MJ/kg DM)**
Crop residues							
Cowpea hay (leaves and stems)	88.46	19.06	36.06	24.57	5.65	72.03	9.83
Groundnut haulm (leaves and stems)	88.67	16.30	54.69	44.22	9.32	61.63	8.85
Cotton straw (leaves and stems)	95.74	13.01	47.42	20.79	6.09	71.21	9.47
Sorghum stover (leaves and stems)	94.41	4.23	71.59	46.29	6.38	51.91	7.68
Agro by-product							
Cotton seed cake	89.33	25.15	65.28	43.54	8.35	71.04	9.73
Maize bran	94.13	16.15	42.19	10.08	1.97	74.64	10.44
Herbage							
Cenchrus biflorus	85.28	17.78	49.79	34.31	7.13	65.76	8.96
Browse							
Vitellaria paradoxa (leaves)	90.43	11.15	41.09	32.79	12.64	58.56	8.69
Sclerocarya birrea (leaves)	93.67	14.98	45.28	44.88	18.27	41.06	6.25
Guiera senegalensis (leaves)	96.69	10.97	49.11	43.43	14.89	55.77	8.62
Ziziphus mauritiana (leaves)	93.77	17.76	45.28	30.87	8.77	64.99	9.70
Saba senegalensis (leaves)	90.07	10.12	36.36	28.47	12.69	51.46	7.86

OM: Organic matter; **CP**: crude protein**; NDF:** neutral detergent fibre; **ADF**: acid detergent fibre; **ADL:** acid detergent lignin; **IVOMD**: In vitro organic matter digestibility; **ME**: metabolizable energy.

The legume residues like cowpea hay and groundnut haulms are normally collected and stored and used to feed household animals in the dry season or sometimes sold as the prices are often high (Ayantunde et al. 2014). The cereal straws are normally left on the crop field to be grazed by the animals. However, some farmers collect and store them at homestead to feed their flock. 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. Fodder trees and shrubs play an important role in ruminant nutrition in the late dry season from March to May (Ickowicz and Mbaye 2001). The preference for browse species varied according to season and animal species. The goats tended to prefer browses compared to sheep; hence, browses form a significant proportion of goat diets during the late dry season (Zampaligré et al. 2013).

Partial cost and benefit analysis

The results of a partial cost and benefit analysis of the control and feed-health intervention showed that the net return from the intervention was significantly higher than for the control (Table 6). The annual net return for the treatment was 95,349±25,388 FCFA per household compared to 88,575±8,693 FCFA per household. The sources of revenue were weight gained, manure collected and animal sale (offtake; Table 6) while the costs were associated with veterinary care and feed cost. The results showed that traditional small ruminant production with low inputs is profitable provided there is no major disease outbreak, which could explain the reason for widespread rearing of small ruminants by smallholder farmers. However, the farmers can generate more revenue through small ruminant production by providing supplementary feed and healthcare for their animals. For households with a large flock size, it is prudent and profitable to provide supplementary feed and standard healthcare (vaccination against PPR and pasteurellosis, deworming and curative measures) to their animals as the risk is high of losing most of the animals in the event of major disease outbreak like PPR with reported mortality rate of 80% (Ba et al. 1996). The annual profits reported in this study were lower than the annual profits obtained from 100 dairy sheep of 362,700 FCFA and 476,400 FCFA for 100 dairy goats in a study by Nantoume et al. (2011) in Kaye region of Mali. If annual profits reported by Nantoume et al. (2011) were to be adjusted to the flock size in our study, the annual profits in our study will be higher than the returns from dairy sheep and goats. Our results confirm that feed and health interventions to improve small ruminant production are profitable. Providing an enabling environment for veterinary services is critical for ensuring farmers can access animal health services.

Table 6: Partial cost and benefit analysis (FCFA/household/year) of control and feed-health intervention of small ruminants in Zanzoni and Sirakele in Koutiala District for 1 year.

Variable	Control (n=20)	Feed-health (n=20)
Revenue from weight gains	46,596±3,364[a]	241,058±14,189[b]
Revenue from manure collected	5,886±519[a]	15,474±844[b]
Revenue from animal sale	38,537±7,560[a]	169,125±26,549[b]
Gross return	91,020±8,738[a]	425,657±34,961[b]
Supplement (cotton seed cake) cost	0[a]	300,988±17,717[b]
Veterinary cost	2,445±176[a]	29,320±1,725[b]
Total cost	2,445±176[a]	330,308±19,442[b]
Net return	88,575±8,693[a]	95,349±25,388[a]

Note: Cotton seed cake 150 FCFA per kg; PPR, pasteurellosis and trypanosomosis vaccinations–175 FCFA per animal; treatments and deworming (200 FCFA per animal per quarter); manure 20 FCFA per kg air dried manure; weight gain–750 FCFA/kg live weight. Values for each variable with different superscript are statistically significant (P<0.05).

Feedback from the farmers about the pilot study

To assess the impression of the participating farmers of the pilot study in both study communities, a meeting was organized on 31 October 2017 and 1 November 2017 in Sirakelé and Zanzoni, respectively. Farmers in Sirakelé expressed their gratitude to the project for the pilot study through which their flocks were provided with cotton seed cake and healthcare. They were really happy for the positive effects of the feed and health intervention on the performance of their animals. They observed that after one year of the study they have seen tremendous improvement in the body weight of their animals and in their flock sizes. Many said their flock size doubled or even tripled. They noted that the way their flock increased rapidly suggested that they could depend on small ruminant rearing for their livelihood.

Specific benefits from the feed and health intervention according to the participating farmers in Sirakelé included drastic reduction in mortality rate, increase in birth rate, additional household income through increased offtake, increased body weight, and high quantity of manure collected. In addition, their knowledge of management of small ruminants improved through the training provided by the project. On the improved small ruminant husbandry, they acquired knowledge on animal healthcare, particularly awareness of the need for vaccination against different diseases and the importance of deworming. They also stated that they acquired knowledge on how to feed their sheep and goats to improve their body weight development. Further, as result of the study, they realized that they could collect significant amount of manure from their animals and this has led some of them to start building pens or hangars for their animals. Farmers in Sirakelé they had not been really interested in small ruminant rearing before as it was considered as activity for women but after one year of the study, they have realized the great potential small ruminant rearing can contribute to their family wellbeing. As a result of this, most of them said that they will continue with the vaccination of their animals and with provision of supplementary feed.

Group discussion with participating farmers in Sirakele (photo credit: Clarisse Umutoni/ILRI).

Picture 5: Group discussion with participating farmers in Zanzoni (photo credit: Clarisse Umutoni/ILRI).

The farmers in the control group in Zanzoni were not enthusiastic about the project because there were no interventions in their village. The project gave a 50 kg bag of rice to each household towards the end of the study for their participation. The farmers reported high mortality rate in their flock and the constraint of feed availability, especially during the rainy season when they had to tether their animals and feed them at home to avoid damage to their crops. However, the farmers said that the study raised their awareness on the potential of collecting large amount of manure from small ruminant rearing for their crop fields. The daily collection of manure also made them clean the animal pens and sheds.

The feedback from farmers in both Sirakelé and Zanzoni suggests that building their capacity in animal husbandry is essential to improving small ruminant production in mixed crop and livestock systems in Mali and in other Sahelian countries in West Africa. Also building awareness of the benefits of small ruminant rearing can motivate farmers to invest in better management of their flocks. For example, construction of pens or hangars for housing the animals will facilitate collection of animal manure for application for crop farming. Extension services, which are weak in Mali and in other countries in the region, need to be strengthened to build the capacity of the farmers in improved animal husbandry.

Conclusion and recommendations

This pilot study was conducted to assess the effects of combined feed and health interventions on small ruminant production in mixed crop and livestock systems in Zanzoni (control) and Sirakele (feed-health intervention) in Koutiala District in southern Mali. Based on the results of this study, the major conclusions are:

i. Feed and health interventions leads to rapid flock growth of sheep and goats within a short period in a profitable manner through significant increase in birth rate and reduction of mortality rate. This flock growth provides opportunity for increased offtake by the households.
ii. Supplementary feeding in addition to basal feeding and vaccination against major small ruminant diseases improves animal body weight development and increases the quantity of manure that can be collected for fertilizing the crop field.
iii. Though traditional small ruminant production with low external inputs is profitable provided there is no major disease outbreak and there is a good feed resource base such as in southern Mali, investing in supplementary feeding and healthcare of the flock can help households generate additional income from small ruminant production.
iv. Small ruminant husbandry can be profitable even with provision of supplementary feed and healthcare as was shown in households in Sirakele whose flocks benefited from feed and health interventions. Farmers in the area indicated a strong commitment to continue with the intervention albeit in a modified version. The main challenge they may face is availability of the necessary veterinary services.

Key recommendations from the pilot study partners are:

i. Provision of a good housing or shed for the flock is necessary for collection of appreciable quantity of manure. To avoid contamination of the manure, the animal house or shed should be kept clean. Daily cleaning of the animal house is also beneficial in terms of reducing favourable conditions for disease.
ii. Nitrogen in urine can be better captured by putting cereal straws on the floor of the animal house or shed as beddings. The beddings can then be used as mulch on the crop field.
iii. Access to veterinary services can be enhanced if the farmers organize themselves and then approach the local government authority in their area to facilitate contact with the animal health workers/veterinarians. It may also be necessary to have a contract with the veterinary agents for the provision of services which can be done much more easily if the farmers are organized.
iv. Building the capacity of the farmers in improved animal husbandry is critical to the success of any community-level livestock-related intervention. It is therefore important that necessary training and capacity development is incorporated into any intervention plan.
v. Though cotton seed cake was used as feed supplement in this study due to availability in southern Mali, any protein rich crop residues such as cowpea hay, groundnut haulms or agro-industrial by-products such as maize bran, millet bran could be used in similar interventions.
vi. Group herding of the sheep and goat flock to the grazing areas is necessary during the cropping season to avoid damage to crops, and this is good from a nutrition point of view compared to tethering the animals around the homestead without adequate provision of feed.

References

1. Avornyo, F. K., Ayantunde A, Shaibu, M. T., Konlan, S. P. and Karbo N. 2015. Effect of feed and health packages on the performance of village small ruminants in northern Ghana. *International Journal of Livestock Research* 5: 91–95.
2. Ayantunde A., Hiernaux P., Fernandez-Rivera S. and Sangare M. 2018. Nutrient management in livestock systems in West Africa Sahel with emphasis on feed and grazing management. In: Bationo A., Ngaradoum D., Youl S., Lompo F., Fening J. (eds) *Improving the profitability, sustainability and efficiency of nutrients through site specific fertilizer recommendations in West Africa agro-ecosystems*, Springer, Cham, UK: 11–23.
3. Ayantunde, A.A, Blummel, M., Grings, E. and Duncan, A.J. 2014. Price and quality of livestock feeds in suburban markets of West Africa's Sahel: Case study from Bamako, Mali. *Revue D'élevage et de Médecine Vétérinaire des Pays Tropicaux* 67:13–21.
4. Ayantunde, A.A., de Leeuw, J., Turner, M.D and Said, M. 2011. Challenges of assessing the sustainability of (agro)pastoral systems. *Livestock Science* 139: 30–43.
5. Ayantunde, A.A., Delfosse, P., Fernández-Rivera, S., Gerard, B., and Dan Gomma, A. 2007. Supplementation with groundnut haulms for sheep fattening in the West African Sahel. *Tropical Animal Health and Production* 39: 207–216.
6. Ba, S.B., Udo, H.M.J. and Zwart, D. 1996. Impact of veterinary treatments on goat mortality and offtake in the semi-arid area of Mali. *Small Ruminant Research* 19: 1–8.
7. Ben Salem, H. and Smith, T. 2008. Feeding strategies to increase small ruminant production in dry environments. *Small Ruminant Research* 77: 174–194.
8. De Boever J.L., Cottyn B.G., Vanacker J.M. and Boucque Ch. V. 1995. The use of NIRS to predict the chemical composition and the energy value of compound feeds for cattle. *Animal Feed Science and Technology* 51: 243–253.
9. Ejlertsen, M., Poole, J. and Marshall, K. 2012. Sustainable management of globally significant endemic ruminant livestock in West Africa: Estimates of livestock demographic parameters in Mali. ILRI Research Report 31. Nairobi, Kenya: ILRI.
10. Ickowicz A and Mbaye, M. 2001. Forêts soudaniennes et alimentation des bovins au Sénégal: Potentiel et limites. *Bois et Forêts des Tropiques* 55: 47–61.
11. Issaka, J. 2006. *Studies on nutritive value of shea nut cake, further studies on the growth response of sheep fed shea nut cake-based diets*. BSc. Thesis, University for Development Studies, Tamale, Ghana.
12. Konlan, S.P., Ayantunde, A., Addah, W. and Dei, H.K. 2017. The combined effects of the provision of feed and healthcare on nutrient utilization and growth performance of sheep during the early or late dry season. *Tropical Animal Health and Production* 49: 1423–1430. DOI:10.1007/s11250-017-1343-3.
13. Lebbie, S.H.B. 2004. Goats under household conditions. *Small Ruminant Research* 51: 131–136.
14. Nantoumé, H., Kouriba, A., Diarra, C.H.T. and Coulibaly, D. 2011. Amélioration de la productivité des petits ruminants: Moyen de diversification des revenus et de lutte contre l'insécurité alimentaire. *Livestock Research for Rural Development* 23 (5).
15. Obese, A. M. 1998. *The effects of agricultural by-products supplementation on the growth performance of the Djallonke sheep*. BSc. Thesis, University for Development Studies, Tamale, Ghana.
16. Statistical Analysis System (SAS) Institute. 1987. SAS/STAT for personal computers. Cary, NC, USA, SAS Institute.
17. Umutoni, C., Ayantunde, A., and Sawadogo, G.J. 2015. Evaluation of feed resources in mixed crop-livestock systems in Sudano-Sahelian zone of Mali in West Africa.

International Journal of Livestock Research 5(8): 27–36. DOI: 10.5455/ijlr.20150813090546.

18. Wilson, R.T. 1991. Small ruminant production and the small ruminant genetic resource in tropical Africa. *Animal Production and Health Paper No. 88*. Rome, Italy. Food & Agricultural Organization of United Nations.
19. Wilson, R.T. 1986*. Livestock production in central Mali: Long-term studies on cattle and small ruminants in the agro-pastoral systems*. ILCA Research Report No. 14. International Livestock Centre for Africa, Addis Ababa, Ethiopia.
20. Zampaligre N, Dossa HL and Schlecht, E. 2013. Contribution of browse to ruminant nutrition across three agro-ecological zones of Burkina Faso. *Journal of Arid Environments* 95: 55–64.