Alternative management practices allowing for sustainable intensification of mixed farming systems with small ruminants in Northern Ghana

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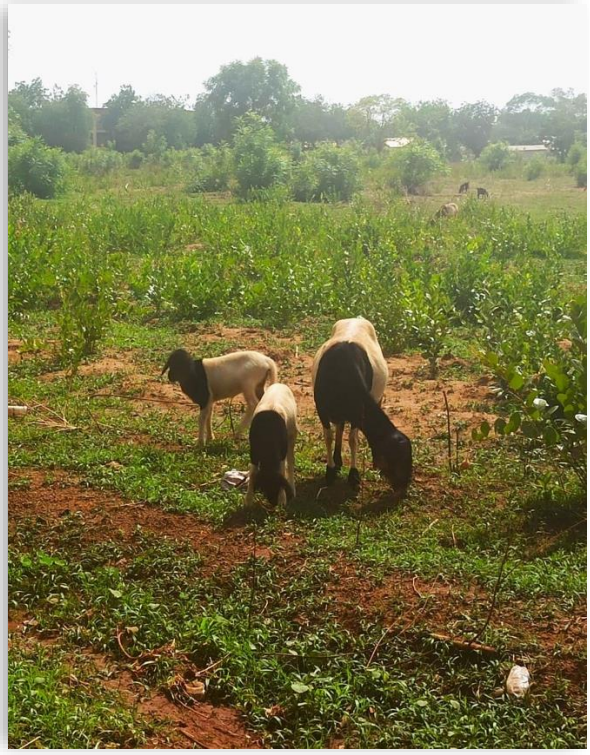

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Published by CIMMYT

{November 2024}

WU Course Code: FSE80436

WU-supervisors: Jeroen Groot

Status: Summary Final Thesis Report

Author: Margherita Senesi / Jeroen Groot

Place of publication:

Wageningen University & Research
Droevendaalsesteeg 4, 6708 PB Wageningen

The Sustainable Intensification of Mixed Farming Systems Initiative aims to provide equitable, transformative pathways for improved livelihoods of actors in mixed farming systems through sustainable intensification within target agroecologies and socio-economic settings.

Through action research and development partnerships, the Initiative will improve smallholder farmers' resilience to weather-induced shocks, provide a more stable income and significant benefits in welfare, and enhance social justice and inclusion for 13 million people by 2030.

Activities will be implemented in six focus countries globally representing diverse mixed farming systems as follows: Ghana (cereal–root crop mixed), Ethiopia (highland mixed), Malawi: (maize mixed), Bangladesh (rice mixed), Nepal (highland mixed), and Lao People's Democratic Republic (upland intensive mixed/ highland extensive mixed).

Table of Contents

Country background and research objective

Mixed farming systems with crop-livestock integration play an important role allow for risk diversification compared to producing a single crop or livestock type, allowing for an increase in the system's resilience in the face of climate change and market-related fluctuations (Cho, 2021). Well-managed mixed systems can also promote the recycling of resources which are already present within the system itself and contribute to the build-up of soil organic matter and fertility (Schiere et al., 2002). In turn, they can reduce negative impacts on the environment (e.g. soil nutrients mining) as well as the need for imported fertilizers.

Agricultural production in Northern Ghana is facing large yield gaps, declining soil fertility, and failure to match the increase in food production with the increase in demand due to population growth (Michalscheck et al., 2018). Several technological innovations have already been investigated for their application in this area, as part of the AfricaRISING project. It has been shown that they have great potential for sustainable intensification, but they often require a large initial investment.

This study focused on the investigation of alternative techniques with little or no financial expenditures, as opposed to technologies. It focused mainly on the management of small ruminants, which are a valuable element in sustainable farming systems, converting residues from the land and several by-products of food production into food that humans can eat (Oltjen & Beckett, 1996). Since low-resource-endowed farms often do not own any ruminant animals, this research focuses on alternative practices specifically for medium-resource-endowed farms, which commonly own small ruminant animals such as goats and sheep and not large ones such as cattle.

The general aim of this research was to investigate how small ruminants could be managed in alternative ways to promote the low-cost sustainable intensification of medium resource-endowed farms, focusing on two districts near the city of Tamale, Northern Ghana.

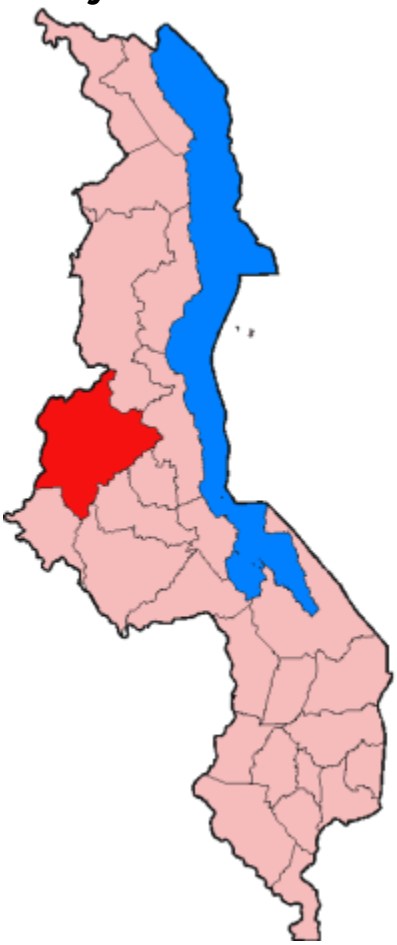
This is achieved by answering the following three research questions (RQs), subdivided into several sub-questions (SQs).

1. RQ1: How can crop residues from commonly cultivated crops be used to provide small ruminants with a complete diet in terms of energy and protein throughout the year?
    - SQ1.1: How are farms currently managed and what is the use of crop residues?
    - SQ1.2: What is the nutritional profile of common crop residues?
    - SQ1.3: What are alternative feeding strategies based on crop residues?
2. RQ2: What is the perception that farmers have towards the use of silage and compost for sustainable intensification?

    - SQ2.1: How do farmers perceive the benefits of silage and compost?
    - SQ2.2: How do farmers perceive the limitations and implications of the production process of silage and compost?
3. RQ3: What is the perception that farmers have towards intensifying small ruminant management?
    - SQ3.1: How do farmers perceive the risks and limitations of free off-farm grazing?
    - SQ3.2: How do farmers perceive the benefits, limitations, and feasibility of intensifying small ruminant management?

Methodology

Study area



This research focused on two districts in the Northern Region of Ghana (see Figure 1) near the city of Tamale, namely Kumbungu and Savelugu. One community per district was selected: Cheyohi No. 2 and Duko, respectively. Their location is within the Guinea savannah ecological zone, generally characterized by an open canopy of scattered trees and bushes, with a continuous grass understory during the rainy season (from April until October) and bare soil during the dry season (from November until March). The climate in the Northern region posed several challenges to agricultural production. It was generally a warm climate, with an annual average temperature of 34°C. The rainfall pattern was erratic, with dry periods of more than 10 days in the dry season. The main challenges and threats posed by this climate included severe and prolongated drought, bush fires and windstorms (Husseini et al., 2020).

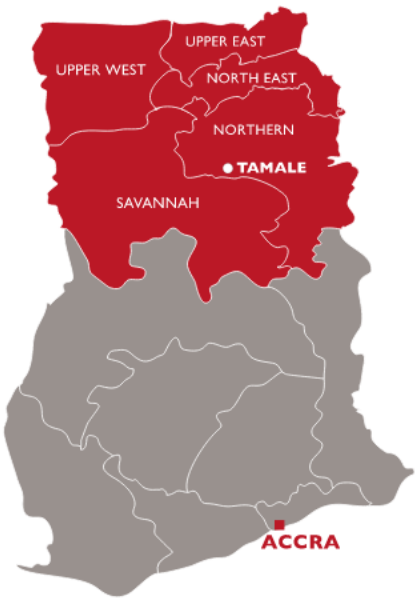


Figure 1. Map of Ghana displaying the location of Tamale in the Northern Region (USAID, n.d.).

Modelling approach

The static modelling software FarmDESIGN was used to analyse the current feed balance and to explore alternative ones. The model has a multi-objective optimization algorithm based on decision variables set by the user, allowing for an exploration of alternative farm configurations which could perform better than the original one for multiple indicators. The modelling process consisted of 4 parts, based on the 4 steps of FarmDESIGN: Describe, Explain, Evaluate and Explore (Groot et al., 2012).

A modelled reference farm was created in FarmDESIGN as a starting point for the analysis and included information on the current management of crops, crop residues, and small ruminants. The feed balance of the current small ruminants' diet was analyzed, and deficits or surpluses were identified. Cropland in the reference farm included only the 3 most cultivated crops. Energy and protein requirements of animals as well as the nutritional values of feed were based on the Dutch feed evaluation system, with energy expressed in VEM units and proteins in DVE units. Yield of crop residues was calculated using the crop's harvest index.

Three alternative diets for small ruminants suitable for sustainable intensification were created. Scenario "STOVER-HAY" was the simplest of the three. It was created using as decision variables the amount of dry grass yearly fed to the animals, as well as the land areas allocated to the 3 most commonly cultivated crops. It was assumed that all the generated crop stover (or straw) was used as feed, and that hay was collected from the grassland surrounding the farm, therefore not interfering with the amount of cropland. The alternative diet generated in the "SIMILAR RESIDUES" scenario, instead, consisted only of bulky crop residues. It was generated using crop

areas as the only decision variables and the model was allowed to choose between all the crops included in the research. As in the “STOVER-HAY” scenario, all the generated crop stover (or straw) was assumed to be used as feed. Lastly, the “DIVERSE RESIDUES” scenario was generated using the same approach as in the “SIMILAR RESIDUES” scenario, but with the addition of some finer crop residues (produced on-farm) to the ruminants’ diet, namely pods and husks. The relative cropland area needed to feed one small ruminant was then calculated for each scenario. After, it was determined whether any of the alternative feeding strategies could allow to increase in the flock size without exceeding a cropland area of about 2 hectares.

Focus Group Discussions (FGDs) were used to discuss with farmers the practices of composting, silaging, and intensifying livestock management. Their perspectives on these practices were collected during this step and mainly used for the scopes of RQ2 and RQ3. A total of two FGDs were conducted, one for each district. The farmers who participated in the FGDs were the same as in the interviews.

Results

Farm characterisation

Farmers in Duko only cultivated maize, groundnut, soybean and rice, while some farmers in Cheyohi N. 2 had a higher crop diversity, including crops such as cassava, yam, pearl millet, cowpea, pepper and eggplant. Maize was cultivated by all interviewed farmers, and it was the most important staple and cash crop. On average, farmers in Duko had 0.9 ha of cropland dedicated to maize cultivation and generated yields of 2075 kg/ha. In Cheyohi N. 2 numbers were lower, with a maize area of 0.7 ha and yields of 1333 kg/ha. Because of its importance, maize was also the only crop for which fertilizer was used regularly. The second most important crop was groundnut.

In Duko, the interviewed farmers did not make any compost with manure and crop residues. Manure was collected from the stable and gathered in a pile located outdoors on bare soil, where it stayed until its application to the fields at the beginning of the growing season. In Cheyohi No. 2 instead, farmers used manure and certain crop residues to make a basic version of compost. The procedure consisted of digging a pit in the ground and filling it with manure, rice chaff, groundnut shells, maize husks and other residues depending on their availability. The pit was neither sealed at the bottom nor covered at the top.

All the interviewed farmers managed the small ruminants in a very similar way. During the wet season, animals were either kept inside the stable, tethered to a tree close to the stable, or accompanied to the fields tethered to a farm worker to allow for controlled grazing of grasses and avoid damage to the crops. Most of the feed given during the wet season was manually provided to the animals by the farmers. During the dry season, instead, animals were kept in the stable at night and they were allowed to freely graze off-farm from early morning until late afternoon.

Farmers had on average 10 small ruminants (5 sheep and 5 goats). In the dry season, animals were fed with a combination of crop residues, as well as grasses and other feed sources which the animals found during off-farm grazing in surrounding fields and while roaming in the streets. During the wet season, they were fed with the following feed sources: cut and carried grasses from the surrounding grassland or directly grazed by the tethered animals; imported feed (mainly consisting of maize bran, rice chaff, pigeon pea stover and cassava peels); fresh maize leaves collected by leaf stripping; and lastly kitchen scraps, which were partly fed in the dry season too.

Small ruminant feeding

The analysis of the nutritional profile of common crop residues showed that there can be large differences between the available feed sources. Figure 2 represents a plot of all the residues included in this study, with a comparison of their energy and protein content per unit of dry matter. On the one hand, it can be seen that pearl

millet bran, sorghum bran, cassava stover, yam stover, soybean hulls and maize bran, are some examples of highly nutritious residues in both energy and protein. On the other hand, some of the least valuable feed sources per unit of dry matter include groundnut hulls, rice chaff, cassava peels and yam peels.

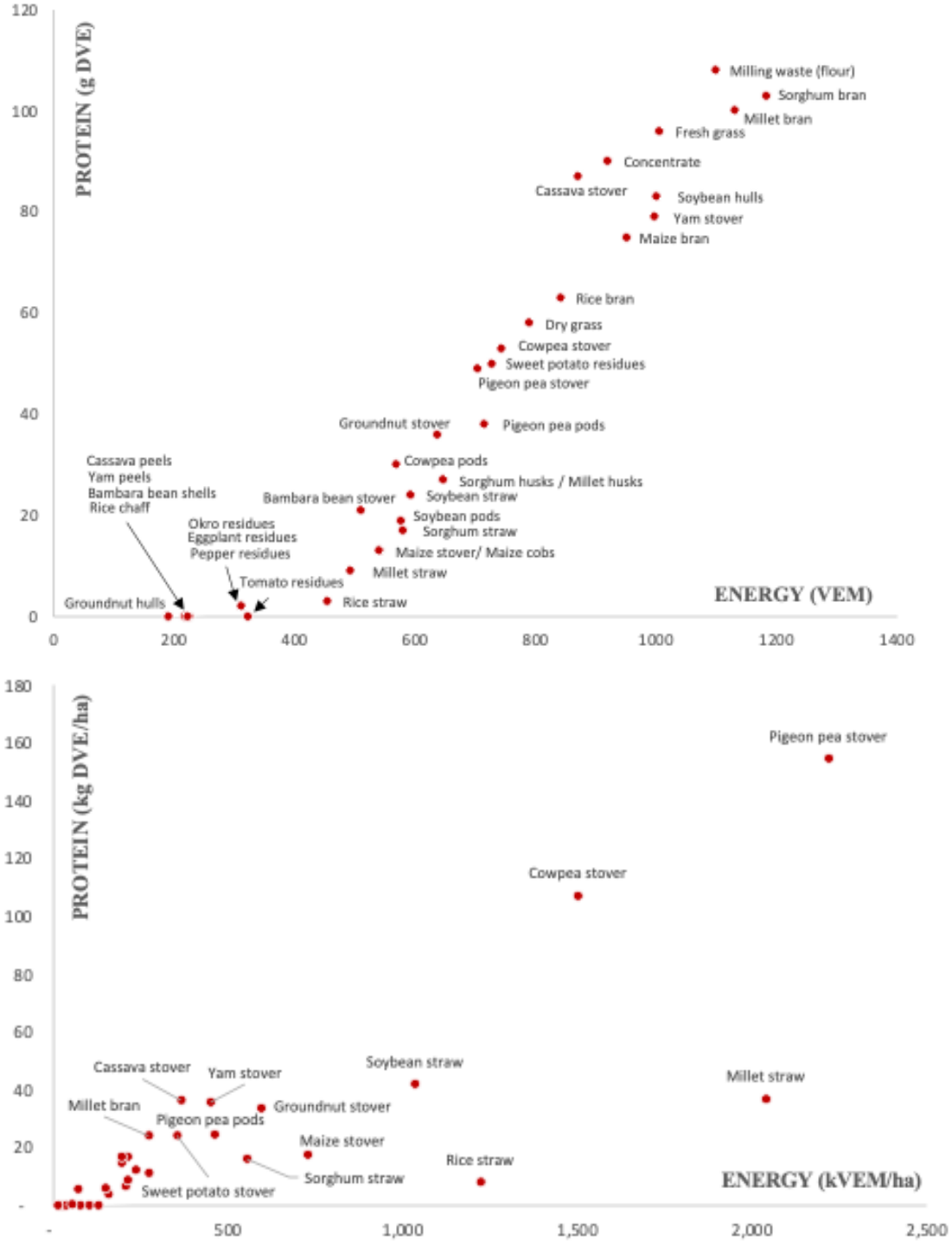


Figure 2. Energy and protein content of crop residues per unit of dry matter (top) and energy and protein yield of crop residues per unit of land area (bottom).

Table 1. Feed sources and cropland allocation in the current and alternative feeding scenarios for small ruminants (expressed in units of measurement).

	Current scenario	Scenario "STOVER-HAY"	Scenario "SIMILAR RESIDUES"	Scenario "DIVERSE RESIDUES"
Feed sources (kg DM/year)*	Soybean stover 580 kg Groundnut stover 495 kg Maize stover 410 kg Maize fresh leaves 250 kg Imports 200 kg Soybean pods 170 kg Fresh grass 50 kg	Groundnut stover 1125 kg Soybean straw 615 kg Hay grass 380 kg	Cowpea stover 940 kg Millet straw 435 kg Rice straw 225 kg Groundnut stover 160 kg Pigeon pea stover 120 kg Cassava stover 100 kg	Cowpea stover 945 kg Pigeon pea stover 555 kg Pearl millet straw 370 kg Cowpea pods 160 kg Rice straw 120 kg Pigeon pea pods 60 kg Pearl millet husks 30 kg Soybean straw 20 kg
TOTAL Feed	2120 kg	2120 kg	1980 kg	2260 kg
Cropland	Maize ~0.8 ha Groundnut ~0.8 ha Soybean ~0.5 ha	Groundnut ~1.3 ha Soybean ~0.4 ha	Cowpea ~0.5 ha Pearl millet ~0.1 ha Rice ~0.1 ha Groundnut ~0.2 ha Pigeon pea ~0.04 ha Cassava ~0.3 ha	Cowpea ~0.5 ha Pigeon pea ~0.1 ha Pearl millet ~0.1 ha Rice ~0.04 ha Soybean ~0.01 ha
TOTAL Cropland	2.1 ha	1.7 ha	1.2 ha	0.75 ha
Intensification	-	0.17 ha/animal 6 animals/ha ~12 animals with 2 ha	0.12 ha/animal 8 animals/ha ~16 animals with 2 ha	0.075 ha/animal 13 animals/ha ~26 animals with 2 ha

Feeding scenarios

Out of the three alternative feeding scenarios generated during modelling (see Table 1 for the extensive list of the specific quantities of feed sources for each scenario, and Figure 3 for the relative amounts of feed sources expressed as percentages in the animal's diet), the "STOVER-HAY" scenario proposed the simplest diet: 53% groundnut stover, 29% soybean straw and 18% grass hay, with approximately 212 kg of biomass dry matter fed to each small ruminant per year. 0.17 ha of cropland would be sufficient to produce the necessary residues to feed one animal. In other words, for each hectare of cropland, 6 animals could be fed, representing a slight increase when compared to the baseline situation of about 5 animals/ha. A more diversified diet with greater intensification opportunities was seen in the "SIMILAR RESIDUES" scenario, based on the most prevalent bulky crop residues such as stover and straw, and where the prevalent feed source was cowpea stover (47%). The latter was used in combination with millet straw (22%), rice straw (11%), groundnut stover (8%), pigeon pea stover (6%) and cassava stover (5%). In this scenario the cropland needed to feed one animal further decreased to 0.12 ha, allowing to feed 8-9 animals with each hectare of cropland.

In the "DIVERSE RESIDUES" scenario, where finer crop residues such as pods and husks were included too, the lowest amount of cropland needed to feed each animal was achieved (0.075 ha), out of the three scenarios. Therefore, the flock size could be intensified by up to 13 small ruminants for each hectare of cropland necessary for feed production, when following this diet. In this scenario, cowpea stover was still the prevalent feed source (42%), this time followed, in terms of descending quantities of dry matter, by pigeon pea stover (25%), pearl millet straw (16%), cowpea pods (7%), rice straw (5%), pigeon pea pods (3%), pearl millet husks (1%) and soybean straw (1%). Regarding the total feed biomass, the three scenarios ranged from 198 to 226 kg of dry matter per animal per year.

Farmer perceptions

Silage was not used as a feed for small ruminants in the study area. During the FGDs, it became clear that most farmers do not know what silage consists of. After listening to the advice, the farmers perceived the silage-making process as too complex for their level of knowledge. They have not directly observed any farmer in the surrounding area making use of this type of feed and would therefore appreciate support for the implementation of the silage-making process to avoid the negative consequences of an incorrectly managed process. In addition, to avoid the necessity to make large investments in the silage-making structures, farmers expressed favor towards the idea of a common facility used by multiple farms in the area which could facilitate the initialization of this process, so that the financial pressure on each farm is reduced.

Farmers perceived the idea of building dedicated aerobic composting structures as too expensive, given the unavailability of free wood or concrete suitable for

construction. What they perceived as feasible was, instead, the use of plastic liners to seal the bottom of the pits where they normally make compost, as well as liners to cover the top of the piles, since these could be obtained more easily and for a cheaper price. They were not aware of the large nutrient losses that can take place through leaching and volatilization.

Farmers perceived the option of fencing the cropped fields to prevent the goats and sheep from leaving the farm, as well as keeping other animals outside of their fields, as a non-feasible option. The reason for this was that they usually did not own the fields they cultivated. The owner of the fields was an external party who was often unknown to the farmers and who could claim the fields at any time. Also, they would need the owner's permission to build any additional structures to the fields. If they would build structures without permission, the risk would be that the owner subsequently asked for removal or would directly remove them without communicating it to the farmers.

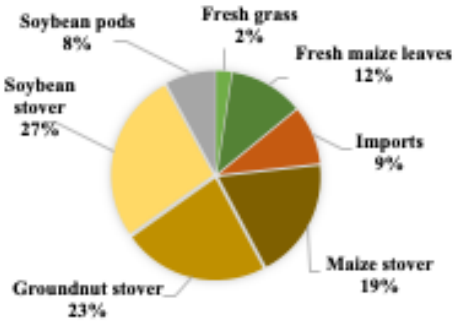
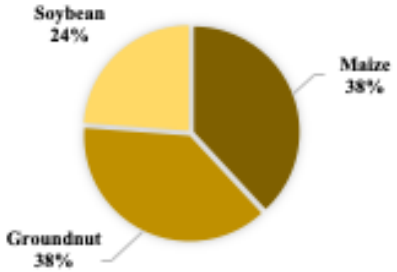
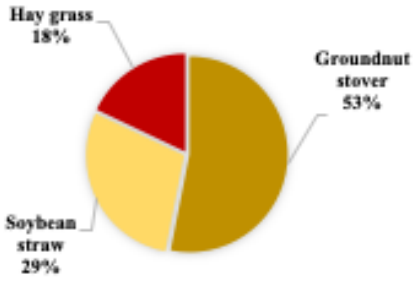
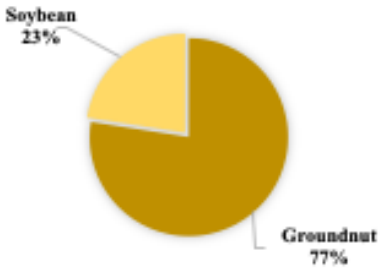
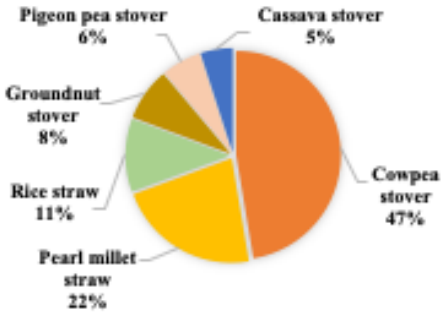
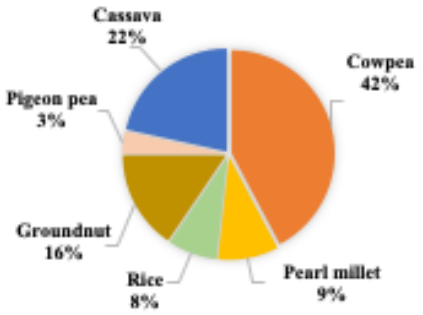
Scenario	Feed sources (%)	Cropland allocation (%)
Current		
"STOVER-HAY"		
"SIMILAR RESIDUES"		

Figure 3. Feed sources and cropland allocation in the current and alternative feeding scenarios for small ruminants (expressed in percentages).

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Discussion

Several combinations of residues from common crops in Northern Ghana could represent a valuable choice to meet the dietary requirements of small ruminants (see Table 1 and Figure 3). Choosing to switch to alternative diets can open up various opportunities for sustainable intensification. A simple but effective feeding strategy could consist of groundnut stover for the major part, together with soybean straw and dry grass (see scenario “STOVER-HAY”). Feeding strategies with a higher degree of diversification, instead, could include other nutritious crop residues such as pigeon pea stover and pods, cowpea stover and pods, pearl millet straw and husks, and cassava stover (see scenarios “SIMILAR RESIDUES” and “DIVERSE RESIDUES”). Pigeon pea and cowpea are two of the most important crops in terms of energy and protein content of the residues, as well as biomass productivity per unit area. In addition, the cultivation of these crops can promote natural soil fertility due to their nitrogen fixation, reducing the need for chemical fertilizers and their associated negative impacts on the soil, as opposed to maize cultivation.

The adoption of beneficial farming practices such as silage preparation and aerobic composting requires a higher investment of time and resources into farmers’ education. Farmers could greatly benefit from increased opportunities to learn and share scientific knowledge on sustainable farming practices. Smallholder farmers utilize their indigenous knowledge for most of their agricultural activities, which is often not sufficient to adequately support the system’s fertility. As explained in detail in a study by File & Nhamo (2023), factors such as limited access to extension services, scarce reliability of farming practices, and socio-cultural beliefs pose a threat to food security in Northern Ghana.

This research, however, had several limitations. Firstly, the feed balance created to analyze the current situation excluded the feed that small ruminants ate during off-farm grazing, given its unpredictability. Secondly, the main focus was on dry residues collected at the end of the harvesting season, but other feed sources such as fresh biomass at different stages of crop development, as well as residues of the processing industry (such as cereal bran and soybean hulls), would be interesting to include in the development of further feeding scenarios. The same goes for residues of different crop cultivars and grass species, which can have large differences in terms of nutritional aspects. Thirdly, the collected nutritional values of the crop residues were obtained from sources based on data from multiple countries, which may differ widely from those in Northern Ghana.

From a broader perspective, this research supported the intensification of mixed farming systems by providing ideas on how to increase feeding efficiency and illustrating potentially beneficial management strategies to local farmers. When approached locally by considering specific challenges and availability of resources, mixed systems can be an extremely valuable sustainable farming practice and source of a multitude of food and economic benefits for smallholder farmers and communities as a whole.

Conclusions

Developing livestock diets based on the most nutritious crop residues could help farmers move towards sustainable intensification, provided that these diets are well-balanced to fulfil the ruminants' metabolism. Pigeon pea and cowpea could be two of the most important crops to move in this direction. These crops produce large amounts of residues which are highly nutritional for ruminants (see Table 3 and Figure 4) and promote soil fertility. Tackling unsustainable traditional farming practices, developing effective feeding strategies such as those explored in this research, and investing further resources into farmers' education could lead to a future of increased food security with minimal economic investment.

Conclusions

Cho, C. (2021). Building resilience by diversifying agricultural systems. PAN – Pesticide Action Network – North America. https://www.panna.org/blog/building-resilience-diversifying-agricultural-systems

File, D.J.M & Nhamo, G. (2023). Farmers' choice for indigenous practices and implications for climate-smart agriculture in Northern Ghana. Heliyon. 9(11).

Groot, J.C.J., Oomen G.J.M. & Rossing W.A.H. (2012). Multi-objective optimization and design of farming systems. Agricultural Systems. 110: 63-77

usseini, R., Aboah D.T. & Issifu H. (2020). Fire control systems in forest reserves: An assessment of three forest districts in the Northern region, Ghana. Scientific African. 7: e00245.

Michalscheck, M., Groot J.C.J., Kotu B., Hoeschle-Zeledon I., Kuivanen K., Descheemaeker K. & Tittonel P. (2018). Model results versus farmer realities. Operationalizing diversity within and among smallholder farm systems for a nuanced impact assessment of technology

Oltjen, J. W. & Beckett, J. L. (1996). Role of ruminant livestock in sustainable agricultural systems. Animal Sciences. 74 (6): 1406-9.

Schiere, J.B., Ibrahim M.N.M. & van Keulen H. (2002). The role of livestock for sustainability in mixed farming: criteria and scenario studies under varying resource allocation. Agriculture, Ecosystems and Environment. 90: 139-153.

cgiar.org/initiative/mixed-farming-systems