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Exploring the current status of ruminant value chains in northern Ghana, and the role of grain legume residues as a livestock feed resource

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Abstract

This study explored the current state of ruminant value chains in two regions of northern Ghana (Northern region (NR); Upper East region (UER)) and studied the role of grain legume residues (GLRs) as a livestock feed among livestock value chain actors. Semi-structured questionnaires were designed to conduct interviews with three different stakeholders: 99 smallholder farmers in two districts (Savelugu-Nanton (NR) and Binduri (UER)); and 108 livestock fatteners and traders in Tamale (NR) and Bawku (UER). Data was analysed by applying value chain mapping and using SPSS Statistics. Results showed that smallholder livestock production mainly contributed to sustaining livelihoods and household food security, based on the importance of non-market roles of livestock keeping (e.g. small ruminants) and overall low market participation (incl. livestock and GLRs). Livestock fattening and trading in the NR focused on a combination of cattle and sheep, as opposed to predominantly cattle in the UER. Two ruminant value chains were identified in each region: local ruminant market chains, mainly for the distribution of small ruminants, and cross-regional market chains, mainly used by UER chain actors for the distribution of cattle. Unlike livestock trading, livestock fattening showed to be characterized by seasonality. Increasing livestock production through fattening schemes may offer a way to improve incomes, increase the value of the overall livestock trade, and to improve the supply of livestock produce. GLRs were among the main feeds used by fatteners and traders, and were especially important during the dry season. Opportunities for increasing urban livestock production and trade strongly depend on the availability and accessibility of feed resources, such as the supply of GLRs by farmers. Based on heterogeneity among smallholder farmers (within and between regions), possibilities to increase market participation and value chain integration through increased livestock production, need to be considered in the context of their current livelihood strategies and changing market demands. In addition, potential trade-offs related to the allocation of GLRs (on-farm/off-farm) should be carefully considered in order to assess the opportunities for the commercialization of farming practices.

Contents

Introduction

For years now, it has been known that drivers such as growing populations, urbanization, increasing incomes and changing dietary patterns have resulted in increasing demands for livestock produce on a global scale (Amankwah, 2013; Tarawali *et al.,* 2011). Consequently, livestock production systems have been undergoing a rapid transformation, especially in developing countries (e.g. sub-Saharan Africa) (IFPRI *et al.,*2016; Amankwah, 2013). So far, smallholder mixed crop-livestock systems have been responsible for the majority of livestock and crops produced in these countries (Amankwah, 2013; Valbuena *et al.,* 2012; Tarawali *et al.,* 2011). Hence, livestock is an important contributor to the rural livelihoods and sustenance of many farmers and their households. Increasing demands for livestock products may therefore provide new opportunities for smallholder farmers through increasing livestock production, which in turn could result in the further improvement of farmers' incomes and their livelihoods (Adams and Ohene-Yankyera, 2014; Amankwah, 2013; Adzitey, 2013; Tarawali et al., 2011; Herrero et al., 2010). However, the extent to which farmers have the means to increase their levels of production (e.g. through intensification; Udo *et al.,* 2011), and as such could actually benefit from these emerging opportunities, depends on e.g. socio-economic, agro-environmental, and institutional factors. Additionally, access to markets can play a significant role in the process of transformation and commercialization of mixed farming systems. Altogether, these factors largely determine the extent to which smallholder mixed farming systems will take part in this trend of transformation (IFPRI *et al.,* 2016; Tarawali *et al.,* 2011).

A similar situation applies to Ghana, where an increase in annual meat consumption has been observed, in particular for beef, mutton and goat meat, as a result of urbanization, increasing incomes of mainly urban citizens and changing dietary patterns of these urban consumers (Konlan *et al.,* 2015; N. Associates Inc., 2014; Owusu-Sekyere, 2014; Adzitey, 2013; Amankwah, 2013). Furthermore, also in Ghana, smallholder mixed crop-livestock systems are the predominant agricultural production system (Kuivanen *et al.,* 2016; Timler *et al.,* 2014; Adams and Ohene-Yankyera, 2014; Amankwah; 2013) (Fig. 1, no.1) and account for the provision of 95% of the total crop and livestock produce (MOFA, 2004). These mixed farming systems are mainly concentrated in three regions of northern Ghana: the Northern region (NR); the Upper West region (UWR); and the Upper East region (UER) (Timler *et al.,* 2014; *Adams* and Ohene-Yankyera, 2014; Amankwah, 2013). These regions account for the majority (75% -85%) of total domestic cattle production (Owusu Sekyere, 2014; Adzitey, 2013; N. Associates Inc., 2014), and 70% of the total domestic sheep and goat production (Amankwah, 2013).

Despite the available market opportunities, smallholder farmers in Ghana are typically not (or very limitedly) commercially oriented with regard to their livestock. Hence, smallholder mixed farming is characterized by generally low levels of market participation (Kuivanen *et al.,* 2016; N. Associates Inc., 2014; Amankwah, 2013). This lack of commercialization can in part be explained by the importance of the many, non-market roles that livestock play in the daily lives of these farmers and their family (Tarawali *et al.,* 2011). Next to contributing to food security, livestock plays a pivotal role in the integration of crops and livestock by contributing to crop production and soil fertility as provider of draught power and manure, thereby further enhancing crop yields (Fig. 1, 1A, 1B). On the other hand, crop residues provide feed for the animals, which in turn can positively affect livestock productivity (Fig. 1, 1C). Thirdly, livestock functions as a 'walking' bank and safety net that allows farmers to quickly access cash in order to meet emergency (e.g. medical) and planned expenditures (e.g. school fees, inputs for crop production such as seeds and fertilizer, etc.) (Fig. 1, 1A), and as insurance against crop failures. Finally, livestock serves important cultural (e.g. status) and religious (e.g. sacrifices) purposes (Kuivanen *et al.,* 2016; Amankwah, 2013; Valbuena *et al.,* 2012; Tarawali *et al.,* 2011; Powell *et al.,* 2004; MOFA, 2004). Therefore, smallholder mixed crop-livestock farming can be considered a livelihoods strategy that is foremost focused on diversification and risk-avoidance (Valbuena *et al.,* 2012; Powell *et al.,* 2004; MOFA, 2004). Furthermore, these systems can be characterized by low levels of crop and livestock production which are generally caused by the limited availability of, and access to resources and (external) inputs (e.g. land, labour, capital, animal housing, feed, and veterinary services) (Kuivanen *et al.,* 2016; Timler *et al.,* 2011). Low livestock productivity results from high disease prevalence and high mortality rates, often due to inadequate management practices (e.g. inappropriate feeding) (Konlan *et al.,* 2016; Kuivanen *et al.,* 2016).

Next to livestock production in mixed farming systems, several studies identified other livestock production systems among which small scale (semi) commercial livestock enterprises in (peri) urban areas (Owusu-Sekyere E, 2014; MOFA, 2004, AFDB, 2001), such as livestock fattening and livestock trading (Fig. 1, no.2).However, the extent to which these types of livestock producers contribute to the domestic supply of ruminant meat, as well as their level of involvement in ruminant value chains are currently unknown (Fig.1).

So far, domestic livestock production has not been able to meet current demands as domestic production accounts for 46% of the total national demand of meat (N. Associates Inc., 2014). As a result, Ghana has been importing livestock products (live animals and meat) from neighbouring Sahelian countries (i.e. Burkina Faso, Mali, and Niger) to compensate for the gap in supply (N. Associates

Inc., 2014; Owusu-Sekyere, 2014; Amankwah, 2013; MOFA, 2004). However, according to a study performed by Owusu-Sekyere (2014), net imports decreased between 2000 and 2013, most likely as a result of a gradual annual increase in the domestic production of especially beef, mutton, and goat meat (N.Associates Inc., 2014; Adzitey, 2013; MOFA, 2013). According to a report from MOFA (2013), the livestock sector has been growing at an annual average growth rate of 5% between 2007 and 2012. As such, these trends strongly suggest that a development in livestock production (ruminants especially) has been and currently still is taking place in Ghana. However, this begs the question, which stakeholders in the ruminant value chain exactly are responsible for this (developments in) livestock production, and which role do they play in the provision and distribution of cattle, sheep, and goats (meat) to both rural and urban consumers or markets (Fig. 1, no.3)

As mentioned before, livestock productivity in Northern Ghana is constrained by many factors of which feed shortages in terms of quantity and quality especially during the dry season constitute a major part (Konlan *et al.,* 2016; Owusu-Sekyere E, 2014; Amankwah, 2013). During the wet season (i.e. cropping season) on the other hand, feed is limitedly accessible due to land use directed specifically towards crop cultivation (Konlan *et al.,* 2014; Amankwah, 2013; Nandwa *et al.,* 2011). Seasonal challenges in feed availability and accessibility mainly result from the extensive (free grazing) management of cattle, sheep and goats and no or limited adoption of supplementary feeding (Konlan *et al.,* 2016; N. Associates Inc., 2014; MOFA, 2004). The implementation of supplementary feeding (during the dry season) is considered crucial in order for livestock to meet their nutritional requirements (Amankwah, 2013; Nandwa *et al.,* 2011; Powell *et al.,* 2004; Savadogo, 2000), as well as to achieve increased livestock productivity (Powell *et al.,* 2004). Supplementary feed resources such as (leguminous) crop residues are therefore becoming increasingly important in ruminant feeding (Konlan *et al.,* 2015; Valbuena *et al.,* 2012; Amankwah, 2013; Savadogo, 2000).

Furthermore, increasing feed scarcity is associated with increasing levels of urbanization due to the declining availability of grazing lands for livestock (Konlan *et al.,* 2015). Consequently, this decline in combination with increasing livestock numbers results in an increasing demand for livestock feeds, especially in the (peri-) urban areas of northern Ghana (Konlan *et al.,* 2015). As such, (peri-) urban livestock producers such as livestock fatteners and livestock traders increasingly need to explore alternative livestock feed resources which have contributed to an increase in demand for leguminous crop residues (i.e. cowpea, groundnut, soybean residues) (Konlan *et al.,* 2015; Valbuena *et al.,* 2012). Due to the high nutritive value of grain legume residues (compared to cereal grain residues) livestock productivity could be enhanced (Odendo *et al.,* 2011), which is essential to e.g. (commercial) livestock fattening. Altogether, several studies reported that overall increasing demands for feeds and the growing value of legume residues as a livestock feed resource have resulted in emerging (local) feed markets throughout West-Africa as well as in northern Ghana (Konlan *et al.,* 2015; Valbuena *et al.,* 2012) (Fig. 1, no. 4). However, the extent of grain legume residue utilization as a livestock feed resource among different ruminant value chain actors (i.e livestock fatteners and traders especially) is currently unknown (Fig.1).

Next to significantly contributing to (household) food security, grain legumes (i.e. cowpea, groundnut, soybean, and pigeon pea) own specific characteristics that have the potential to improve soil fertility and enhance the integration of crops and livestock, which in turn may further improve crop yields (Odendo *et al.,* 2011). However, crop productivity in Ghana, as well as in other sub-Saharan countries, is generally low due to the many challenges facing crop production in e.g. declining soil fertility, harsh climatic conditions, and pests and diseases (Batiano *et al.,* 2011). As a result, research-in-development program projects emerged such as N2Africa (*Putting nitrogen fixation to work for smallholder farmers in Africa*) which focuses on the potential role of legumes in sustainable intensification in the three northern regions of Ghana e.g. by introducing and applying productivity enhancing technologies (Fig. 1, no. 5). Grain legumes and residues do not only provide opportunities to improve the livelihoods of farmers in terms of food security and income generation (through improved crop yields and livestock productivity) (Odendo *et al.,* 2011), but also offer additional developmental trajectories for smallholder farmers, e.g. directed towards specialization and (increased) commercialization of farming practices. However, it is unknown whether this development is actually taking place in northern Ghana, as well as the extent to which these farming systems contribute to the supply of grain legumes residues to other (peri-) urban livestock producers (Fig. 1, no. 5). Therefore, the importance of grain legume cultivation and the (on- and/or off-farm) allocation of grain legumes and residues among smallholder farmers in northern Ghana need to be further investigated.

As part of the N2Africa project, a PhD study is currently performed (Akakpo.) on the use of grain legume residues as a livestock feed resource among livestock value chain actors. Preliminary findings showed that livestock fattening especially takes place in the UER, and to a lesser extent in the NR. These results were obtained by using a feed assessment tool (FEAST) which included focus group discussions with different livestock producers. In addition, the use of grain legume residues as a livestock feed resource was mainly limited to the UER and NR (N2Africa podcaster 32; and 39, 2015 and 2016). Therefore, and based on similar agro-ecological conditions in the NR and UWR (i.e. sub-humid Guinea Savanna) (MOFA, 2013), the NR and UER have been selected for the scope of this study. Currently no knowledge exists with regard to the overall use of grain legume residues as a livestock feed among different value chains

actors in these regions, nor is there information available on the current situation of ruminant livestock production by these different value chain actors.

Therefore, the overall purpose of this study is to:
I. To describe and explore the current status of ruminant value chains in the Northern region and Upper East region of Ghana
II. To describe and understand the role of grain legumes residues among rural and urban livestock producers within these ruminant value chains

In order to do so, the following research objectives were formulated:
1. Characterize and describe ruminant value chain actors who are part of ruminant value chains in the Northern region and Upper East region
2. Identify and describe value chain (actor) interrelationships and connections to livestock markets in the Northern region and Upper East region
3. Compare ruminant value chains in the two regions of northern Ghana
4. Describe the production of grain legumes and trading of grain legume residues by smallholder farmers in the Northern region and Upper East region
5. Describe the contribution to, and utilization of grain legume residues as a livestock feed resource among livestock fatteners and traders in the Northern region and Upper East region

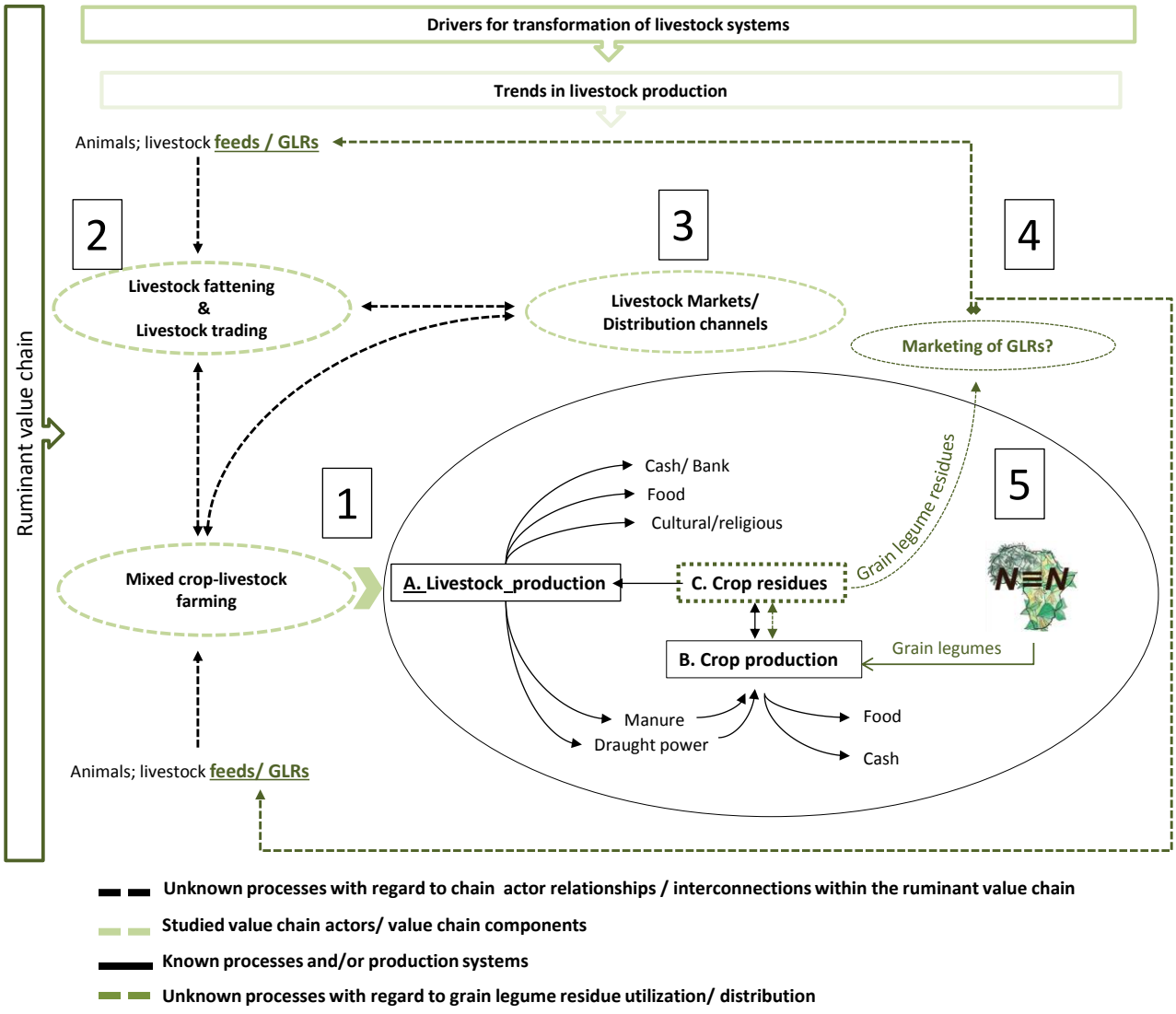

Figure 1. Overview of a ruminant value chain structure in northern Ghana; and grain legume residue distribution structure to and from value chain actors in northern Ghana

Materials and methods

Study Area

The study was conducted in two northern regions of Ghana: the Northern region (NR) and the Upper East region (UER) (Fig. 2a.), which are considered to be among the more poverty stricken areas of Ghana (Kuivanen *et al.,* 2016; AQUASTAT, 2005). The NR comprises 29.5% (70 383 km^2) of Ghana's total surface area (238 53 km^2), whereas the UER accounts for 3.7% of the total surface area (8 840 km^2). Northern Ghana is populated by 4.5 million people and accounts for 17.1% of the total Ghanaian population (± 25 million) of which 10.1% lives in the NR and 4.2% in the UER, mainly in rural areas (70% in NR; 80% in the UER) (MOFA, 2013). The selection of these two regions was mainly based on their differences in agro-ecological conditions and opportunities for livestock production. The NR and the UER fall within two distinctive agro-ecological zones: the Guinea-Savanna zone (NR) and the Sudan-Savanna zone (UER) (Fig. 2b). Both zones are characterized by uni-modal rainfall patterns (May-October), and a prolonged dry season with high temperatures (up to 40˚C) (MOFA, 2013; Siaw, 2001). Average annual rainfall in these zones ranges from 1000 mm in the Sudan Savanna up to 1100 mm in the Guinea Savanna (MOFA, 2013). Due to the uni-modal rainfall pattern and harsh climatic conditions in northern Ghana, traditional farming systems, which are mainly rain-fed, low input smallholder mixed farming systems, have developed over time as a way to adapt to these different agro-ecological conditions (AQUASTAT, 2005; Siaw, 2001). Crop production in the Guinea Savanna and Sudan Savanna is focused on staple crops (for food and cash) such as maize, millet, and sorghum. In addition, rice, cassava, yam, and legumes among which cowpea, soybean and groundnut (mainly as cash crops) are cultivated across the different areas (Kuivanen *et al.,* 2016; Timler *et al.,* 2014; Konlan *et al.,* 2015; AQUASTAT, 2005). Common livestock species reared in northern Ghana are cattle, sheep, goats, and poultry. To a lesser extent, donkeys, horses and pigs are kept (Konlan *et al.,* 2015; Adams and Ohene-Yankyera, 2014; Timler *et al.,* 2014).

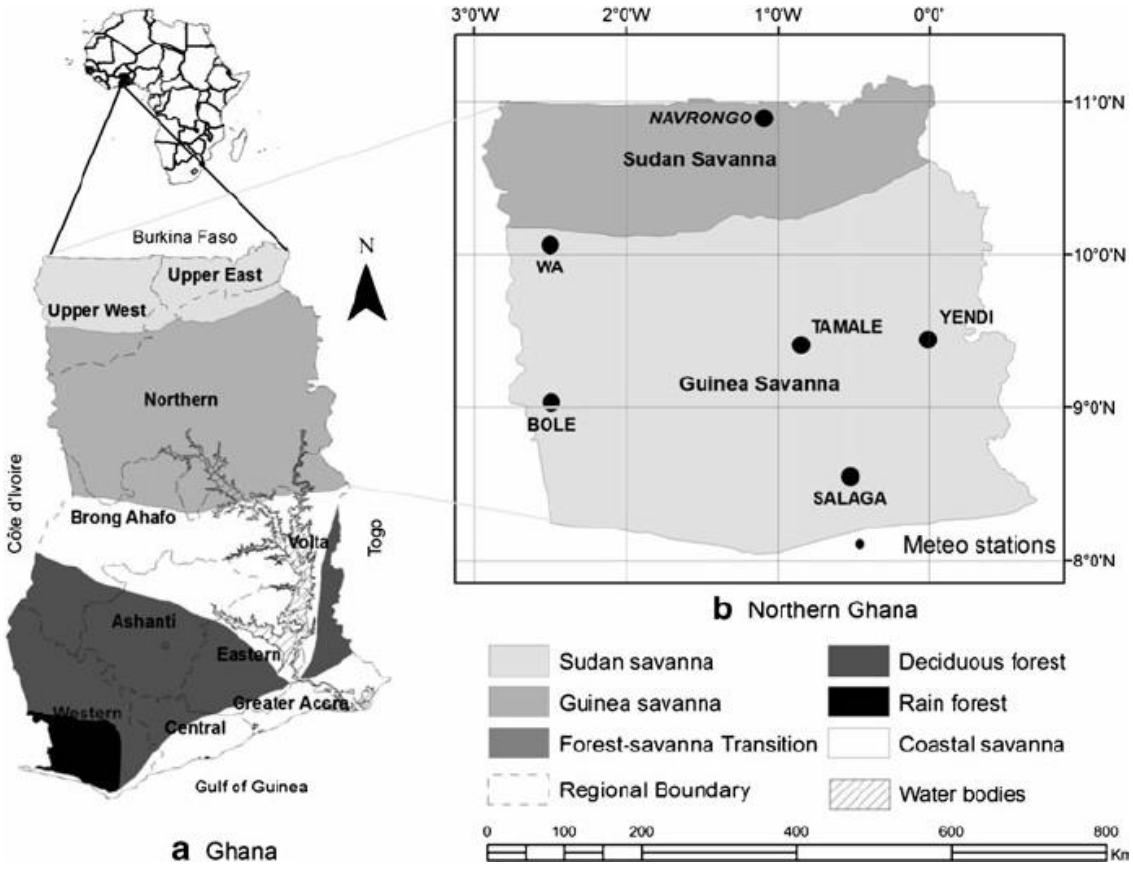

Figure 2 a) Map of Ghana and its regions; b) Guinea and Sudan savanna agro-ecological zones. Source: Armah *et al.,* 2011

Study design and data collection

Smallholder farmers, livestock fatteners and livestock traders were the main value chain actors studied during this research based on their (potential) connection to both livestock production, and production of grain legumes and/or utilization of grain legume residues. Selection of the sampling locations of smallholder farmers in the two regions was based on the target areas (districts) of the N2Africa project among which were the district of Savelugu-Nanton in the NR, and the district of Binduri in the UER. Both districts were situated about 30-40 minutes away from Tamale (i.e. regional capital of NR) and Bawku (major city in the UER). In each district, we visited 5 different farm communities in which each about 10 farmers were interviewed at their homesteads (Table 1). These farmers were often the household head or a family member. In total, 99 smallholder farmers were interviewed (Table 1). Data collected on livestock fattening and livestock trading took place in and around the two major cities of the NR and UER: Tamale and Bawku. There, we identified and interviewed 45 livestock fatteners, 38 livestock traders and 25 both livestock fatteners and traders (Table 2). Interviews with livestock fatteners mainly took place at their homesteads, whereas we interviewed livestock traders mainly at livestock markets. Overall, conducting one interview took approximately 1½- 2½ hours

Table 1. Data collection sites and sample size of smallholder farmers per region, district and community

Region	District	Community	Total (n)
1. Northern Region (NR)	Savelugu-Nanton	Bunglung	10
		Balshei	10
		Dingoni	10
		Langa	10
		Sandu	10
			50
2. Upper East Region (UER)	Binduri	Sakpa Natinga	9
		Tansia	10
		Tambiigu	10
		Tetauko	11
		Kumpalgoga	9
			49
Total			**99**

Table 2. Data collection sites and sample size of livestock fatteners and/or livestock traders per region and district

Region	District	Fatteners (n)	Traders (n)	Both fatteners/traders (n)	Total (n)
1. Northern Region (NR)	Tamale Metro	21	30	4	55
2. Upper East Region (UER)	Bawku Municipal	24	8	21	53
Total					**108**

Selection of respondents for the survey was based on contact lists that were composed during prior focus group discussions with (potential) smallholder farmers, livestock fatteners, and livestock traders. During these focus group discussions, attendants in turn identified and recommended other potential stakeholders and respondents (i.e. snowball method) (Kumar, 2014). The selection of listed farm households for the survey on site was mainly based on their eligibility (ruminant ownership was a prerequisite), and from there selection occurred at random depending on their availability and their willingness to cooperate. The selection of listed livestock fatteners and livestock traders for the survey on site was mainly based on whether or not they had met the by us predefined definitions of a livestock fattener or livestock trader:

1.Livestock fattening: commercial livestock production that is profit driven and is characterized by long term livestock keeping (months) (and value addition through investing in targeted feeding and management practices).

2.Livestock trading: commercial livestock “production” (more keeping) that is profit driven and characterized by short term (lower input) livestock keeping (days or weeks).

In addition, both livestock fatteners and livestock traders needed to be distinguished from smallholder farmers: smallholder livestock farming mainly focuses on the non-market related functions of livestock (see Introduction), and therefore livestock production in these systems is not commercialized but rather subsistence based (Amankwah, 2013; Tarawali *et al.,* 2011)

Surveys were conducted based on the design of two separate semi-structured questionnaires: one for smallholder farmers, and one for livestock fatteners and traders. Semi-structured questionnaires allow for the collection of both quantitative and qualitative data (Hague, 2006). However, during this study mainly qualitative data were gathered. Questionnaires comprised of mainly closed (qualitative), and to a lesser extent open ended (quantitative) questions. Coding was applied to the majority of closed ended questions, including multiple choice and yes/no options; scoring on a Likert scale; and ranking. Surveys included multiple topics of which socio-economic data, and data related livestock (incl. animals and feed) and crop production of respondents were used for the scope of this study. Table 3 and Table 4 provide a more detailed overview and description of the different topics that were included in the questionnaires, and the subsequent description of variables used for data analysis. The complete contents of the questionnaires can be found in the Appendix (A1; A2).

Data collection took place during October 2016 until the beginning of January 2017. In each region, questionnaires were administered with the help of a group of 2-5 trained enumerators. Enumerators received training in order to explain the overall purpose of the study, and to provide them with tips and tricks on how to perform the interview as well as to help and guide the respondents through the questionnaire. Assistance with the administration of questionnaires was needed because of the many different languages spoken across the two regions. Interpreters were also present (e.g. other farmers), and if possible, interviews were administered in English. In addition, a team of 4 trained people assisted with the data entry into SPSS.

Table 3. Summary of smallholder questionnaire topics and description of variables used

Questionnaire summary for smallholder farmers	
Farm Location	Region, district, and community
Personal information	Name, gender (male/female), age No. of years in farming Highest level of education (coded) Religion, marital status (coded)
Household composition	No. of females/males in household according to age class
Income sources	Contribution (%) of different work activities to income (e.g. crop farming, crop residues, livestock, labouring service, formal employment, etc.)
Livestock production	No. of animals (e.g. cattle, sheep, goats) in stock No. of animals bought / sold / died / slaughtered / sacrificed over the past 12 months Market value (price range for buying and selling livestock; GHC1) Distribution channels for cattle, sheep, and goats (MR*) (e.g. middlemen, butcher, fellow farmer, livestock trader, livestock fattener, etc.) Reasons for keeping livestock (Likert Scale) (e.g. meat, manure, cash, traction, etc.)
Crop production	Land holdings: size (hectares), no. of individual plots, land use purposes (e.g. (inter)crop, fodder, grazing, fallow, etc.) Types of crops produced (coded, MR*) Crop residue utilization (%) (E.g. mulch, fuel, feed, compost, sold, etc.) Marketing of crop residues (coded, MR*) (incl. types of crops marketed, distribution channels)
Grain legumes	Importance of and reasons for growing grain legumes (Likert Scale) (e.g. food, feed, seeds, cash, soil fertility, etc.)

MR * = Multiple response questions (i.e. respondents were allowed to choose out of multiple (coded) answers); other variables were coded but not multiple choice, or were open ended questions (e.g. price or numbers, names, etc.)
Currency: 1 GHC = 0.20 EUR

Table 4. Summary of questionnaire topics for livestock fatteners and traders and description of variables used

Questionnaire summary for livestock fatteners and traders	
(Interview) Location	Region, district, and community
Personal and business characteristics	Are you a fattener, trader or both? (coded) No. of years in business Name, gender (male/female), age Highest level of education (coded) Religion, marital status (coded)
Income sources and production costs	Income sources (%) (e.g. fattening and selling livestock, trading, crops, laboring/ service, formal employment, etc.) Annual expenditures related to livestock business (GHC1) (e.g. veterinary services, animal housing (maintenance), water, etc.) Utilization of own/family and/or hired labour Monthly costs of hired labour (GHC1)
Livestock production	No. of female/male animals (cattle, sheep, goats) currently in stock No. of female/male animals bought/ that died/ slaughtered/ sacrificed over the past 12 months Sources of animal stock (per animal species) (MR*) (e.g. breeding with own stock, farmers, open markets, etc.) Distribution channels used (per animal species) (MR*) (e.g. butcher, farmer, middleman) Fattening period (no. of months), duration of stay (no. of weeks) Price ranges for selling/buying female/male animals (GHC1) Factors affecting price variation (e.g. breed, health, age, season, etc.)(coded; MR*) Timing of livestock purchases and sales (months) (MR*)
Livestock markets	Name, location of livestock markets used (max. 4) (open ended; MR) Purpose of market visit (coded: buying, selling, both) Frequency of visits to livestock market (coded)
Challenges related to livestock production	Identification and ranking of main challenges related to livestock business (max. 6) (e.g. feed/water shortages, access to cash/credit, etc.)
Feed use and feed security	Main feeds used per animal species (coded; MR*) Main feeds purchased over the past 12 months (max. 4) (coded; MR*) Factors to consider in feed purchases (coded; MR*) (e.g. costs, nutritive value, ease of transportation, animal acceptance, etc.) Feed calendar: contribution of feed classes to ruminant feed security throughout the year (scale 0-10) (entered in Excel)

MR* = Multiple response questions (i.e. respondents were allowed to choose out of multiple (coded) answers); other variables were coded but not multiple choice, or were open ended questions (e.g. price or numbers, names, etc.)

Currency: 1 GHC = 0.20 EUR

Methodology

Preliminary analysis: selection and re-grouping of respondents

As shown in Table 2, some respondents appeared to be both livestock fattener and livestock trader, resulting in an additional group. However, due to the small sample size of the group of both fatteners and traders in the NR, it was decided to regroup these respondents based on the distribution of their income sources. Livestock trading comprised >60% of the total income among three out of four respondents, hence were re-classified as livestock traders. As crop sales comprised >60% of the total income of the fourth respondent, it was decided to remove this respondent from the sample population entirely. Similarly, among livestock traders in the NR, one trader had 80% of the income coming from crop sales hence was removed from the sample population. As such in total 5 groups remained for further analysis: fatteners in the NR (n=21); fatteners in the UER (n=24); traders in the NR (n=32); traders in the UER (n=8); both fatteners and traders in the UER (n=21).

Value chain mapping

Value chain mapping is a descriptive and/or analytical tool that is often used in the first stages of value chain research to provide a systemic overview of a value chain and to provide information on the current situation and context of a value chain from a holistic point of view (Herr and Muzira, 2009; Umberger W, 2014). Main aspects of value chain mapping include i.a. the characterization of value chain actors, identification and understanding chain actor relationships and interconnections as well as the identification of markets. Therefore, during this study, value chain mapping was used as a manual for how to perform a first inventory of a ruminant value chain. Characterization of value chain actors (Research objective 1) was done by using both qualitative and quantitative data concerning the socio-economic and livestock production characteristics of each of these actors (i.e. smallholder farmers, livestock fatteners, and livestock traders). Value chain relationships and connections to markets (Research objective 2) were identified by analyzing and visualizing qualitative data regarding e.g. source of livestock, the utilization of distribution channels, and locations of livestock markets and their subsequent market activity on each of these locations.

Computation of new variables

Livestock market utilization by livestock fatteners and traders

Livestock fatteners and traders were asked to indicate up to 4 different livestock markets they used as well as their subsequent market activity on each of these locations (i.e. buying, selling, or both buying and selling livestock). Due to the various numbers of livestock markets in the NR, UER, UWR (Upper West region) and in foreign countries, livestock markets of these regions/countries were combined and recoded into new variables in order to provide a clear overview of livestock market utilization and activities (i.e. local livestock markets in the NR; local livestock markets in the UER; local livestock markets in the UWR; and foreign livestock markets). Livestock markets in Accra, Kumasi, and Techiman remained unchanged. An overview of the different livestock markets in the NR, UER, and UWR can be found in the Appendix (Table A7). In order to get insight into the importance of specific livestock markets used in combination with the subsequent market activity, the utilization of a particular market was weighted in proportion to the total number of markets used by a fattener or trader. New variables in SPSS were computed which obtained new frequencies comprised of the extent of utilization of a particular market in combination with a particular market activity per respondent in proportion to the total number of markets used by an individual. Subsequently, these frequencies were multiplied with a weighing factor (use of 4 markets = 0.25; use of 3 markets = 0.33; use of 2 markets = 0.5; use of 1 market = 1) to obtain a systemic overview of livestock market utilization per group.

Calculating the average contribution of livestock feeds to ruminant feed security

To get insight into the average contribution of different feeds to annual ruminant feed security, livestock fatteners and traders were asked to score the contribution of each of these feed types on a scale 0-10 for each month (January-December, 2016). The average contribution of a feed type/month was calculated based on the average scores of all respondents from a group in a particular region, resulting in one feed security calendar per group per region. However, in some cases the feed security calendar contained errors (e.g. monthly contribution of different feeds did not add up to ten), and were therefore excluded from the calculation. As a result, not all bars in the final bar graph added up to a total of ten. Furthermore, the cumulative rainfall (mm/month) in each region was plotted on a secondary axis. Data on rainfall (2016) were retrieved from the National Climatic Data Center (NCDC) and were based on the precipitation measured (daily) in 2016 at two different meteorological stations in Ghana: Tamale (NR) and Navrongo (UER).

Transforming livestock holdings into Tropical livestock units (TLU)

To be able to describe and compare livestock holdings among smallholder farmers, the total number of livestock species kept (excl. Calves, lambs, kids, piglets, etc.) were transformed into a common unit: the Tropical livestock unit (TLU). The following formula was used to compute the total number of livestock species kept into tropical livestock units which were based on the global livestock units published by the FAO (1987) (1 TLU equalled an animal of 250 kg): $TLU_{farm} = TLU_{cattle} + TLU_{sheep} + TLU_{goat} + TLU_{pig} + TLU_{poultry} + TLU_{donkey/horse}$ for which the following conversion coefficients were used: $TLU_{cattle} = 0.7$; $TLU_{sheep} = 0.1$; $LU_{goat} = 0.1$; $TLU_{pig} = 0.2$; $TLU_{poultry} = 0.01$; $TLU_{donkey/horse} = 0.65$ (average of donkeys and horses was taken). In this study, the TLU/species was an average that was calculated based on the average number of livestock species kept per farmer keeping that species in proportion to the total population sampled in a region. Hence, the average TLU was calculated over all interviewed farmers in a region.

Data Analysis

Data was analysed using IBM SPSS statistics 24. Standard statistical procedures such as descriptive statistics were performed in order to describe quantitative data of the different populations sampled (i.e. mean, standard deviation and minima and maxima) (e.g. farm size, livestock holdings, livestock prices, income distribution, etc). Furthermore, to describe qualitative data (i.e. categorical variables such as levels of education, religion, marital status, gender, etc.) frequency tables were created. From multiple response questions multiple response sets were created in SPSS. Multiple response sets were analysed through frequency tables and cross-tabulations. Frequency tables of multiple response sets included both the percentage of responses (out of the total responses given, i.e. out of a total of 100%), as well as the percentage of respondents that "ticked" one or more different answers out of the given options. Consequently, the total percentage of respondents adds up to more than 100%. As the main interest was in describing groups or sample populations, the percentage of respondents was predominantly used to analyze and describe the data.

The chi-square test or Fischer's exact test (2x2 tables only) (and cross-tabulations) were used to test whether or not categorical variables were equally distributed among different groups (e.g. labour allocation, levels of education, religion, marital status). These tests could only be performed when the expected frequencies (count) for each cell were at least one, and when ≥80% of the cells had an expected cell count of at least 5. For non-parametric data (data were tested on normality of distributions using the Shapiro-Wilk test) and groups with unequal sample sizes (e.g. groups of fatteners and traders in the NR and UER; smallholder groups according to region and market activity) the Kruskal-Wallis test was used to test for differences in distributions of continuous variables between groups (e.g. age, business experience, income sources, livestock prices, fattening periods and length

of stay, TLU, farm size). Post-hoc multiple comparisons were performed using the Bonferroni correction, which adjusted the p-value as a way to correct for the possibility of finding significant differences between groups by chance. An independent sample T-test was used to test for differences in mean values between the two smallholder populations in the NR and the UER (e.g. age, no. of years in farming, sources of income, farm size, and TLU). In order to identify potential relationships between (continuous) variables as well as the strength of their association (e.g. between land holdings and livestock holdings) the non-parametric Spearman's correlation test was used. Main reason for choosing Spearman's correlation test was because of its lower sensitivity to outliers in a population.

Results

1. Socio-economic profiles of fatteners and traders in the Northern and Upper East region

1.1 Fatteners and traders in the Northern region

All fatteners (n=21) and traders (n=32) sampled in the NR were male, with an average age of 41 (± 9.0) and 47 (± 12.0) years respectively. While all traders and the majority of fatteners were Muslim, 10% of the fatteners were Christian (Table 5). Business experience in the NR ranged from 15 (± 9.2) years in livestock fattening up to 22 (± 11.0) years of experience in livestock trading (Table 5). Fatteners had significantly less business experience than the group of both fatteners and traders in the UER (24 ± 7.8) ($p < 0.05$) (Table 5). Experience in livestock trading did not significantly differ between groups. Most fatteners (71%) used own and/or family labour for their fattening business, whereas about one-third of the fatteners (also) made use of hired labour (Table 5). In livestock trading, about one-third made use of own/family labour, hired labour, or both hired and own/family labour. The majority of fatteners (85%) had some form of education, among which about one-third attained junior high, followed by senior high (24%), primary school (19%), and tertiary level (10%). Nearly 80% of the traders in this region on the other hand, did not have any form of education.

Fatteners had five different sources of income. Fattening and selling of livestock was the primary source of income followed by crop sales which comprised 67% and 11% of the total income respectively (Fig. 3; see Appendix Table A 4.1). In descending order, formal employment, labour/service and petty trading contributed with 9%, 7%, and 5% to the overall income of fatteners respectively (Fig. 3; see Appendix Table A 4.1). Traders had four activities that contributed to their income: trading of livestock, crop production, fattening and selling of livestock, and petty trading (Fig. 3; see Appendix Table A 4.2). The main source of income, livestock trading, comprised 84% of the total income followed by crop sales, which comprised 11% of the total income of traders in this region. Costs for hired labour comprised about 70% of the costs related to livestock fattening and 80% of the costs related to livestock trading in the NR, ranging between 1517 GHC (± 2400) for livestock fattening and 2775 GHC (± 3027) for livestock trading (Table 6a, 6b). Costs spent on hired labour by fatteners in the NR were significantly higher than costs spent on hired labour by fatteners in the UER (135 GHC ± 298.8) ($p < 0.05$) (Table 6a). Medication, veterinary services and maintenance/housing comprised less than 20% of the annual expenditures for livestock fatteners and traders in the NR (Table 6a, 6b).

Table 5. Socio-economic parameters of (both) fatteners and traders in the Northern region (NR) and Upper East region (UER)

	Fatteners NR (n=21)		Fatteners UER (n=24)		Traders NR (n=32)		Traders UER (n=8)		Both fattener/ trader UER (n=21)		P-value
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Age *(y)*	41	±9.0	42	±12.0	47	±12.0	43	±8.2	47	±12.0	0.190[1]
Business experience *(y)*	15[a]	±9.2	20[ab]	±10.6	22[ab]	±11.0	18[ab]	±5.2	24[b]	±7.8	0.006[1]
Labour allocation *(%)*	100		100		100		100		100		0.000[2]
Own/family labour	71		79		34		38		43		
Hired labour	10		-		34		-		-		
Both	19		21		31		63		57		
Education *(%)*	96		96		100		100		100		n.a*
None	14		58		78		63		62		
Primary	19		13		6		25		19		
Junior High	29		21		6		13		14		
Senior High	24		-		6		-		5		
Tertiary	10		4		3		-		-		
Marital Status *(%)*	21		24		100		88		100		n.a*
Single	2		1		-		-		5		
Married	18		23		100		88		95		
Divorced	1		-		-		-		-		
Religion *(%)*	100		100		100		88		100		n.a.*
Christian	10		-		-		-		-		
Muslim	90		100		100		88		100		

Continuous variables (i.e. age and no. of years in business) are represented by mean and standard deviation (SD);
Categorical variables (i.e. allocation of labour, educational levels, marital status, and religion) represented by % = percentage of respondents per group
p-value[1]: p-values based on non-parametric Kruskal Wallis test between all groups (categories); p-value[2]: p-values based on Chi-square test; chi-square test only performed if ≥ 80% of cells had expected cell count of ≥ 5 and individual expected count ≥ 1, otherwise n.a* (not available)

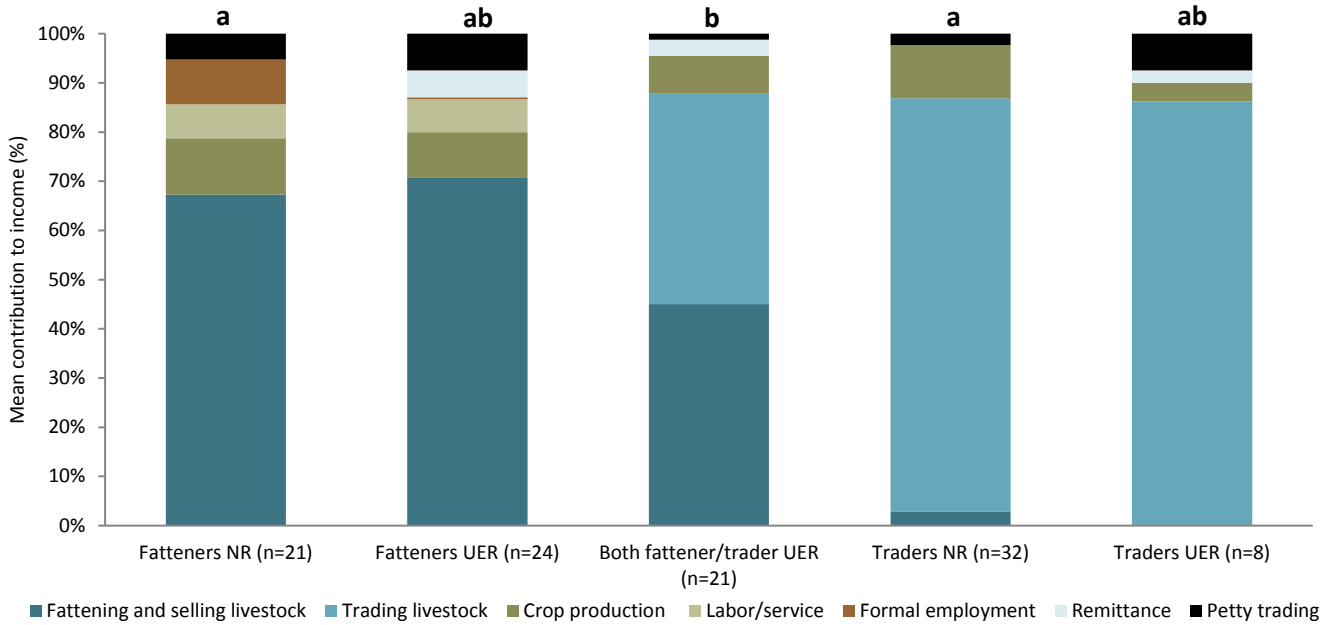

Figure 3. Average contribution (%) of seven different income sources to the total income of livestock fatteners and traders in the Northern region (NR) and Upper East region (UER); Superscripts indicate significant differences in mean contribution of an income source between groups based on a (non)parametric Kruskal Wallis test

1.2 (Both) fatteners and traders in the Upper East region

All fatteners (n=24), traders (n=8), and both fatteners and traders (n=21) in the UER were male, Muslim and married with an average age of 42 (± 12.0), 43 (± 8.2) and 47 (± 12.0) years respectively (Table 5). Business experience in the UER ranged from 18 (± 5.2) years in livestock trading, 20 (± 10.6) years in livestock fattening, up to 24 (± 7.8) years in both livestock fattening and trading (Table 5). The majority of fatteners (79%) used own and/or family labour for fattening their livestock, whereas the majority of traders (63%), and both livestock fatteners and traders (57%) used both own/family and hired labour in their business (Table 5). On average, 60% of the respondents in the UER did not have any form of education. Highest levels of education attained in this region were primary level (19%) or junior high (16%) (Table 5).

Fatteners had five different sources of income. Fattening and selling of livestock was the primary source of income and comprised 71% of the total income (Fig. 3; see Appendix Table A 4.1). Other income source were crop production, petty trading, labour/service and remittances, which comprised 9%, 7.5%, 7%, and 5% of the total income of fatteners in this region respectively (Fig. 3; see Appendix Table A 4.1). Traders from this region had four different income sources among which livestock trading was the primary source of income and comprised 86% of the total income. In descending order, petty trading, crop production and remittances comprised 7.5%, 4%, and 2.5% of the total income respectively (see Appendix Table A 4.2). Both fatteners and traders had five different activities that contributed to their income among which were mainly the fattening and selling of livestock (45%), and livestock trading (43%) (Fig. 3; see Appendix Table A 4.1). Other income sources were crop production (7.6%), remittances (3.3%), and petty trading (1.2%) (Fig. 3; see Appendix Table A 4.1).

Annual costs for hired labour comprised about two-third of the costs related to livestock trading (1500 GHC ± 2078) and both livestock trading and fattening in the UER (1452 GHC ± 1637), whereas for fatteners this was about 10% (135 GHC ± 298.8) (Table 6a, 6b). Fatteners spent most on medication (522 GHC ± 316.8), which comprised about 40% of the production related costs (Table 6a). Costs spent on medication by livestock traders in the UER (546 GHC ± 689) were significantly higher than costs spent on medication by traders in the NR (233 GHC ± 279) ($p<0.05$) (Table 6b). Fatteners spent on average more on veterinary services (252 GHC ± 640) and maintenance/housing (312 GHC ± 636), whereas traders spent the least on these activities (83 GHC ± 79; 140 GHC ± 247 resp.) (Table 6a, 6b).

Table 6. Average costs per year (GHC) for activities related to livestock fattening and trading for (both) fatteners (a) and traders (b) in the Northern region (NR) and Upper East region (UER)

a)	Fatteners NR (n=21)		Fatteners UER (n=24)		Both fattener/trader UER (n=20)		P-value[1]
	Mean	SD	Mean	SD	Mean	SD	
Hired labour	1517[ab]	±3400	135[a]	±298.8	1452[b]	±1637	**0.013**
Medication	314	±263.6	522	±316.8	447	±375.0	0.082
Veterinary services	152	±135.2	252	±640.0	141	±162.7	0.689
Maintenance/Housing	137	±124.7	312	±636.0	246	±324.0	0.901
Total	2120	-	1221	-	2286	-	

b)	Traders NR (n=30)		Traders UER (n=8)		Both fattener/trader UER (n=20)		P-value[1]
	Mean	SD	Mean	SD	Mean	SD	
Hired labour	2775	±3027	1500	±2078	1452	±1637	0.135
Medication	233[a]	±279.0	546[ab]	±689.0	447[b]	±375.0	**0.049**
Veterinary services	232	±540.0	83	±79.00	141	±162.7	0.641
Maintenance/Housing	171	±325.4	140	±247	246	±324.0	0.194
Total	3411	-	2269	-	2286	-	

P-values based on non-parametric Kruskal Wallis test between groups of fatteners, and between groups of traders

*** Currency: 1 GHC= 0.20 EUR**

2. Livestock fattening and trading in northern Ghana

2.1 Livestock fattening in the Northern and Upper East region

2.1.1 Fatteners in the Northern region (n=21)

The majority of fatteners in the NR fattened sheep (81%), followed by cattle (76%) and to a lesser extent goats (24%) (Table 7). Fatteners from the NR mainly fattened a combination of (at least) two different animal species. About half of the respondents combined the fattening of cattle and sheep, while only one respondent combined the fattening of sheep and goats. Few cases were reported where respondents combined the fattening of cattle, sheep, and goats (14%). Furthermore, a small portion of the fatteners fattened only cattle (14%) or sheep (14%) or goats (5%).

Table 7. Ruminant species fattened in the Northern region (NR) and Upper East region (UER)

	Fatteners NR (n=21)	Fatteners UER (n=24)	Both fattener/trader UER (F)[3] (n=21)
%			
Cattle	76	96	95
Sheep	81	25	38
Goats	24	17	10

F[3]: refers specifically to the fattening business of the group of both fatteners and traders in the Upper East region

Current cattle stock of fatteners in the NR consisted of 27 animals (± 33.6) (incl. males and females). Over the past twelve months fatteners on average bought five cattle (± 7.05), whereas they sold four (± 4.6). One animal was lost (± 0.89) due to premature death or slaughter, or for other purposes such as religious or cultural events (e.g. sacrifices). Fattening periods of cattle in the NR differed between male and female cattle. Female cattle were fattened for an average period of 50 months (3-120 months), whereas male cattle were fattened for on average 30 months (9-72 months) (Table 8). Fattening periods of both female and male cattle were significantly longer compared to fattening periods of cattle recorded among fatteners in the UER (4-6 months) ($p<0.05$) (Table 8). Cattle fatteners from the NR (n=16) mainly purchased cattle from livestock markets (n=9), whereas about one third purchased cattle from farmers (Table 9). Twenty five percent of the fatteners (also) had cattle with Fulani herdsmen. Main distribution channels used for selling cattle were butchers (n=14) or directly to consumers (n=6) (Table 9).

Current sheep stock comprised of 20 animals (± 20.2). Over the past twelve months, fatteners on average bought 6.5 sheep (± 11.2), whereas nine sheep were sold (± 9.4). Six animals were lost (± 9.8) due to premature deaths or slaughter or for other purposes such as religious or cultural events (e.g. sacrifices). Fattening periods of sheep differed between male and female sheep (Table 8). Female sheep were fattened for on average 29 months (3-72), whereas male sheep were fattened for an average period of fourteen months (6-36) (Table 8). Fattening periods of female sheep were significantly longer than fattening periods recorded among sheep fatteners in the UER (7-14) ($p < 0.05$) (Table 8). Fattening periods of male sheep did not significantly differ between groups. Sheep fatteners (n=17) purchased sheep mainly at livestock markets (n=12) or used their own animals for breeding (n=7)

(Table 9). Sheep fatteners used two main distribution channels: sheep were mainly sold to butchers (n=11) or directly to consumers (n=10). Furthermore, to a lesser extent sheep were sold to farmers (n=3), middlemen (n=3) or were used for sacrifices (n=1) (Table 9).

Table 8. Average fattening period of cattle, sheep and goats (male and female; no. of months) by fatteners in the Northern region (NR) and Upper East region (UER)

	Fatteners NR (n=21)			Fatteners UER (n=24)			Both fattener/trader UER (F) (n=21)			P-value*
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	
Cattle										
male	9	72	30[a]	3	24	6[b]	2	12	4[b]	p=0.000
female	3	120	50[a]	2	24	8[b]	3	12	4[b]	p=0.000
Sheep										
male	6	36	14	5	48	14	2	12	7	p=0.209
female	3	72	29[a]	5	48	14[b]	2	12	7[b]	p=0.033
Goats										
male	6	12	10	3	48	22	2	8	5	p=0.254
female	12	60	24	3	48	22	2	7	5	p=0.164

***p-value: based on non-parametric Kruskal Wallis test**

Current goat stock of fatteners consisted of thirteen animals (± 12.8). Over the past twelve months, fatteners on average bought three goats (± 5.8), whereas six goats were sold (± 5.9). Six goats were lost (± 5.4) due to premature deaths or slaughter or for other purposes such as religious or cultural events (e.g. sacrifices). Fattening periods of goats differed between male and female animals (Table 8). Female goats were fattened for on average 24 months (12-60), whereas male goats were fattened for an average period of ten months (6-12) (Table 8). Average fattening periods of goats did not significantly differ between groups. Goats fatteners (n=4) mainly bred with animals from own stock (n=3) or purchased goats from farmers (n=2) or livestock markets (n=2) (Table 9). Goat fatteners used two main distribution channels: goats were mainly sold directly to consumers (n=4) and to butchers (n=4) (Table 9).

Table 9. Source(s) of livestock and distribution channel(s) used by fatteners in the Northern region (NR) and Upper East region (UER)

	Fatteners NR (n=21)			Fatteners UER (n=24)			Both fattener/trader UER[2] (F)[3] (n=21)		
	Cattle (n=15)	Sheep (n=17)	Goats (n=5)	Cattle (n=23)	Sheep (n=6)	Goats (n=4)	Cattle (n=20)	Sheep (n=8)	Goats (n=2)
1. Source(s) of livestock *(n)*									
Breeding with own stock	1	7	3	7	4	2	7	5	1
Stock kept with Fulani herdsmen	4	2	-	3	-	1	3	-	-
Bought from farmers	5	3	2	1	-	1	-	-	-
Bought at markets	9	12	2	17	3	1	13	5	1
Other sources	-	-	-	-	-	-	-	-	-
Total no. of responses[4]	19	24	7	28	7	5	23	10	2
2. Distribution channel(s) *(n)*									
Consumers	6	10	4	12	1	1	8	3	-
Farmers	2	3	1	2	1	-	3	1	-
Middlemen	1	3	2	22	6	4	18	7	2
Butchers	14	11	4	7	-	-	8	2	1
Others	-	1 *(sacrifice)*	-	-	-	-	-	-	-
Total no. of responses[4]	23	28	11	43	8	5	37	13	3

(F) [3]: refers to the fattening business of the group of both fatteners and traders in the UER

Total no. of responses[4] > total no. of individuals fattening a particular animal species (i.e. >100%) due to multiple responses given for both sections (source of livestock and distribution channels).

Main challenges related to the livestock fattening business in the NR were a lack of cash (86%) and pests and diseases (57%) (Table 10). About two-fifth of the fatteners had issues with feed shortages (43%) whereas about one-third were challenged by water shortages (29%) (Table 10). Other challenges related to livestock fattening included health risks associated with the free ranging of animals in urban areas, and adaptation problems of livestock after transportation (14%).

Table 10. Challenges related to livestock to livestock fattening and/or trading in the Northern region (NR) and Upper East region (UER)

	Fatteners NR (n=21)	Fatteners UER (n=24)	Both fattener/trader UER (n=21)
Challenges *(%)*[1]			
Feed shortages	43	50	43
Water shortages	29	46	57
Pests and diseases	57	33	38
No/limited access to credit	24	21	38
Lack of cash	86	96	86
Animal housing	14	33	24
No/limited access to vet services	19	38	38
Other(s)	14	-	-

Percentages (%)[1]: represent the % of respondents within a group; total % > total number of individuals within a group (>100%) due to multiple responses given per individual

2.1.2 Fatteners in the Upper East region (n=24)

Nearly all fatteners in the UER primarily fattened cattle (96%), whereas a smaller portion of the fatteners fattened sheep (25%) or goats (17%) (Table 7). Two-third only fattened cattle, whereas one respondent only fattened sheep. A small portion of fatteners combined the fattening of cattle and sheep (13%), cattle and goats (13%), or cattle, sheep, and goats (8%).

Current cattle stock of fatteners in the UER comprised of nine animals (± 12.6). Over the past twelve months, fatteners on average bought eleven cattle (± 14.3), whereas six cattle were sold (± 6.7). One animal was lost (± 2.1) due to premature death or slaughter, or for other purposes such as religious or cultural events (e.g. sacrifices). Average fattening periods of male and female cattle in the UER were more or less similar: males were fattened for on average six months (3-24), while females were fattened for eight months (2-24) (Table 8). The average fattening period of male and female cattle was significantly shorter than male and female fattening periods in the NR ($p < 0.05$) (Table 8). Cattle fatteners (n=23) mainly purchased cattle at livestock markets (n=17), whereas about one-third of the fatteners also practiced breeding with their own animals (n=7) (Table 9). Cattle fatteners mainly used two distribution channels: cattle were sold to middlemen (n=22) and directly to consumers (n=7). In addition, about one-third of the fatteners also sold to butchers (Table 9).

Current sheep stock consisted of nineteen animals (± 18.5). Over the past twelve months, sheep fatteners on average bought ten sheep (± 16.0), whereas twelve sheep were sold (± 15.0). Six sheep were lost (± 8.0) due to premature deaths or slaughter or for other purposes such as religious or cultural events (e.g. sacrifice). Male and female sheep in the UER were fattened for an average period of fourteen months (5-48) (Table 8). Fattening periods of female sheep in the UER region were significantly shorter than the average fattening period of female sheep in the NR (29 months) ($p < 0.05$) (Table 8).Sheep fatteners (n= 6) purchased sheep at livestock markets (n=3) or practiced breeding with their own animals (n=4) (Table 9). All sheep fatteners sold to middlemen whereas some also sold directly to consumers or farmers (n=1) (Table 9).

Current goat stock consisted of eighteen animals (± 17.8). Over the past twelve months, fatteners on average bought six goats (± 4.8), whereas four goats were sold (± 4.6). Four animals were lost (± 2.6) due to premature deaths or slaughter or for other religious or cultural events (e.g. sacrifice). Male and female goats in the UER were fattened for on average 22 months (3-48) (Table 8). Average fattening periods of goats did not significantly differ between groups. Goat fatteners in the UER (n=4) mainly practiced breeding with their own stock (n=2) (Table 9). All goat fatteners sold their animals to middlemen (n=4), whereas one case sold directly to consumers (Table 9).

Main challenges related to the fattening business in the UER (n=24) were a lack of cash (96%), whereas about half of the fatteners were challenged by feed shortages, and water shortages (Table 10). Two-fifth of the fatteners had issues with limited access to veterinary services (Table 10).

2.1.3 Both fatteners and traders in the Upper East region (n=21)

The following results of the group of both fatteners and traders specifically refer to the ruminants meant for fattening (the trading component is discussed in 2.2.3). Nearly all respondents from this group fattened cattle (95%), whereas a smaller portion also

fattened sheep (38%) or goats (10%) (Table 7). The majority fattened only cattle (62%), whereas 24% combined the fattening of cattle and sheep. Ten percent combined the fattening of sheep and goats, whereas one respondent only fattened sheep.

Current cattle stock meant for fattening consisted of nine animals (± 6.5). Over the past twelve months, (both) fatteners on average bought ten animals (± 8.2), whereas seven cattle were sold (± 6.2). One animal was lost (± 1.2) due to premature death or slaughter or for other purposes such as religious and cultural events (e.g. sacrifice). Male and female cattle were fattened for an average period of four months (male: 2-12; female: 3-12) (Table 8). Average fattening periods of male and female cattle were significantly shorter than fattening periods recorded in the NR ($p < 0.05$) (Table 8). Respondents from this group who fattened cattle (n=20) mainly purchased cattle at livestock markets (n=13) or practiced breeding with their own stock (n=7) (Table 9). A small portion of these respondents also kept their cattle with Fulani herdsmen (n=7). Fattened cattle were sold through four different distribution channels among which: middlemen (n=18), butchers (n=8), directly to consumers (n=8), and to a smaller extent to farmers (n=3) (Table 9).

Current sheep stock meant for fattening consisted of fifteen animals (±9.9). Over the past twelve months (both) fatteners on average bought sixteen sheep (± 28.5), whereas fifteen sheep were sold (± 26.5). Two sheep were lost due to premature death or slaughter or for other purposes such as religious or cultural events (e.g. sacrifice). Male and female sheep were fattened for an average period of seven months (2-12) (Table 8). Fattening periods of female sheep were significantly shorter than fattening periods for female sheep recorded in the NR ($p < 0.05$) (Table 8). Respondents from this group who fattened sheep (n=8) bought their animals at livestock markets (n=5) and practised breeding with their own stock (n=5) (Table 9). Fatteners mainly sold their sheep to middlemen (n=7), and to a lesser extent also directly to consumers (n=3), to butchers (n=2), and farmers (n=1) (Table 9).

Current goat stock meant for fattening consisted of ten animals (± 7.1). Over the past twelve months, goat fatteners on average bought 4.5 animals (± 2.1), whereas 3.5 goats were sold (± 3.5). One and half goats were lost due to premature deaths or slaughter or for other purposes such as religious or cultural events (e.g. sacrifice). Male and female goats were fattened for an average period of five months (male 2-8; female 2-7) (Table 8). Fattening periods of goats did not significantly differ between groups. Respondents who fattened goats (n=2) either purchased at livestock markets (n=1) or practised breeding with their own stock (n=1) (Table 9). Furthermore, all fattened goats were sold to middlemen (n=2), whereas one fattener also sold to butchers (Table 9).

Main challenges related to livestock production by the group of both livestock fatteners and traders in the UER were a lack of cash (86%) and water shortages (57%) (Table 10). About two-fifth of both fatteners and traders were challenged by feed shortages (43%), pests and diseases (38%), and no/limited access to credit and veterinary services (38%) (Table 10).

2.2 Livestock trading in the Northern and Upper East region

2.2.1 Traders in the Northern Region (n=32)

The majority of traders traded in sheep (72%), whereas half of the respondents traded in cattle or goats (Table 11). Part of the traders combined the trading of multiple ruminant species among which sheep and goats (28%), or cattle, sheep, and goats (19%). Twenty-five percent of the traders only traded in cattle, while 22% only traded in sheep. The remainder of traders combined cattle and sheep trading (3%) or cattle and goat trading (3%).

Table 11. Ruminant species traded in the Northern region (NR) and Upper East region (UER) (n)

	Traders NR (n=32)	**Traders UER** (n=8)	**Both fattener/trader UER (T)[3]** (n=21)
(%)			
Cattle	50	63	81
Sheep	72	63	33
Goats	50	13	5

T[3]: refers specifically to the trading business of the group of both fatteners and traders in the Upper East region

Current cattle stock of traders from the NR comprised of six animals (± 8.4). Over the past twelve months, traders on average bought 188 cattle (± 358.0), whereas 204 animals were sold (± 352.8). Three animals were lost (± 4.1) due to premature deaths or slaughter or for other purposes such as religious or cultural events (e.g. sacrifices). Traders from the NR kept cattle (female and male) for an average of period of two weeks (1-4), which was similar to other groups of traders in the UER (2.5 weeks) (Table 12). Cattle traders (n=16) mainly purchased cattle from farmers (n=13) or at livestock markets (n=13) (Table 13). All cattle traders sold to butchers (n=16), whereas the majority of traders (n=14) also sold directly to consumers. Furthermore, half of the cattle traders sold cattle to farmers (n=8) or, to a lesser extent, to middlemen (n=4) (Table 13).

Current sheep stock of traders comprised of ten animals (± 10.4). Over the past twelve months, traders on average bought 126 sheep (± 106.8), whereas 120 sheep were sold (± 90.4). Seven sheep were lost (± 7.7) due to premature deaths or slaughter or for

other purposes such as religious or cultural events (e.g. sacrifices). Traders kept sheep (male and female) for an average of period of three weeks (1-8) (Table 12). A non-parametric Kruskal Wallis showed a significant difference in average length of stay of sheep between groups of (both) traders (male sheep p=0.013; female sheep p= 0.022) (Table 12). However, the post-hoc test that performed multiple comparisons did not show between which groups the average length of stay was significantly different (p-value after Bonferroni correction > 0.05). All sheep traders (n=23) bought at livestock markets, whereas about half of the traders also purchased sheep from farmers (n=11) (Table 13). Furthermore, sheep traders made use of three main distribution channels: nearly all traders sold sheep directly to consumers (n=22), while the majority also sold to farmers (n=17), and butchers (n=16) (Table 13).

Table 12. Average length of stay of cattle, sheep and goats (male and female; no. of weeks) with traders in the Northern region (NR) and Upper East region (UER)

	Traders NR (n=32)			**Traders UER** (n=8)			**Both fattener/trader UER (T)*** (n=21)			**P-value***
	Min.	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**	**Min.**	**Max**	**Mean**	
Cattle										
male	1	4	2	1	3.5	2.5	0.5	12	2.5	p=0.539
female	1	4	2	1	3.5	2.5	0.5	12	2.5	p=0.580
Sheep										
male	1	8	3	0.5	3	1.5	0.5	3	2	p=0.013*
female	1	8	3	0.5	3	1.5	0.5	3	2	p=0.022*
Goats										
male	1	8	3	1	1	1	1	1	1	p=0.115
female	1	8	3	1	1	1	1	1	1	p=0.115

***p-value: based on non-parametric Kruskal Wallis test; p-value post-hoc test (Multiple comparisons with Bonferroni correction) was > 0.05;**
(T)*: refers to the trading business from the group of both fatteners and traders in the Upper East region

Current goat stock consisted of seven goats (± 9.8). Over the past twelve months traders on average bought 88 goats (± 79.9), whereas 87 goats were sold (± 70.1). Five goats were lost (± 9.7) due to premature deaths or slaughter or for other purposes such as religious or cultural events (e.g. sacrifices). Similar to sheep, goats (male and female) in the NR stayed for an average period of three weeks (1-8) with traders, which was similar to other groups of trader in the UER (Table 12). Most traders bought goats at livestock markets (n=14) and from farmers (n=11) (Table 13). Goat traders made use of three main distribution channels: traders sold goats directly to consumers (n=14), to butchers (n=13), and to farmers (n=10) (Table 13).

Main challenges related to the trading business in the NR were a lack of cash (72%), feed shortages (47%), and pests and diseases (44%) (Table 14). In addition, about two-fifth of the traders indicated to have other specific challenges such as a lack of means of own transportation for livestock to and from livestock markets (n=6), instability of the market (demands) (n=3), and (governmental) corruption (n=2) (Table 14).

Table 13. Source(s) of livestock and distribution channels used by traders in the Northern region (NR) and Upper East region (UER)

	Traders NR (n=32)			Traders UER (n=8)			Both fattener/trader UER (T)[3] (n=21)		
	Cattle (n=16)	Sheep (n=23)	Goats (n=16)	Cattle (n=5)	Sheep (n=5)	Goats (n=1)	Cattle (n=17)	Sheep (n=7)	Goats (n=1)
1.Source(s) of livestock *(n)*									
Breeding with own stock	-	1	-	-	-	-	5	-	-
Stock kept with Fulani herdsmen	2	-	-	-	-	-	-	-	-
Bought from farmers	13	11	11	-	-	-	-	-	-
Bought at markets	13	23	14	5	5	1	14	7	1
Other sources	-	-	-	-	-	-	-	-	-
Total no. of responses[4]	28	35	25	5	5	1	19	7	1
2.Distribution channel(s) *(n)*									
Consumers	14	22	14	4	4	1	8	4	-
Farmers	8	17	10	2	2	-	4	1	-
Middlemen	4	4	4	5	4	1	17	6	1
Butchers	16	16	13	4	3	1	8	4	-
Others	-	-	-	-	-	-	-	1 *(NGO's)*	-
Total no. of responses[4]	38	59	41	15	11	3	37	16	1

(T) [3]: refers to the trading business from the group of both fatteners and traders in the UER

Total no. of responses[4] > total no. of individuals trading a particular animal species (i.e. >100%) due multiple responses given for both sections (source of livestock and distribution channels)

Table 14. Challenges related to livestock trading in the Northern region (NR) and Upper East region (UER)

	Traders NR (n=32)	Traders UER (n=8)	Both fattener/trader UER* (n=21)
Challenges *(%)[1]*			
Feed shortages	47	63	43
Water shortages	31	60	57
Pests and diseases	44	13	38
No/limited access to credit	25	25	38
Lack of cash	72	100	86
Animal housing	22	13	24
No/limited access to vet services	9	50	38
Other(s)	44	-	-

Percentages (%) [1]: represent the % of respondents within a group; total % > total number of individuals within a group (>100%) due to multiple responses given per individual

*** Challenges of the group of both fatteners and traders are similar to those presented in table 10**

2.2.2 Traders in the Upper East region (n=8)

The majority of respondents from this group traded in cattle (63%), and sheep (63%), and to a lesser extent in goats (13%) (Table 11). Most traders only traded in cattle (38%), whereas 25% traded only in sheep, or combined the trading of cattle and sheep. One respondent combined the trading of sheep and goats.

Current cattle stock of traders from this region consisted of fourteen animals (± 8.4). Over the past twelve months traders on average bought 85 cattle (± 63.3), whereas 81 animals were sold (± 64.7). One animal was lost (± 1.3) due to premature death or slaughter or for other purposes such as religious or cultural events (e.g. sacrifices). Traders kept cattle (female and male) for an average period of 2.5 weeks (1-3.5), which was similar to other groups of traders in the NR and UER (2-2.5) (Table 12). All cattle traders (n=5) purchased their animals only at livestock markets, whereas they made use of multiple distribution channels among which: middlemen (n=5), consumers (n=4), and butchers (n=4), and to a lesser extent, farmers (n=2) (Table 13).

Current sheep stock consisted of ten animals (± 5.7). Over the past twelve months traders on average bought 49 sheep (± 37.8), whereas 47 sheep were sold (± 33.6). Two sheep were lost (± 2.2) due to premature deaths or slaughter or for other purposes such as religious or cultural events (e.g. sacrifices). Traders kept sheep (male and female) for an average period of 1.5 week (0.5-3) (Table 12). Similar to cattle, all sheep traders (n=5) purchased sheep only at livestock markets, whereas they mainly sold to middlemen (n=4), consumers (n=4), butchers (n=3), and farmers (n=2) (Table 13).

Current goats stock consisted of seven animals (of one trader). Over the past twelve months the trader bought 70 goats, and sold 70 goats. One goat was lost due to premature death or slaughter or for other purposes such as religious or cultural events (e.g. sacrifices) The single goat trader in this region kept goats (male and female) for on average one week, which was similar to other groups of goat traders in the NR and UER (1-3 weeks) (Table 12). The trader purchased goats at livestock markets (n=1) and subsequently sold to consumers (n=1), to middlemen (n=1), and to butchers (n=1) (Table 13).

A lack of cash was the main challenge for all traders (n=8) in the UER (Table 14). About 60% of traders also had issues with feed and water shortages, while half of the traders had no or limited access to veterinary services (Table 14).

2.2.3 Both fatteners and traders in the Upper East region (n=21)

The following results of the group of both fatteners and traders in the UER specifically refer to the ruminants meant for trading. Most traders from this group traded in cattle (81%) followed by sheep (33%), and to a small extent in goats (5%) (Table 11). Two-third of the respondents only traded in cattle, while about 20% only traded in sheep. Only few traders combined the fattening of multiple ruminant species (cattle and sheep 10%; cattle, sheep, and goats 5%).

Current cattle stock meant for trading consisted of seven animals (± 4.9). Over the past twelve months, respondents from this group on average bought 57 animals (± 94.2), whereas 60 cattle were sold (± 96.7). Two animals were lost (± 2.9) due to premature deaths or slaughter or for other purposes such at religious or cultural events (e.g. sacrifice). Cattle traders kept cattle for an average period of 2.5 weeks (0.5-12), which was similar to other groups of traders in the NR and UER (2-2.5) (Table 12). Respondents from this group who traded in cattle (n=17) mainly purchased their animals at livestock markets (n=14), while a small part of the traders (also) practised breeding with their own stock (n=5) (Table 13). All cattle traders from this (both) group (n=17) sold their cattle to middlemen, while about half of the traders sold to consumers and butchers (n=8) (Table 13).

Current sheep stock meant for trading consisted of nineteen animals (± 24). Over the past twelve months, sheep traders on average bought 347 sheep (± 761.6), whereas 339 sheep were sold (± 735.8). Eight sheep were lost (± 11.1) due to premature deaths or slaughter or for other purposes such as religious or cultural events (e.g. sacrifice). Traders from this group kept sheep (female and male) for an average period of 2 weeks (0.5-3) (Table 12). All traders from this (both) group purchased sheep only at livestock markets (n=7), whereas they made use of multiple distribution channels among which: middlemen (n=6), consumers (n=4), and butchers (n=4) (Table 13). Only one respondent indicated to sell to farmers or to NGO's (non- governmental organisations) (Table 13).

Challenges related to livestock trading were similar those challenges discussed in section 2.1.3 (Both fattener and trader: *fattening*) (see Table 10 and Table 14).

2.3 Seasonality of livestock fattening and trading in the Northern and Upper East region

2.3.1 Livestock fattening

Based on Figure 4 (A-C) a trend can be observed in which the total number of fatteners that purchased male cattle (in 2016) in the NR and the UER increased between the months of February-April (i.e. late dry season), with peak purchases observed in March. The total number of fatteners in the NR that purchased male cattle also increased between September and October. Based on Figure 5 (A-C), a similar trend in timing of sheep purchases (February-April) could only be observed among livestock fatteners in the NR, with peak purchases occurring in February. Price ranges for male cattle and male sheep among fatteners in both regions (especially in the UER) did not show any coherent pattern and fluctuated throughout the year (especially cattle in the UER: and sheep in the NR and UER). Average prices at which fatteners in the NR purchased male cattle were significantly lower (823-1130 GHC) than in the UER (1474- 1869 GHC) ($p < 0.05$) (see Appendix Table A3.1) A higher variation in average buying prices of male sheep could be observed among fatteners in the NR (540-771 GHC) than in the UER (447-553 GHC). However, buying prices for male sheep were not significantly different between groups of fatteners in the two regions (see Appendix Table A3.1)

Similarly, based on Figure 4 (D-F) and Figure 5 (D-F) a trend can be observed in which the total number of fatteners that sold male cattle and male sheep (in 2016) in the NR and the UER increased around September (i.e. Eid-al-Adha, which is the Muslim sacrificial feast) and December (i.e. Christmas). While average selling prices for male sheep in the UER increased during this period (Fig. 5, E, and F), this was not the case in the NR, where selling prices dropped between August-December compared to average selling prices during the rest of the year (Fig. 5, D). Overall, average prices at which fatteners sold male cattle were not significantly different: in the NR selling prices ranged between 2133-3147 GHC, while in the UER selling prices of male cattle ranged between 2082- 2762 GHC (see Appendix Table A3.2). Selling prices of male sheep observed in the NR selling prices were higher (980-1344 GHC) compared to the UER (681-872 GHC), but not significantly different (see Appendix Table A3.2). The average prices at which the group of both fatteners and traders sold their fattening animals (incl. cattle and sheep) varied more compared to the other group of fatteners in the UER (Fig 4 E and F, Fig. 5 E and F).

2.3.2 Livestock trading

No trends in ruminant purchases or sales were observed among groups of livestock traders in the NR and UER, as they purchased and sold animals throughout the year. Average buying prices for male cattle in the NR ranged between 1169-2575 GHC and were significantly higher compared to groups of traders in the UER, where average buying prices ranged between at least 733-1088 GHC and at most 1058-1315 GHC ($p<0.05$) (see Appendix Table A 3.3). Maximum prices at which traders in the NR sold male cattle were significantly higher (2897 GHC) than in the UER (1704 GHC) ($p<0.05$) (see Appendix Table A 3.4). Average buying prices for male sheep in the NR ranged between 332-533 GHC and were significantly higher than in the UER, were average buying prices for male sheep ranged between 272-340 GHC ($p<0.05$) (see Appendix Table A 3.3). Similarly, average selling prices for male sheep in the NR were significantly higher (1377-2897 GHC) compared to selling prices in the UER (1164-1704 GHC) (see Appendix Table 3.4)

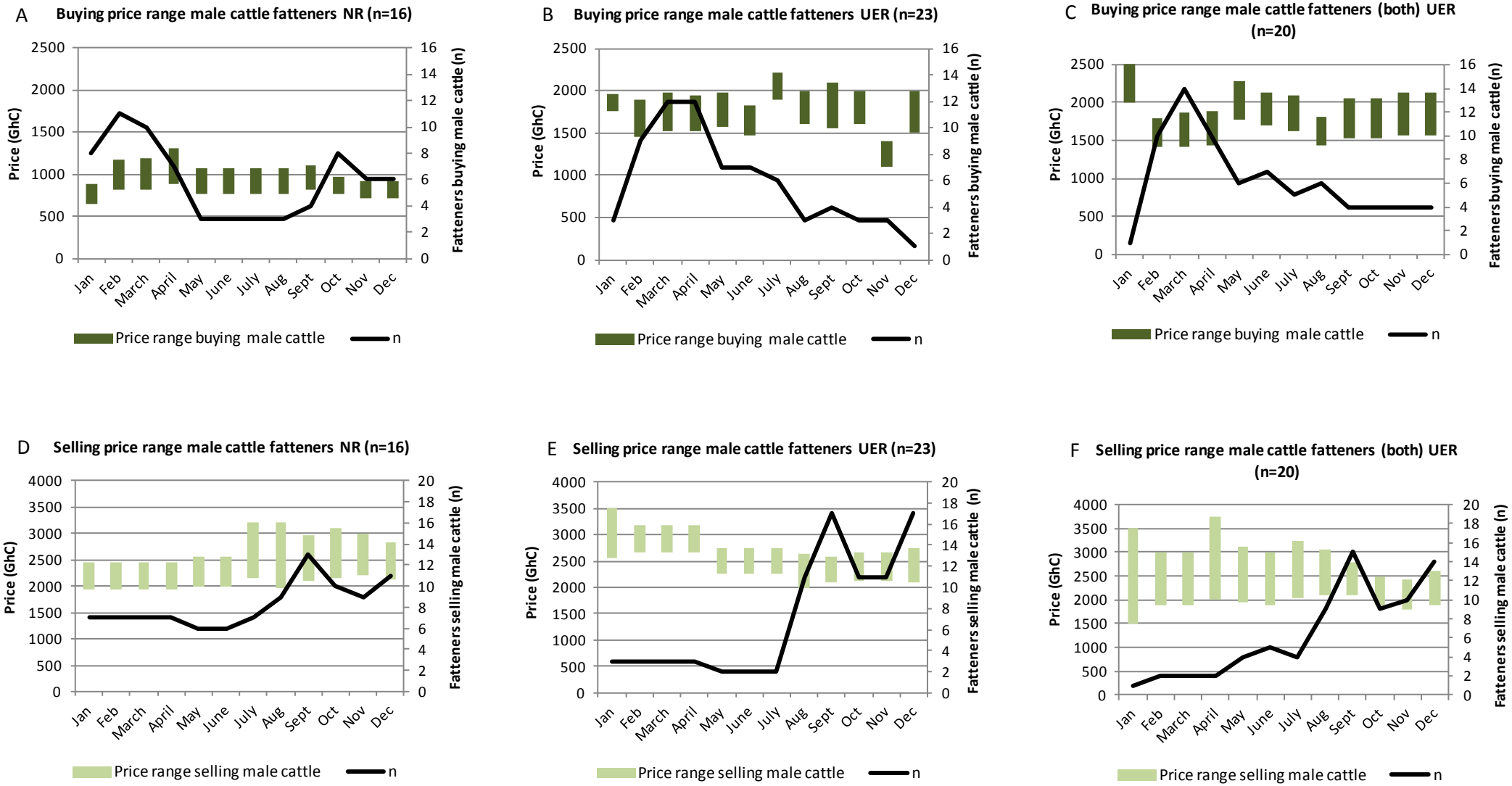

Figure 4 (A-F)

(A-C) Average buying price range of male cattle per month (GHC) (2016) among (both) livestock fatteners in the Northern region (NR) and Upper East region (UER) and number of fatteners that purchased male cattle per month (n) (2016); (D-F) Average selling price range of male cattle per month (GHC) (2016) among (both) livestock fatteners in the Northern region (NR) and Upper East region (UER) and number of fatteners that purchased male cattle per month (n) (2016). Currency: 1 GHC = 0.20 EUR

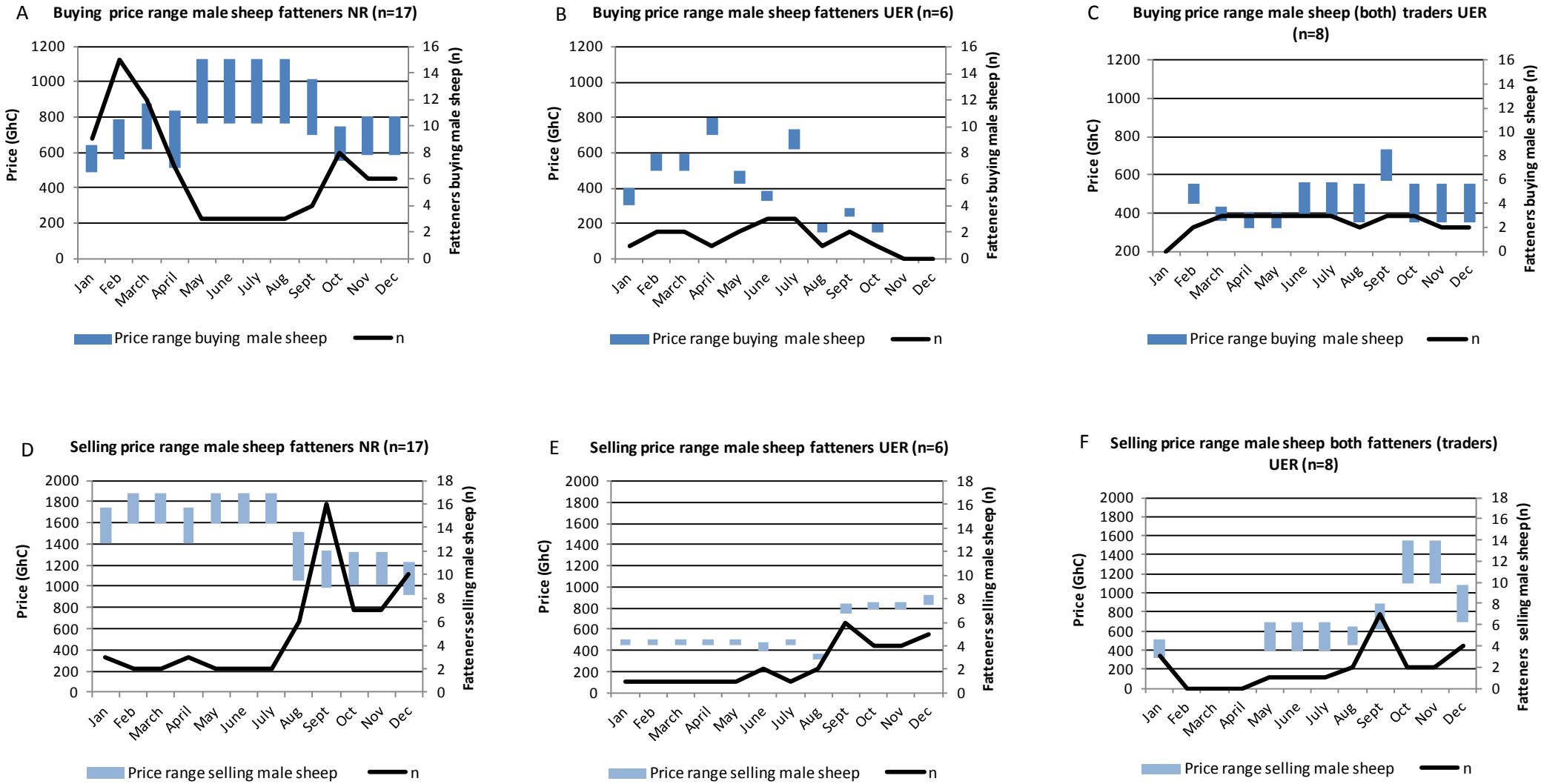

Figure 5 (A-F)

(A-C) Average buying price range of male sheep per month (GHC) (2016) among (both) livestock fatteners in the Northern region (NR) and Upper East region (UER) and number of fatteners that purchased male sheep per month (n) (2016); (D-F) Average selling price range of male sheep per month (GHC) (2016) among (both) livestock fatteners in the Northern region (NR) and Upper East region (UER) and number of fatteners that purchased male sheep per month (n) (2016). Currency: 1 GHC = 0.20 EUR

2.4 Other factors affecting buying and selling prices of livestock

2.4.1 Factors affecting buying and selling prices of livestock in the Northern region

According to livestock fatteners and traders in the NR, main factors that influenced both buying and selling prices of cattle, sheep, and goats were breed, size, and health status of the animal (Table 15a; Table 15b.). Livestock fatteners from this region considered breed the most influential factor of both buying (92%), and selling prices (89%), followed by size (71% and 63% resp.), and health status (73% and 63% resp.) (Table 15a; Table 15b.). Livestock traders considered health status the most influential factor of both buying (91%) and selling (91%) prices of all livestock, followed by breed (78%), and size (74% and 75% resp.) (Table 15a; Table 15b). A larger portion of livestock traders also considered age as a factor affecting buying (43%) and selling (46%) prices of livestock, whereas this was not the case for livestock fatteners in this region.

2.4.2 Factors affecting buying and selling prices of livestock in the Upper East region

In the UER, factors affecting buying and selling prices of livestock varied according to group, and according to the animal species fattened and/or traded (Table 15a.; Table 15b.). For cattle fatteners, main factors affecting the buying price were: size (96%), age (64%), and cattle breed (59%), whereas selling prices were mainly affected by size (100%), season (74%), and breed (52%) (Table 15a). Buying and selling prices of fattened sheep (n=6) were mainly affected by size (83% and 100% respectively), breed (67%), and health condition (50%) (Table 15a). According to half of the sheep fatteners, selling prices of sheep were affected by the season. Furthermore, buying prices of fattened goats (n=3) were mainly influenced by size (100%), age (67%) and to a lesser extent by health condition (33%) (Table 15a). Selling prices were mainly affected by size (100%) and season (67%). Buying and selling prices of traded cattle were predominantly affected by size, breed, age (buying), and season (selling) (Table 15b). All sheep traders considered size the most important factor affecting both buying and selling prices. While breed and age were more important for determining buying prices of traded sheep (60%), health condition and season were more important factors affecting selling prices of sheep (60%).

Both fatteners and traders

Buying and selling prices of fattening/fattened cattle, sheep, and goat were mainly affected by breed (97%), size (94%), and health status of the animal (59%) (Table 15a). In addition, season was an important factor affecting the selling price of cattle (60%). According to more than half of the respondents from this group, colour was an important factor affecting the buying and selling prices of sheep (57%) meant for fattening (Table 15a). Buying prices of traded cattle, sheep, and goats were mainly affected by size and breed (Table 15b). Furthermore, health status was an important factor affecting the buying price of cattle (59%), whereas age was an important factor affecting the buying prices of sheep (43%) and goats (100%) (Table 15b). Size was the main factor affecting the selling prices when trading cattle (88%), and sheep (86%) (and goats) (Table 15b). Health status (65%) and season (59%) were more important for cattle selling prices, whereas breed and age were more important for sheep (57%) and goat selling prices (100%) (Table 15b).

Table 15. Factors affecting buying and selling prices of livestock according to fatteners (a) and traders (b) in the Northern region (NR) and Upper East region (UER)

a)	Fatteners NR (n=21)			Fatteners UER (n=24)			Both fattener/trader UER (F)[2] (n=21)		
	Cattle (n=15)	**Sheep** (n=17)	**Goats** (n=4)	**Cattle** (n=22)	**Sheep** (n=6)	**Goats** (n=3)	**Cattle** (n=20)	**Sheep** (n=7)	**Goats** (n=2)
1. Buying price *(%)*									
breed	87	88	100	59	67	-	90	100	100
age	7	6	-	64	33	67	45	14	50
size	80	82	50	96	83	100	95	86	100
health	73	71	75	50	50	33	70	57	50
season	27	35	-	14	-	-	-	-	-
colour	7	24	50	18	33	-	30	57	50
	Cattle (n=14)	**Sheep** (n=17)	**Goats** (n=5)	**Cattle** (n=23)	**Sheep** (n=6)	**Goats** (n=3)	**Cattle** (n=20)	**Sheep** (n=7)	**Goats** (n=2)
2. Selling price *(%)*									
breed	86	82	100	52	67	33	55	57	50
age	-	6	-	26	33	33	35	14	-
size	71	77	40	100	100	100	90	86	100
health	64	65	60	44	50	33	55	43	-
season	21	35	40	74	50	67	60	29	50
colour	29	29	60	17	33	-	30	57	50

Percentages (%)[1]: represent the % of cases within a group; sum of percentages per group per section (buying/selling) >100% due to multiple responses given per individual

F[2]: refers to the fattening business of the group of both fatteners and traders in the Upper East region

Table 15. Factors affecting buying and selling prices of livestock according to fatteners (a) and traders (b) in the Northern region (NR) and Upper East region (UER)

b)	Traders NR (n=32)			Traders UER (n=8)			Both fattener/trader UER (T)[2] (n=21)		
	Cattle (n=16)	**Sheep** (n=23)	**Goats** (n=16)	**Cattle** (n=5)	**Sheep** (n=5)	**Goats** (n=1)	**Cattle** (n=17)	**Sheep** (n=7)	**Goats** (n=1)
1. Buying price *(%)*									
breed	75	78	81	67	60	-	59	71	100
age	44	35	50	83	60	-	53	43	100
size	81	61	81	100	100	100	94	86	200*
health	88	91	94	50	60	-	59	29	100
season	38	35	50	-	-	-	12	-	-
colour	6	9	6	-	-	-	18	14	-
	Cattle (n=15)	**Sheep** (n=23)	**Goats** (n=16)	**Cattle** (n=5)	**Sheep** (n=5)	**Goats** (n=1)	**Cattle** (n=17)	**Sheep** (n=7)	**Goats** (n=1)
2. Selling price *(%)*									
breed	80	74	81	67	20	-	47	57	100
age	53	35	50	50	20	-	53	57	100
size	80	65	81	100	100	100	88	86	200*
health	87	91	94	50	60	-	65	29	100
season	27	35	50	83	60	-	59	43	100
colour	7	9	6	-	-	-	18	14	-

Percentages (%)[1]: represent the % of cases within a group; sum of percentages per group per section (buying/selling) >100% due to multiple responses given per individual

T[2]: refers to the trading business from the group of both fatteners and traders in the Upper East region

2.5 Utilization of livestock markets by fatteners and traders in the Northern region

2.5.1 Fatteners in the Northern region

Most of the fatteners from the NR (76%) made use of livestock markets to buy and/or sell their livestock (Table 16). Fatteners, who did not attend any livestock market, were all cattle and sheep fatteners (except for one, who fattened goats), and sold only to butchers or from their homesteads. Fatteners from this region made use of two different livestock markets: local markets in the NR (n=14) or local markets in the UER (n=8) (Table 16), while about one-third made use of markets in both regions (n=6). None of these fatteners used local livestock markets in the UWR (Upper West region). Livestock fatteners in the NR only made use of local livestock markets in the UER to buy livestock (29%), especially small ruminants (Fig. 6; Table 16). Local markets in the NR were most prominently used to buy (35%), to both sell and buy (25%), or specifically to sell cattle, sheep, and goats (11%) (Fig. 6). Cattle fatteners either made use of local markets in the NR (n=11) or of livestock markets in the UER (n=5) (Table 16). The majority of sheep fatteners made use of local livestock markets in the NR (n=11), whereas about half of the sheep fatteners made use of livestock markets in both regions (n=6) (Table 16). Seventy-five percent of the goat fatteners used either livestock markets in the NR or in the UER, whereas half of the goat fatteners made use of both regional markets (n=2). Livestock markets in the NR were attended most frequently (weekly, quarterly, or on an annual basis), whereas local livestock markets in the UER were often attended on a quarterly or annual basis.

2.5.2 Traders in the Northern Region

All traders from the NR (n=32) made use of livestock markets to buy and/or sell their livestock (Table 17). Overall, these traders made use of 5 different livestock markets: local livestock markets in the NR (n=32), local livestock markets in the UER (n=13), markets in Accra (n=9), Kumasi (n=8), and to a small extent, foreign livestock markets (n=1) (Table 17). None of these traders used livestock markets in the UWR. The traders who went to livestock markets in Kumasi, all went to Accra (n=8) (Table 17). The one trader who went to foreign markets also went to livestock markets in the UER. On the other hand, none of the traders who went to livestock markets in the UER went to Accra or Kumasi. Livestock markets in the NR were most prominently used, whereby all cattle, sheep, and goat traders bought and sold (24%), bought (24%), or specifically sold their animals (15%) (Fig, 7; Table 17). Especially small ruminant traders used livestock markets in the UER (21%), and to a small extent, foreign livestock markets (1%) to buy animals (Fig 7; Table 17). Mainly cattle traders made most use of southern livestock markets (i.e. Accra and Kumasi), specifically to sell animals (5% to Kumasi; 6% to Accra) (Fig. 7, Table 17). Generally, traders made use of these markets on a weekly basis, or every two weeks.

2.6 Utilization of livestock markets by fatteners and traders in the Upper East region

2.6.1 Fatteners in the Upper East region

Nearly all respondents from this group (n=22) used livestock markets to buy and/or sell their animals (Table 16). Those who did not attend livestock markets, were cattle (and sheep) fatteners, and indicated to only sell to butchers and middlemen. Fatteners made use of 5 different livestock markets: local livestock markets in the UER (n=22), livestock markets in Accra (n=17), livestock markets in Kumasi (n=9), foreign livestock markets (n=8), and to a smaller extent livestock markets in Techiman (n= 3) (Table 16). None of these fatteners made use of livestock markets in the NR or in the UWR. The majority of fatteners who went to markets in Kumasi (n=9), also went to Accra (n=8). Two-third of the fatteners who went to markets in Techiman, also went to livestock markets in Kumasi and Accra. The majority of fatteners who went to foreign markets (n=8) also made use of southern livestock markets (incl. Accra (n=6); and Kumasi (n=7)). All cattle (n=21), sheep (n=5) and goats (n=4) fatteners used local livestock markets in the UER mainly to both buy and sell (33%), and to a lesser extent to only buy (10%) or only sell their animals (2%) (Fig. 6; Table 16). Southern livestock markets, including Accra, Kumasi, and Techiman were mainly used to sell cattle, represented by 29%, 9%, and 5% of the fatteners respectively (Fig. 6; Table 16). Foreign livestock markets were mainly used to buy animals (11%), especially cattle (Fig. 6; Table 16). Fatteners visited local livestock markets in the UER as well as foreign livestock markets mainly on a weekly basis and to a lesser extent quarterly or on a biannual basis. Southern livestock markets were also used on a weekly or monthly basis and to a smaller extent quarterly or biannually.

Table 16. Livestock markets used by fatteners (per animal species fattened) in the Northern region (NR) and Upper East region (UER)

	Fatteners NR (n=21)				**Fatteners UER** (n=24)				**Both fattener and trader UER (F)*** (n=21)			
1. Use of livestock markets (n)												
Yes	16				22				21			
No	5				2				-			
*2.Livestock markets used (n)**	**n**	**Cattle** (n=16)	**Sheep** (n=13)	**Goats** (n=4)	**n**	**Cattle** (n=21)	**Sheep** (n=5)	**Goats** (n=4)	**n**	**Cattle** (n=20)	**Sheep** (n=8)	**Goats** (n=2)
Local livestock markets NR[1]	14	11	11	3	-	-	-	-	-	-	-	-
Local livestock markets UER[2]	8	5	8	3	22	21	5	4	21	20	8	2
Local livestock markets UWR[3]	-	-	-	-	-	-	-	-	-	-	-	-
Livestock markets Accra [4]	-	-	-	-	17	16	3	2	13	13	4	-
Livestock markets Kumasi [5]	-	-	-	-	9	9	1	1	12	12	4	1
Livestock markets Techiman[6]	-	-	-	-	3	3	-	-	4	4	-	-
Foreign livestock markets [7]	-	-	-	-	8	8	2	2	8	8	3	1

n*: represents the number of respondents making use of a particular market (subdivided into markets used according to animal species)

(F)* refers specifically to livestock markets used to buy animals meant for fattening and/or to sell fattened animals

[1]NR: Northern Region: includes 22 different markets (see Appendix Table A7 for markets/locations)

[2]UER: Upper East Region: includes 3 different markets (see Appendix Table A7 for markets/locations)

[3]UWR: Upper West Region (see Appendix Table A7 for markets/ locations)

[4]Accra: located in Greater Accra Region

[5]Kumasi: located in Ashanti Region

[6]Techiman: located in Brong-Ahafo Region

[7]Foreign markets: e.g. Burkina Faso, Niger, Togo, etc

Table 17. Livestock markets used by traders (per animal species traded) in the Northern region (NR) and Upper East region (UER)

	Traders NR (n=32)				**Traders UER** (n=8)				**Both fattener and trader UER(T)*** (n=21)			
1.Use of livestock markets (n)												
Yes	32				8				21			
*2. Livestock markets used (n)**	**n**	**Cattle** (n=16)	**Sheep** (n=23)	**Goats** (n=16)	**n**	**Cattle** (n=5)	**Sheep** (n=5)	**Goats** (n=1)	**n**	**Cattle** (n=17)	**Sheep** (n=7)	**Goats** (n=1)
Local livestock markets NR[1]	32	16	23	16	-	-	-	-	-	-	-	-
Local livestock markets UER[2]	13	1	13	8	8	5	5	1	21	17	7	1
Local livestock markets UWR[3]	-	-	-	-	-	-	-	-	-	-	-	-
Livestock markets Accra [4]	9	9	2	2	4	3	1	-	13	10	5	-
Livestock markets Kumasi [5]	8	8	2	2	4	2	2	1	12	9	4	-
Livestock markets Techiman[6]	-	-	-	-	2	2	-	-	4	3	1	-
Foreign livestock markets [7]	1	-	1	1	2	1	1	-	8	6	2	-

n*: represents the number of respondents making use of a particular market (subdivided into markets used according to animal species)

(T)* refers specifically to livestock markets used to buy and/or sell animals meant for trading

[1]NR: Northern Region: includes 22 different markets (see Appendix Table A7 for markets/locations)

[2]UER: Upper East Region: includes 3 different markets (see Appendix Table A7 for markets/locations)

[3]UWR: Upper West Region (see Appendix Table A7 for markets/ locations)

[4]Accra: located in Greater Accra Region

[5]Kumasi: located in Ashanti Region

[6]Techiman: located in Brong-Ahafo Region

[7]Foreign markets: e.g. Burkina Faso, Niger, Togo, etc

2.6.2 Traders in the Upper East region

All traders from the UER (n=8) made use of livestock markets to buy and/or sell their animals (Table 17). Traders from this region made use of 5 different livestock markets: local livestock markets in the UER (n=8), livestock markets in Accra (n=4), livestock markets in Kumasi (n=4), livestock markets in Techiman (n=2), and foreign livestock markets (n=2) (Table 17). None of these traders used livestock markets in the NR or in the UWR. Most traders who made use of livestock markets in Kumasi (n=3) also went to Accra, and all traders who went to Techiman (n=2), went to both Kumasi and Accra. All cattle (n=5), sheep (n=5), and goat (n=1) traders mostly used local livestock markets in the UER to buy and sell their animals (57%) (Fig. 7; Table 17). Traders went to markets in Accra, Kumasi, and Techiman only to sell animals, represented by 14%, 16%, and 6% of the traders respectively (Fig. 7). At these markets mainly cattle was sold (Table 17). Foreign livestock markets were used to a limited extent for buying or selling livestock (cattle and sheep) (Fig. 7; Table 17). Most of the local and southern markets were attended on a weekly basis, and to a lesser extent on a monthly basis.

2.6.3 Both fatteners and traders in the Upper East region

All respondents from the group of both fatteners and traders (n=21) used livestock markets to buy and/or sell their animals (Table 16, Table 17). Both components (fattening and trading) made use 5 different livestock markets: local livestock markets in the UER (n=21), livestock markets in Accra (n=13), livestock markets in Kumasi (n=12), foreign livestock markets (n=8), and to a lesser extent livestock markets in Techiman (n=4) (Table 16; Table 17). None of the respondents from this group used livestock markets in the NR or in the UWR. The majority of respondents, who went to Kumasi (n=12), also went to Accra (n=9), whereas all who went to Techiman (n=4) went to Kumasi and Accra. Most respondents who used foreign livestock markets (n=8), also went to Accra (n=6) and Kumasi (n=5). All cattle, sheep, and goat fatteners as well as traders used local livestock markets in the UER, mainly to buy and sell (36%), or to buy animals (11%) (Fig 8; Table 16; Table 17). Southern livestock markets (incl. Accra, Kumasi, and Techiman) were solely used to sell animals (19%; 16%; 5% resp.), especially fattened cattle (Table 16; Table 17; Fig. 8). Sheep were more often traded at southern livestock markets (i.e. Accra and Kumasi) than fattened sheep were sold/bought at these locations (Table 16; Table 17). Foreign livestock markets were especially used to buy (10%) and to a limited extent to both buy and sell (2%) (Fig.8). These markets were mainly used to buy and sell cattle (for fattening and trading purposes) (Table 16; Table 17). The frequency of visits to either of these livestock markets was highly various. Most markets were visited on a weekly or monthly basis.

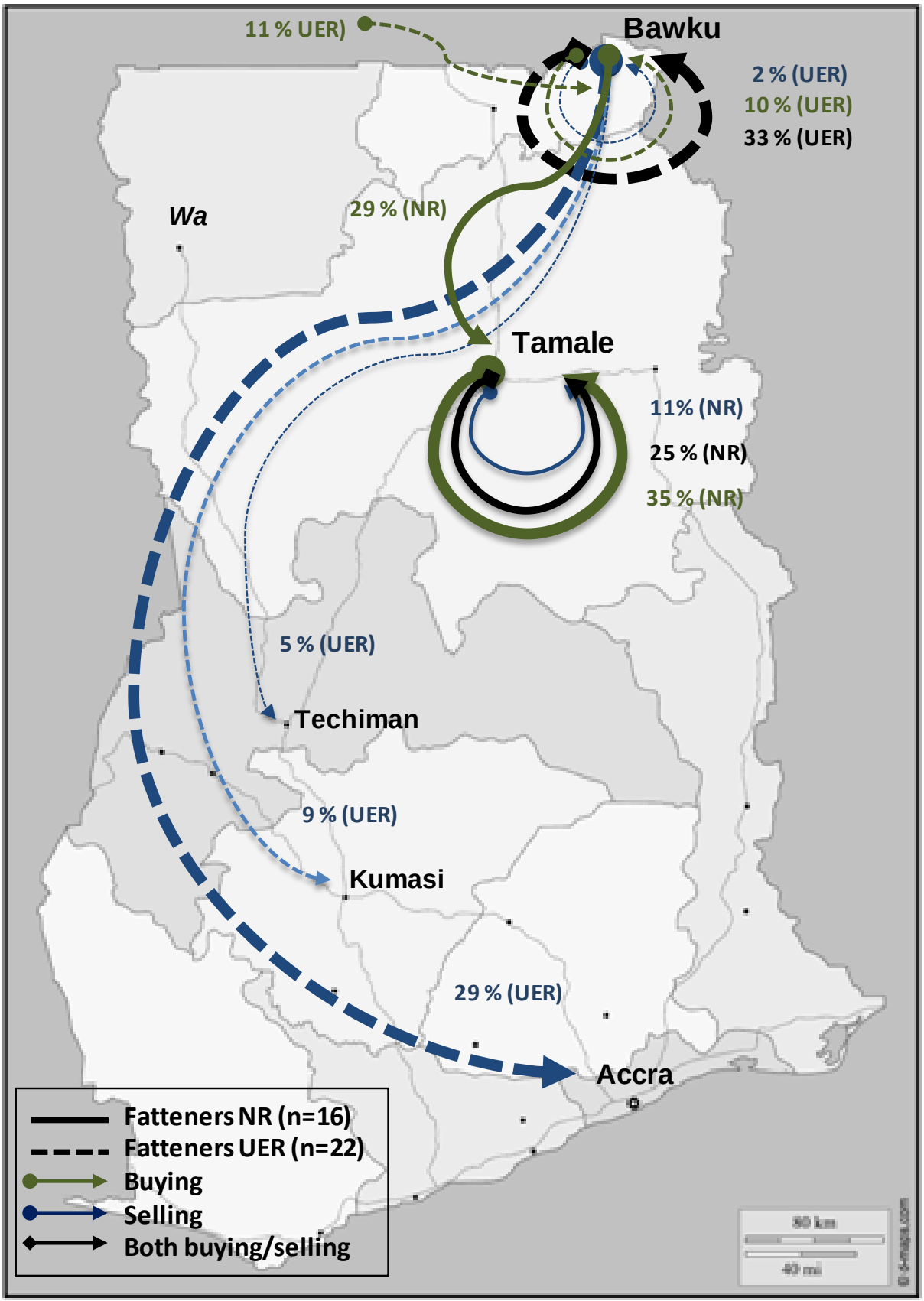

Figure 6. Livestock market utilization and subsequent market activity by livestock fatteners from the Northern region (NR) and the Upper East region (UER) (%).

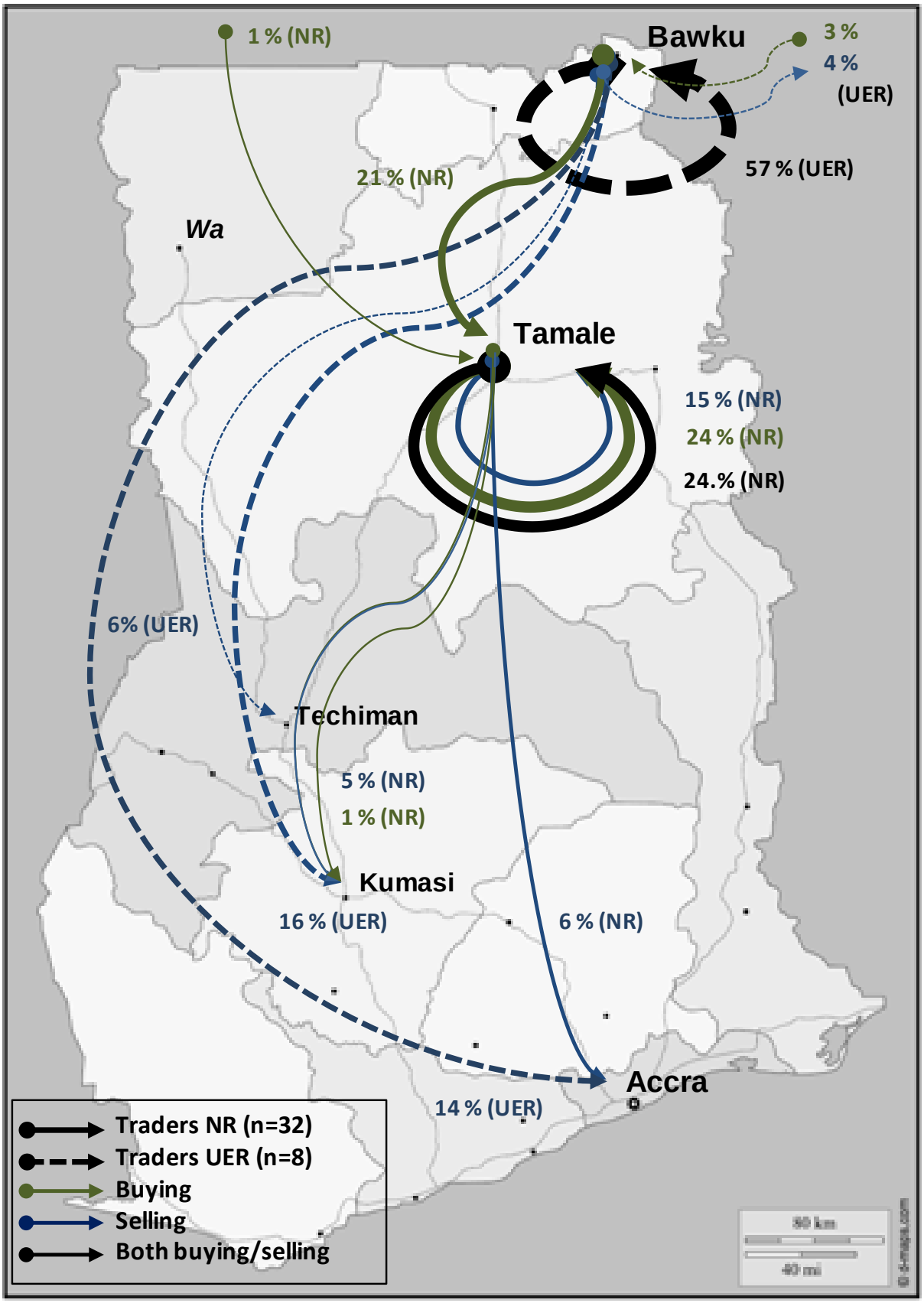

Figure 7 Livestock market utilization and subsequent market activity by livestock traders from the Northern region (NR) and the Upper East region (UER) (%).

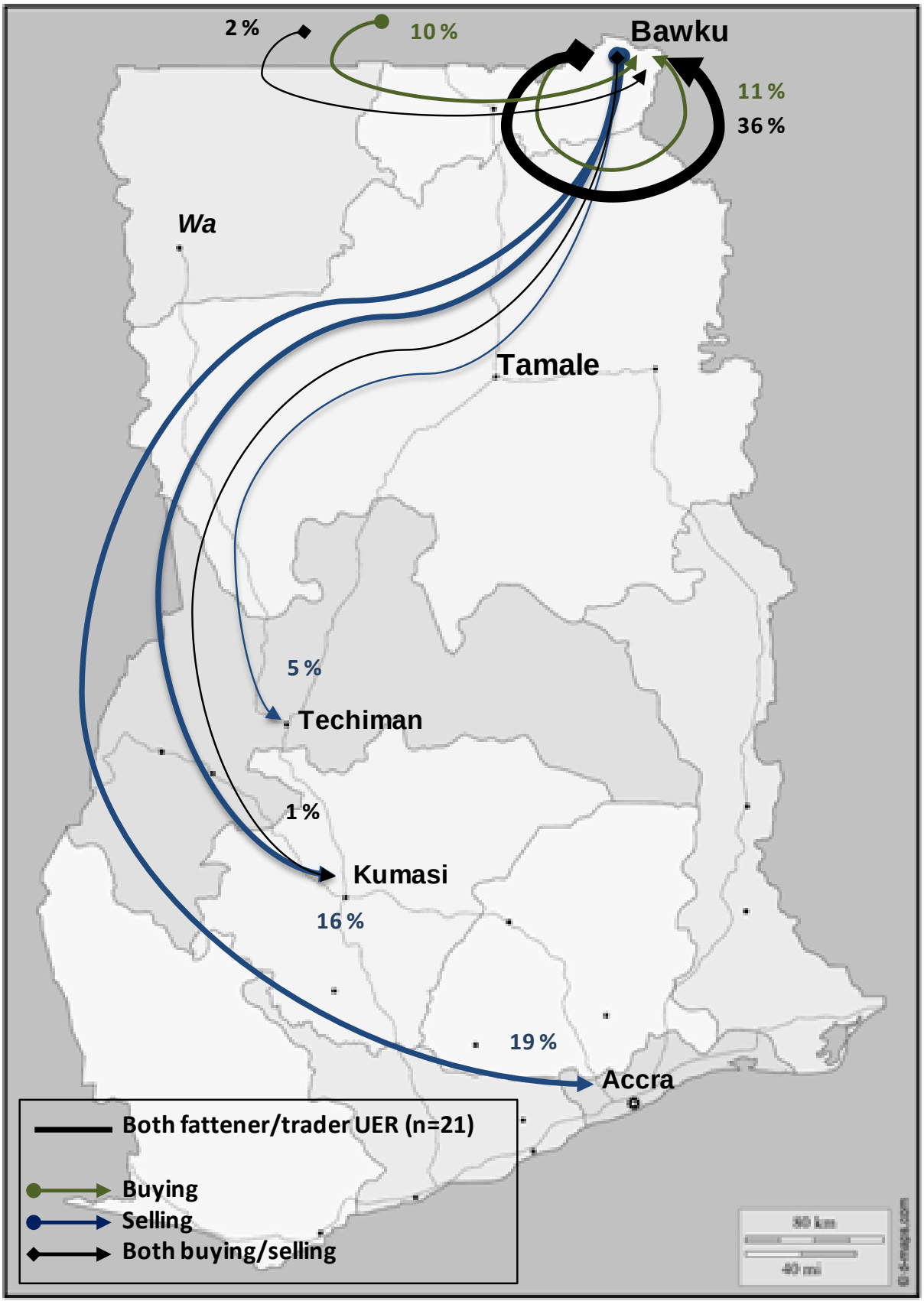

Figure 8. Livestock market utilization and subsequent market activity by both livestock fatteners and traders from the Northern region (NR) and the Upper East region (UER) (%).

3. Livestock feed use and feed security in Northern Ghana

3.1 Livestock feeds purchased and grain legume residue utilization in the Northern region

Almost all fatteners (n=21) and traders (n=32) from the NR used grain legume residues as a livestock feed resource (88%) (Table 19). Fatteners and traders mainly purchased groundnut residues (81%), and to a lesser extent pigeon pea (38%) residues and cowpea residues (34%) (Table 20), in particular for feeding small ruminants (sheep especially) (Table 21; Table 22). When livestock fatteners and traders purchased grain legumes residues in the NR, two main factors were considered: animal acceptance (93% of the responses) and nutritional value (86% of the responses) (Table 18). Storability was also considered, represented by 34% of the given responses. Both groups of livestock keepers in the NR practiced grazing, especially those working with cattle (44% of cattle fatteners; 88% of cattle traders) (Table 21; Table 22). Additionally, it appeared that fatteners and traders from the NR, whom did not make use of any grain legume residues, always included grazing in their animals' diet. Overall, the extent to which and the variation of cereal grain residues used was relatively small for both groups in this region (3-50%) (Table 20). Main cereal grain residues purchased and/or used were rice straw and maize stalks (Table 20). Throughout, industrial by-products were the second most frequently purchased livestock feed resource by fatteners and traders in the NR (77%) (Table 20).

Table 18. Factors considered at the purchase of grain legume residues by fatteners and traders in the Northern region (NR) and Upper East region (UER)

	NR[1] (n=81)*	UER[2] (n=94)*
Factors *(%)*		
Costs	-	14
Nutritional value	86	93
Animal acceptance	93	66
Ease of transportation	-	30
Storability	34	32
Not molded	4	10

NR[1]: includes fatteners and traders; UER[2]: includes fatteners, traders and both fattener and trader;
n*: no. of responses given per region

3.1.1 Fatteners in the Northern Region

The majority of fatteners (67%) purchased at least two different types of grain legume residues (Table 19), among which groundnut residues (81%) and pigeon pea residues (48%) (Table 20). About one-third of the fatteners only used one type of grain legume residues (Table 19). The majority of cattle (56%), sheep (88%), and goat (80%) fatteners used groundnut residues as a feed resource (Table 21). Pigeon pea residues were mostly used to feed sheep (47%) and goats (60%) rather than cattle (25%) (Table 21). Fatteners from this region mainly bought their grain legume residues from farmers (81%) and/or middlemen (71%). Two cases were reported where grain legume residues were purchased from industrial companies (i.e. soybean and groundnut residues). Next to mainly groundnut residues, industrial by-products were one of the four main feeds purchased by fatteners from this region (76%), followed by cassava and/or yam peels (62%) (Table 20), of which all were mainly fed to small ruminants (sheep in particular) (Table 20; Table 21). Generally, goat fatteners used fewer feeds (5 feeds) as compared to feeds used for fattening cattle and sheep (9 feeds) (Table 21).

Table 19. Extent of utilization of grain legume residues as a livestock feed resource by fatteners and/or traders in the Northern region (NR) and Upper East region (UER)

	Fatteners NR (n=21)	Fatteners UER (n=24)	Traders NR (n=32)	Traders UER (n=8)	Both fatteners/traders UER (n=21)
GLRs used as livestock feed (*%***)**					
None	4.8	-	18.8	12.5	4.8
1 type of GLR	28.6	37.5	15.6	12.5	28.6
2 types of GLRs	66.7	50	65.6	37.5	57.1
3 types of GLRs	-	12.5	-	37.5	9.5
4 types of GLRs	-	-	-	-	-

3.1.2 Traders in the Northern Region

Most traders (66%) used two different types of grain legume residues to feed their animals (Table 19). The traders that did not purchase any grain legume residues (20%) (Table 19), all applied grazing. On the other hand, the traders who did purchase grain legume residues, all purchased groundnut residues (81%) (Table 20). Moreover, cowpea residues and pigeon pea residues were purchased by 38% and 28% of the traders respectively (Table 20). Overall, traders from the NR mainly used grain legume residues to feed small ruminants (Table 22).Traders bought grain legume residues mainly from middlemen (81%), while about two-fifth of the traders (also) bought their grain legume residues from farmers. Next to groundnut residues, industrial by-products (78%), and rice straw (50%) were among the four main feeds purchased by this group (Table 20). Industrial by-products were mainly used by traders to feed their sheep (100%) and/or goats (94%), while only 13% of the traders used these by-products to feed their cattle (Table 22). Instead of grazing, bundles of grass were purchased by 22% of the traders to feed small ruminants (Table 20; Table 22).

3.2 Livestock feeds purchased and grain legume residue utilization in the Upper East region

Nearly all (both) fatteners and traders in the UER used (up to three different types of) grain legume residues to feed their animals (94%) (Table 19). Fatteners and traders mainly purchased cowpea residues (90%), and to a lesser extent groundnut (48%) and soybean residues (47%) (Table 20). While cowpea residues were used to feed all ruminant species, soybean residues were more used to feed cattle, whereas groundnut residues were more used to feed sheep (and goats) (Table 21; Table 22). Overall, all groups in the UER used more various feed types for feeding cattle than for feeding small ruminants (Table 21; Table 22). When (both) fatteners and traders from the UER purchased grain legume residues, two main factors were considered: nutritional value (93% of total responses) and animal acceptance (66% of total responses) (Table 18). Other factors considered were: storability (32%), ease of transportation (30%), and costs (14%) (Table 18). Besides grain legume residues, industrial by-products were the second most frequently purchased feed (76%) (Table 20). Next to maize stalks (25-42%) and rice straw (25-38%), (both) fatteners and traders also purchased other cereal grain residues such as millet (8- 25%) and sorghum stalks (4-13%). Especially (both) cattle fatteners and traders used these cereal grain residues (Table 21; Table 22). Typically, the majority of livestock producers (except for traders) in this region used concentrates (13-33%), whereas grazing was only very limitedly practiced (19%) (Table 21; Table 22).

Table 20. Main feeds purchased over the past 12 months and practice of grazing by fatteners and/or traders in the Northern region (NR) and Upper East region (UER) (%).

	Fatteners NR (n=21)	Fatteners UER (n=24)	Traders NR (n=32)	Traders UER (n=8)	Both fattener/trader UER (n=21)
1 .Grain legume residues (%)					
Cowpea residues	29	96	38	89	86
Groundnut residues	81	42	81	63	38
Soybean residues	5	42	-	50	49
Pigeon pea residues	48	-	28	-	-
2. Industrial by-products[1] (%)	76	83	78	75	71
3. Cereal grain residues *(%)*					
Maize stalks	14	42	3	25	33
Sorghum stalks	-	4	-	13	10
Millet stalks	-	8	-	25	14
Rice straw	38	38	50	25	38
4. Tuber crop residues *(%)*					
Cassava/Yam (peels)	62	4	13	-	5
Sweet potato (vines)	-	4	-	-	5
5 .Concentrates *(%)*	-	33	-	13	33
6. Green fodder[2] *(%)*	-	-	-	-	-
7. Green grass[3] *(%)*	-	-	22	-	-
8. Other(s) *(%)*	-	-	3 *(i.e. fruit peels)*	-	-
9. Grazing[4] *(%)*	33	4	41	-	33

Industrial by-products[1] included: wheat/rice bran, brewers' spent grain, maize/rice chaffs

Green fodder[2] are cut and carry leaves/branches

Green grass[3] are purchased in bundles

Grazing [4]: grazing was not included in main feed purchases over the past twelve months, but was included as part of main feed resources used (yes/no) by different groups of fatteners and traders

Table 21.Feed use (%)* per animal species by fatteners in the Northern region (NR) and Upper East region (UER)

	Fatteners NR (n=21)			Fatteners UER (n=24)			Both fattener/trader (F)[1] UER (n=21)		
	Cattle (n=16)	**Sheep (n=17)**	**Goats (n=5)**	**Cattle (n=23)**	**Sheep (n=6)**	**Goats (n=4)**	**Cattle (n=20)**	**Sheep (n=8)**	**Goats (n=2)**
1 .Grain legume residues *(%)*									
Cowpea residues	19	29	-	91	83	100	85	88	100
Groundnut residues	56	88	80	35	67	75	35	50	-
Soybean residues	6	24	-	44	17	25	50	25	50
Pigeon pea residues	25	47	60	-	-	-	-	-	-
2. Industrial by-products *(%)*	50	65	100	87	83	75	70	88	50
3. Cereal grain residues *(%)*									
Maize stalks	6	24	-	39	50	-	45	-	-
Sorghum stalks	-	-	-	4	-	-	15	-	-
Millet stalks	-	-	-	9	-	-	15	25	50
Rice straw	25	35	20	39	-	-	40	-	-
4. Tuber crop residues *(%)*									
Cassava/Yam (peels)	38	71	60	4	-	-	5	-	-
Sweet potato (vines)	-	-	-	4	-	-	10	25	-
5. Concentrates *(%)*	-	-	-	30	-	-	35	38	50
6. Green fodder *(%*	-	6	-	-	-	-	-	-	-
7. Green grass *(%)*	-	-	-	-	-	-	-	13	50
8. Grazing *(%)*	44	-	-	4.3	-	-	-	-	-

%:proportion of individuals (per group per animal species) making use of a feed; total percentage of respondents per group using a feed for a certain animal species>100 % due to multiple responses
F[1]: For the group of both fattener and traders, feed use is presented specifically for animals meant for fattening

Table 22.Feed use (%)* per animal species by traders in the Northern region (NR) and Upper East region (UER)

	Traders NR (n=32)			Traders UER (n=8)			Both fattener/trader (T)[1] UER (n=21)		
	Cattle (n=16)	**Sheep (n=23)**	**Goats (n=16)**	**Cattle (n=5)**	**Sheep (n=5)**	**Goats (n=1)**	**Cattle (n=17)**	**Sheep (n=7)**	**Goats (n=1)**
1. Grain legume residues (%)									
Cowpea residues	13	44	19	80	100	100	82	57	100
Groundnut residues	31	100	94	40	80	100	29	71	-
Soybean residues	-	-	-	40	40	-	47	14	-
Pigeon pea residues	-	35	50	-	-	-	-	-	-
2. Industrial by-products *(%)*	13	100	94	60	100	100	41	86	100
3. Cereal grain residues *(%)*									
Maize stalks	-	4	-	40	-	-	29	-	-
Sorghum stalks	-	-	-	20	-	-	18	-	-
Millet stalks	6	-	-	40	-	-	12	14	-
Rice straw	25	35	19	40	-	-	24	-	-
4. Tuber crop residues *(%)*									
Cassava/Yam (peels)	6	-	-	-	-	-	-	-	-
Sweet potato (vines)	-	-	-	-	-	-	6	29	-
5. Concentrates *(%)*	-	-	-	20	-	-	24	43	100
6. Green fodder *(%)*	-	-	-	-	-	-	-	-	-
7. Green grass *(%)*	-	30	44	-	-	-	-	-	-
8. Grazing *(%)*	88	-	-	-	-	-	24	29	-

%: proportion of individuals (per group per animal species) making use of a feed; total percentage of respondents per group using a feed for a certain animal species>100 % due to multiple responses
T[1]: For the group of both fattener and traders, feed use is presented specifically for animals meant for trading

3.2.1 Fatteners in the Upper East Region

All fatteners from the Upper East region (n=24) used grain legume residues as a livestock feed resource (Table 19). Most fatteners (96%) purchased cowpea residues (Table 20), which were used to feed cattle (91%), sheep (83%), and goats (100%) (Table 21). Forty-two percent of the fatteners (n=10) bought soybean residues and groundnut residues (Table 20). Soybean residues were used more by cattle fatteners (44%), whereas groundnut residues were used more by sheep (67%) and goat fatteners (75%) (Table 21). Opposed to fatteners from the NR, all except for one fattener (i.e. groundnut residues from middlemen) bought their grain legume residues from farmers (n=23). Next to cowpea residues, industrial by-products were the second most bought feed type by fatteners from this region (83%), which were used to feed the majority of cattle, sheep, and goats (82%) (Table 20; Table 21). Overall, more various feeds were used to feed cattle (e.g. concentrates, cereal grain residues) than small ruminants (Table 21).

3.2.2 Traders in the Upper East Region

The majority of traders (88%) used grain legume residues as a livestock feed resource (Table 19). Cowpea, groundnut and soybean residues were among the four main feeds purchased, represented by 89%, 63% and 50% of traders respectively (Table 20). Cowpea residues were used to feed cattle (80%), sheep (100%) and goats (100%, n=1), whereas groundnut residues were mainly used for feeding sheep (80%) and to a lesser extent for cattle (40%) (Table 22). Traders from this region foremost bought their residues from farmers (75%), whereas two cases were reported to buy from middlemen (i.e. cowpea and groundnut residues). Seventy-five percent of traders bought industrial by-products making this feed the second most purchased feed (Table 20). Traders who purchased other feeds, such as cereal grain residues and concentrates, mainly used these feeds for feeding cattle (Table 22).

3.2.3 Both fatteners and traders in the Upper East Region

Nearly all respondents (95%) from this group used grain legume residues as livestock feed (Table 19). Both fatteners and traders mainly purchased cowpea residues (86%), and to a lesser extent soybean residues (49%), and groundnut residues (38%) (Table 20). Similarly, soybean residues were more often used to feed cattle (fattened and traded), whereas groundnut residues were more used to feed sheep (and goats) (fattened and traded) (Table 21; Table 22). Grain legume residues were mainly bought from farmers (95%), while one respondent bought his grain legume residues from middlemen (i.e. soybean residues). Table 21 and Table 22 show that the variation in and types of feed resources used for the fattening or trading of ruminants did not largely differ between groups. Slightly more cereal grain residues were used for the fattening of cattle (i.e. maize stalks 45%; and rice straw 40%), the fattening of sheep and goats (i.e. millet stalks: 25% and 50% resp.) (Table 21). While none of the respondents from this group practiced grazing with fattening animals (Table 21), respondents did practice grazing with cattle (24%) and sheep (29%) meant for trading (Table 22). Overall, industrial by-products were the second most purchased feed, represented by 71% of the respondents from this group (Table 20), and were used for both the fattening (50-88%) and trading (41-100%) of cattle, sheep and goats (Table 21; Table 22). Concentrates were used as a feed resource in the fattening and trading of mainly cattle and sheep (Table 21; Table 22).

3.3 Contribution of livestock feeds to annual ruminant feed security in the Northern region

Main contributors to ruminant feed security meant for fattening were grain legume residues, industrial by-products (i.e. stall fed supplementary feeds), and communal grazing in open areas (Fig. 9). In Figure 9, a trend can be seen in which industrial by-products, and grain legumes in particular, became more important contributors from October until April, whereas grazing became increasingly important during the months of May until September. An increase in contribution of grain legume residues and industrial by-products corresponded to a strong decrease in monthly rainfall (i.e. dry season), whereas an increase in the contribution of grazing, coincided with an increase in monthly rainfall (May-September) (i.e. rainy season). Other feed types that contributed, albeit to a limited extent, were cereal grain residues, cut and carry feeding, tethering in the open field, and concentrates. According to Table 20-22, concentrates were however not among the feeds used by this group of fatteners, whereas the contribution of cassava/yam peels were, but are missing in this figure.

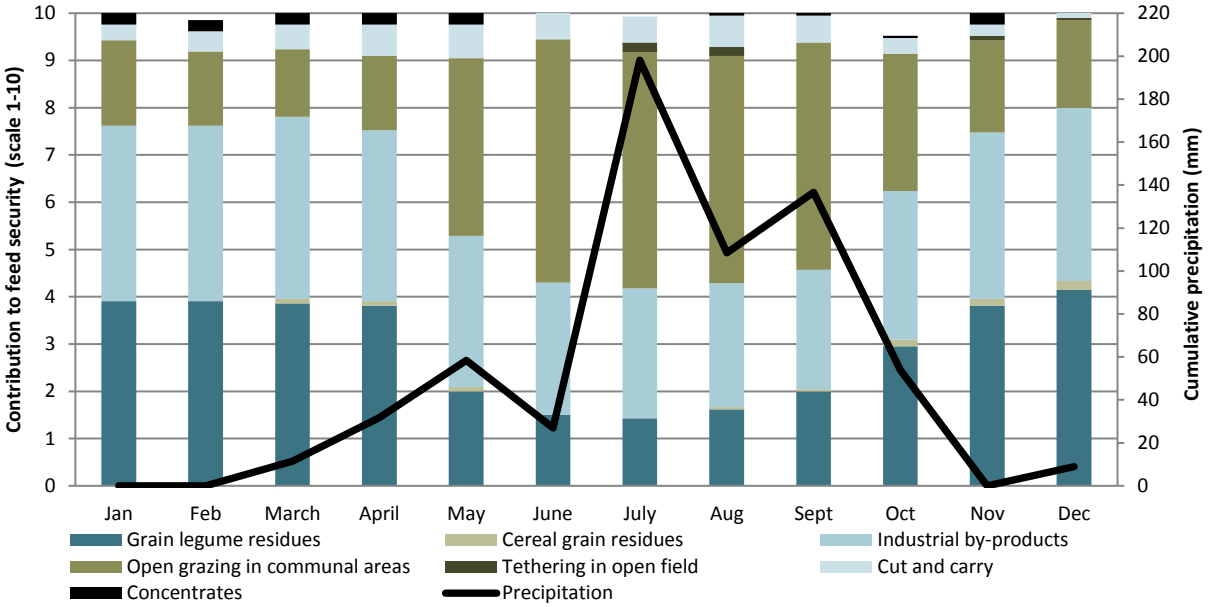

Figure 9. Livestock fattening in the Northern region: contribution of different feed types to ruminant feed security (per month; on a scale 1-10) and cumulative precipitation (mm) per month in the Northern region (NR) (2016)

Main contributors to ruminant feed security meant for trading were grain legume residues, industrial by-products and open grazing in communal areas (Fig. 10). In Figure 10 a similar, although less prominent trend is seen in which the contribution of grain legume residues was more important to ruminant feed security during the months of October-April, whereas grazing (and to a small extent cut and carry feeding) became more important between May and September. The importance of grain legume residues decreased between May-August (i.e. rainy season). Throughout the year, the contribution of industrial by-products to feed security remained relatively stable. A decrease in contribution of grain legume residues and an increase in contribution of grazing to feed security (May-September) coincided with an increase in monthly rainfall.

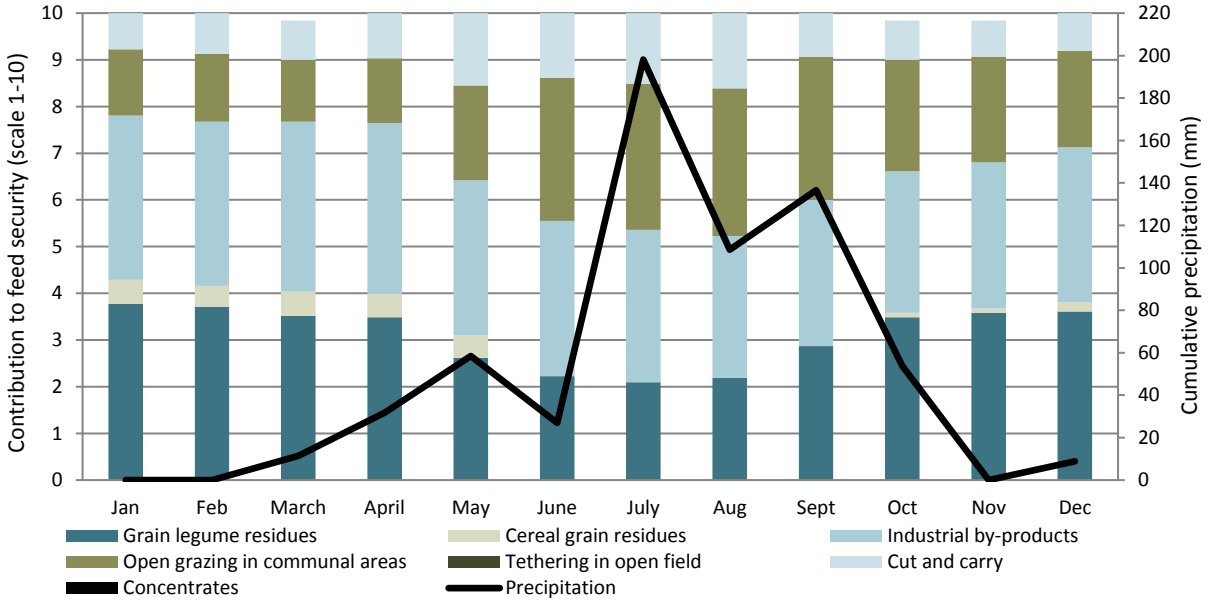

Figure 10. Livestock trading in the Northern region: contribution of different feed types to ruminant feed security (per month; on a scale 1-10) and cumulative precipitation (mm) per month in the Northern region (NR) (2016)

3.4 Contribution of livestock feeds to annual ruminant feed security in the Upper East region

3.4.1 Fatteners, traders, and both fatteners and traders

According to fatteners from the UER, main contributors to ruminant feed security were supplementary feeds among which grain legume residues, industrial by-products, and cereal grain residues (Fig. 11). Grain legume residues and industrial by-products were more important between November and April, whereas cereal grain residues were became increasingly important during the first 4 months of the year (i.e. late dry season) (Fig. 11). Grazing became increasingly important from May until October (i.e. rainy season), especially between June-September. Similar to the NR, a trend could be observed in which an increase in the contribution of grazing (and cut and carry to a small extent), and a decrease in the contribution of grain legume residues, cereal grain residues and industrial-byproducts corresponded with an increase in monthly rainfall in the UER (March-Sept) (Fig. 11). Cumulative monthly rainfall recorded in the UER was less (max. ± 112 mm/month) than in the NR (max. 200 mm/month) (Fig.9; Fig 11). The contribution of concentrates was more prominent between October-April (i.e. dry season). As can be seen in Figure 12, the group of both fatteners and traders reported to have a similar distribution of feeds contributing to annual feed security of their animals.

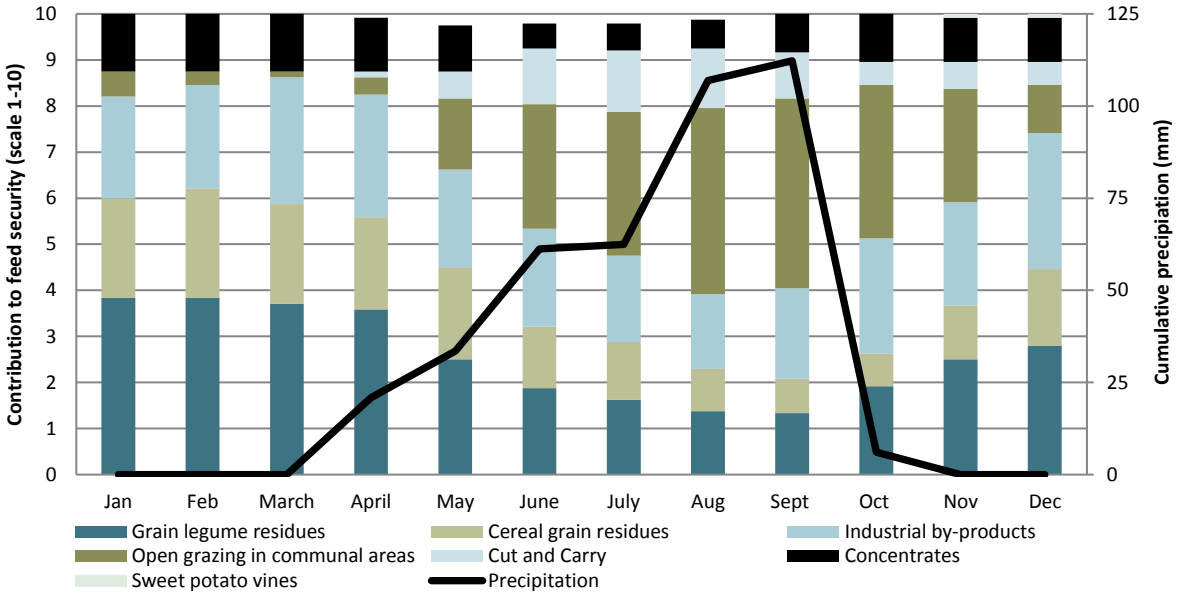

Figure 11. Livestock fattening: contribution of different feed types to ruminant feed security (per month; on a scale (1-10) and cumulative precipitation (mm) per month in the Upper East region (UER) (2016)

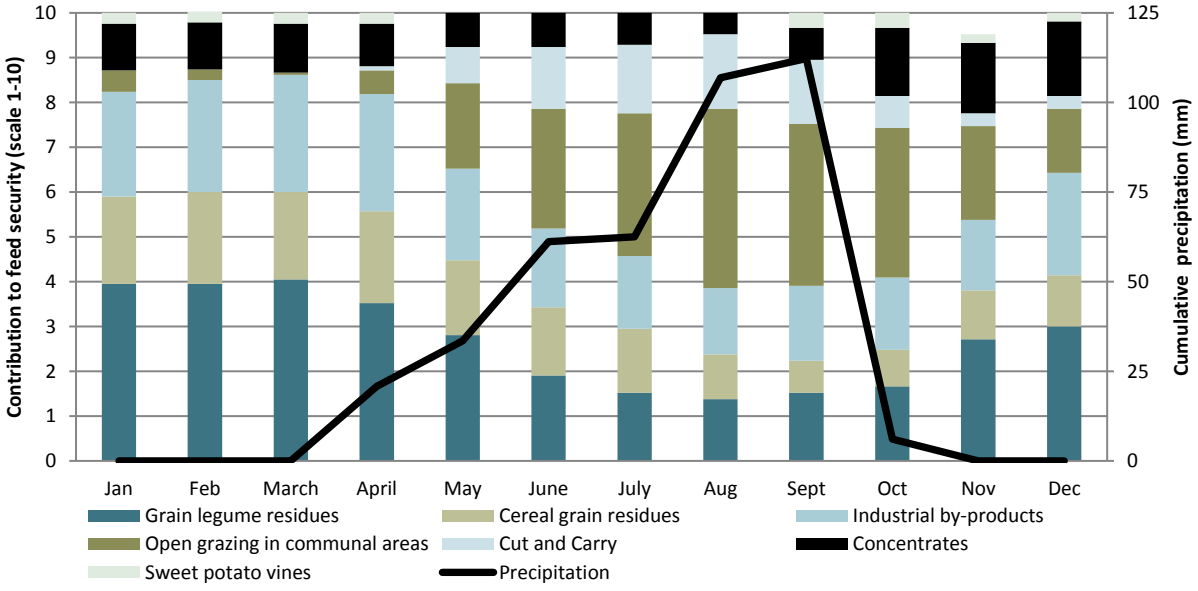

Figure 12. Both livestock fattening and trading in the Upper East region: contribution of different feed types to ruminant feed security (per month; on a scale 1-10) and cumulative precipitation (mm) per month in the Upper East region

Main contributors to feed security for ruminants meant for trading were grain and cereal grain residues, especially during the first four months of the year (Fig. 13). Industrial by-products contributed to feed security throughout the year, although became slightly more important between May-September. A decrease in the contribution of cereal grain- and grain legume residues corresponded with an increase in the contribution of grazing (and to a small extent cut and carry feeding and tethering) (May-October), and increase in monthly rainfall (Fig. 13).

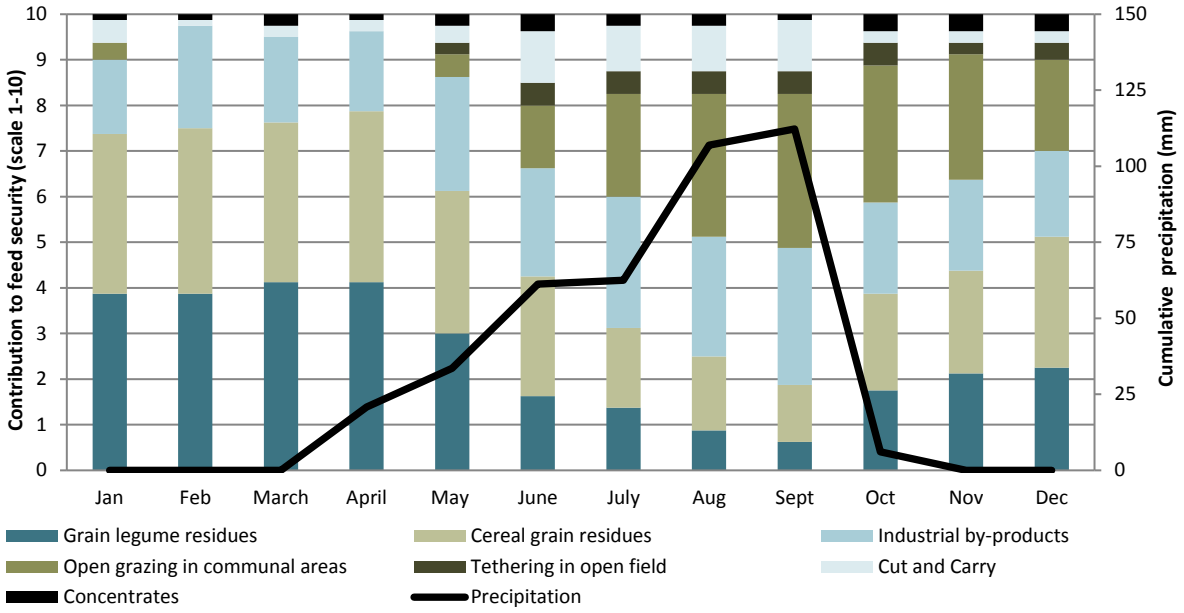

Figure 13. Livestock trading in the Upper East region: contribution of different feed types to ruminant (traded) feed security (per month; on a scale 1-10) and cumulative precipitation (mm) per month in the Upper East region (UER) (2016)

4. Smallholder mixed farming in Northern Ghana

4.1 Socio-economic background of smallholders farmers in the Northern and Upper East region

Overall, sampled farm households in both the NR (n=50) and UER (n=49) were relatively similar in terms of age (± 50 years), number of years in farming (± 25 years), gender (male), marital status (married), and household size (± 16.5 persons) (Table 23). However, while the majority of farmers interviewed in the NR were not educated (84%), more than half of the sampled farmers in the UER attained some level of education (i.e. mainly primary education (27%); and senior high (14%)) (Table 23). Farm households in the NR were predominantly Muslim (92%), whereas in the UER two-fifth of the farm households was Christian or Traditionalist, and one-fifth Muslim (Table 23).

Table 23. Social background information from smallholder farmers in the Northern region (NR) and Upper East region (UER)

		Smallholders NR (n=50)		Smallholders UER (n=49)		P-value
		Mean	SD	Mean	SD	
Age	*(years)*	48	±13.0	52	±17.1	0.206[2]
No. of years in farming		23	±9.7	27	±16.7	0.108[2]
Household size[1]	*(n)*	18	7.50	15	9.62	0.078[2]
Gender	*(%)*	100		100		0.631[3]
	Male	92		92		
	Female	8		8		
Education	*(%)*	98		100		n.a.*
	None	84		45		
	Primary school	4		27		
	Junior high	2		6		
	Senior high	8		14		
	Tertiary level	-		8		
Marital status	*(%)*	98		100		0.357[3]
	Single	6		10		
	Married	92		90		
Religion	*(%)*	98		96		0.000[4]
	Christian	6		37		
	Muslim	92		22		
	Traditionalist	-		37		

Household size[1]: number of household members incl. family and those who live there for more than 6 months during the year;
P-values calculations were based on: independent T-test[2]; Fischer's exact test[3]; and Chi-square[4]; chi-square test only performed if ≥ 80% of cells had expected cell count of ≥ 5 and individual expected count ≥ 1, otherwise n.a* (not available)

Overall, both smallholders in the NR and UER had two main (agricultural) sources of income: selling of crops and the selling of livestock (Fig. 14). In the NR, the contribution of crop sales was significantly higher (59%) than in the UER (37%) ($p < 0.05$) (see Appendix Table A 4.3). Sales of crop residues on the other hand, barely contributed to the household income of farmers in both regions (Fig. 14) (Table A 4.3). In the NR, the livestock component contributed less to the overall household income of farmers (31%) as opposed to crops, whereas in the UER the contribution of livestock sales was slightly higher (than crop sales) (38%) (Fig. 14).

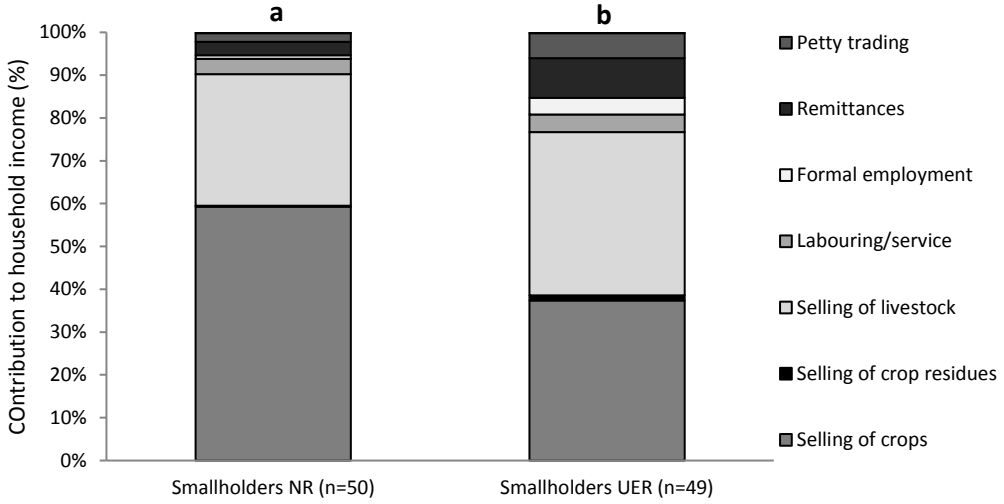

Figure 14. Average contribution (%) of eight different income sources to the total household income of smallholder farmers in the Northern region (NR) and Upper East region (UER); a-b indicate significant differences between regions ($p<0.05$) (p-values based on independent T-test)

Other off-farm (non-agricultural) income sources comprised about 20% of the total household income in the UER whereas in the NR this was 10% (Fig. 14). Although to varying extents, other off-farm income sources that contributed were labour/service, remittances, petty trading, and formal employment (UER) (Fig. 14). Mean contribution of remittances was significantly higher to the income of farmers in the UER (9.3%) than to farmers in the NR (3.2%) ($p<0.05$) (Table A 4.3).

4.2 Crop production and marketing of crop residues by smallholder farmers in the Northern and Upper East region

4.2.1 Farm size and main crops produced

Sampled farmers in the NR (n=50) on average had 5.5 hectares of land (± 3.8 ha), which was significantly more than the average farm size in the UER (3.8 ± 2.4 ha) ($p < 0.05$) (Table 24). In both regions, positive correlations were found between farm size and household size, although this correlation was more apparent among farm households in the NR ($r_s = 0.429$; $p= 0.002$) than in the UER ($r_s= 0.331$; $p= 0.020$).

In the NR, farmers cultivated three main types of crops among which maize (94%), rice (88%), and groundnut (68%). Furthermore, cowpeas, soybeans and pigeon pea were grown by 20 to 30% of the smallholders in this region (Table 24). The majority of farmers applied intercropping (66%) (Table 24), in which often cereal grains were intercropped with grain legumes (e.g. sorghum and groundnut; maize and groundnut or pigeon pea). In the UER on the other hand, four main crops were found to be cultivated by farmers among which maize (98%), millet (88%), cowpea (78%), and soybean (67%) (Table 24). Similar to the NR, the majority of farmers applied intercropping (78%) (Table 24), in which often different cereal grains (e.g. maize and millet), or cereal grains and grain legumes (e.g. maize with cowpea or soybean) were intercropped.

Table 24. Farm characteristics of smallholder farmers in the Northern region (NR) and Upper East region (UER).

		Smallholders NR (n=50)			Smallholders UER (n=49)			P-value
		Range	Mean	SD	Range	Mean	SD	
Farm size	*(ha)*	1.2-22	5.5[a]	±3.8	0.8-12	3.8[b]	±2.4	0.008[1]
Intercropping	*(%)*							0.265[2]
	Yes		66			78		
	No		34			22		
1. Grain legumes	*(%)*							n.a.*
	Cowpea		32			78*		
	Groundnut		68*			12		
	Soybean		28			67*		
	Pigeon pea		20*			-		
	Bambara bean		2			14		
2. Cereal grains	*(%)*							n.a.*
	Maize		94*			98*		
	Millet		12			88*		
	Sorghum		36			10		
	Rice		88*			37		
3. Tuber crops	*(%)*							n.a.*
	Yam		30			-		
	Cassava		14			-		
	Sweet potato		2			-		
4. Vegetables	*(%)*		22			6		n.a.*
5. Other(s)	*(%)*		-			4		n.a.*

P-value 1: p-value calculations based on T-test; a-b indicate a significant difference between regions

p-value 2: p-value calculations based on Fischer's exact test; N.A.*: not available: due to multiple response no tests could be performed

***Smallholders NR/UER: indicates that multiple plots were used to grow these crops**

4.2.2 Grain legume production and allocation of grain legume residues

Overall, in both regions grain legumes were cultivated for several reasons: to contribute to household food security (in NR and UER), as a way of generating an income (through crop sales in both NR and UER), as a feed resource (more important in the UER), and to contribute to (enhancement of) soil fertility (slightly more important in the NR). Growing grain legumes in order to obtain seeds (especially in the UER) or as a way to reduce risks for pests and diseases in (neighboring) crops (especially in the NR) were also among the reasons for cultivation, however less important compared to previously mentioned reasons.

In both the NR and UER, grain legume residues were often left in the field for animals to graze, and/or to serve as mulch (i.e. cowpeas, groundnut, and pigeon pea residues in the NR; cowpea and soybean residues in the UER). More than in the UER, farmers

in the NR burned their grain legume residues on the field (i.e. soybean and cowpea residues), whereas farmers in the UER more often used grain legume residues for the production of fuel (i.e. cowpea and soybean residues). Furthermore, both regions stored their residues at the homestead to feed them to their livestock (i.e. groundnut, pigeon pea and cowpea residues in the NR; cowpea and soybean residues in the UER).

Marketing of grain legume residues

Overall, the majority of farmers in the NR (52%) and UER (65%) did not buy or sell any crop residues (Table 25). Farmers that did participate in the marketing of grain legume residues, mainly purchased crop residues, as can be seen in the table below. Furthermore, these farmers often marketed more than one type of crop residues, among which were grain legume residues (Table 26). Farmers from one community in the NR (Balshei) bought pigeon pea residues (37.5%), and groundnut residues (25%) (Table 26) mainly from other farmers at their homesteads (n=12). Few farmers from the NR bought at local or district markets from fellow farmers (groundnut, n=1; and pigeon pea residues, n=2) or middlemen (soybean residues, n=1). Only pigeon pea residues were sold by farmers from the NR (17%) (Balshei, Bulung, Sandu) (Table 26). These were sold from the farmers' homestead to mainly livestock fatteners. Farmers from different communities in the UER (Tambiigu, Tansia, and Tetauko) on the other hand, especially bought cowpea residues (59%) and soybean residues (18%) (Table 26) from farmers at the homestead. Typically, farmers from the UER made use of more different market channels through which they sold their residues among which livestock fatteners, livestock traders, middlemen, and fellow farmers. All transactions took place at the homestead.

Table 25. Marketing of crop residues by smallholder farmers in the Northern region (NR) and Upper East region (UER)

		Smallholders NR (n=50)	Smallholders UER (n=49)
Do you buy and/or sell crop residues?			
Yes	*(%)*	**48.0**	**35.0**
	buy	40.0	20.4
	sell	8.0	10.2
	both	-	4.1
No	*(%)*	**52.0**	**65.0**

Table 26. Distribution of grain legume residues purchased and/or sold by smallholder farmers in the Northern region (NR) and Upper East region (UER) (%)*

		Smallholders NR (n=24)[1]	Smallholders UER (n=17)[1]
1. Cowpea residues	*(%)*	-	**88.0**
	buy	-	59.0
	sell	-	23.5
	both	-	6.0
2. Groundnut residues	*(%)*	**25.0**	**6.0**
	buy	25.0	-
	sell	-	-
	both	-	6.0
3. Soybean residues	*(%)*	**4.0**	**18.0**
	buy	4.0	6.0
	sell	-	6.0
	both	-	6.0
4. Pigeon pea residues	*(%)*	**54.0**	-
	buy	37.5	-
	sell	16.7	-
	both	-	-
5. Other crop residues[2]	*(%)*	58.0	35.0

n[1] is based on the percentage of smallholder farmers in the Northern/ Upper East region that bought and/or sold crop residues (see Table 25)
Percentage (%) was calculated based on the total number of smallholders per region that bought/sold crop residues (n);
***Overall percentage > 100% because each smallholder could indicate >1 crop residue to sell/buy**
Other crop residues include[2]: cereal grain residues (i.e. maize, millet, sorghum, rice), cassava, yam, sweet potato, vegetables, etc.).

Farm size among groups of farmers (not) purchasing or selling crop residues

Across the two regions, farm size did not significantly differ between groups of farmers that bought or sold crop residues, neither were there significant differences between these groups within regions (Fig. 15). However, farm size was significantly different between the groups of farmers that didn't buy or sell crop residues in the NR (n=26) and UER (n=32) ($p < 0.05$): average farm size in the UER was significantly lower (3.4 ha ± 2.2) than average farm size in the NR (6.4 ha ± 4.6) (Fig. 15). Overall, the group of farmers from the UER who didn't buy or sell crop residues showed to be below their regional average farm size (3.8 ha) (Table 24), whereas the same group of farmers in the NR was above their regional average (5.5 ha) (Table 24). Groups of crop residue buyers and sellers from the UER had on average more land (4.7 ha) compared to their regional average. The group of crop residue buyers in the NR on the other hand, had on average less land (4.5 ha) compared to the regional average.

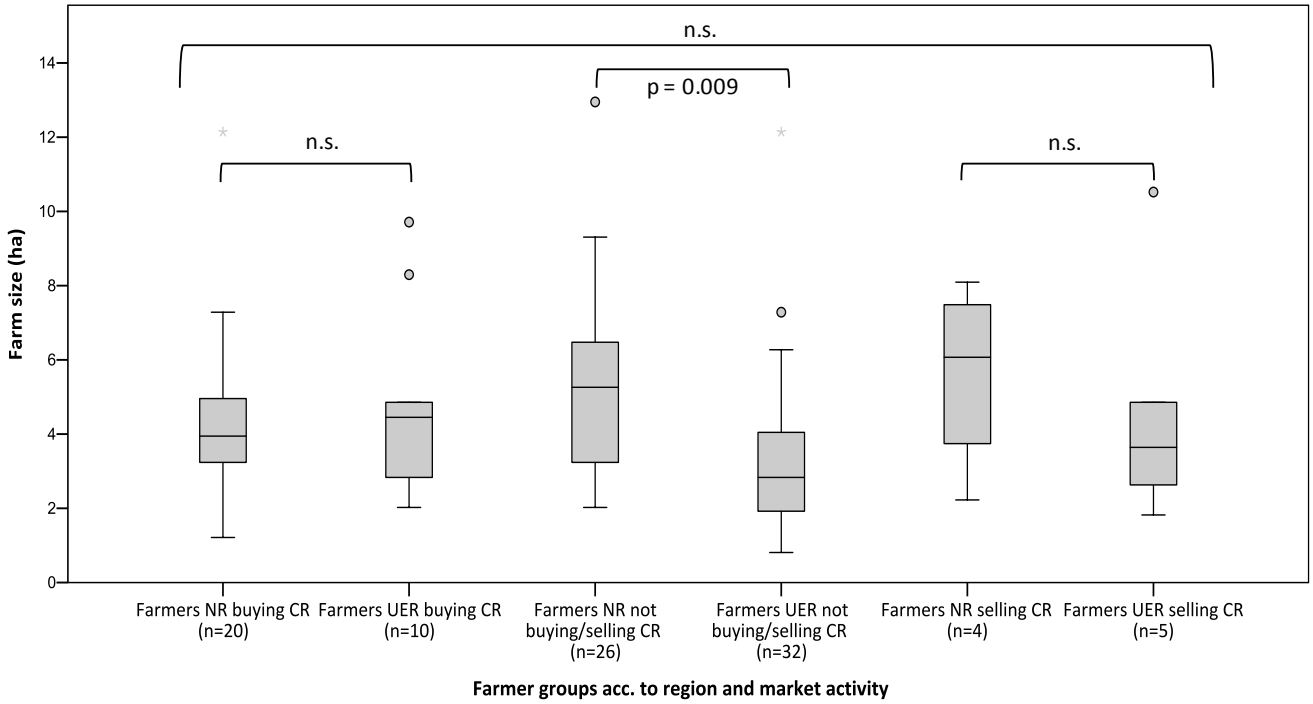

Figure 15. Distribution of farm size (median and range) among different groups of farmers in the Northern region (NR) and Upper East region (UER) according to residue (CR) related market activities (i.e. buying, selling, or not buying nor selling); p-value was based on a non-parametric Kruskal Wallis test

4.3 Livestock keeping by smallholder farmers in the Northern and Upper East region

4.3.1 Farmers' livestock holdings

A large part of farmers in the NR (n=50) and UER (n=49) kept various livestock species (Table 27). In the NR, farmers mainly kept poultry (98%), and small ruminants (88%; especially sheep), whereas two-fifth of the farmers kept cattle (Table 27). Altogether, farmers from this region owned on average 4.9 animals (TLU) (Table 28). In the UER on the other hand, nearly all farmers kept goats (98%) and poultry (96%), while more than half of the farmers also kept cattle (76%) and sheep (67%) (Table 27). Furthermore, only farmers from the UER kept pigs (41%), and donkeys/horses (20%) or other animal species (e.g. dogs) (Table 27). Farmers from this region owned on average 5.7 animals (TLU) (Table 28). In both regions, ruminants (especially cattle) contributed for at least 80% to the total number of livestock owned by smallholders.

Table 27. Distribution of livestock species (and other animals) kept by smallholder farmers in the Northern region (NR) and Upper east region (UER) (%).

		Smallholders NR (n=50)	Smallholders UER (n=49)
Ruminants	*(%)*		
	Cattle	40	76
	Sheep	94	67
	Goats	82	98
Other livestock species	*(%)*		
	Pigs	6	41
	Poultry	98	96
	Donkeys/Horses	2	20
Other(s) [1]	*(%)*	-	22[1]

Others [1] in UER: dogs (n=10); doves (n=1)

Table 28. Average number of livestock species kept (Herd size; TLU) by smallholder farmers in the Northern region (NR) and Upper East region (UER)

	Smallholders NR (n=50)			Smallholders UER (n=49)		
	Farmers (n)	**Herd size (±SD)[1]**	**TLU (±SD)[2]**	**Farmers (n)**	**Herd size (±SD)[1]**	**TLU (±SD)[2]**
1. Ruminants			**4.1 (± 4.13)**			**4.7 (±6.33)**
Cattle	20	8.5 (± 5.54)	2.38	37	6.5 (± 9.05)	3.44
Sheep	47	11.3 (± 8.62)	1.06	33	8.6 (± 8.58)	0.58
Goats	41	8.0(± 6.39)	0.66	48	6.7 (± 4.46)	0.66
2. Pigs and poultry[3]			**0.8 (± 2.61)**			**0.8 (± 0.90)**
Pigs	3	37.7 (± 45.55)	0.45	20	5.0 (± 4.19)	0.41
Poultry	49	36.0 (± 32.65)	0.35	47	41 (± 34.33)	0.39
3. Equines			**0.01**			**0.3**
Donkeys and horses	1	1	0.01	11	1.82 (± 1.17)	0.27
Total	50	58.2 (± 42.53)[4]	**4.9 (± 4.79)[a]**	49	59.0 (± 46.95)[4]	**5.7(±7.12)[ab]**

Livestock herd size (n) [1] included mature male and female animals;
No. of farmers represent the number of farmers keeping a certain animal species
Herd size[1]: herd size per species represent the average number of a livestock species kept by a farmer keeping that species.
Mean TLU[2] per animal species was calculated over all smallholders interviewed per region;
Poultry[3]: included chickens and (guinea) fowls
Total TLU a- ab: Superscripts show that TLU_{tot} in NR and UER were not significantly different (p=0.502 based on T-test)
Total herd size[4] (incl. all livestock species) per region was calculated over all smallholder farmers interviewed per region

Relation between TLU and household size, and between TLU and farm size

Spearman's correlation showed a significant (positive) relationship between average farm size and livestock holdings in both regions. This relationship was stronger among sampled households in the NR (rs = 0.5; p= 0.000) than in the UER (r_s= 0.428; p=0.002). In addition, significant, although relatively weak relationships were identified between TLU and average household size in the NR (r_s= 0.412; p=0.003) and in the UER (r_s= 0.354; p=0.013).

Distribution of livestock holdings among groups of farmers (not) purchasing or selling crop residues

Farmers from the UER who bought crop residues (n=10) owned significantly more livestock (12.2 ±12.8) than farmers who bought crop residues in the NR (n=20) (3.6 ± 2.8) (p= 0.037) (Fig. 16). While this group from the UER owned the largest number of livestock compared to their regional average (5.7 TLU), the same group of farmers from the NR owned the least number of livestock compared to their regional average (4.7 TLU) (Fig. 16; Table 28). Farmers from the UER that bought crop residues owned significantly more livestock than farmers that didn't buy or sell crop residues within the same region (3.8 ± 3.0) (p=0.037) (Fig. 16).

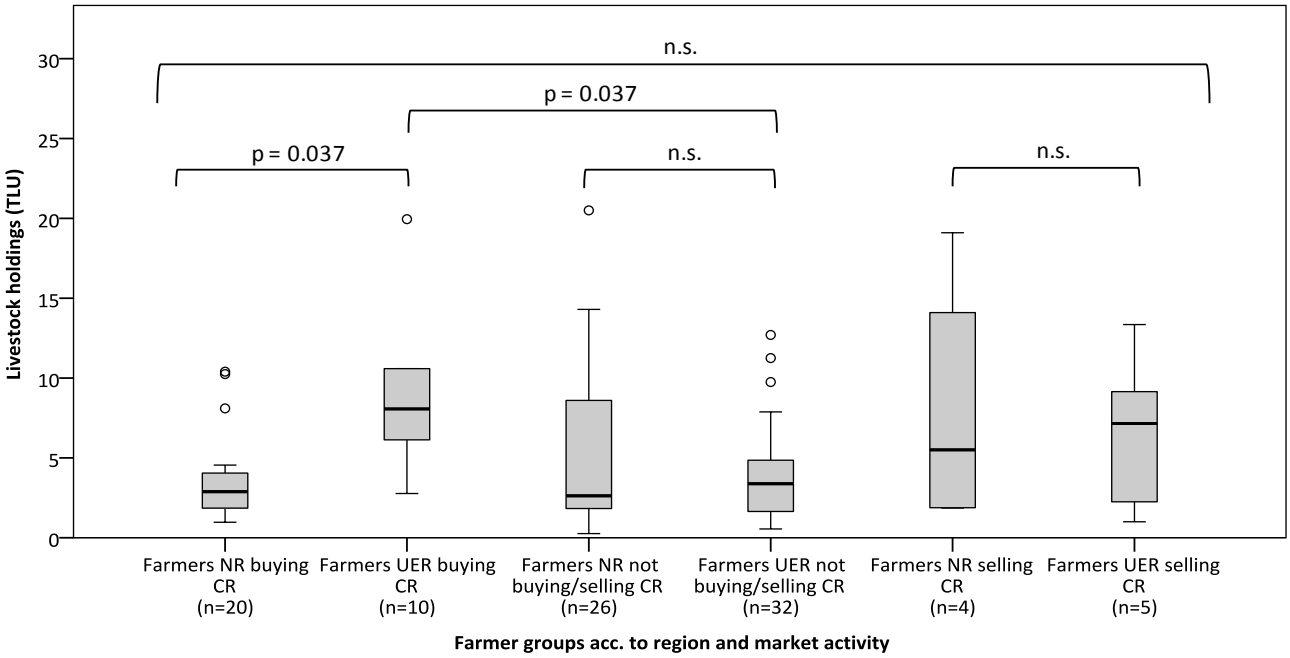

Figure 16. Distribution of total livestock holdings (TLU) (median and range) among different groups of farmers in the Northern region (NR) and Upper East region (UER) according to residue (CR) related market activities (i.e. buying, selling, or not buying nor selling); P-values were based on a non-parametric Kruskal Wallis test

4.3.2 Main reasons for keeping livestock

Overall, cash was one of the primary reasons for keeping both large and small ruminants in the NR and UER (Fig. 17; Fig. 18). Provision of draught power by cattle was considered equally important in the UER, whereas the provision of manure was the second most important reason for keeping cattle in both the UER (81%) and the NR (75%) (Fig. 17). Farmers from the UER considered status a (very) important reason for keeping livestock, particularly sheep (82%) and cattle (62%), whereas this was not the case in the NR (Fig. 17). Furthermore, livestock keeping in the UER was more often related to cultural and religious events (e.g. dowry and sacrifices) (Fig. 17; Fig. 18). Besides access to cash, small ruminants (i.e. sheep and goats) were especially important as a household food resource (70% - 90%) and as a provider of manure (70%-75%) to farmers in the NR (Fig.18) (for main reasons for keeping goats see Appendix Fig. A6).

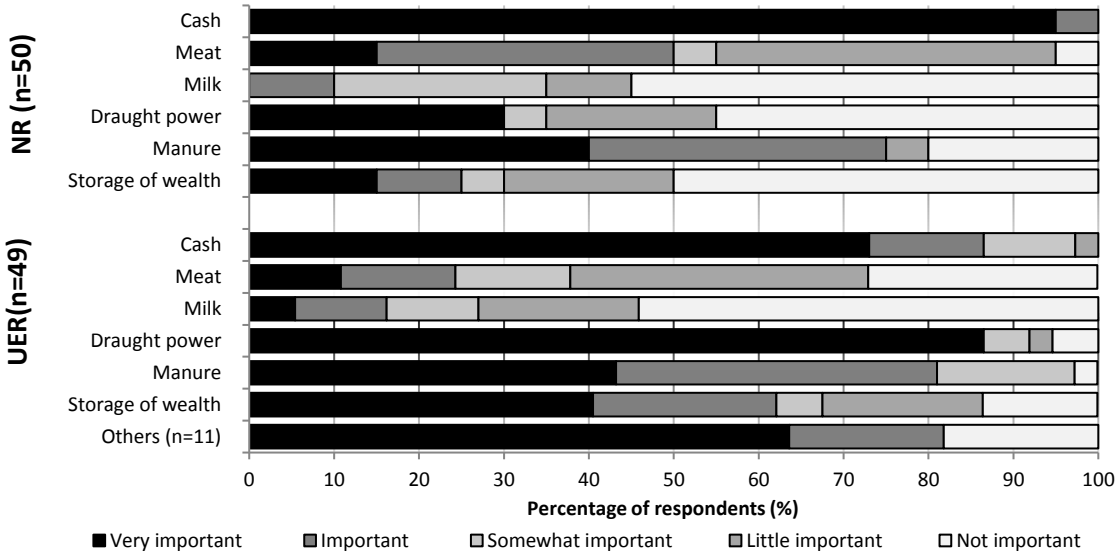

Figure 17 Main reasons for keeping cattle by smallholder farmers in the Northern region (NR) and Upper East region (UER) according to level of importance ***Other(s) = Dowry and sacrifices***

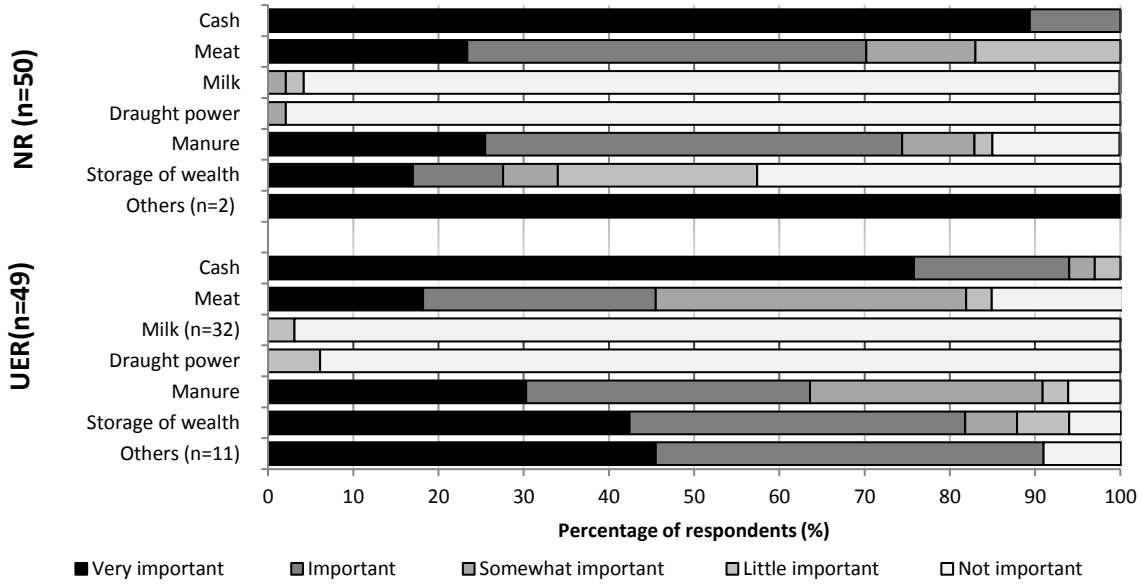

Figure 18. Main reasons for keeping sheep by smallholder farmers in the Northern region (NR) and Upper East region (UER) according to levels of importance; ***Others NR*****= Animal exchange and donation of animals;** ***Others UER*****= Dowry and sacrifices**

4.3.3 Livestock distribution, sales and prices

Farmers in the UER used multiple distribution channels among which livestock traders, fatteners or middlemen, through which all large and small ruminants, were sold (especially male animals) (Table 29). As opposed to cattle, farmers in the UER sold sheep and goats (male and female animals) more often directly to consumers (Table 29). The vast majority of farmers in the NR on the other hand, mainly sold large and small ruminants (both male and female animals) to butchers (Table 29). About one-third of the farmers in this region sold their small ruminants to livestock traders, fatteners, or middlemen. Unlike farmers from the UER, most farmers from the NR did not sell their animals directly to consumers (Table 29).

Table 29. Distribution channels used for the selling of cattle, sheep, and goats (incl. males, females) by smallholder farmers in the Northern region (NR) and Upper East region (UER).

	Smallholders NR (n=50)		**Smallholders UER** (n=49)	
Distribution channel(s) *(n)*				
	Cattle (n=20)*		**Cattle (n=37)***	
	Male (n=16)	*Female (n=17)*	*Male (n=34)*	*Female (n=25)*
Total no. of responses[1]	16	17	42	31
Consumers	-	-	2	2
Livestock traders/fatteners/middlemen	5	6	35	25
Fellow farmers	-	-	2	2
Butchers	11	11	3	2
	Sheep (n=47)*		**Sheep (n=33)***	
	Male (n=45)	*Female (n=44)*	*Male (n=30)*	*Female (n=28)*
Total no. of responses[1]	46	45	40	36
Consumers	-	-	6	5
Livestock traders/fatteners/middlemen	15	16	30	28
Fellow farmers	1	1	1	1
Butchers	30	28	3	2
	Goats (n=41)*		**Goats (n=48)***	
	Male (n=36)	*Female (n=37)*	*Male (n=38)*	*Female (n=42)*
Total no. of responses[1]	*37*	*37*	*51*	*51*
Consumers	1	1	8	7
Livestock traders/fatteners/middlemen	13	15	38	42
Fellow farmers	-	-	2	1
Butchers	23	22	3	1

n represents the number of farmers within a region using a distribution channel for a particular animal species

Total no. of responses[1] ≥ total number of farmers keeping cattle/sheep/goats due to multiple responses given for distribution channels used;

***Calves, lambs, and kids were excluded from this table**

On average, farmers in the NR and UER had bought less than one animal (incl. cattle, sheep, and goats) during the past year (see Appendix Table A 5.1). Over the past twelve months smallholders in the NR region had sold on average 0.7 cattle, 0.9 sheep, and one goat (i.e. average of male and female animals together) (see Appendix Table A 5.1). Smallholders in the UER had sold on average 0.4 cattle, 0.8 sheep, and 0.8 goats (i.e. average of male and female animals together) (see Appendix Table A 5.1).

When and if farmers sold their livestock, selling prices varied per animal species and per region (Fig. 19-21). As can be seen in Figure 19, farmers from the NR sold their cattle (males and females) within a broader price range than farmers in the UER. The minimum price at which farmers sold their male cattle in the UER was significantly higher (1143 GHC ± 484.6) than the minimum price at which farmers sold in the NR (859 GHC ± 348.9) ($p < 0.05$) (Fig. 19) (see Appendix Table A 3.5). Maximum selling prices for male cattle in the NR and UER ranged between 1394 (± 500.0) GHC and 1427 (± 601.9) GHC respectively (Fig. 19). Selling prices (min. and max.) for sheep (males and females) on the other hand, were significantly higher in the NR than in the UER ($p < 0.05$) (Fig. 20) (see Appendix Table A 3.5). At most, male sheep in the NR were sold for 201 (± 52.74) GHC, whereas in the UER male sheep were sold at best for 159 (± 60.17) GHC (Fig. 20). Overall, selling prices for goats (male and female) in both regions were the lowest compared selling prices for other ruminants (Fig. 21).

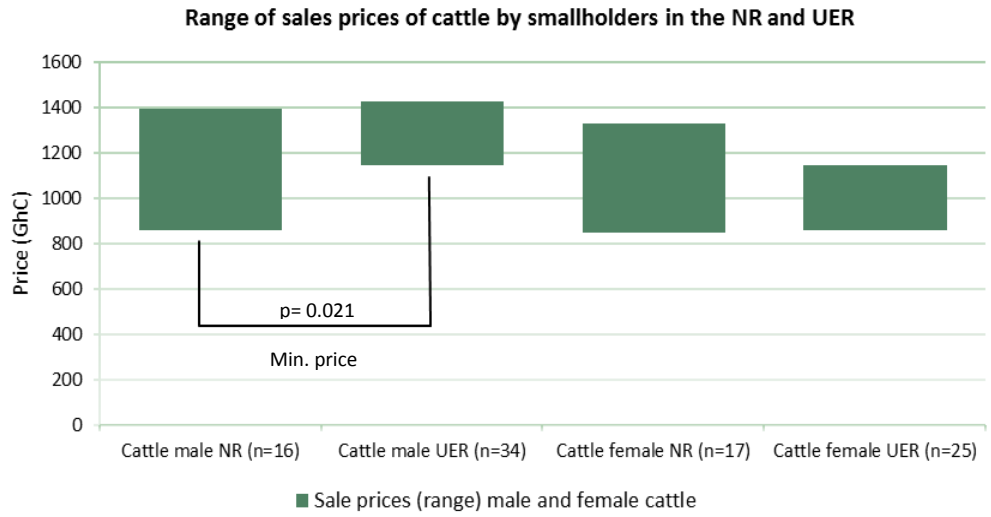

Figure 19. Selling price ranges (min. and max.) for male and female cattle according to farmers in the Northern region (NR) and Upper East region (UER); P-value shows a significant difference in the minimum selling price of male cattle between regions;
Currency: 1 GHC = 0.20 EUR

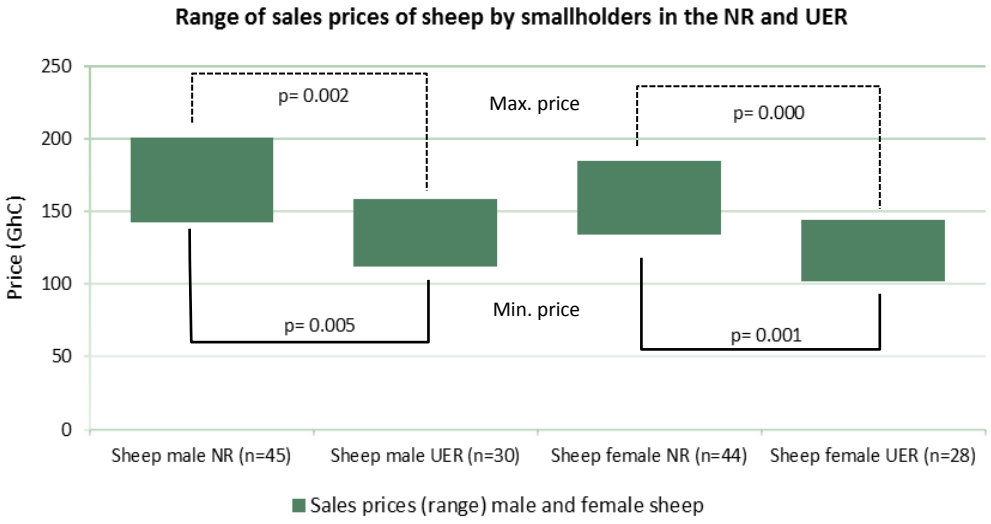

Figure 20. Selling price ranges (min. and max.) for male and female sheep according to farmers in the Northern region (NR) and Upper East region (UER); P-values show a significant difference in both minimum and maximum selling prices of male and female sheep between regions
Currency: 1 GHC = 0.20 EUR

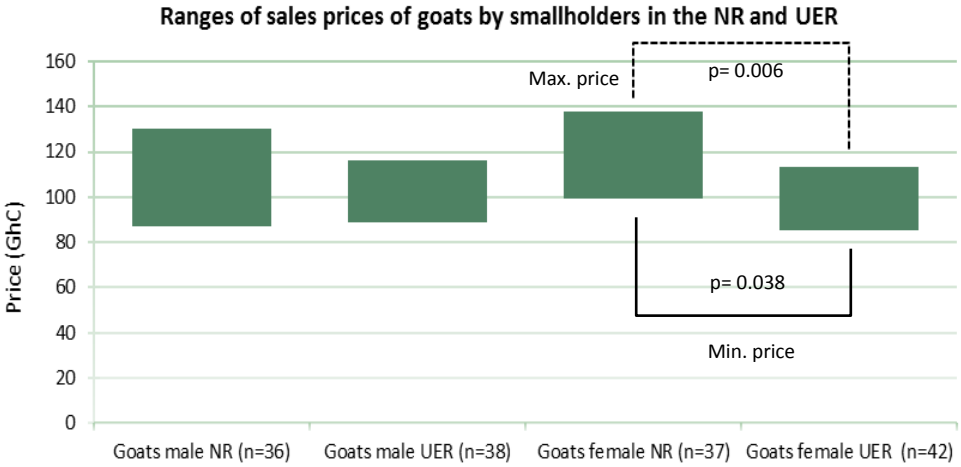

Figure 21. Selling price ranges (min. and max.) for male and female goats by smallholder farmers in the Northern region (NR) and Upper East region (UER); P-values show a significant difference in both minimum and maximum selling prices of female goats between regions
Currency: 1 GHC = 0.20 EUR

Discussion and conclusions

The main purpose of this explorative study was to provide an overview of the current state of the ruminant value chains in two regions (Northern Region; Upper East Region) of northern Ghana. In addition, we investigated the role of grain legume residues as a livestock feed resource among value chain actors. Therefore, three different value chain actors were interviewed, who were specifically involved in livestock production, and also were connected to the production of grain legume and/or utilization of grain legume residues: smallholder (mixed crop-livestock) farmers, livestock fatteners and livestock traders. Main aspects of interest for the scope of this study were to characterize and describe these value chain actors; to identify and describe chain actor relationships as well as the extent of value chain integration and market participation followed by a comparison of the two identified ruminant value chains.

Ruminant value chains in the Northern region and Upper East region

Characterization of livestock fattening and trading

Livestock fattening and trading in the NR is predominantly focused on a combination of (mainly) cattle and sheep, with a slightly higher preference for sheep among both groups in this region. In the UER however, livestock fattening and trading seems to be predominantly focused on male cattle, with only few respondents combining the fattening or trading of multiple ruminant species. This difference may be due to differences in religions across the two regions, hence causing differences in cultural relevance of certain livestock species and consumer preferences. For example, the NR is predominantly Muslim, hence the higher cultural importance of and preference for sheep (meat). Furthermore, the extent of goat keeping and fattening was remarkably low (except for traders in the NR). The limited extent of goat fattening among respondents could be because goats are simply unsuitable for fattening, hence long term keeping would render ineffective and unprofitable. In addition, this may be due to the overall larger extent of small ruminant production throughout the country (MOFA, 2004). Next to regional differences in species orientation, the livestock fattening business, especially in the NR seemed to be mainly focused on the fattening and selling of male animals. The overall higher appreciation of male animals is well reflected by the lower (buying and selling) prices for female cattle, sheep, and goats in both regions, and longer relative fattening periods of female livestock in the NR. Most likely, female animals are predominantly used for breeding purposes and not for fattening. Breeding with own stock was particularly seen among sheep and goat fatteners in the NR and UER as a way to add new animals to their current stock. This may be due to their prolific nature and relatively shorter gestation period of small ruminants as opposed to cattle (Adams and Ohene-Yankyera, 2014). Furthermore, from a practical point of view, small ruminants may be more easily kept under intensive circumstances in urban areas than cattle. Unlike for livestock traders, for livestock fatteners breeding seems a more appropriate management strategy to obtain new animals due to the long term nature of their business.

Unlike livestock trading, livestock fattening across both regions seems to be characterized by seasonality (Fig. 4; Fig. 5). Across the two regions, peak purchases of male cattle and sheep (mainly NR) by livestock fatteners occurred during February-April (i.e. late dry season), which suggests that these months correspond to the onset of livestock fattening. Although availability of feed from natural pastures and forages decreases during the dry season, livestock fatteners (and traders) instead, increase the use of (more nutritious) supplementary feeds (e.g. crop residues, industrial by-products, concentrates, etc.) (Fig. 9-13). This is most likely the result of the higher availability of and lower prices for crop residues (especially during Jan-Feb), including grain legume residues, due to the increase in supply by farmers (i.e. end of the cropping season and harvesting period (Oct-beginning of Dec) (Timler *et al.,* 2014). The onset of livestock fattening during the dry season also implies that storage of feed is essential. The type of storage methods used as well as storage capacity (i.e. in terms of space and storability of feeds) could be essential to making resources available for a prolonged time. Therefore, the quantity of feed stored as well as feed quality (after storage) could be essential to the efficiency of livestock fattening (i.e. the length of the fattening period). However, the effects and importance of feed storage (methods) and feed quality to livestock production were not within the scope of this study, and will therefore require further research. Furthermore, peak sales of (male) cattle and sheep (mainly NR) across the two regions took place around September and December. Both months correspond with religious events: Eid-al-Adha (i.e. the Muslim Sacrificial feast; 13th -16th of September), during which the sacrifice (and consumption) of especially sheep (and goats) is important; and Christmas (December) (Fig.4; Fig. 5). These findings correspond to findings by Amankwah (2013), and N. Associates Inc. (2014). Therefore, livestock fatteners seem to aim at specific (religious) events during which certain animal species are highly valued, whereas livestock trading can be considered the all-round provider of livestock.

This seasonality in livestock fattening is not necessarily reflected by the prices found for the purchasing and selling of livestock. According to Amankwah (2013) and N. Associates Inc. (2014) livestock prices strongly fluctuate according to the seasons. Typically, during the (religious) high season (i.e. Ramadan, Sacrificial feast, Christmas, Easter), selling prices increase (up to 20%). Remarkably however, in some cases, study results even showed the opposite situation, in which the high season coincided with a decrease in selling prices (e.g. sheep sales in the NR) (Fig. 5D). However, this could be the result of a higher increase in supply of livestock during these periods.

It was expected that livestock fattening is logically characterized by value addition along the production process, hence higher selling prices for fattened animals. This added value supposedly results from long term livestock keeping combined with targeted feeding and overall higher investments made in e.g. veterinary care, medication, and housing. Livestock trading was expected to require fewer inputs per animal due to the short term keeping of livestock. However, this hypothesis did not reflect the current situation in the NR, where buying and selling prices for male cattle were higher when traded instead of fattened and sold afterwards. First, higher selling prices may be due to the higher costs found related to livestock trading in the NR (60% higher) than costs related to livestock fattening in that region (mainly due to high costs for hired labour) (Table 6a; 6b). However, among both groups these costs were subjected to high variation. In addition, other production related costs, among which costs for transportation to and from livestock markets, and costs for feed, were not calculated. Therefore, no further conclusions can be drawn on the effect of production costs on the overall pricing of livestock by each of these actors. Second, these contradictory findings may be due to differences in valuation of cattle in relation to livestock market utilization by livestock fatteners on the one hand (i.e. local livestock markets or none) and livestock traders on the other hand (i.e. local and southern livestock markets). In addition, valuation of livestock showed to be affected by other factors among which breed, size (weight) and health conditions of the animals fattened or traded. This is confirmed by a study by Okike *et al.* (2004a) on livestock marketing channels, flows, and prices in West Africa. Next to these factors, the large differences in sample size between groups of fatteners and traders may have altogether resulted in different livestock prices among different livestock producers and regions. Buying and selling prices for ruminants (cattle, sheep) among the group of both fatteners and traders (UER) were often slightly higher or at least more varied than prices found among fatteners and traders within the same region. Possibly, due to the dual-nature of their profession and significantly more years of experience (24 years, p= 0.006), respondents of this group may be better informed about (the day-to-day) market prices, and may therefore be better negotiators. In addition, some overlap may be expected to exist between the two business components, which in turn allow them to more easily respond to changing (market) opportunities. Altogether, livestock producers from this group may be better equipped to supply livestock with more value added.

Livestock traders obtained their income predominantly from livestock trading. Most likely, livestock trading is a more time consuming business (i.e. market bound), hence providing less opportunities for alternative income sources. The income of livestock fatteners however, was more diversified, as fatteners had up to six different income sources (except for the *both* group in the UER). This may be due to the long fattening periods of livestock and seasonality of livestock sales, hence the need for additional income sources to correct for the inconsistent flow of income from the livestock fattening business. Only livestock fatteners in the NR had a higher contribution (not significant; p= 0.129) of formal employment, probably due to the higher number of educated fatteners in this region.

Despite the base of livestock fattening and trading being mainly in urban areas, crop sales showed to be an income source to all groups of (both) traders and fatteners in both regions, especially in the NR (Fig. 3). No information was obtained regarding the characteristics and extent of crop production among these respondents. However, the (varying extent of) contribution of crop production suggests that livestock fatteners and livestock traders might as well be urban farmers, who reside in varying (developmental) stages of specialization and commercialization of their livestock production component.
The current study did not directly provide insight into the actual profitability of livestock fattening and trading in the two regions, as this study did not collect all necessary data on costs and revenues associated with the production and distribution of livestock. However, the distribution of groups across the regions may give us an indication about which type of livestock production/keeping is considered a more viable livelihood strategy in a region. In the UER, this is reflected by the overall larger share of livestock fatteners as opposed to the higher share of livestock traders in the NR.

Connecting (peri)-urban and rural livestock production: value chain interrelationships

Overall, it appears that this study was unable to expose the precise extent to which smallholder livestock producers in rural areas are directly connected to (peri-) urban livestock fatteners and traders in both regions. However, the inability to link rural-urban livestock flows may in part be due to a missing link in the ruminant value chain. Table 30 shows that smallholder selling prices (ranges) for especially small ruminants in both regions were much lower than the prices (ranges) at which livestock fatteners, and to lesser extent livestock traders, indicated to purchase. This discrepancy suggests the presence of a middleman or even several middlemen in order to connect rural livestock production to urban livestock production. However, the large difference in farm gate and market prices may also be due to transportation costs. According to N.Associates Inc. (2014), and Okike (2004a), costs of transportation (and handling of animals), account for the largest share of marketing costs of livestock. Middlemen already showed to play a significant role in the UER as main distribution channel used by (both) fatteners and traders. The more prominent role of middlemen in the UER may be related to cross-border trading and transportation activities. However, the exact operative range of these middlemen within (rural-urban) or even between regions as well as their link to other chain actors in the ruminant value chain is unknown and will require further research. Furthermore, a value chain analysis performed by N. Associates Inc. (2014) pointed out that livestock value chains in northern Ghana generally have weak links, with spot purchases throughout the chain. These spot purchases suggest that the nature of ruminant value chains is still relatively informal, and therefore more difficult to properly analyze and describe. Furthermore, a mismatch in livestock sourcing and distribution in the NR may be due to the unidentified sales location of livestock by smallholders on the one hand and unknown identity of sellers at livestock markets on

the other hand. As such, potential rural-urban linkages may not have been properly exposed due to inconsistencies in the design of the different questionnaires.

Table 30. Overview of prices (range) for male ruminants including selling prices of smallholder farmers and buying prices for (both) fatteners and traders in the Northern region (NR) and Upper East region (UER).

Northern region			
Selling price range (GHC)*	**(male) Cattle**	**(male) Sheep**	**(male) Goats**
Smallholders (n=50)	859-1394	143-201	87-130
Buying price range (GHC)*			
Fatteners (n=21)	823-1130	540-771	266-332
Traders (n=32)	1169-2575	332-533	137-263
Upper East region			
Selling price range (GHC)*	**(male) Cattle**	**(male) Sheep**	**(male) Goats**
Smallholders (n=49)	1143-1427	112-159	89-116
Buying price range (GHC)*			
Fatteners (n=24)	1452-1861	433-522	200-240
(Both) Fatteners (n=21)	1497-1876	460-583	185-225
Traders (n=8)	733-1058	240-310	120-150
(Both) Traders (n=21)	1088-1315	304-370	150-160

*** Currency: 1 GHC = 0.20 EUR**

Next to the limited rural-urban distribution of ruminants through the interlinkage between farmers, and livestock traders, fatteners and vice versa, three more chain actors were identified being part of the ruminant value chain in the two regions: Fulani herdsmen, butchers, and (final) consumers. Albeit to a limited extent, fatteners across both regions made use of Fulani herdsmen to take care of (part of) their livestock herds (mainly cattle). Fulani herdsmen are known cattle caretakers for "absentee" livestock owners who live away from their livestock holdings (MOFA, 2004). Livestock fatteners, who are mainly situated in and around urban areas, hence have less space available to keep larger numbers of cattle, are likely to be among this group of absentee livestock owners. Butchers were a major distribution channel used by smallholder farmers as well as livestock fatteners and traders in the NR. According to a report from Nathan Associates Inc. (2014) two types of butchers can be distinguished in the livestock value chain of northern Ghana: formal butchers, who can be found in urban areas, and informal butchers, who represent the majority of butchers and are mainly found in rural areas.

Distribution of livestock and connection to markets

The distribution of and focus on ruminant species fattened and traded across the two regions can be considered based on the extent to which livestock fatteners and traders make use of local, regional, and/or foreign livestock markets. Based on the maps that represented the distribution of livestock market utilization by (both) livestock fatteners and traders (Fig. 6-8) roughly two different types of value chains can be distinguished: a local ruminant market chain within each region, and a cross-regional ruminant market chain. This characterization of livestock market distribution and utilization more or less corresponds with the two livestock value chains described by N. Associates Inc. (2014): the Northern distribution market chain, and the North-South distribution market chain. The difference however, is that the current study only gives a general insight into the distribution of livestock over different market locations and subsequent market activity on these locations, whereas N. Associates Inc. (2014) in addition identified and described the buyers and sellers at the different livestock markets.

The local ruminant market chain

The local market chain comprises the use of (multiple) local livestock markets within the NR or within the UER. The distribution of ruminants through this local chain network was predominantly used by livestock fatteners and traders from both regions to buy and sell their sheep, goats, and cattle. The local ruminant market chain was especially important for the distribution of small ruminants. This may be due to the fact that small ruminant production also occurs in some of the more southern regions of Ghana (MOFA, 2004), which therefore may not provide profitable marketing opportunities for livestock fatteners (UER) and livestock traders (NR;UER). The distribution and marketing of cattle however, took place at both local and cross-regional levels. For fatteners from the NR, this was the main chain network used (except for buying mainly sheep from the UER). However, as market utilization in the NR consisted of twenty-two different local markets, whereas in the UER this were only three (see Appendix Table A7), livestock producers from the NR have a larger area to cover within the "borders" of their own region.

The cross-regional ruminant market chain

The cross-regional market chain includes the distribution of ruminants to (and from) livestock markets outside the home (base) region of livestock fatteners and traders. This market chain applies to mainly livestock traders in the NR, and (both) livestock fatteners and traders in the UER. Livestock traders and fatteners from the NR mainly went to livestock markets in the UER specifically to purchase sheep, and to a lesser extent, to purchase goats. The purchase of sheep (and goats) in the UER may be due to lower prices for sheep in the UER, and a higher preference for sheep meat by the predominantly Muslim consumers in the NR. Furthermore, (both) fatteners (UER) and traders (NR; UER) especially sold cattle at the livestock markets situated in Accra,

Kumasi, and to a lesser extent in Techiman. The limited availability of livestock markets in the UER (compared to the NR) may be a reason for why livestock fatteners and traders from this region have expanded their distribution routes (towards the southern regions). Furthermore, beef is one of the primary meats in Ghanaian diets and among the most frequently purchased meat products in Ghana (followed by chicken and goat) (Osei-Asare and Eghan, 2014; Owusu-Sekyere, 2014). Higher income levels in urban areas are often associated with higher meat consumption, where in turn increasing incomes and urbanization have resulted in an increasing demand for meat products, and beef in particular (Owusu-Sekyere, 2014; Osei-Asare and Eghan, 2014; N. Associates Inc., 2014). Northern Ghana in total is responsible for the majority of domestic cattle (75%-85%) (Owusu Sekyere, 2014; Adzitey, 2013; N. Associates Inc., 2014) and small ruminant production (70%) (Amankwah, 2013), hence further explaining the overall large flow of especially large ruminants to the larger cities in the South. In addition, this general higher preference for beef in, and strong dependency on the northern regions for the subsequent supply to the South may explain the relatively higher selling prices found for cattle among (both) livestock traders (NR;UER) and livestock fatteners (UER).

Domestic ruminant production has so far been unable to meet the (increasing) demands, which therefore means that the remainder is currently met by imports from Burkina Faso, Niger, and Mali (N. Associates Inc., 2014; Amankwah, 2013). Especially (both) livestock fatteners (and traders) from the UER showed to buy cattle from e.g. markets in Burkina Faso, which partly reflects the inflow of livestock coming from foreign countries. However, the exact extent to which livestock imports supply the different regions with additional live animals and meat (cold chain), by whom and at which price is unknown. As such, it is currently unknown to which extent domestic livestock production has to compete with livestock imports, and whether (or not) livestock imports (live animals and meat) have an effect on the current state of domestic livestock production and marketing. Therefore, and in order to better assess the future possibilities for development of the domestic livestock sector, further research is required.

Livestock markets in Techiman were predominantly used by cattle fatteners and traders from the UER, but none of the traders in the NR. However, Techiman is the first large city to pass through in the southern part of Ghana. Most likely, livestock marketing opportunities in Techiman are limited and therefore not considered profitable. Furthermore, none of the livestock fatteners and traders from the UER made use of livestock markets in the NR. This may due to the differences in market prices for especially sheep and cattle as well as the regional demand and preference for certain ruminant species. Due to these differences, no interesting profitable market opportunities exist in the NR for fatteners and traders from the UER and vice versa. Finally, it appeared that none of the livestock fatteners and traders in either of the two regions, made use of livestock markets in the Upper West region (UWR). This may be due to the lack of proper infrastructure connecting the regions (especially UWR-UER, see Fig. 6-8), as well as the lack of profitable market opportunities in this region. A study on livestock marketing channels, flows and prices in West Africa (Okike *et al.,* 2004b) confirms that livestock producers and traders make use of what they consider to be the most profitable market channel.

A minority of livestock fatteners from the NR and UER did not make use of any livestock market to sell their animals. Instead, these fatteners possibly made use of other unidentified (informal) distribution channels. Additionally, livestock fattening for these respondents could be a secondary activity, which may explain for the occurrence of home sales (*field observation*). However, one could question whether these respondents could then be considered 'actual' livestock fatteners, as these forms of selling imply that the livestock fattening business, especially in the NR, is not purely profit driven and for commercial purposes.

Characterization of smallholder mixed farming in the Northern and Upper East region

Smallholder farming across the two regions could be distinguished based on their differences in total land holdings, income distribution, and livestock holdings. Total farm size in the NR was found to be highly various and significantly larger (5.5 ha; 1.2-22 ha) than total farm size in the UER (3.8 ha; 0.8-12 ha) (p= 0.008). Smaller sized farms tend to be located in regions with a high population density, and thus in regions with limited availability of land, as is the case in the UER where the population density is 118 persons per km^2 as opposed to 35 persons per km^2 in the NR (Adams and Ohene-Yankyera, 2014; IFPRI, 2013; IFPRI, 2008; MOFA, 2013).

In turn, non-agricultural income sources (e.g. formal employment, petty trading, labouring/service) are more prevalent in cases where farm size is smaller and the population density is higher (IFPRI, 2008). This is due to the fact that total farm production is less likely to ensure food security and satisfy household incomes (IFPRI, 2008). This well reflects the current situation in the UER, where off-farm income activities comprised approximately 20% of the total household income as opposed to 10% in the NR. In turn, a relatively higher contribution of off-farm income activities tends to occur when the household income increases, and therefore may serve as a proxy for the wealth status of the household (Kuivanen *et al,* 2016). A higher contribution of non-agricultural income sources, and therefore a possible higher welfare of farm households in the UER could be related to the majority of sampled households being educated (55%). Moreover, off-farm income activities are more prevalent in areas closer to markets, thereby making alternative employment opportunities more accessible (Kuivanen *et al.,* 2016; IFPRI, 2008). Therefore, the relatively lower contribution of off-farm income activities in the NR implies that off-farm opportunities in this region are either unavailable or inaccessible due to the remoteness of (sampled) farm locations and/or due to an overall lack of education among sampled households. Among these off-farm income sources, remittances contributed significantly more to the household income of farmers in the UER than in the NR. Remittances are a complementary source of income and may be the result of rural-urban

migration (Kuivanen *et al.,* 2016). According to Kuivanen *et al.* (2016), migrant households are typically more labour constrained, while labour availability in turn is largely determined by the total household size. Total household size in the UER was smaller (± 15 pers.) than in the NR (± 18 pers.), although these differences were not significant. Nevertheless, smaller households in the UER, which are more likely to be labour constrained, may therefore be more dependent on the contribution of (indirect) off-farm income sources (such as remittances).

In the NR, agricultural activities (i.e. crop and livestock production) contributed for 90% to the total household income in which crop production was found to be the main contributor to livelihoods of farmers (59%). In the UER however, agricultural activities comprised approximately 75% of the total household income, with a (only) slightly higher contribution of livestock sales (livestock: 38%; crops: 37%). According to IFPRI (2008), farm income may be taken as a proxy for farm productivity, and also reinforces that off-farm income activities are particularly important for household with limited landholdings. Despite significant correlations found between farm size and TLU, farm size and household size, and TLU and household size, relations were weak ($r_s \leq 0.5$) and did not reflect the current situation of smallholder mixed farming in the two regions. Therefore, it seems that farmers across the two regions have adopted alternative livelihoods strategies. On the one hand, farmers in the NR seem to have directed their farming practices towards crop production based on the significantly higher contribution of crop sales, larger farm size, lower livestock holdings (TLU = 4.7), higher labour availability, and relatively lower contribution of non-agricultural income sources. In the UER however, livestock production may be more important from a sustenance and/or commercial point of view based on the significantly lower contribution of crop production and higher contribution of livestock production to the total income (compared to the NR; not significant), smaller farm size, and higher total livestock holdings (TLU=5.7; $p>0.05$). This livelihoods strategy could have emerged as a result of the increasing population pressure, and subsequent declining availability of (grazing) land in the UER, as well as available market opportunities. In addition, the relatively higher importance of off-farm income sources and livestock in the UER could be the result of the harsh climatic conditions (semi-arid Sudan Savanna zone), thereby making crop production a riskier undertaking compared to the NR (sub-humid Guinea Savanna zone) (Powell *et al.,* 2004).

Overall, all sampled households in both regions kept several livestock species. Besides mainly poultry (>90%), small ruminants were kept by the majority of smallholder farmers in both the NR (goats by 82%; and sheep by 94% of farmers) and UER (goats by 98%; sheep by 67% of farmers). Cattle on the other hand, were mainly kept by farmers in the UER. Poultry is a livestock species that is quite easily accessible to even the poorest among smallholders, as well as it is economical due to only little input that is needed (e.g. land, labor, (costs for) housing, feed) to maintain a flock (Kuivanen *et al.,* 2016; MOFA, 2004). Cattle on the other hand, are considered the most valuable livestock species and as such are seen as an important wealth indicator of the farm family (Kuivanen *et al.,* 2016; MOFA; 2004). This importance of status well reflects the current status in the UER, where farmers considered the storage of wealth among the main reasons for keeping livestock in general. As such, the poultry to cattle ratio may provide insight into level of resource endowment of farmers within and between regions. The relatively higher portion of farmers keeping cattle in the UER (76%; NR: 40%), hence lower poultry to cattle ratio, despite a smaller farm size, suggests that the sampled households may have been among the wealthier category of smallholder farmers in Northern Ghana, and therefore would be more likely to develop towards commercialization of farming practices. While farmers in the NR may own relatively less livestock (cattle especially), larger land holdings also account for some degree of welfare and therefore may opt for a different developmental trajectory that is focused on the commercialization of crop production (e.g. through farm expansion). On the other hand the overall high prevalence of small ruminant keeping across the two regions is characteristically for subsistent agricultural systems (Adams and Ohene-Yankyera, 2014) Small ruminants are commonly kept mainly because of their hardy and prolific nature, and therefore relatively low maintenance requirements (Kuivanen *et al.,* 2016; Adams and Ohene-Yankyera, 2014; Amankwah, 2013).

Furthermore, based on the multiple roles of livestock that are currently still attributed to livestock keeping in both regions, and (therefore) the infrequent selling of livestock in general (0.2-1.3 animals per year NR/UER) smallholder mixed farming in both regions is still mainly subsistence based. However, no clear conclusions can be drawn regarding their level of resource endowment and therefore their actual extent and potential for commercialization. This is based on the observed heterogeneity among farmers within and between regions, and due to the complexity of interactions between both farm characteristics, and external influences that altogether affect the production orientation of farmers as well as the (market) opportunities

Role of grain legume residues among value chain actors

Allocation of grain legume residues by smallholder farmers

In general, grain legumes showed to have a wide range of functions for smallholder farmers in both regions, among which the contribution to household food security and household income, improvement of soil fertility, and use as a livestock feed resource were especially important. These findings correspond to earlier findings reported by Odendo *et al.* (2011). In addition, farmers in both regions had multiple ways of allocating their grain legume residues. Besides differences in specific grain legume residues used across regions, the general tendency of farmers in both regions was to leave residues in the field, either to be used as mulch or grazed by livestock. Furthermore, farmers in both regions also collected residues from the field (to store) to use as feed. Adams and Ohene-Yankyera (2014) reported similar finding in crop residue utilization by farmers in Northern Ghana. According to

Valbuena *et al.,* (2012) the increasing use of crop residues for purposes other than mulching suggests that these are becoming a private good with an explicit economic value, which in turn results from increasing pressure on land and feed resources, especially in combination with high livestock densities. This suggests that crop residues in general may be valued more as a livestock feed resource (than as e.g. mulch) in the UER than in the NR.

Despite a significant growing demand for livestock feeds as a result of increasing demands for livestock products (Konlan *et al.,* 2015; Valbuena *et al.,*2012), smallholder farmers from both regions were not commercially oriented with regard to their crop residues. As such, the hypothesis of emerging feed markets in northern Ghana as a result of before mentioned transitions in livestock production and increasing demands for feed and livestock produce cannot be directly derived from data obtained through this study. A study performed by Konlan *et al.* (2015) on the other hand, did elaborate on (the opportunities and challenges of) emerging feed markets in Northern Ghana (in the UWR; UER; and NR). Konlan *et al.* (2015) however, did not elaborate on the specific identity of feed sellers, whereas main feed buyers were identified as being mainly (peri-) urban livestock farmers or livestock traders (small ruminants especially). Furthermore, most of feed transactions took place at the homestead and nearby local markets, and occurred often between acquainted feed sellers and buyers. These findings correspond to the findings of this study, where crop residues were mainly purchased at and sold from the farm. Overall, the location and rather informal nature of feed trading suggests that the development of these so-called emerging feed markets is still in a rudimentary stage.

While this study may not give answer to the possible existence of a (emerging) feed value chain, this study may provide insight into understanding the limited extent of commercialization of crop residues by farmers. The extent of commercialization, hence market participation, may in part be explained by the interaction between the total average of land and livestock holdings. Especially in the UER, the buying of crop residues seems to be related to the need for additional livestock feed resources due to limited availability of land on the one hand, and significantly higher livestock holdings on the other hand (above regional average) (Table 31). Sales of crop residues in both regions however, seem to be related to the relatively larger farm size (above regional average), potentially due to higher crop productivity, and therefore a surplus in crop production (Table 31). Yet, these farmers show to have an above regional average number of livestock, which would suggest the need for buying crop residues rather than selling. However, due to the large variation in TLU for farmers selling residues in both regions and low sample size (Table 31), no further conclusions can be drawn from this data.

Table 31. Total average land holdings (ha) and livestock holdings (TLU) according to region, and according to region and market activity of crop residues (CR) of farmers in the Northern region (NR) and Upper East region (UER)

	Farm size (ha)	**Livestock holdings (TLU)**
	Mean(± SD)	Mean(± SD)
Overall average NR (n=50)	5.5 (±3.8)[a]	4.9 (±4.8)[a]
Overall average UER (n=49)	3.8 (± 2.4)[b]	5.7(±7.1)[ab]
Farmers buying CR:		
NR (n=20)	4.5(±2.3)[ab]	3.6(±2.8)[a]
UER (n=10)	4.7(±2.5)[ab]	12.2(±12.8)[b]
Farmers not buying/selling CR:		
NR (n=26)	6.4(±4.6)[a]	5.4(±5.3)[ab]
UER (n=32)	3.4(±2.2)[b]	3.8(±3.0)[a]
Farmers selling CR:		
NR (n=4)	5.6(±2.5)[ab]	8.0(±8.2)[ab]
UER (n=5)	4.7(±3.5)[ab]	6.6(±5.1)[ab]

Tests to compare mean values were computed among: Groups of smallholder farmers according to region (i.e. overall average) (T-test) ; Subgroups of smallholder farmers according to region and marketing activity (i.e. farmers (not) buying, selling crop residues) (Kruskal Wallis)
Different superscripts indicate significant differences between groups ($p<0.05$)

Overall, the ability to buy or to sell suggests the (relatively) higher level of resource endowment (e.g. more financial resources, higher farm productivity) of these farmers. As such, these farmers may be considered positive deviants among farmers from a region. However, sales of crop residues showed to hardly contribute (0.2% in the NR; 1.2% in the UER; Fig. 14) to the household income of farmers in both regions. This further confirms that, despite the potential, grain legume residue marketing remains an underutilized outlet by farmers, let alone pointing towards a trajectory of specialization. Furthermore, farmers may have a multitude of reasons for not selling and/or buying any crop residues. For example, farmers may either be able to provide feed for their animals in terms of the sufficient availability of lands for grazing (e.g. in the NR) and /or the collection and storage of residues (e.g. in the UER). In addition, the importance of crop residues as a feed resource may vary depending on the (number of) livestock species owned. On the other hand, farmers may simply not have the financial means to provide additional feed resources for their animals, whether they may be land constrained or not, resulting in recurrent (seasonal) feed shortages for their animals. Finally, it should be considered that the possibility of marketing crop residues is related trade-offs between the allocation of grain legume residues on-farm (e.g. used for soil amendment, fuel, construction material) (Valbuena *et al.,* 2012).

Utilization of grain legume residues as a livestock feed resource among livestock fatteners and traders and the contribution to ruminant feed security

Grain legume residues were among the main feed sources used by (both) livestock fatteners and traders in the NR and the UER (next to industrial by-products). As opposed to the expectation that livestock fattening would require the use of more specific and nutritious feeds, the overall combination of livestock feed resources used for livestock fattening and trading did not largely differ across the two regions. This suggests that the overall use and choice of feeds, including grain legume residues, is at least partly determined by what the region or locality has to offer, rather than with e.g. the aim to increase animal productivity. This is further confirmed by the fact that the types of grain legume residues used by fatteners and traders corresponded to the grain legumes produced by smallholder farmers in the region (i.e. groundnut and pigeon pea in the NR; cowpea and soybean in the UER)(Table 21; Table 22; Table 24).

In the NR, it appeared that grain legume residues were more important for feeding small ruminants (especially sheep), and that grazing was more prominent among cattle fatteners and traders. In the UER however, grain legume residues were fed to all ruminants, although the type of grain legume residue differed between ruminant species (e.g. soybean residues for feeding cattle; groundnut residues for feeding sheep). Overall, (both) fatteners and traders in the UER used a higher variation of feeds for cattle. Altogether, the number and type of feeds used in each region reflected the species orientation of fatteners and traders (i.e. mainly cattle in the UER; mainly sheep in the NR). Furthermore, the proportion of grazing as opposed to the use of supplementary feeds could explain for the significantly longer fattening periods of (male) cattle observed in the NR. Livestock fatteners and traders in the UER generally practiced less grazing throughout the year, while making use of more nutrient dense livestock feeds such as concentrates cereal grain residues, and grain legume residues. This, and the shorter fattening periods observed among groups of fatteners suggests that these groups (especially the group of both) are better equipped to invest in their livestock business. However, during this study, no quantitative information could be obtained on the exact diet composition of ruminants, and therefore, total daily nutrient intake of ruminants remains unknown. In order to get insight into the potential benefits of feeding grain legume residues on livestock productivity as opposed to other (supplementary) feeds, further research is required. Furthermore, as no calculations were performed on the total expenditures related to livestock feeding, among which grain legume residues, we cannot compare the potential effects of costs on the accessibility, and therefore the extent to which livestock fatteners and traders invest in this feed resource.

The availability and extent of utilization of grain legume residues showed to be seasonally bound. Figures 9-13 showed that the importance of grain legume residues to ruminant feed security increased during the dry season, whereas their contribution decreased during the rainy season. Several studies showed that (peri) urban livestock keepers indeed rely on supplementary feeding during the dry season, resulting in a high feed demand and peak purchases of grain legume residues during this season (Konlan *et al.,* 2016; Konlan *et al.,* 2015; N. Associates Inc., 2014). On the other hand, during the rainy season the availability of feed resources from natural forages and pastures increases (Konlan *et al.,* 2016; Konlan *et al.,* 2014), hence reducing the need for supplementary feeds to meet the nutritional requirements of their animals. This explains for the increase in grazing and use of natural forage during these months. According to Konlan *et al.,* (2016) the fodder grazed comprised of natural grown grass and legume pasture and uncollected crop residues on cultivated fields. This situation however, applied to smallholder farmers in Northern Ghana, not to peri-urban livestock fatteners and traders.

Finally, data collected on the use of livestock feed resources among livestock fatteners and traders contained some discrepancies. The distribution of feed purchases among groups did not always match with feeds used according to ruminant species and/or feeds presented in the annual feed calendar. Differences between feeds used per animal species and overall main feeds purchased may in part be explained by the fact that e.g. feeds may also have been collected for free (e.g. cut and carry feeding) or exchanged with e.g. manure. In the feed security calendar however, some important feed types were missing (e.g. tuber crop residues in the NR) or appeared for the first time as being among the feeds used (e.g. concentrates in the NR). Despite the similar theme and nature of feed related questions in the questionnaire, different questions may have been misinterpreted.

Connecting feed supply and feed utilization

Based on the limited marketing of grain legume residues by farmers on the one hand, and the strong dependence of livestock fatteners and traders on the (in) direct distribution of grain legume residues by rural producers on the other hand (especially in the UER), a gap exists in the supply of these residues to the more urban areas. In the NR, middlemen seem to be the main distributor of grain legume residues to livestock fatteners and traders. Similar to the (rural-urban) distribution of livestock, the operational range of middlemen within (rural-urban) or even between regions is unknown, hence the possibility exists that the supply of feed residues is not necessarily locally bound, as it would seem at first. However, in order to better understand the function of middlemen within this value chain as well as the origin of livestock feed resources, a more extensive analysis of feed producers, feed sellers, distributors, and buyers/users is required. Furthermore, the supply of grain legume residues may occur through other informal channels which may not have been identified during this study such as trade between community or village members, or random on spot purchases/sales. Finally, livestock fatteners and traders may possibly provide part of the grain legume residues or other crop residues themselves, as income sources showed that these actors still participate in crop production.

However, this study did not look further into the importance of crop production for the supply of food, feed and means of income to these group of (peri-)urban livestock producers.

Conclusions and recommendations

Smallholder mixed farmers in the NR and UER are characterized by low market participation and therefore are only partially integrated in the ruminant value chain. More important, livestock production for these actors contributes to household food security and the sustaining of livelihoods. Different levels of resource endowment may be assumed, based on the differences found between production orientation of farming practices across the two regions (crop production in NR, livestock production in the UER) and observation of heterogeneity among farming systems within and between regions. However, this study did not allow for a diagnosis of the extent of resource endowment of these different smallholder farmers, nor for the quantification and assessment of farm productivity. Therefore, the possibility to increase domestic livestock production through smallholder farming, and to increase market participation and value chain integration without compromising farmers' livelihoods, needs to be realistically and practically considered in the context of their current livelihood strategies and changing market demands. Furthermore, this study established the importance of grain legume residues as a livestock feed resource among urban livestock producers, which is why increasing demands for livestock feeds offer a way to improve farmers' livelihoods by increasing the marketing of crop residues. However, the inherent nature of mixed farming often implies competing uses for crop residues. Therefore, potential trade-offs of on-farm/off-farm allocation of residue resources should be carefully considered in the context of current livestock strategies of farmers in other to assess the opportunities for the commercialization of grain legume residues as a livestock feed resource for (peri) urban livestock producers.

Livestock fatteners and traders showed to be both important providers of livestock to different (urbanized) areas on a (cross) regional scale, but especially in their locality. However, the extent of value chain integration and market participation in a broader context differs between the two regions and among groups. Furthermore, we saw that livestock fattening is characterized by seasonality. Increasing livestock production through fattening schemes may offer a way to improve the incomes of these livestock producers and to increase the value of the overall livestock trade as well as to improve the supply of livestock produce. As such, these fatteners could potentially bridge the seasonal gap in supply. In addition, as was seen in the UER, combining livestock fattening and livestock trading may be a way to overcome risks related to market fluctuations, as well as to make better use of changing market opportunities through improved awareness of the market situation. However, more information is needed on the actual profitability of livestock fattening and trading, in order to determine the (future) viability of these forms of livestock production. Altogether, the opportunities for increasing (peri)urban livestock production and trade strongly depend on the availability and accessibility of sufficient feed resources. In turn, this is strongly linked to the supply of feed resources, such as grain legume residues, by smallholder farmers, which is why a comprehensive value chain analysis would be advised.

The current study was an explorative study which allowed for a first identification and characterization of ruminant value chain actors in the northern part of Ghana. We were able to get a good impression of the current structure and operational reach of ruminant value chains in the two different regions. In addition, we established the importance of a missing link in the value chain (i.e. the middleman), that serves a crucial yet undefined role in connecting rural and urban production (livestock and feeds). In order to get better insight into value chain actor interrelationships and value chain efficiency, more information about these middlemen is essential. Considering that the livestock sector is an important contributor to the livelihoods of many (rural and urban) farmers, both in terms of food security and income generation. The value chain based approach used in this study may be considered a stepping stone for future studies to better fine tune the implementations of targeted interventions in livestock production and implications for all stakeholders involved.

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Appendix

A1. Livestock fattener and trader Survey

Evaluating the use of grain legume residues use as livestock feed resource among livestock fatteners and traders in northern Ghana.

Introduction and Consent

Dear Respondent(s),

My name is ..... I am a member of a team of enumerators assisting Mr. Daniel Brain Akakpo (a student) to collect data on the '**use of grain legume residues as livestock feed resource for smallholders in Northern Ghana'** This research is conducted under the N2Africa project being implemented in your district by International Institute of Tropical Agriculture (IITA). You have been randomly selected from the list of farmers in this community to provide information for this research. The information you provide will help us to gain insights into the use of grain legume residues in your community. We also take GPS measurements of your homestead and farms for reference. Filling this questionnaire may take approximately an hour. Any information you provide will be strictly confidential and will not be used for any purpose other than research. Thanks for your cooperation and understanding.

Consent given? ☐ Yes ☐ No

Survey Staff Information			
Name of enumerator			
Enumerator's Tel. No:			
Supervisors name			
Date of interview			
Interview start time			
Language used		Was translator used?	Yes =1 No= 2
Interview location: □ Household □ Farm/Market			
Region			
District			
Community			
GPS Coordinates			
Longitudes	_____._____^{0}		
Latitudes	_____._____^{0}		
Elevation (metres)			

PERSONAL AND BUSINESS CHARACTERISTICS

Are you a livestock fattener or trader?	1= fattener	2= trader	3=both

Questions	Response
Name of fattener or trader	
Sex of respondent	Male / Female
Age of the respondent	_____Years
Number of years in the business	_____Years
Highest level of education	□None □ Primary □ Junior high □ Senior high □ Tertiary
Marital status of the respondent	□ Single □ Married □ Divorced
Religion of the respondent	□ Christianity □ Islam □ Traditionalist □ Others
Is the respondent the owner of the business?	Yes/ No
If no, what is your relationship with the owner?	□ Family member □ Hired employee □ Others

Additional Notes:

SECTION 1: KIND OF LIVESTOCK FATTENED

Animal species	Sub group	Current stock (n)	Source of your stock (Code1)**	How long do you fatten to acceptable weight (No.of months)	Which feeds do you use? (Code 2)**	Quantity of feed offered per animal/ day (Kg)*	Bought in past 12 months (n)	Died, gift/ slaughtered in 12 months (n)	Sold out in the past 12 months (n)	Animals mainly sold to (Code 3)**
Cattle	Female									
	Male									
Sheep	Female									
	Male									
Goats	Female									
	Male									
Others (specify)	Female									
	Male									
	Female									
	Male									

Code 1: 1 = from own stock through breeding; 2 = own stock kept with Fulani herdsmen; 3 = fellow farmers; 4= open markets; 5: others (specify)

Code 2: 1= cowpea residues; 2= groundnut residues; 3= soybean residues; 4= pigeon pea residues; 5= maize stock; 6= sorghum stock; 7= millet; 8= rice straw; 9= green fodder; 10= green grass; 11= concentrates; 12= industrial by-products; 13= cassava peels; 14= yam peels; 15= sweet potato vines; 16= grazing; 17= others (specify)

Code 3: 1= directly to consumer; 2= fellow farmers; 3= middlemen/ traders; 4= butchers; 5= others (specify)

* Ask the quantity of feed in terms of local units
** Multiple responses are allowed (Max 3 please; Max 4 for the FEEDS only)

Additional notes:

SECTION 1.1: MARKET PRICE OF ANIMALS & TIMING OF PURCHASES/SALES OF ANIMALS

Code 1: 1= Breed; 2= Age; 3= Size; 4= Health status of the animal; 5= Sex; 6= Seasons; 7= Colour

Animals	Subgroup	BUYING			SELLING		
		Price range (GHC)	Variation in price is mainly caused by : (code 1)**	During which months do you mainly buy? (e.g Jan or Jan-May)	Price range (GHC)	Variation in price is mainly caused by: (code 1)**	During which months do you mainly sell? (e.g Jan or Jan-May)
Cattle	Female						
	Male						
Sheep	Female						
	Male						
Goats	Female						
	Male						
Others	Female						
	Male						

** Multiple responses are allowed (Max. 3 please)

Additional notes:

SECTION 2: KIND OF LIVESTOCK TRADED

Animal species	Sub group	Current stock (n)	Source of your stock (Code1)**	How long do your animals stay with you (No. of weeks)	Which feeds do you use? (Code 2)**	Quantity of feed offered per animal/ day (Kg)*	Bought in past 12 months (n)	Died, gift/ slaughtered in 12 months (n)	Sold out in past 12 months (n)	Animals mainly sold to (Code3)**
Cattle	Female									
	Male									
Sheep	Female									
	Male									
Goats	Female									
	Male									
Others (specify)	Female									
	Male									
	Female									
	Male									

Code 1: 1 = from own stock through breeding; 2 = own stock kept with Fulani herdsmen; 3 = fellow farmers; 4= open markets; 5: others (specify)

Code 2: 1= cowpea residues; 2= groundnut residues; 3= soybean residues; 4= pigeon pea residues; 5= maize stock ; 6= sorghum stock; 7= millet; 8= rice straw; 9= green fodder; 10= green grass; 11= concentrates; 12= industrial by-products; 13= cassava peels; 14= yam peels; 15= sweet potato vines; 16=Grazing; 17= Others (specify)

Code 3: 1= directly to consumer; 2= fellow farmers; 3= middlemen/traders; 4 = butchers; 5 = others (specify)

*****Ask quantity in terms of local units

** Multiple responses are allowed (Max. 3 please; Max 4 for the FEEDS only)

Additional notes:

SECTION 2.1: MARKET PRICE OF ANIMALS & TIMING OF PURCHASE/SALES OF ANIMALS

Code 1: 1= Breed; 2= Age; 3= Size; 4= Health status of the animal; 5= Sex; 6= Seasons; 7= Colour

Animals	Subgroup	BUYING			SELLING		
		Price range (GHC)	Variation in price is mainly caused by : (code 1)**	During which months do you mainly buy? (e.g. Jan or Jan-May)	Price range (GHC)	Variation in price is mainly caused by: (code 1)**	During which months do you mainly sell? (e.g. Jan or Jan-May
Cattle	Female						
	Male						
Sheep	Female						
	Male						
Goats	Female						
	Male						
Others	Female						
	Male						

** Multiple responses are allowed (Max. 3 please)

Additional notes:

SECTION 3: LABOUR COSTS RELATED TO FATTENING AND TRADING OF LIVESTOCK

Types of labour	Do you use (Yes/No)	Proportion of total labour (%)
Family Labour		
Hired Labour		

In case you use hired labour, what are the estimated costs of hired labour? .....GHC/ Month

SECTION 4: OTHER COSTS RELATED TO FATTENING AND TRADING OF LIVESTOCK

Code 1: 1= daily; 2= weekly; 3= fortnightly; 4= monthly; 5= quarterly; 6= biannually; 7= annually

Items /services	Frequency (Code 1)	Estimated costs per year (GHC)
Medication (vaccines, antibiotics etc.)		
Veterinary services		
Animal housing (maintenance)		
Water		
Others (specify)		

SECTION 5: ACCESS TO LIVESTOCK MARKETS

Do you use livestock markets to buy and/or sell your animals? □ yes □ no
If yes, please continue with the following questions in this section:

Markets used (Location)	What do you do at this market? (buy or sell or both)	Distance to market (Miles)	Method of transportation of animals (Code 1)	Costs of transportation per animal (GHC)*	Frequency of visits (code 2)
1.					
2.					
3.					
4.					

Code 1: 1= on foot; 2= bicycle; 3= motorbikes; 4= motorized tricycle; 5= commercial vehicle; 6= trucks
Code 2: 1= daily; 2= weekly; 3= fortnightly; 4= monthly; 5= quarterly; 6= biannually; 7= annually
***** If both Small and Large ruminants are transported, please make a distinction between these two categories.

SECTION 6: SOURCES OF INCOME

Income source (select 4 main sources)	Estimated income in 2015 (%)
Crops	
Fattening and selling of livestock	
Trading in livestock	
Labouring/service (e.g. artisans)	
Formal employment (e.g. teachers)	
Remittance (local and foreign) (i.e. supported by others and/or family)	
Petty trading	
Others	
Must add up to 100%	**100**

SECTION 7: PURCHASED FEEDS AND COLLECTED FEEDS FROM THE COMMUNITY

Please choose the 4 most important feeds you have purchased over the past 12 months, and RANK them accordingly.

Feeds (Code 1)	Source of feed (Code 2)**	Price/ local unit	Typical quantity per purchase in local units	How often do you buy feed (Code 3)	Factors to consider in feed purchase (Code 4)**	Percentage of feed bought, feed collected freely yourself and/or exchanged with manure (must add up to 100%)		
						Bought	Free collection	Exchanged with manure
1.								
2.								
3.								
4.								

Feed Code 1*: 1= Cowpea residues; 2 = Groundnut residues; 3= Soybean residues; 4= Pigeon pea residues; 5= Maize stock; 6= Sorghum stock; 7= Millet; 8= Rice straw; 9= Green fodder;10= Green grass; 11= Concentrates; 12= Industrial wastes; 13= Cassava/ Yam peels; 14= Cottonseed cake; 15= Grazing; 16= Others (specify); 17= Sweet potato vines*

Code 2: 1= farmers; 2= middlemen; 3= brewers; 4= industries; 5= others (specify)
Code 3: 1=daily 2=weekly, 3=fortnightly 4=monthly 5=quarterly 6=seasonally; 7=biannually; 8= annually; 9= others (specify)
Code 4:1= costs; 2= nutritional value; 3= animal acceptance; 4= ease of transportation; 5= storability;6= not molded; 7= others

*** Multiple responses are allowed (Max. 3 please)*

Additional notes:

SECTION 8: FEED STORAGE AND RANKING ON FEEDING VALUE

Feed (as formulated above)	**Any feed in storage? Yes / No**	**Quantity of total purchase/ production in storage (%)**	**Storage method use (Code 1)**	**Quantity lost/spoilt during storage (%)**	**Main cause of lost / spoilage (Code 2)**	**How long do you store the feed? (Months)**	**Mode of feeding animals with stored feed (Code 3)**	**Score for Animal preference (1 – 5)**	**Score for storability (1 – 5)**	**Rank on feeding value (1 – 5)**
1.										
2.										
3.										
4.										

Feed code: *1= Cowpea residues; 2 = Groundnut residues; 3= Soybean residues; 4= Pigeon pea residues; 5= Maize stock; 6= Sorghum stock; 7= Millet; 8= Rice straw; 9= Green fodder;10= Green grass; 11= Concentrates; 12= Industrial waste; 13= Cassava/ Yam peels; 14= Cottonseed cake; 15= Grazing; 16= Others (specify; 17= Sweet potato vines*

Code 1:*1=Sacks/bags 2= Room 3=tree fork 4= lined Pit in ground 5=Drums 6=Cribs 7=Raised open platforms 8=Raised roofed platforms 9=Open ground-covered 10=Open ground-uncovered 11=Commercial storage 12= Multiple methods 13= Others (Specify)*

Codes 2: *1=Theft 2=strayed animals 3=rain 4=wind 5=fire 6=insects 7=mold 8=multiple reasons 9=others*

Code3: *1=chopped dry; 2=whole dry; 3=chopped sprinkled with water(brine;) 4=Mixed with other feeds; 5= Whole sprinkled with water(brine); 6=Others(specify)*

Scoring and Ranking: *1=Not good at all 2=Quite good 3=Good 4= Very good 5=Excellent*

SECTION 9: FEED QUALITY DETERMINATION

How do you determine the feeding quality of your purchased feed?

Feeds (as formulated above)	**Colour**	**Smell**	**Texture of the leaves**	**Number of leaves**	**Size of leaves**	**Acceptance by animals**	**Others (specify)**
1.							
2.							
3.							
4.							

Feed code: *1= Cowpea residues; 2 = Groundnut residues; 3= Soybean residues; 4= Pigeon pea residues; 5= Maize stock; 6= Sorghum stock; 7= Millet; 8= Rice straw; 9= Green fodder;10= Green grass; 11= Concentrates; 12= Industrial waste; 13= Cassava/ Yam peels; 14= Cottonseed cake; 15= Grazing; 16= Others (specify); 17= Sweet potato vines*

Codes: 1*= not important; 2= less important; 3= somewhat important; 4= important; 5= very important*

SECTION 10: TRENDS IN CROP RESIDUE UTILIZATION

Over the past 10 years, what has changed about the use and management of crop residues in your business?

Crops	Quantity used for feeding	Availability	Price	Quality	Selling of feeds	Storability	Ease of Transportation	Animal acceptance	Animal health risks
1.									
2.									
3.									
4.									

Feed code: *1= Cowpea residues; 2 = Groundnut residues; 3= Soybean residues; 4= Pigeon pea residues; 5= Maize stock; 6= Sorghum stock; 7= Millet; 8= Rice straw; 9= Green fodder; 10= Green grass; 11= Concentrates; 12=Industrial wastes; 13= Cassava/ Yam peels; 14= Cottonseed cake; 15= Grazing; 16=Others (specify; 17= Sweet potato vines*

Change Codes*: 1= decreased; 2=no change 3= increased*

Please gives some general reasons for the changes in the use and management of crop residues

_____

_____

_____

_____

_____

Please specify the negative health effects on your animals which are associated with using certain livestock feeds (those indicated above)

***** Only answer if any change in health risks for the listed feeds has occurred***

_____

_____

_____

_____

_____

SECTION 11: TRADERS'/ FATTERNERS' PERCEPTION ON THE USE OF GRAIN LEGUME RESIDUES (GLRs) AS LIVESTOCK FEED AS COMPARED TO OTHER FEED RESOURCES

State your position whether you agree or not on the following statements on a scale of 1 – 5:

**Grain legume residues (GLRs) are: cowpea residues, soybean residues, groundnut residues, pigeon pea residues

No	Statement	Response				
1	GLRs are a good source of animal feed	**1**	**2**	**3**	**4**	**5**
2	GLRs are a cheap source of feed for my animals	**1**	**2**	**3**	**4**	**5**
3	Animals perform better when fed with GLRs than other feed sources	**1**	**2**	**3**	**4**	**5**
4	I preferably use GLRs as livestock feed compared to concentrates	**1**	**2**	**3**	**4**	**5**
5	GLRs are more easily accessible than concentrates	**1**	**2**	**3**	**4**	**5**
6	GLRs are only available in the dry season	**1**	**2**	**3**	**4**	**5**
7	GLRS are only useful in the dry season	**1**	**2**	**3**	**4**	**5**
8	GLRs cannot store longer than 5 months	**1**	**2**	**3**	**4**	**5**
9	I have increased the use of GLRs as livestock feed over the past 10 years	**1**	**2**	**3**	**4**	**5**

1. Strongly disagree 2. Disagree 3. Neutral 4.Agree 5. Strongly agree

SECTION 12: CHALLENGES AND COPING STRATEGIES

Please mention the 4 major challenges facing your enterprise and your coping strategies.

No.	Major challenges (Code 1)	Ranking (1-4)**	Coping strategies
1.			
2.			
3.			
4.			

***Code 1**: 1= Feed shortages; 2= Water shortage; 3=Pests and diseases; 4=Access to credit; 5= Lack of cash; 6= Animal housing; 7= Access to veterinary services; 8= Others (specify)*

*** Rank on a scale from 1-4, with 1 being the most important challenge.*

SECTION 13: FEED CALENDAR AND FEED SECURITY FOR RUMINANTS

Score (on the scale of 1-10) the months in 2016 in which animals are fed with one of the sources listed below

Feed sources	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Legume residues												
Cereals residues												
Industrial wastes												
Open grazing in communal areas												
Tethering in open field												
Cut and carry												
Concentrates												
Others (Specify)												
Must add up to 10	10	10	10	10	10	10	10	10	10	10	10	10

A2. Smallholder Survey

Wageningen Institute of Animal science (WIAS), Wageningen University, The Netherlands. Survey questionnaire on the use of grain legume residues as livestock feed resource for smallholders in Northern Ghana

Consent given? ☐ Yes ☐ No

Survey Staff Information			
Name of enumerator			
Enumerator's Tel. No:			
Supervisors name			
Date of interview	_____-_____-_____		
Interview start time			
Language used		Was translator used?	1= Yes 2= No
Interview location: 1= □ Household 2 = □ Farm 3 = □ Both			
Region	1= Northern region	2= Upper East	3= Upper West
District			
Community			
GPS Coordinates			
Longitudes	W_____._____^{0}		
Latitudes	N_____._____^{0}		
Elevation (metres)	_____m		

PERSONAL CHARACTERISTICS

Questions	Response
Name of farmer	
Telephone number of respondent	
Sex of respondent	1= Female 2= Male
Age of the respondent	_____Years
Number of years in farming	_____Years
Highest level of education	1= None 2= Primary 3= Junior high 4= Senior high 5= Tertiary
Marital status of the respondent	1= Single 2= Married 3= Divorced
Religion of the respondent	1= Christianity 2= Islam 3= Traditionalist 4= Others
Is the respondent the Household head (HH)?	1= Yes 2= No
If no, what is your relationship with the (HH)?	1= Family member 2= Hired employee 3= Others

SECTION A: Household composition

* A "**household**" includes all members of a residence that are sharing consumption of food and other items. Include permanent workers or servants as members of the household only if resident at least six months in the household.

Age Class	No. of Males	No. of Females	Total Number
	A1	A2	A3
1.Below 6 years			
2.Between 6-9 years			
3.Between 10-15 years			
4.Between 16-60 years			
5.Above 60 years			

SECTION B: Crop production

BA1. How many plots of land do you have for farming? _____ **BA2**. What is the total size of the farm land you have/own?_____

BA3. Do you practice intercropping? **1=Yes 2 = No**.

Indicate plots intercropped in **Code 1** (if intercropping involves more than two crops, please consider the two major crops)

Plots (Land owned)	Size of plot (acres)	Current use of plot (code 1)	If used for crops, which crops do you grow? (code 2)	2016 Yields (no. of bags)	Tenure system (code 3)	If rented-**in** this year how much did you pay?	If rented-**out** this year, how much did you earn?	If share- cropped this year, what % of harvest did you pay?	How long does it take you to get to your farm on foot (minutes, one way)? (code 4)
	B1	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**
Plot cropped **(1)**									
Plot cropped **(2)**									
Plot cropped **(3)**									
Plot cropped **(4)**									
Plot cropped **(5)**									

Code 1: 1=Sole crop;2= Intercrop; 3= Fodder; 4= Grazing; 5= Fallow; 6= Others (specify)

Code2: 1=Maize; 2=Millet; 3=Sorghum; 4= Rice; 5=Cowpea; 6= Groundnuts; 7= Soybean; 8=Bambara; 9= Pigeon pea;10= yam 11=Cassava; 12= Sweet potato; 13=vegetables; 14 = Other

Code 3: 1= Own land (i.e. through inheritance); 2= Land rented in; 3= Land rented out; 4= Sharecropped; 5= Family land; 6=Outright purchase; 7=Communal; 8= Others (specify)

Code 4: 0= <1 minute; 1= 1-30 minutes; 2= 31-60 minutes; 3= More than 60 minutes

SECTION C: Livestock production

CA1. Does your household own any livestock? **1 = Yes 2 = No**

If yes, **indicate** the **numbers of animals** for the different species owned by the household

Livestock Species		Current stock (n)	Bought in past 12 months (n)	Died, gift/ slaughtered in past 12 months (n)	Sold out in past 12 months (n)	If you would sell, what is the current price range in GHC? (min-max)	To whom do you mainly sell? (code 1)
		C1	**C2**	**C3**	**C4**	**C5**	**C6**
1. Cattle	**a**.Male						
	b.Female						
	c.Calves						
2. Sheep	**a**.Male						
	b.Female						
	c.Kids						
3. Goat	**a**.Male						
	b.Female						
	c.Kids						
4. Pig	**a.**Male						
	b.Female						
	c.Piglets						
5.Poultry							
6.Donkeys/Horses							
7.Other, specify:							

Code 1: 1= directly to consumers; 2= livestock traders/ middlemen; 3= fellow farmers; 4= butchers; 5= others

SECTION D: What are the major reasons why you keep the major classes of animals? (code 1)

Animal	Cash	Meat	Milk	Draught power	Manure	Store of wealth	Others (Specify)	Others (Specify)
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**
1.Cattle								
2.Sheep								
3.Goats								
4.Pigs								
5.Poultry								
6.Donkeys/Horses								
7.Others (specify)								

Codes 1: 1= not important; 2= less important; 3= somewhat important; 4= important; 5= very important

D 9.1: Over the past 5 years, have there been any changes in the reasons for keeping animals?

1= Yes 2= No

D9.2: If yes, could you please explain why and how the reasons for keeping animals have changed?

(*how: e.g. "five years ago I kept my cattle mainly to feed my own family but over the years I have started to sell animals more often to make an extra income")*

.....
.....
.....
.....

SECTION E: Crop Residue (CR) Utilization

CR (code 1)	Residue types (code 2)	Left in field			Sold out of farm		**Livestock Feed (%)** (i.e. brought home from the field)	Compost (%)	Fuel (%)	Others (Specify)	%
		Mulch (%)	Grazed (%)	Burnt (%)	Sold (%)	Total Value (GHc)					
E1	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**	**E10**	**E11**	
1.											**100**
2.											**100**
3.											**100**
4.											**100**

Code 1: 1=Maize; 2=Millet; 3=Sorghum; 4= Rice; 5=Cowpea; 6= Groundnut; 7= Soybean; 8=Bambara; 9= Pigeon pea; 10= yam; 11=Cassava; 12= Sweet potato; 13=vegetables; 14 = Others

Code 2: 1=cob; 2=stalk; 3=leaves; 4=husk; 5=shells; 6=vines; 7= Stems; 8=Others

**** If any crop residues are used as Livestock Feed (E8) please ask the respondent whether he/she has one or more of these crop residues in storage****

If YES, do continue to fill in the table below; If NO, please skip SECTION F below

SECTION F: Residues storage and ranking on feeding value

CR (code 1)	Any crop residues in storage? *1=Yes 2=No*	**If yes**, what is the quantity of total production in storage (%)	Storage method used (codes 2)	Quantity lost/spoilt during storage (%)	**If yes**, what is the main cause of lost / spoilage (Code 3)	How long do you store the residues? (Months)	Mode of feeding animals with stored residues (Codes 4)	Score for animal preference (1 – 5) (code 5)	Score for storability (1 – 5) (code 5)	Ranking for feeding value (1 – 5) *1= lowest 5=highest*
F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**	**F11**
1.										
2.										
3.										
4.										

Code 1: 1=Maize;2=Millet;3 =Sorghum; 4= Rice; 5=Cowpea; 6= Groundnuts; 7= Soybean; 8=Bambara; 9= Pigeon pea; 10= yam; 11=Cassava; 12= Sweet potato; 13=Vegetables; 14 =Others

Code 2:1=Sacks/bags; 2= Room ; 3=tree fork; 4= lined Pit in ground; 5=Drums; 6=Cribs; 7=Raised open platforms; 8=Raised roofed platforms; 9=Open ground-covered; 10=Open ground-uncovered; 11=Commercial storage; 12= Multiple methods; 13= Others

Codes 3: 1=theft; 2=strayed animals; 3=rain; 4=wind; 5=fire; 6=insects; 7=mold; 8=multiple reasons; 9=others

Code4: 1=chopped dry; 2=whole dry; 3=chopped sprinkled with water(brine); 4=Whole sprinkled with water(brine)

Code 5: 1=Not good at all; 2=Quite good; 3=Good; 4= Very good; 5=Excellent

****If the respondent does NOT sell and/or buy crop residues, please skip SECTION G below****

SECTION G: Marketing of crop residues

CR (code 1)	Do you sell or buy? *1=sell 2=buy 3=both*	Who do you sell to or buy from? (code 2)	Where do you sell or buy? (code 3)	Distant to market center (miles)	Quantity sold or bought /year (local unit) **i.e. bowls, bags, bundles, sacks etc.**		Score on salability (1-5) *1= difficult 5= easy*
					Sold	Bought	
G1	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**
1.							
2.							
3.							
4.							

Code 1: 1=Maize; 2=Millet; 3=Sorghum; 4= Rice; 5=Cowpea; 6= Groundnuts; 7= Soybean; 8=Bambara; 9= Pigeon pea; 10= yam; 11=Cassava 12= Sweet potato; 13=vegetables; 14 =Others (specify)
Code 2: 1= fellow farmers; 2=livestock fatteners; 3= livestock traders; 4=middlemen; 5=others (specify)
Code 3: 1=Farm gate; 2=Local market; 3=District market; 4=Regional market; 5=others (specify)

**** If the respondent does not use any crop residues as Livestock Feed (E8) please skip SECTION H ****
If YES, do continue to fill in the table below:

SECTION H: Trends in crop residue utilization (code 2)
Over the past 10 years, what has changed about the use and management of crop residues in your community? Mention the four (4) most important CR used in feeding livestock

Code 1: 1=Maize; 2=Millet;3=Sorghum; 4= Rice; 5=Cowpea; 6= Groundnuts;7= Soybean; 8=Bambara; 9= Pigeon pea; 10= Yam

CR (code 1)	Quantity used for feeding (code 2)	Availability (code 2)	Price (code 2)	Quality (code 2)	Selling of CR (code 2)	Storability (code 2)	Ease of Transportation (code 2)	Animal acceptance (code 2)
H1	**H2**	**H3**	**H4**	**H5**	**H6**	**H7**	**H8**	**H9**
1.								
2.								
3.								
4.								

11=Cassava; 12= Sweet potato; 13=vegetables; 14 =Other
Code 2: 1= decreased; 2=no change; 3= increased

Please gives some general reasons for the changes that have occurred as indicated in the table above

SECTION I: Reasons for growing grain legumes (GL)

What are the major reasons why you grow the major grain legumes? Please indicate the reasons by rating on a scale of 1-5 (code 2)

GL (code 1)	Cash	Food	Feed/ residues	Soil fertility	Seed	To control pests and diseases in other crops	Others (Specify)	Others (Specify)
I1	**I2**	**I3**	**I4**	**I5**	**I6**	**I7**	**I8**	**I9**
1.								
2.								
3.								
4.								

Codes 1: 1= cowpea; 2= groundnut; 3= soybean; 4= bambara; 5= pigeon pea

Code 2: 1= not important; 2= less important; 3= somewhat important; 4= important; 5= very important

I10. 1: Over the past 5 years, have there been any changes in the reasons for growing grain legumes? 1= yes 2= no

I10.2: If yes, could you please explain why and how the reasons for growing grain legumes have changed?

……
……
……
……
……
……

**** If the respondent does not use any stored grain legume residues to feed his/her animals, please skip SECTION J below****

If YES, please do continue to fill in the table below.

SECTION J: Quality determination of grain legume residues (GLRs)

How do you determine the feeding quality of your **stored GLRs**? (code 2)

GLR (code 1)	Colour	Smell	Texture of the leaves	Number of leaves	Size of leaves	Acceptance by animals	Others (specify)
J1	**J2**	**J3**	**J4**	**J5**	**J6**	**J7**	**J8**
1.							
2.							
3.							
4.							

Code 1 : 1= cowpea; 2= groundnut; 3= soybean; 4= bambara; 5= pigeon pea

Code 2: 1= not important; 2= less important; 3= somewhat important; 4= important; 5= very important

SECTION K: Farmers' perception on the use of GLRs as a livestock feed resource and source of income (GLRS: i.e. cowpea, groundnut, soybean, pigeon pea, bambara residues)

State your position whether you agree or not on the following statements on a scale of 1 – 5:

1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree

No	Statement	Response				
K1.	GLRs are a good source of animal feed	**1**	**2**	**3**	**4**	**5**
K2.	GLRs are a cheap source of feed for my animals	**1**	**2**	**3**	**4**	**5**
K3.	Animals perform better when fed with GLRs than with other feed sources	**1**	**2**	**3**	**4**	**5**
K4.	For feeding my animals I prefer to use GLRs over concentrates	**1**	**2**	**3**	**4**	**5**
K5.	GLRs are easier to access than concentrates	**1**	**2**	**3**	**4**	**5**
K6.	The quality of animal manure is better when animals are fed with GLRs	**1**	**2**	**3**	**4**	**5**
K7.	I would rather feed my GLRs to animals than use it as mulch	**1**	**2**	**3**	**4**	**5**
K8.	I would rather feed my GLRs to animals than compost it	**1**	**2**	**3**	**4**	**5**
K9.	I would rather feed my GLRs to animals than burn it as fuel wood	**1**	**2**	**3**	**4**	**5**
K10.	GLRs are only available in the dry season	**1**	**2**	**3**	**4**	**5**
K11.	GLRs are only useful in the dry season	**1**	**2**	**3**	**4**	**5**
K12.	GLRs cannot be stored longer than 5 months	**1**	**2**	**3**	**4**	**5**
K13.	I would prefer animals to graze on GLRs left in the field than bringing GLRs home	**1**	**2**	**3**	**4**	**5**
K14	I have increased the use of GLRs as a livestock feed resource for my animals over the past five years	**1**	**2**	**3**	**4**	**5**
K15.	I have increased the sales of GLRs over the years	**1**	**2**	**3**	**4**	**5**
K16.	I make more money from selling GLRs than from the selling of grains	**1**	**2**	**3**	**4**	**5**
K17.	There is more ready market for GLRs than grains	**1**	**2**	**3**	**4**	**5**

****If the respondent does not buy any additional feeds for his/her animals, please skip SECTION L ****

SECTION L: Purchased livestock feeds and feeds collected for free from the community

Apart from crop residues as a livestock feed resource, which other feeds have you purchased over the past 12 months?

Feeds (Code 1)	Source of feed (Code 2)	Price/ local unit (e.g. bowl, bundle, bag)	Typical quantity per purchase in local units	How often do you buy feed (Code 3)	Factors to consider in feed purchase (Code 4)	Percentage of feed bought, feed collected freely yourself and/or exchanged with manure (must add up to 100%)		
						Bought	Free collection	Exchanged with manure
L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**
1.								
2.								
3.								
4.								

Code 1: 1= Rice straw; 2= Green fodder;3= Green grass (i.e. bundles of green grass); 4= Concentrates (i.e. high nutrient formulated feeds) ; 5= Industrial by-products (e.g. wheat, maize, rice bran); 6= Cassava/ Yam peels;7= Cottonseed cake; 8= Others (specify)

Code 2: 1= farmers; 2= middlemen; 3= brewers; 4= industries; 5= others (specify)

Code 3: 1=daily 2=weekly, 3=fortnightly 4=monthly 5=quarterly 6=seasonally; 7=biannually; 8= annually; 9= others

Code 4:1= costs; 2= nutritional value; 3= animal acceptance; 4= ease of transportation; 5= storability;6= not molded; 7= others

** Grazing ≠ Green grass (i.e. bundles of green grass), and is also not part of Purchased Feeds!

SECTION M: Feed calendar and feed security for <u>RUMINANTS</u>

Score (on the scale of 1-10) the months in 2016 in which animals are fed with one of the sources listed below

Feed sources	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
	M1.	**M2.**	**M3.**	**M4.**	**M5.**	**M6.**	**M7.**	**M8.**	**M9.**	**M10.**	**M11.**	**M12.**
1.Legume residues												
2.Cereals residues												
3.Industrial wastes												
4.Open grazing in communal areas												
5.Tethering in open field												
6.Cut and carry												
7.Concentrates												
8.Others (Specify)												
Must add up to 10	10	10	10	10	10	10	10	10	10	10	10	10

SECTION N: Sources of income

Income source (select <u>max</u>.4 main sources)	**Estimated income in 2015 (%)**	
Crops	**N1.**	
Selling of crop residues	**N2.**	
Selling of livestock	**N3.**	
Labouring/service (e.g. artisans)	**N4.**	
Formal employment (e.g. teachers)	**N5.**	
Remittance (local and foreign) (i.e. supported by others and/or family)	**N6.**	
Petty trading	**N7.**	
Others	**N8.**	
Must add up to 100%	**100 %**	

SECTION R: Costs related to livestock and crop production on a yearly basis

If there are any additional costs related to the keeping/rearing of livestock and/or production of crops, please indicate which proportion (%) of your expenditures go out to one or more of the following activities/services

Activities	**Estimated costs per year in %**	**Have the costs decreased, increased or remained the same over the past 5 years (code 1)**
	R1	**R2**
1.Veterinary services		
2. Medication (antibiotics, vaccination etc.)		
3.Animal housing (maintenance)		
4.Land preparation (ploughing)		
5.Seeds		
6.Chemical fertilizer		
7.Pesticides/herbicides		
8.Labour related to livestock		
9.Labour related to crops		
10.Others:		

<u>Code 1:</u> 1= decreased; 2= no change; 3= increased

SECTION P: Knowledge and adoption of new grain legume and livestock technologies in the last 3 years

Name of technology	Ever used? *1= yes* *2= no*	**If yes**, what is your source of information? (code 1)	Rate the outcome *1=profitable* *2=normal* *3=least profitable*	Will you try it again? *1=yes* *2=no* *3= don't know*	**If no,** what are the reasons for not adopting or stopping with applying this technology? (code 2)
	P1	**P2**	**P3**	**P4**	**P5**
1.Use of inoculants					
2.Chemical fertilizers					
3.Improved seeds					
4.Intercropping					
5.Storage of crop residues used as feed					
6.Cut and carry feeding					
7.Purchased feeds					
8.Pasture growing					
9.Housing of animals					
10.Veterinary products &services					
11.Other (specify)					

Code 1: 1= fellow farmer, 2=ministry of food and agriculture, 3=research institute, 4=media, 5=NGO, 6=Agro dealer shop, 7=others

Code 2: 1= Shortage of labour; 2= Shortage of land; 3= Shortage of capital/credit; 4= Unavailability of the technology in the locality; 5= Limited awareness about the technology and its benefits; 6= Limited market demand for the product; 7= Not profitable to invest; 8=Lack of cooperation with neighbour; 9= Shortage of proper technical advice from extension agents; 10= Others

SECTION Q: Household Assets

Please tell me the number of the following assets you owned in the household and their current monetary value.

Name of asset	Number owned	If you were to sell all of them today, how much would they be worth in GHc
	Q1	Q2
1.Tractor		
2.Car/Truck		
3.Motorcycle (s)		
4.Tricycle		
5.Bicycle(s)		
6.Cart (animal drawn)		
7.Hoes		
8.Spades/shovel		
9.Ploughs		
10Crop Thresher/ Sheller		
11.Knapsack Sprayer		
12.Water pump		
13.Wheelbarrow		
14.Water tank		
15.Watering can		
16.Stores		
17.Feed lot		
18.Incubator		
19.Grinding mill		
20.Computer		
21.TV		
22.Radio		
23.Normal mob. Phone		
24.Smart phone		
Residential		
25.Thatched mud house		
26.Mud house with corrugated iron sheet		
27.Block house with corrugated iron sheet		
28.Ware house		
29.Pit Latrine		
30.Water well		
31.Water pond/Dam		

A3. Buying and selling prices of livestock

A 3.1 Minimum and maximum buying prices for (both) livestock fatteners in the Northern region (NR) and in the Upper East region (UER)

Minimum buying prices

	Fatteners NR (n=21)			Fatteners UER (n=24)			Both fattener/trader UER (F)[1] (n=21)			P-value*
	n	Mean	SD	n	Mean	SD	n	Mean	SD	
Cattle										
male	15	**823**[a]	±294.5	23	**1452**[b]	±617.1	20	**1496.5**[b]	±623.3	**0.002**
female	12	808	±320.4	13	1100	±365.2	13	1115	±454.3	0.060
Sheep										
male	17	540	±570.7	6	433	±345.0	7	460	±261.5	0.858
female	16	350	±461.5	6	338	±342.7	6	258	±135.7	0.960
Goats										
male	5	266	±215.1	3	200	±80.00	2	185	±91.92	0.972
female	5	232	±172.9	3	170	±87.17	2	160	±56.57	0.933

***p-values : based on a non-parametric Kruskal Wallis test (and a post hoc multiple comparison test with Bonferroni correction), superscripts (a-b) indicate significant differences between groups**
F[1]: refers to the prices given by the group of both fatteners and traders for fattening animals

Maximum buying prices

	Fatteners NR (n=21)			Fatteners UER (n=24)			Both fattener/trader UER (F)[1] (n=21)			p-value*
	n	Mean	SD	n	Mean	SD	n	Mean	SD	
Cattle										
male	15	**1130**[a]	±453.5	23	**1861**[b]	±588.3	20	**1876**[b]	±708.4	**0.001**
female	12	1150	±429.6	13	1260	±368.1	13	1335	±452.5	0.580
Sheep										
male	17	771	±721.8	6	522	±403.5	7	583	±267.2	0.652
female	16	592	±644.6	6	420	±356.7	6	363	±179.1	0.742
Goats										
male	5	332	±246.4	3	240	±17.32	2	225	±106.1	0.988
female	5	288	±208.6	3	200	-	2	215	±91.92	-

***p-values : based on a non-parametric Kruskal Wallis test (and a post hoc multiple comparison test with Bonferroni correction), superscripts (a-b) indicate significant differences between groups**
F[1]: refers to the prices given by the group of both fatteners and traders for fattening animals

A 3.2 Minimum and maximum selling prices for (both) livestock fatteners in the Northern region (NR) and in the Upper East region (UER)

Minimum selling prices

	Fatteners NR (n=21)			Fatteners UER (n=24)			Both fattener/trader UER (F)[1] (n=21)			P-value
	n	Mean	SD	n	Mean	SD	n	Mean	SD	
Cattle										
male	15	2133	±977.4	22	2155	±606.1	20	2008	±769.9	0.735
female	10	1310	±490.9	13	1446	±542.9	13	1454	±554.7	0.781
Sheep										
male	16	980	±562.9	6	748	±671.0	7	614	±357.9	0.263
female	14	624	±474.6	6	592	±706.0	6	388	±185.5	0.324
Goats										
male	5	382	±302.0	4	260	±54.16	1	130	-	0.450
female	5	350	±295.8	4	195	±80.21	2	205	±106.1	0.879

***p-values : based on a non-parametric Kruskal Wallis test (and a post hoc multiple comparison test with Bonferroni correction), superscripts (a-b) indicate significant differences between groups**
F[1]: refers to the prices given by the group of both fatteners and traders for fattening animals

Maximum selling prices										
	Fatteners NR (n=21)			Fatteners UER (n=24)			Both fattener/trader UER (F)[1] (n=21)			P-value
	n	Mean	SD	n	Mean	SD	n	Mean	SD	
Cattle										
male	15	3147	±1521	22	2739	±655.7	20	2784	±778.0	0.933
female	10	1740	±696.3	13	1704	±523.0	13	1823	±593.2	0.914
Sheep										
male	16	1344	±716.2	6	847	±694.9	7	896	±522.0	0.119
female	14	814	±580.6	6	717	±702.6	6	462	±217.8	0.163
Goats										
male	5	498	±450.6	4	287.5	±62.92	1	205	-	0.663
female	5	474	±444.2	4	230	±89.10	2	290	±127.3	0.926

***p-values : based on a non-parametric Kruskal Wallis test (and a post hoc multiple comparison test with Bonferroni correction), superscripts (a-b) indicate significant differences between groups**

F[1]: refers to the prices given by the group of both fatteners and traders for fattening animals

A 3.3 Minimum and maximum buying prices for (both) livestock traders in the Northern region (NR) and Upper East region (UER)

Minimum buying prices										
	Traders NR (n=32)			Traders UER (n=8)			Both fattener/trader UER(T)[1] (n=21)			P-value*
	n	Mean	SD	n	Mean	SD	n	Mean	SD	
Cattle										
male	16	1169	±573.6	6	733	±81.65	17	1088	±396.7	0.050
female	16	**925[a]**	±409.1	5	**540[b]**	±108.4	17	**859[ab]**	±327.9	**0.033**
Sheep										
male	23	332	±174.7	5	240	±41.83	8	304	±92.11	0.682
female	23	216	±106.7	4	182.5	±23.62	8	208	±54.97	0.857
Goats										
male	16	137	±128.1	1	120	-	2	150	±42.43	0.488
female	16	144	±106.6	1	100	-	2	110	±14.14	0.767

***p-values : based on a non-parametric Kruskal Wallis test (and a post hoc multiple comparison test with Bonferroni correction), superscripts (a-b) indicate significant differences between groups**

T[1]: refers to the prices given by the group of both fatteners and traders for trading animals

Maximum buying prices										
	Traders NR (n=32)			Traders UER (n=8)			Both fattener/trader UER(T)[1] (n=21)			P-value
	n	Mean	SD	n	Mean	SD	n	Mean	SD	
Cattle										
male	16	**2575[a]**	±814.5	6	**1058[b]**	±249.8	17	**1315[b]**	±485.7	**0.000**
female	16	**1700[a]**	±545.6	5	**880[b]**	±213.9	16	**1016[b]**	±351.5	**0.000**
Sheep										
male	23	**533[a]**	±258.8	5	**310[b]**	±65.19	8	**370[b]**	±116.1	**0.016**
female	23	312	±102.4	4	243	±72.28	8	273	±62.28	0.316
Goats										
male	16	263	±161.8	1	150	-	2	160	±56.57	0.461
female	16	223	±107.6	1	120	-	2	135	±21.21	0.138

***p-values : based on a non-parametric Kruskal Wallis test (and a post hoc multiple comparison test with Bonferroni correction), superscripts (a-b) indicate significant differences between groups**

T[1]: refers to the prices given by the group of both fatteners and traders for trading animals

A 3.4 Minimum and maximum selling prices for (both) livestock traders in the Northern region (NR) and Upper East region (UER)

Miminum selling prices

	Traders NR (n=32)			Traders UER (n=8)			Both fattener/trader UER (T)[1] (n=21)			P-value
	n	Mean	SD	n	Mean	SD	n	Mean	SD	
Cattle										
male	15	1377	±636.4	6	1023	±245.5	17	1305	±452.5	0.415
female	16	1094	±423.4	5	810	±74.16	17	1003	±318.9	0.172
Sheep										
male	23	383	±183.1	5	328	±121.1	7	361	±132.6	0.842
female	23	258	±118.8	4	257.5	±99.46	7	271	±94.10	0.889
Goats										
male	16	164	±138.0	1	150	-	2	175	±35.35	0.471
female	16	166	±115.9	1	110	-	2	125	±7.100	0.453

p-values : based on a non-parametric Kruskal Wallis test (and a post hoc multiple comparison test with Bonferroni correction), superscripts (a-b) indicate significant differences between groups

T[1]: refers to the prices given by the group of both fatteners and traders for trading animals

Maximum selling prices

	Traders NR (n=32)			Traders UER (n=8)			Both fattener/trader UER (T)[1] (n=21)			P-value
	n	Mean	SD	n	Mean	SD	n	Mean	SD	
Cattle										
male	15	**2897**[a]	±862.0	6	**1600**[b]	±626.1	17	**1809**[b]	±691.1	**0.001**
female	16	**1969**[a]	±477.1	5	**1180**[b]	±216.8	16	**1259**[b]	±345.1	**0.000**
Sheep										
male	23	592	±285.2	5	480	±246.5	8	485	±202.3	0.450
female	23	360	±104.7	4	332.5	±116.4	8	338	±95.13	0.721
Goats										
male	16	309	±187.6	1	200	-	2	225	±35.35	0.57
female	16	258	±119.4	1	150	-	2	180	-	0.187

***p-values : based on a non-parametric Kruskal Wallis test (and a post hoc multiple comparison test with Bonferroni correction), superscripts (a-b) indicate significant differences between groups**

T[1]: refers to the prices given by the group of both fatteners and traders for trading animals

A 3.5 Selling prices smallholder farmers in the Northern region (NR) and Upper East region (UER)

Minimum selling prices

	Smallholders NR (n=50)			Smallholders UER (n=49)			p-value[1]
	n	Mean	SD	n	Mean	SD	
Cattle							
male	16	859[a]	± 348.9	37	1143[b]	± 484.6	0.021
female	17	847	± 203.5	29	858	± 308.1	0.894
Sheep							
male	42	143[a]	± 45.12	31	112[b]	± 45.01	0.005
female	45	134[a]	± 42.08	31	102[b]	± 32.32	0.001
Goats							
male	38	87	± 22.81	39	89	± 25.31	0.598
female	38	99[a]	± 39.55	44	85[b]	± 20.77	0.038

p-value[1]: based on independent T-test between two groups of smallholder farmers; p-values <0.05 indicate significant differences between regions

Maximum selling prices							
	Smallholders NR (n=50)			Smallholders UER (n=49)			p-value[1]
	n	Mean	SD	n	Mean	SD	
Cattle							
male	16	1394	± 500.0	32	1427	± 601.9	0.852
female	17	1329	± 315.8	29	1147	± 428.4	0.133
Sheep							
male	41	201[a]	± 52.74	31	159[b]	± 60.17	0.002
female	44	185[a]	± 47.91	31	144[b]	± 37.82	0.000
Goats							
male	37	130	± 36.67	37	116	± 34.99	0.102
female	37	138[a]	± 46.22	43	113[b]	± 29.67	0.006

p-value[1]: based on independent T-test between two groups of smallholder farmers; p < 0.05 indicates a significant difference between regions

A 4. Income sources

A4.1 Income sources of (both) livestock fatteners and livestock traders in the Northern (NR) and Upper East region (UER)

	Fatteners NR (n=21)			**Fatteners UER** (n=24)			**Both fattener and trader UER** (n=21)			**p-value[1]**
Income sources (%)	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	
Fattening and selling livestock	30-100	**67.3[a]**	±25.9	20-100	**70.8[a]**	±23.2	20-70	**45[b]**	±13.8	**0.001**
Trading livestock	-	-	-	-	-	-	20-60	42.9	±12.3	n.a.
Crop production	0-50	11.4	±16.8	0-50	9.2	±17.2	0-40	7.6	±12.2	0.813
Labor/service	0-60	6.9	±15.5	0-60	6.7	±13.7	-	-	-	n.a.
Formal employment	0-67	9.14	±23.0	0-10	0.42	±2.04	-	-	-	0.129
Remittance	-	-	-	0-70	5.4	±15.6	0-20	3.3	±7.3	0.123
Petty trading	0-40	5.2	±12.5	0-70	7.5	±17.3	0-20	1.2	±4.4	0.482

p-values[1] : based on a non-parametric Kruskal Wallis test (and a post hoc multiple comparison test with Bonferroni correction)

A 4.2. Income sources of (both) livestock fatteners and livestock traders in the Northern (NR) and Upper East region (UER)

	Traders NR (n=32)			**Traders UER** (n=8)			**Both fattener and trader UER** (n=21)			**p-value[1]**
Income sources (%)	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	
Fattening and selling livestock	0-30	2.8	±8.9	-	-	-	20-70	45	±13.8	n.a.
Trading livestock	50-100	84.1[a]	±18.3	60- 100	86.3[a]	±14.1	20-60	42.9[b]	±12.3	0.000*
Crop production	0-45	10.8	±15.1	0-20	3.8	±7.4	0-40	7.6	±12.2	0.459
Labor/service	-	-	-	-	-	-	-	-	-	-
Formal employment	-	-	-	-	-	-	-	-	-	-
Remittance	-	-	-	0-20	2.5	±7.1	0-20	3.3	±7.3	n.a.
Petty trading	0-30	2.3	±7.5	0-40	7.5	±14.9	0-20	1.2	±4.4	0.400

p-values[1] : based on a non-parametric Kruskal Wallis test (and a post hoc multiple comparison test with Bonferroni correction)

A 4.3 Income sources of smallholder farmers in the Northern region (NR) and Upper East region (UER)

	Smallholders NR (n=50)			Smallholders UER (n=49)			P-value[3]
Income sources (%)	Range	Mean	SD	Range	Mean	SD	
Selling of crops	10-90	59.4[a]	±16.5	0-90	37.4[b]	±25.2	0.000
Selling of crop residues	0-10	0.2	±1.4	0-20	1.2	±3.8	0.084
Selling of livestock	5-70	30.8	±13.9	0-100	38.2	±28.1	0.105
Labor/Service	0-50	3.6	±10.4	0-70	4.1	±15.0	0.847
Formal employment	0-20	1.0	±4.0	0-100	3.9	±15.9	0.194
Remittances	0-30	3.2[a]	±8.2	0-80	9.3[b]	±16.7	0.025
Petty trading	0-35	2.0	±7.6	0-60	5.8	±15.0	0.114
Other source(s)	0-10	0.2	±1.4	0-10	0.2	±1.4	0.989

p-values[1] : based on a non-parametric Kruskal Wallis test (and a post hoc multiple comparison test with Bonferroni correction)

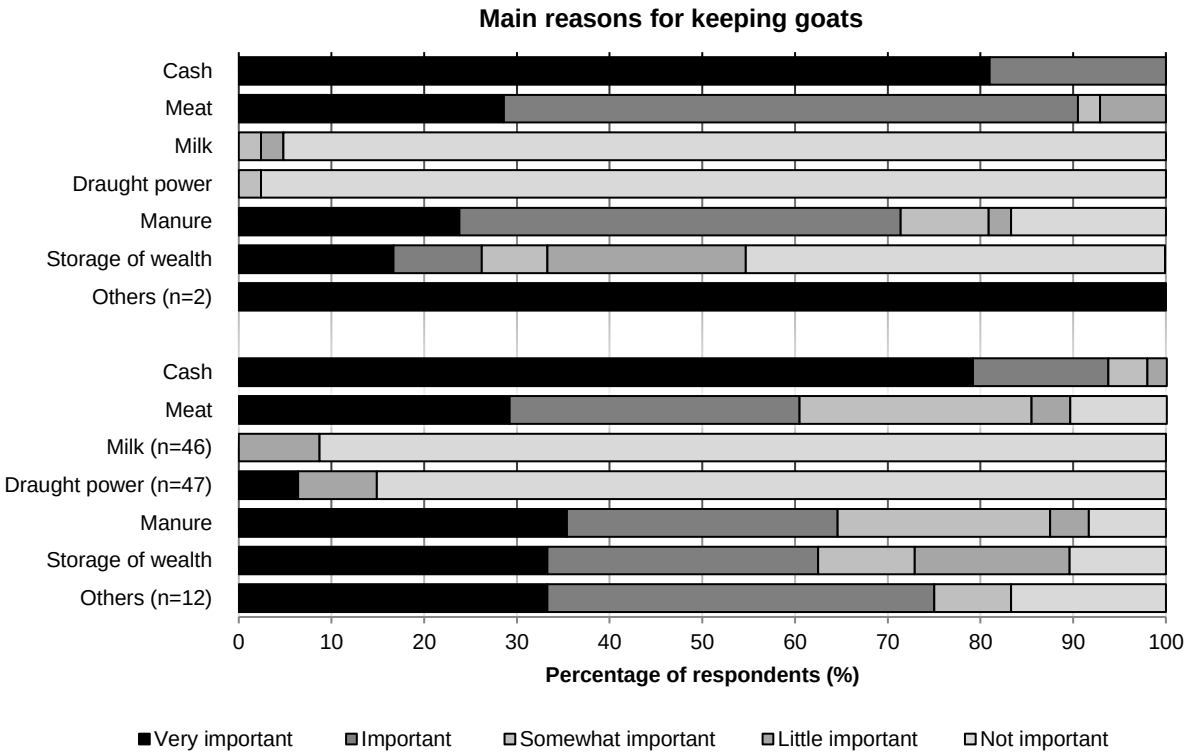
A 5. Livestock numbers of smallholder farmers in the Northern region(NR) and Upper East region (UER)

A5.1 Livestock bought/ sold / slaughtered by smallholder farmers over the past twelve months

		Smallholders NR (n=50)			Smallholders UER (n=49)		
No. of animals[1]:		**Bought**	**Sold**	**Died/slaughtered/ other**	**Bought**	**Sold**	**Died/slaughtered /other**
Cattle	*Male*	0.4 (± 0.59)	1 (± 1.00)	0.2 (± 0.54)	0.4 (± 0.77)	0.5 (± 0.80)	0.4 (± 0.87)
	Female	0.3 (± 0.64)	0.3 (± 0.47)	0.5 (± 0.98)	0.3 (± 0.90)	0.2 (± 0.63)	0.4 (± 0.75)
	Calves	-	-	0.5 (± 1.21)	0 (± 0.33)	0 (± 0.16)	-
Sheep	*Male*	0.13 (± 0.4)	1.3 (± 1.99)	1.8 (± 1.98)	0.3 (± 1.4)	0.7 (± 1.13)	1.2 (± 1.93)
	Female	0 (± 0.25)	0.9 (± 1.83)	2.3 (± 2.27)	0.4 (± 1.0)	0.9 (±1.82)	1.00 (± 1.91)
	Lambs	-	0 (± 0.44)	1.4 (± 2.00)	-	-	0.3 (± 1.16)
Goats	*Male*	0 (± 0.22)	1.1 (± 1.47)	1.4 (± 1.64)	0.2 (± 0.66)	0.8 (±1.26)	0.7 (± 1.13)
	Female	0 (± 0.35)	1.0 (± 1.34)	1.4 (± 1.66)	0.3 (± 0.83)	0.7 (± 1.33)	1.3 (± 1.54)
	Kids	-	-	1.0 (± 1.73)	-	-	0.4 (± 1.15)

No. of animals[1] are represented by mean value ± standard deviation (SD)

A 6 Main reasons for keeping livestock



A7. Lists of livestock markets used by (both) livestock fatteners and traders from the Northern region (NR) and in the Upper East region (UER)

Name/ Location of Livestock market	Region/ Country	Code
1. Aboabo	**NR**	
2. Bolini	**NR**	
3. Buipe	**NR**	
4. Guunayili	**NR**	
5. Kbalbe	**NR**	
6. Kumbungu	**NR**	
7. Savelugu	**NR**	
8. Tamale abattoir	**NR**	
9. Tolon	**NR**	
10. Nyankpala	**NR**	
11. Jangtong	**NR**	**Local livestock markets in the NR**
12. Sankpala	**NR**	
13. Shishegu	**NR**	
14. Tuna	**NR**	
15. Kalyba	**NR**	
16. Daboya	**NR**	
17. Yapei	**NR**	
18. Gushegu	**NR**	
19. Nyoli	**NR**	
20. Tampiong	**NR**	
21. Kpenchili	**NR**	
22. Warevey	**NR**	
23. Bawku	**UER**	
24. Bolgatanga	**UER**	**Local livestock markets in the UER**
25. Wedyango	**UER**	
26. Busie	**UWR**	
27. Fadama	**UWR**	
28. Zang	**UWR**	
29. Tizza	**UWR**	
30. Viere	**UWR**	
31. Wechau	**UWR**	**Local livestock markets in the**
32. Dorimon	**UWR**	**UWR**
33. Tangasie	**UWR**	
34. Babile	**UWR**	
35. Bulenga	**UWR**	
36. Tabiahi	**UWR**	
37. Sankana	**UWR**	
38. Burkina Faso	**Burkina Faso**	
39. Yelwango	**Burkina Faso**	
40. Bitu	**Burkina Faso**	**Foreign livestock markets**
41. Togo	**Togo**	
42. Niger	**Niger**	

***NR: Northern region; UER: Upper East region; UWR: Upper West region**