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Socioeconomic assessment of the relevance of a community-based goat breeding project in smallholding systems

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ABSTRACT

In the last decade, community-based animal breeding programs have gained attention for the genetic improvement of small ruminants in the tropics. Nevertheless, implementing such programs remains challenged by the issue of smallholders' participation. To shed light on this issue of participation, a goat genetic improvement project has been assessed for its socioeconomic relevance through participatory methods, taking account of goat multifunctionality. We quantified the gross margins per flock and per animal as indicators of viability. We assessed then the correspondence between the goat functions defined through a proportional piling tool with the relative share of these functions in the gross revenue. For that purpose, 160 smallholders were surveyed and 77 among them were monitored for one year. A cluster analysis of factors linked to the dynamic of goat farming identified three groups of farmers. The first group gathered farmers with the smallest goat flocks, who were goat oriented in the future. Their sustainable participation in goat breeding project was impeded by the excessive sales of goats. The second group involved farmers with the highest farm size, who planned to buy cattle to replace part of their goats. The third group included farmers who were members of the project with the largest goat flocks. This group emphasized the importance of goat for their future but showed weak abilities to manage large flocks. The gross margin per animal was the highest in the third group. The relative importance of goat functions as defined through participatory tools did not correspond to the relative share of these functions in the composition of the gross revenue from goats. Participatory tools and economic calculation then appear as complementary to understand farmers' priorities. Consolidating breeders' associations and supporting farmers to diversify their sources of income are two ways proposed here to ensure an enabling environment to goat husbandry and farmers' well-being.

Implications

This study proposes a combined socioeconomic approach to evaluate the relevance of community-based animal breeding programs in smallholding systems. It illustrates the complementary contribution of participatory tools and formal economic analysis to the understanding of the system. The approach sheds light on the challenges posed to the sustainable implementation of a goat breeding project in a densely populated and agriculture-based system such as in Burundi. These challenges are mainly tied to the constrained flock size and an overall strategy of diversification of livelihoods. It highlights the importance of large flocks in economic efficiency per animal, although farmers had weak abilities to manage large flocks.

Introduction

In the last decade, community-based animal breeding programs have gained attention as a promising approach for the genetic improvement of small ruminants in the tropics (Wurzinger et al., 2011; Mueller et al., 2015; Yaekob et al., 2017). Such community-based programs may be seen as substitutes to the state-led breeding programs that have often focused on cattle and poultry (Mueller et al., 2015). Nevertheless, implementing such programs remains a challenge, mainly due to the issue of breeders' participation (Camara et al., 2019). Some literature shows that the sustainability of breeding programs for local breeds of small ruminants in low-input production systems depends on farmers' interest and involvement, which have to be understood as resulting from the socioeconomic context of production (Ogola et al., 2010; Biscarini et al., 2015).

According to the concept of sustainability, agricultural production requires to be economically viable, socially just and ecologically sound, not only at the farm level but also for the overall system (Udo and Steenstra, 2010). Regarding the economic component, estimation of

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the value produced (profit, gross margin, or value-added) per unit of the most limiting resource was used by many authors as an indicator of viability (Ayalew et al., 2003; Moll, 2005; Mwebe et al., 2011). Nevertheless, this approach is not easily understood by smallholders who are mostly illiterate or have a weak educational background. Being a strain on the participation of the poorest breeders in the evaluation process, this barrier poses important questions of social justice, the second pillar of sustainability. Therefore, several participatory tools were developed to fit the farmers' interest and promote communication despite uneven levels of education. However, these tools provide little economic interpretation of priorities of smallholders (Gizaw et al., 2018). In animal breeding, the use of participatory tools was mostly focused on the direct definition of breeding objectives (Woldu et al., 2016a; Tindano et al., 2017), but most often paying little attention to dynamic strategies of households and the role of livestock species in these (Camara et al., 2019). Therefore, to better address the evaluation of genetic improvement in developing countries, considering the context and own dynamic of low-input systems, it sounds relevant to integrate participatory and formal economic analysis tools.

This study suggests such a combined socioeconomic approach to evaluate the relevance of a goat breeding project initiated in a smallholding system of Burundi. Based on a community-based approach, the project was initiated in 2015 through the creation of pilot farmer associations, called "Burundi goat breeders associations" (**BGBA**). These BGBAs aimed at improving the goat husbandry practices with the purpose of enabling a genetic selection of the local breed. However, although goat is among the most important livestock species in the country, it raises little interest compared to dairy cattle, not only among policymakers but also among farmers (Desiere et al., 2015). This might be due to the low response of goat to intensification compared to dairy cattle (Udo et al., 2011). In fact, goats in Burundi, as in many developing countries, are mostly raised by low-income rural households. Goats are then an asset to ensure financial security and are part of a composite agriculture-based livelihood strategy. Thus, the main motives for keeping goats are to sell those in case of necessity and to produce manure for crop fertilization. The lack of farmers' interest for improving goat husbandry could in fact mirror our own lack of understanding of the contribution of goat farming to their livelihoods. Indeed, no study has been conducted yet in Burundi to assess the viability and income contribution of goat farming to the livelihood of households. Our hypothesis is that the lack of stability and symbolic importance of goat in low input systems of Burundi are major limiting factors in breeding program implementation. This participatory socioeconomic assessment then aims more particularly at identifying internal diversity among breeders and understanding how animal breeding may fit into the livelihood strategies at play.

Material and methods

Methodological approach

The overall methodology rests on a participatory assessment of farmers' knowledge about the dynamic of goat keeping and their perception of its economic contribution to the household livelihoods, including their strategy for the future. For that purpose, farmers were subjected to semi-structured interviews and were asked to rank their priorities by proportional piling with 100 counters. Then, we quantified the gross margins per flock and per animal as indicators of the economic viability based on a set of stated and measured parameters. This was estimated taking account the multifunctionality of goat keeping (as disaggregated and ranked by smallholders), using market prices for marketable products and opportunity costs for nonmarketable products and services (Ayalew et al., 2003; Moll, 2005). Finally, farmers' proportional piling results about the relative importance of goat functions were compared with the relative share of these functions in the composition of the gross revenue.

Study area

This study was conducted in the goat breeding project's area. This includes Gitega province (1350 à 2000 m above sea level) located in the central highlands (**CHL**), and Rutana province (1100 à 1400 m above sea level) located in Eastern depressions (**EDP**) in Burundi. The CHL climate presents an average annual rainfall between 1200 and 1500 mm, an average annual temperature between 17 and 25 °C and a dry season of 3 to 4 months (Nzigidahera, 2012). The EDP climate presents an average annual rainfall between 900 and 1200 mm, an average annual temperature between 22 and 28 °C, and a dry season of 5 to 6 months (Nzigidahera, 2012). In terms of demography, CHL has the highest population pressure (over 300 inhabitants per km^2) while EDP is less densely populated (around 200 inhabitants per km^2) according to the Ministère de l'intérieur (2010). Agriculture is the main subsistence activity of households. An association of several crops characterizes the cropping system, with a predominance of maize from September to January and beans from February to May. Banana is the main cash crop in CHL, while rice holds this role in EDP.

Setting-up of breeders associations

In 2015, two communes were identified in each of the two provinces and 30 members in each commune were identified to form a BGBA (i.e. a total of four BGBAs). Farmers were trained in integrating forage crops in their crop fields, animal health, improving goat barn and reproduction management. Veterinary technicians had to follow up farmers' activities, assisted by trained community animal health workers. After one year of training and preparation (February 2016), each farmer received five indigenous goats and two neighbor farmers had to share one buck. Visits of experience exchange were regularly organized within BGBA members. Then a protocol for recording growth performances and pedigree of kids was initiated. This was entrusted to the trained community animal health workers, in collaboration with communal veterinary technicians. Researchers followed up all activities and gathered data recorded in a central data set.

Sampling

We sampled 160 goat-keeping households in the 2 provinces with 90 households in Gitega and 70 in Rutana, from July to November 2017. Among them, 85 households (40 in Gitega and 45 in Rutana) were members of BGBA. Purposive sampling was conducted to include both members known to meet success in their activities ($n = 48$) and those lagging behind ($n = 37$) according to the evolution of the flock size and the observed dynamism in meetings' participation. Nonmembers of BGBA were selected by respondent-driven sampling ($n = 75$), starting from three first respondents who were identified by a community animal health worker from each commune.

Data collection

Seven focus groups were conducted, of which four within the BGBA, in order to familiarize breeders with the research topic and to collect the first provisional data used in the second step of in-depth individual interviews. For this purpose, we used a checklist of investigation themes to animate the semi-structured interviews. Those themes were mainly: (1) characteristics of the households, (2) economic activities practiced and their contribution in household's livelihoods, (3) multiple functions of goat keeping, (4) main constraints impairing goat productivity, (5) strategy for the household's future and the role of goats in this strategy, and (6) history of herd size (goat, cattle) distinguishing three periods: 5 years before the survey, at the time of the survey, and a projection for the future. Relevant items cited in focus groups were then proposed for ranking in individual interviews, through proportional piling with 100 counters. These proportional piling exercises

targeted the relative contribution of economic activities in livelihoods, the relative perceived importance of goat and cattle farming in their envisioned future, the relative importance of the goat functions, and relative importance of constraints in goat breeding. Respondents were also asked to give motives for the chosen ranking.

Among 160 farmers, 77 collaborating farms (of whom 31 members of BGBA) were identified and monitored, from the July 2017 to July 2018, to evaluate the gross margin from goat farming. Goat flocks were identified and weighed at the beginning and the end of the period. Goat weight was converted into monetary units using market prices, collected through a trader with experience in selling goats in collaboration with the farmer. An agent was recruited on each site and trained to regularly record animal outflow (sales, mortalities, or gifts transferred out), inflow (births, purchases, or gifts received), and costs (mainly veterinary care and fodder).

Data analysis

All analyses were performed with the statistical software R (version 3.5.1). Categorical variables were described by percentages, and numerical variables through their mean, standard deviation, medians, and extreme values. Proportional piling results were expressed as percentages ascribed to each of the categories to be ranked.

Typological analysis

We performed multivariate analyses (principal component and hierarchical classification analyses – FactoMineR package) to explore relationships between 10 numerical variables influencing the evolution of goat farming (Lê et al., 2008). Four qualitative illustrative variables were also added to assess their distribution among the defined typology (Table 1). Illustrative variables did not contribute to the calculation of principal components and clustering, but were projected a posteriori on the calculated axes to help interpreting the defined typological groups. The variables were selected within the sample after computing a matrix correlation test. Only those with a significant correlation coefficient and with a theoretically supported relation with the evolution of goat farming were kept. Chi-square or Fisher's exact test was applied to assess the significance of differences in the distribution of qualitative illustrative variables among typological groups. Kruskal-Wallis test was used to determine the dependence between the typological groups and the different functions of goat farming, the flock size of goats and cattle in the past, and the desired size for the future. This nonparametric test was chosen based on normality test applied to those variables (Shapiro–Wilk test). Significance thresholds were set at $P < 0.05$.

Economic performance analysis

We calculated the annual gross margin (**AGM** = annual gross revenues minus annual variables costs) per goat flock and per animal. Revenue was composed of the variation of flock value, the value of manure, credit, and insurance services. The variation of flock value included monetary and nonmonetary flows. Monetary flows included sales (gain) and purchases (costs). Gifts transferred out of households were counted as a gain, while gifts received were counted as a cost, to take account of sociological realities underpinning this practice. In the absence of market valuation of manure, its economic value was indirectly assessed through the yield response due to application of goat manure on bean fields, which is the main crop that benefits from goat manure and the yields of which are easily quantifiable by famers. Indeed, the harvested beans are kept in bags of 50 or 100 kg depending on the quantity obtained and farmers recalled the number of bags harvested. In the absence of manure, farmers commonly used mineral fertilizer alone, which generates other fees to the farmers (Table 2). We used the Kruskal-Wallis test to determine whether medians for the AGM per farm and per animal differed among typological groups, according to BGBA membership and between regions. This nonparametric test was chosen because residuals of a fixed effect model were not normally distributed with a null mean and a variance σ^2 (with a visual shape of the histogram and Shapiro–Wilk test). A p-value below 0.05 was considered significant.

Finally, we estimated the divergence between the relative importance of the diverse functions of goat farming as stated through proportional piling and as calculated through gross revenue decomposition (relative importance of each goat function minus percentage of the correspondent function in the gross revenue). This divergence was the absolute value of the difference between the two estimated percentages for each function in each household. We then used a Spearman's rank correlation test to assess the significance of this divergence. The functions considered were manure, sale, saving (including credit and insurance functions), and social functions. The latter function was calculated based on the relative importance of gifts transferred out in the overall gross revenue because those received were considered as a cost.

Table 1
Variables used in the cluster analysis of the dynamic of goat farming in smallholding system of Burundi.

Items	Used codes
Quantitative variables	
1, Indicators of household wealth:	
Arable land[2] (ha)	Land
Number of goat owned at the survey period	Ngoat
Relative importance of off-farm activities in household's livelihood (%)[1]	Offarm
2, Main constraints on goat breeding:	
Relative importance of the challenge to manage a large flock size (%)[1]	Hflock
Relative importance of the challenge of early and excessive sales (%)[1]	Exsale
3, Level of consideration or disinterest for goats:	
Relative importance of cattle farming for the future (%)[1]	ImpCattle
Relative importance of goat farming for the future (%)[1]	ImpGoat
4, On-going dynamic of goats' herd;	
Variation rate of goat flock size at the survey period compared to the size of the past: Formula: (Ngoat_survey - Ngoat_past)/Ngoat_past	Var1
Variation rate of goat flock size wished for the future relative to goat flock size owned at survey period: Formula: (Ngoat_wished - Ngoat_survey)/ Ngoat_survey	Var2
5, Level of education of the household head	Educ
Qualitative variables	
1, Economic impact of goat farming in the past with:	Impact
- High impacts: sales that have contributed to high investments such as purchase of arable land or cattle, or building a house (VisImp);	
- Small impacts: sales that have contributed mainly to regular cash needs such as school fees, healthcare, chemical fertilizer, or food: (small)	
2, First source of household income in case of difficulties with: goat (goat); off-farm activities (Nagr); harvest crops (crops); banana (Ban); renting workforce (rentforc)	SoucInc
3, Types of smallholders with:	Typhousehold
- Non- BGBA farmers (no BGBA)	
- Successful BGBA members (BGBA _succ)	
- BGBA members lagging behind (BGBA _lag)	
4, Region: central Highland and Eastern depressions:	Region

BGBA = Burundi goat breeders associations.
[1] The percentages of relative importance were obtained through proportional piling by the farmers using 100 counts.
[2] Estimated with a global positioning system, Garmin.

Results

Characteristics of surveyed farmers and their livestock species

All the farmers surveyed subsisted on an average cultivated land of 0.9 ha. The average age was 43 years old. The level of education was

Table 2
Estimation of the annual gross margin of goat farming in smallholding system of Burundi

Production factors	Estimation
Variables costs:	
a. Veterinary care	Regularly registered
b. Feed costs	Consisted of eventual purchases of forages
c. Hired labor costs	Estimated in the equivalent value of man-day of the relative importance of the daily time allocated to goat farming (expressed by proportional piling)
Gross revenue:	
d. Value of flock at beginning	Weight * estimated market price
e. Value of inflow:	Value of goats transferred as gifts + value of births + sales
f. Value of outflow:	Purchases + value of deaths + value of goats received as gifts
g. Value of initial flock at the end:	Weight * estimated market price
h. Variation of flocks:	(g - d)[1] + e – f
i. Value of manure:	Estimated based on opportunity cost of the difference in the monetary value of the bean yields that farmers would have obtained when simultaneous applying goat manure and mineral fertilizers and those they would have obtained by using mineral fertilizers alone [2]
j. Credit interest:	Estimated on the value of goat sold. An interest rate of 10% applied in the Cooperative of Savings and Credit present in all municipalities of the country was used
k. Insurance:	Estimated on the value of stock of live goats. A rate of 3% was used, corresponding to the saving rate in Cooperative of Savings and Credit
l. Total Gross margin	(h + i + j + k) – (a + b + c)
m. Gross margin per adult animal	l/number of adult equivalent of the flock at the beginning

In the "h" equation: see the numeration before for the signification of the terms: g, d, e, and f; in the "l" equation: see the numeration before for the signification of the terms: h, i, j, k, a, b, and c;
[1] Due to the loss or gain of weight of live animals;
[2] These yields were estimated according to the declarations of smallholders. Indeed, the bean is the main crop benefiting from organic and inorganic manure in rural smallholdings and whose yields are easily quantifiable by smallholders.

Table 3
Means and standard deviations (sd), medians, and ranges (minimum-maximum) for the characteristics of goat farmers surveyed in smallholding system of Burundi.

Characteristics	Respondents' percentage	Mean (SD)	Median	Range
Farm size (ha)		0.9 (0.4)	0.8	0.3–2.5
Year of formal education		4 (3)	5	0–14
Age of the head of the household (years)		43 (11)	43	22–71
Year of keeping goats		17 (9)	17	2–39
Household head sex:				
Man	89			
Women	11			
Female respondents	60			
Number of children		5	5	0–10
Maximum number of goats reared in the past		7 (4)	6	2–20
Number of goats owned at the survey period		8 (5)	7	1–22
Maximum number of goats foreseen for the future		10 (6)	10	4–30
Number of cows	28	2 (1)	1	1–6
Number of pigs	31	1 (1)	1	1–4
Number of chicken	61	7 (5)	5	1–25

low, with an average of four years of schooling. The majority of these farms (89%) were headed by men, although 60% of respondents were women. The average number of goats was eight heads. Among the 160 respondents, 44 also had cows, 49 had pigs, and 98 had chickens (Table 3). According to the proportional piling, livestock system contributed around 27% to the livelihoods of respondents, of which around two-thirds (i.e. 17% of the total) was ascribed to goat farming, whereas crop production accounted for 62% and off-farm activities for 11%. Regarding the future, farmers expressed their willingness to emphasize goat and cattle compared to other species, to provide cash for emergencies or daily needs and to produce manure for crop production, respectively. Proportional piling established an expressed relative preference of 61% for goats, while cows gathered 39% of counters. The perceived relative importance of a cow in manure production was significantly higher (62%) compared to goat herds (38%). Conversely, the perceived relative importance of goat herds in cash generation was significantly higher (56%) than that of cows (44%).

Farmer's diversity according to the dynamic of goat keeping

From the principal component analysis, three axes were retained, representing 66.6% of the total variation (Figs. 1 and 2).

Axis 1 (31.8% of the total variance) discriminated between wealthier households that emphasized cattle farming in the future (positive values) from the poorest that preferred goat farming in the future (negative values) (Fig. 1). Variables with the highest positive correlations with that axis were the number of goats owned at the time of the survey (0.7), the relative importance of cattle in the future (0.62), the managerial challenge due to goat flock size (0.56), the level of education (0.55), and the farm size (0.47). Those with the highest negative correlations were the variation rate of goat flock foreseen for the future (−0.67), the perceived relative importance of goat for the future (−0.62), and the challenge due to early and excessive sales of goats (−0.61).

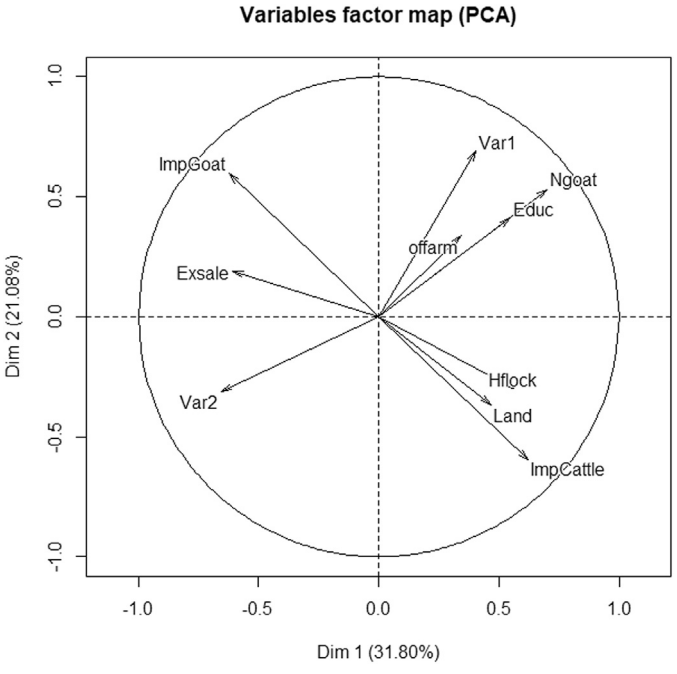

Fig. 1. Circle of correlation between factors influencing the dynamic of the goat farming system in Burundi: axes 1 and 2. Educ = level of education; Exsale = relative importance of constraint of excessive sales; Hflock = relative importance of managerial constraint of a high flock; ImpCattle = relative importance of cattle farming in the future; ImpGoat = relative importance of goat farming in the future; Land = arable land size; Ngoat = number of goats at the survey period; offarm = relative importance of off-farm activities in the household incomes; Varl1 = variation rate of the goat's flock size in the past; Var2 = variation rate of goat's flock size foreseen for the future.

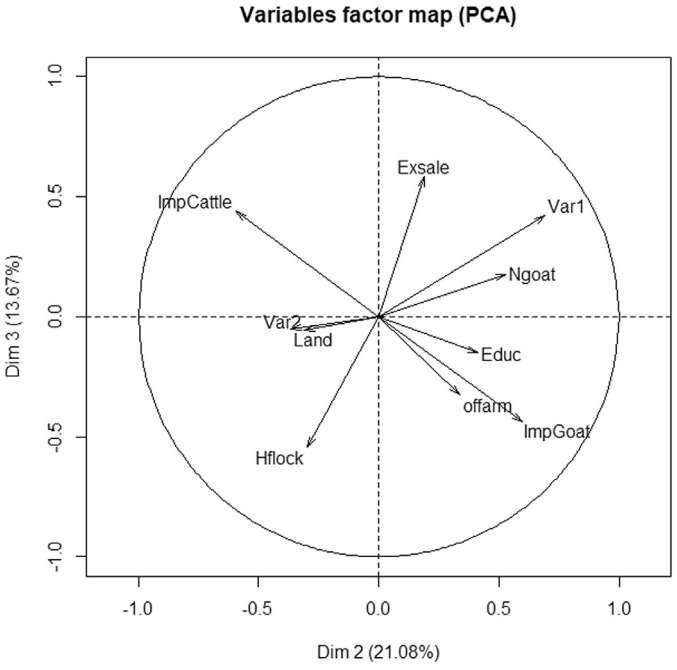

Fig. 2. Circle of correlation between factors influencing the dynamic of goat farming system in Burundi: axes 2 and 3 (see code signification in Fig. 1).

Axis 2 (21.1% of the total variance) opposed smallholders with a positive evolution of their goat flock in the past and who preferred goat farming in the future to those with a negative evolution of their goat flock foreseen in the future and who preferred cattle farming in the future (Fig. 1). The variables with the highest positive correlations were the variation rate of goat flock in the past (0.69) and the relative importance of goat for the future (0.61). Those with the highest negative correlation were the relative importance of cattle in the future (−0.61), the farm size (−0.37), and the variation rate of goat flock foreseen for the future (−0.31).

Axis 3 (13.7% of the total variance) opposed smallholders who preferred cattle in the future but with goat farming being limited by early and excessive sales of goats to those who preferred goat in the future but faced managerial difficulties due to flock size (Fig. 2). Indeed, the highest positive correlations were found for the challenge of early and excessive sales of goats (0.59) and for the relative importance of cattle in the future (0.44). The highest negative correlations were for the managerial challenge due to goat flock size (−0.54) and for the relative importance of goat in the future (−0.44).

The hierarchical classification led us to define three groups of farmers (Fig. 3). The variance within groups was 58.5% of total variance and that between groups was 41.5%. This means that those groups were not well separated and that each group contained a sizable variability to be considered in their interpretation. All variables significantly contributed to the construction of all clusters (Table 4).

Cluster 1 (n = 54; 33.8% of the sample): nonmembers of Burundi goat breeders associations, goat-oriented

Farmers from cluster 1 had significantly fewer goats at the time of the survey as compared to other clusters. The main challenge for goat farming was an excessive sale of goats. The main sources of incomes were sales of goats or renting workforce. Thus, the variation rate of their goat flock in the past was negative. In the future, they emphasized goat farming rather than cattle. Hence, the variation rate of their goat flock that they envisioned for the future was higher than in other clusters. However, the number of goats desired in the future was significantly fewer (7 heads) than in the other clusters (10 heads for cluster 2 and 12 heads for cluster 3). The level of education was lower than in other clusters. In the past, incomes from goats sold have contributed mainly to emergencies and regular needs such as health care, school fees, chemical fertilizer, or even food, for 73% of farmers. Most members of this cluster (81%) were not participating in BGBA. The manure and sale functions were significantly more ranked than sale and social functions.

Cluster 2 (n = 65; 40.6%): nonmembers of Burundi goat breeders associations, cattle-oriented

For cluster 2, the average of arable land was significantly higher compared to other clusters and the relative importance of cattle farming envisioned for the future was higher than that of goats. The main challenge was managing large flocks rather than to excessively selling goats. Crop harvests were the main source of incomes in case of necessity. In the past, the number of goats (10) was significantly higher

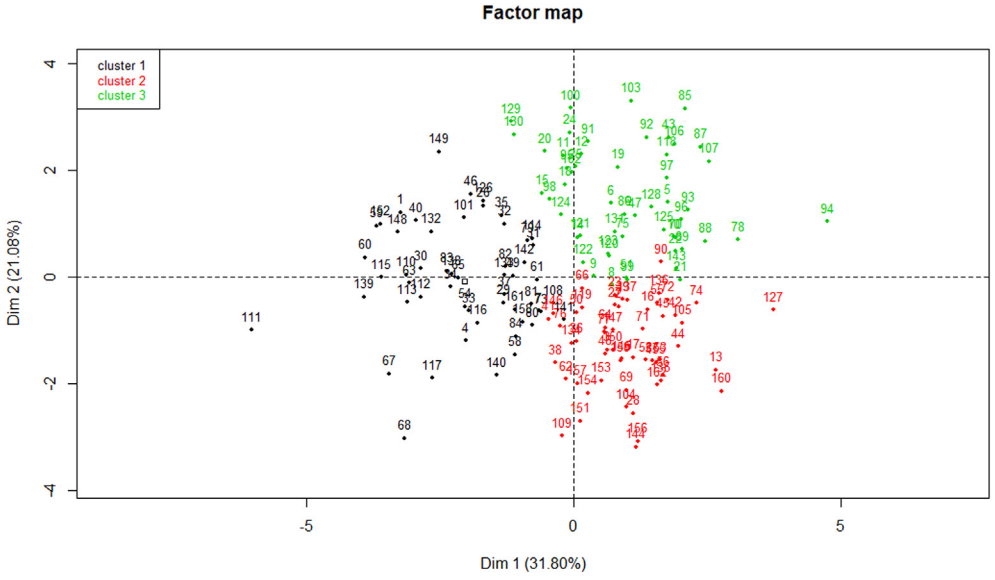

Fig. 3. Distribution of the clusters defined by hierarchical classification of goat farmers surveyed in smallholding system of Burundi according to the first two principal components (see cluster definition in Table 4).

Table 4
Characteristics of three groups defined by hierarchical classification of goat farmers surveyed in smallholding system of Burundi.

	Mean (standard deviation)			
	Cluster 1	Cluster 2	Cluster 3	Total
Quantitative variables				
Arable land (ha)	0.6 (0.3)	1.2 (0.4)	0.8 (0.4)	0.9 (0.4)
Number of goat owned at the survey period	4 (2)	8 (3)	13 (4)	8 (5)
Relative importance of off-farm activities in livelihood (%)	6 (9)	7 (10)	18 (15)	11 (14)
Variation rate of goat flock size in the future (%)	1.7 (0.7)	0.4 (0.7)	−0.1 (0.4)	0.7 (1.3)
Variation rate of goat flock size in the past (%)	−0.3 (0.5)	−0.1 (0.4)	1.3 (0.8)	0.2 (0.9)
Relative importance of goat farming for the future (%)	80 (22)	43 (15)	60 (21)	61 (25)
Relative importance of cattle farming for the future (%)	20 (12.0)	57 (15)	40 (21	39 (25)
Relative importance of managerial constraints of large goat flock (%)	35 (19)	45 (19.4)	68 (14)	51 (22)
Relative importance of the constraints excessive sales of goats (%)	65(19)	55 (19)	32 (14)	49 (22)
Education (years)	2.6 (2.1)	4 (2.3)	6.2 (2.2)	4,2 (2.6)
Illustrative variables	% according to individuals of group			
First source of income in case of difficulties				
Banana	4	27	16	15
Other crops	5	31	7	15
Goat	44	20	19	31
Off-farm activities	15	20	54	31
Renting workforce	32	2	4	8
Economic impact of goat farming in the past				
High impact[1]	27	73	49	52
Small impact[2]	73	27	51	48
Sampling groups				
Member of BGBA with success	4	15	72	30
Member of BGBA lagging behind	15	36	26	26
No member of BGBA	81	49	2	44
Region				
Eastern depressions	41	42	50	43
Central highlands	59	58	50	57

[1] Investment such as purchase of arable land, cattle or building a house.
[2] Regular cash needs such as school fees, healthcare, chemical fertilizer, or foods; BGBA = Burundi goat breeders association.

Table 5
Mean (standard deviation) of costs and revenues of goat farmers surveyed in smallholding system of Burundi according to clusters and region.

Parameters	Overall	Clusters			Regions	
		Cluster 1 (n = 25)	Cluster 2 (n = 29)	Cluster 3 (n = 23)	EDP (n = 24)	CHL (n = 53)
Variables costs						
Veterinary care	5 (4)	2 (1)	4 (3)	8 (4)	8 (4)	3 (2)
Fodder purchase	19 (9) (n = 34)	17 (8) (n = 6)	13 (7) (n = 10)	26 (8) (n = 18)	21 (8) (n = 14)	17 (9) (n = 20)
Hired labor	49 (7)	46 (5)	51 (10)	51 (5)	53 (10)	48 (6)
Total costs	62 (16)	52 (10)	59 (12)	77 (17)	73 (16)	57 (14)
Total costs per animal	14 (6)	18 (7)	13 (6)	10 (2)	10 (3)	15 (7)
Inflows						
Stock variation[1]	15 (62)	−11 (43)	−1 (45)	63 (42)	60 (52)	−5 (45)
Value of goats sold	46 (28) (n = 69)	45 (25) (n = 21)	51 (29) (n = 29)	41 (27) (n = 19)	45 (32) (n = 24)	47 (26) (n = 45)
Value of manure	43 (27)	26 (21)	36 (18)	71 (21)	53 (14)	39 (21)
Transferred as gifts	20 (8) (n = 2)	–	20 (8) (n = 2)	–	–	20 (8) (n = 2)
Insurance	6 (3)	3 (2)	6 (3)	9 (2)	9 (2)	5 (3)
Credit	4 (10)	4 (3)	5 (3)	4 (3)	5 (3)	4 (3)
Outflows						
Purchases	23 (11) (n = 15)	20 (5) (n = 9)	27 (16) (n = 6)			23 (11) (n = 15)
Received as gifts	19 (1) (n = 3)	19 (1) (n = 2)	20 (n = 1)	–	–	19 (1) (n = 3)
Revenues						
Total gross revenue	110 (71)	58 (42)	97 (46)	181 (67)	171 (66)	82 (54)
Total gross margin	57 (53)	22 (34)	58 (49)	91 (55)	105 (50)	35 (39)
Gross margin per animal	7 (9)	1 (11)	7 (6)	13 (7)	13 (6)	4 (9)

[1] Live animal's weight + births deaths; parameters are expressed in dollars (USD), 1 USD = 1792.79 Burundian francs in October 2018 in the Republic Bank of Burundi.

compared to other clusters (five for cluster 1 and six for cluster 3) and incomes from goat sales have contributed to important investments for more than 70% of farmers in the cluster. The desired number of cattle in the future (two heads) was significantly higher than in cluster 1 (one head) and similar to cluster 3. The manure function was significantly more ranked than other functions.

Cluster 3 (n = 47; 29.4%): members of Burundi goat breeders associations, goat-oriented

In cluster 3, the number of goats at the time of the survey was significantly higher than in other clusters. The relative importance of off-farm activities in household incomes was significantly higher compared to other clusters. Off-farm activities constituted the main source of incomes for 54% of them. The variation rate of the goat flock in the past was higher but was envisioned as becoming negative in the future. Still, the relative importance of goat in the future was higher compared to cattle. There was no significant difference in farm size between this cluster and cluster 1. Their level of education was significantly higher. More than 70% of them are BGBA members that were *a priori* considered as successful. The manure and saving functions were significantly more expressed than other functions.

Viability of goat farming according to farmers' diversity

The total costs per flock (veterinary expenses, fodder purchase, and labor costs) were significantly higher in cluster 3 compared to others. Inversely, total costs per animal were lower in cluster 3 than in others. The total costs per flock were significantly higher in EPD than in CHL, whereas the costs per animal were higher in CHL than in EDP. In terms of return, manure, insurance, and flock variation values as well as the total gross revenue and gross margin per flock were significantly higher in cluster 3 than in the two other clusters and higher in EDP than in CHL. The average gross margin per animal was around seven USD. It was significantly higher in cluster 3 than in others. It was also significantly higher in EDP than in CHL (Table 5).

The relative contribution of manure and saving functions to the gross revenue of goats was significantly higher in cluster 3 than in other clusters. However, the relative contribution of goat sales was significantly higher in cluster 1 than in cluster 3. The social contribution to the gross revenue was almost null (Table 6).

Table 6
Mean (standard deviation) and median of relative importance of goat functions obtained through proportional piling and economic calculations of gross revenue (%).

		Relative importance of goat functions through proportional piling (%)		Contribution of goat functions to the gross revenue (%)	
Groups	Functions	Mean(SD)	Median	Mean(SD)	Median
Overall	Manure	38 (10)	39	50 (26)	34
	Selling	31 (10)	29	45 (27)	37
	Saving	24 (10)	24	5 (26)	22
	Social	7 (6)	6	–	–
Cluster 1	Manure	44 (11)	43	71 (160.1)	32
	Selling	30 (9)	29	69 (96.8)	53
	Saving	21 (10)	22	−40 (243)	16
	Social	5 (6)	3	–	–
Cluster 2	Manure	37 (10)	35	33 (16)	33
	Selling	29 (12)	26	47 (28)	42
	Saving	27 (9)	23	19 (63)	24
	Social	7 (6)	7	1 (10)	0
Cluster 3	Manure	39 (10)	37	47 (19)	47
	Selling	27 (8)	26	20 (17)	16
	Saving	27 (11)	33	33 (25)	36
	Social	7 (7)	6	–	–

Correspondence between goat multifunctionality stated through proportional piling and gross revenue decomposition

The relative contributions of manure as defined through proportional piling and economic calculation presented a divergence that ranged between 0 and 43%, with an average at 15%. The divergence between the two modes of estimation for the sale function ranged between 0.6 and 62%, with 23.6% of average. That for the saving function ranged between 0.5 and 73% with 23.9% of average. For the social function, the divergence ranged between 0 and 43% with 7% of average. A student t-test showed that these divergences were statistically significant. Moreover, the ranking of these values did not correlate closely: only the saving contribution showed a Spearman rank correlation coefficient significantly greater than 0 (0.28). Manure function obtained through proportional piling was higher than that estimated through gross revenue, with a median relative importance of 39 and 34% for the 2 methods, respectively. On the other hand, the sale function was ascribed a lower relative importance through proportional piling (median of 29%) than through gross revenue calculation (37%).

In cluster 1, the relative importance of manure and saving functions defined through proportional piling were higher than those estimated through gross revenue calculation, whereas that of sale was lower. In cluster 2, the relative importance of manure function appeared higher through proportional piling and that of sale was lower, whereas the saving function was significantly correlated with its correspondent in gross revenue (rho = 0.38). In cluster 3, the relative importance of sale function appeared higher through proportional piling and that of saving appeared lower, whereas manure function was significantly correlated with its correspondent in gross revenue (rho = 0.48). In all clusters, proportional piling delivered higher relative importance of the social function compared to gross revenue estimation.

Discussion

Methodological approach

The present socioeconomic approach, which combines participatory tools and economic calculations, helps to understand the strategies of smallholders and the role of livestock species in these, as well as smallholders' priorities regarding goat functions. However, the assessment of the economic productivity for low-input livestock systems remains challenged by the lack of market value of certain functions, which may be of significant endogenous value to farmers. This is the case of the manure function, which was ranked first through proportional piling while manure is not marketed in the Burundian smallholding system. Therefore, this value was estimated indirectly from farmer declarations in the increase in yields of beans due to its application. To minimize possible bias related to this approach, strategies were applied to gain the confidence of farmers and interviews were anonymous. Directly measuring the bean yields in the fields would be useful as a complement to the present approach.

Farmers' diversity according to the dynamic of goat farming

The non-BGBA, goat-oriented farmers had the smallest goat herds (on average less than four heads). However, the fundamental constraint to goat farming was their excessive sale rate. Thus, the greater importance of sale function compared to other groups may be tied to the lack of alternative sources of cash revenues. Therefore, in case of cash need, most of them sell goats when available and otherwise rent their labor (Table 4). These results tend to indicate a high level of poverty, where the insufficient farm size and food insecurity act as mutually reinforcing disabling factors for many households in Burundi (Verschelde et al., 2013). This vulnerability leads to flocks' instability, precluding their participation in the BGBA-based breeding project. In the same light, Ogola et al. (2010) and Udo et al. (2011) argue that such an

excessive offtake rate for small flocks contradicts the need for well-planned sales and mating for genetic improvement. In addition, the low educational level of these farmers hinders access to information and non-farm activities, thereby representing an additional factor of poverty (Burke et al., 2007). These farmers then appear as victims of a poverty-trap, of which their de facto exclusion from BGBA is an unfortunate expression, further excluding them from the needed solidarity networks. Indeed, several authors have reported that the role of such small ruminants associations would not be limited to genetic improvement (Ahuya et al., 2005; Peacock, 2005; De Vries, 2008). Related benefits such as spontaneous mutual practical help, mutual credit systems, training, and exchange of experience between smallholders are important spill-overs, although those are not always planned by the intervening organizations.

The non-BGBA, cattle-oriented farmers with the greatest farm size (1.2 ha on average) preferred to convert a part of their goat flock into a cow to exploit the comparative advantages of both species. Farmers expressed clearly that a cow appeared to them as more profitable than their goat herds. These considerations are consistent with findings of Desiere et al. (2015) who reported that the probability of having a cow increases with the farm size under the high demographic pressure of the Burundi highlands. Farmers perceived that a cow would provide more manure and milk than a herd of goats, with positive effects on crop yields and family welfare, while goats would serve as a bank account for other cash needs. Indeed, in dairy smallholding of Burundi, the daily milk yield not sucked of a cow appears low (3.6 l/day on average) but is enough to represent a valuable improvement of family nutrition and to provide extra income, with 60% of milk being regularly sold (Manirakiza et al., 2017). However, although dairy cattle are more advantageous as they produce a higher quantity of manure compared to goats, farmers recognize that goat manure is of a higher quality than that of cattle, as also shown experimentally by Wuta and Nyamugata (2012).. Despite the ability of these farmers to capitalize on goats and further invest in other activities, the cyclical evolution of their goat flocks appears as a weakness for a sustainable participation to BGBA. The risk, indeed, is that the selection nucleus is sold and culled before the diffusion of the genetic progress. Furthermore, the orientation toward cattle farming in the future would compete with the attention devoted to goat farming. Biscarini et al. (2015) also reported that the perceived low performance of local small ruminants often limits the attention paid by farmers, who favor large ruminants, regarded as more productive.

The BGBA goat-oriented farmers corresponded to those a priori considered as successful, according to the multiplication of goat herds and meeting participation. Furthermore, more than half of them (54%) have adopted off-farm alternative activities to mitigate the deficit of agricultural incomes. Nevertheless, Burke et al. (2007) showed that such activities only provide temporary mitigation of poverty and that livestock diversification constitutes a more viable option in the fight against poverty. In the present study, these activities would have contributed to the purchase of veterinary treatments and fodder, which were the highest in this cluster. They would have also contributed to the protection of goats against excessive sales, thus stabilizing the herd and allowing for the observed herd growth in the past. However, a causal or reinforcing role of BGBA participation may be proposed to explain this trend. Indeed, this behavior might not be fully spontaneous and could have been induced by the BGBA regulation, which imposed restrictions on goat sales before growth performance recording. Herd growth in these farms then partly corresponds to goats that were donated by the project.

The negative variation rate of goat flocks that cluster 3 households envisioned for the future nevertheless suggests that flocks have exceeded the optimal size they are able to raise. Their major challenges in managing large flocks lie in the lack of adequate animal housing and insufficient availability of fodder. These farmers also expressed that the susceptibility to diseases increased with flock size, as also reported by Mwebe et al. (2011) in a densely populated area of Uganda. Therefore, community-based breeding programs for this cluster are facing a fundamental challenge in this limit of individual farmers to increase their flock size.

Viability of goat farming according to farmers diversity

The cost results indicated that total costs per flock were estimated to be the greatest in BGBA goat-oriented farmers with larger flocks (13 heads in mean), whereas those per animal were estimated in this group as the lowest. This was also observed according to the region, with lower values of total cost per animal in EDP, together with larger flocks, compared to CHL. This suggests a positive relationship between cost efficiency and high flock size as reported by Toro-Mujica et al. (2015).

In terms of return, total gross revenues per flock and per animal were significantly higher for goat-oriented farmers compared to others. Results also showed that manure and saving provided a higher contribution to the gross revenue for BGBA goat-oriented farmers compared to others, and in EDP than in CHL. Thus, in addition to improvement of bean yield through manure production, the high goat flock size may also be interesting for its intangible benefits, providing social security for smallholders. This may allow them to cope with various risks while the majority had no access to formal credit and insurance institutions (Peacock, 2005; Woldu et al., 2016b). Furthermore, total gross margins per flock and per animal were significantly the greatest in BGBA goat-oriented farmers and in EDP. Altogether, these results suggest that high economic efficiency per goat in relatively high flock size (from 10 to 20 animals) is tied to manure function through bean production and saving function. Thus, increasing goat flock size appears as one way to improve economic viability of goat farming. However, the ability of farmers to manage flock size above 10 animals clearly appeared as an issue in this densely populated and highly fragmented agricultural system of Burundi.

Therefore, reproduction performances of goats and kids' survival appear as more economically relevant parameters to raise the flock size up to the households' management limit, which increase the number of marketable kids. The role of BGBA would be to assist farmers in selecting animals to be retained for breeding and those to be sold, based on the few and most valuable traits defined by smallholders through participatory approaches. Obviously, the tight management limit in increasing herd size forces such projects to work over a wider number of households to allow for the needed width of selection basis. This limit also entails the need for a tight follow-up, evaluation, selection, and removal of rejected animals, in order not to immobilize stocks beyond the time technically needed for evaluation.

Correspondence between goat multifunctionality stated through proportional piling and gross revenue decomposition

The divergences between values estimated through proportional piling and gross revenue decomposition were significant. The lack of correlation between the two modes of estimation would indicate that both perspectives are needed to reflect the farmers' interests (Gizaw et al., 2018). Indeed, while accountancy provides an estimation of which all constitutive hypotheses are known, the stated relative importance reflects farmers' perceptions, the bulk value of which can then allow for further interviewing, to explore underlying explanations. In accordance with the classic agricultural household model (Taylor and Adelman, 2003), one might also notice that an economic calculation making use of market prices may fail at providing a faithful image of different values (products, wages), given the constraints of households in accessing these markets and the lack of separation between production and consumption. Hence, the higher estimation of manure function through proportional piling by non-BGBA farmers could indicate the high importance of their own harvests as compared to market foods, since their subsistence is closely linked to own production and unconnected to food markets (Sibhatu and Qaim, 2017). The lower estimation of goat sale function through proportional piling could indicate that

farmers would prefer to keep their goats for manure and saving function, but are forced to sell goats because of the lack of alternative cash sources. Conversely, BGBA goat-oriented farmers ascribed to the sale function a higher importance through proportional piling than calculated by gross revenue decomposition, whereas the reverse held for saving function. This may be interpreted as caused by the limitation imposed by the project on goat sale among participants, leading them to state a relative importance that is more in line with their wished evolution. Finally, the proportional piling provided a higher estimate of social function compared to gross revenue decomposition. This might reflect that market prices underestimate the value of the social principles of mutual assistance, which characterized the Burundian society. However this social function was of minor importance as it ranked lowest among functions. As shared by Desiere et al. (2015), it might translate a progressive scarcity of animal resources or a deterioration of this traditional social value of mutual assistance (Boogaard and Moyo, 2015).

Conclusion

Goat farming in Burundi tends to be well adopted by smallholders with a small arable land area compared to those with a relatively large area; the latter prefer small goat flocks and a dairy cow to exploit the comparative advantages of both species. However, the contribution of goat farming to the smallholders' livelihoods remains limited by the low productivity, due to the high offtake rate in flocks for farmers lacking alternative sources of cash. Our hypothesis of lack of interest in this species may be confirmed by the perception of its low production of manure in this agriculture-based livelihood system. The hypothesis may also be confirmed by the tendency toward cattle farming as the farm size increase, supposed to have a high manure productivity. Raising awareness could promote goat adoption and improve its economic productivity, as observed for some BGBA members, but smallholders would be limited by their weak abilities to manage large flocks. Thus, it may be less relevant and difficult to implement and sustain a genetic selection based on breeding value, because smallholders prefer to limit their goat flocks and diversify species. While the study showed the role of off-farms activities in preserving goat flocks from excessive sales in BGBA members, we propose to consolidate BGBA by promoting complementary activities, in order to protect goats from excessive sales while improving the welfare of smallholders. This would involve a deep commitment of all stakeholders of rural development including researchers, for financial and technical support.

Ethics approval

Not applicable.

Data and model availability statement

None of the data were deposited in an official repository. Data are available upon request.

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Author contributions

JM, JD, GH and NA participated in the design of the study. JM collected and performed the statistical analysis and drafted the manuscript. NM and NA corrected the manuscript. All authors read and approved the final manuscript.

Declaration of interest

The authors declare that they have no conflicts of interest.

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References

Ahuya, C.O., Okeyo, A.M., Mwangi, N., Peacock, C., 2005. Developmental challenges and opportunities in the goat industry: the Kenyan experience. Small Ruminant Research 60, 197–206.

Ayalew, W., Rischkowsky, B., King, J.M., Bruns, E., 2003. Crossbreds did not generate more net benefits than indigenous goats in Ethiopian smallholdings. Agricultural Systems 76, 1137–1156.

Biscarini, F., Nicolazzi, E., Alessandra, S., Boettcher, P., Gandini, G., 2015. Challenges and opportunities in genetic improvement of local livestock breeds. Frontiers in Genetics 6, 33–39.

Boogaard, B., Moyo, S., 2015. The multi-functionality of goats in rural Mozambique: contributions to food security and household risk mitigation - ILRI research report 37. International Livestock Research Institute (ILRI), Nairobi, Kenya.

Burke, W.J., Jayne, T.S., Freeman, H.A., Kristjanson, P., 2007. Factors associated with farm households' movement into and out of poverty in Kenya: the rising importance of livestock - Food security international development working papers 54563. Michigan State University, Department of Agricultural, Food, and Resource Economics, East Lansing, MI, USA.

Camara, Y., Moula, N., Sow, F., Sissokho, M.M., Antoine-Moussiaux, N., 2019. Analysing innovations among cattle smallholders to evaluate the adequacy of breeding programs. Animal 13, 417–426.

De Vries, J., 2008. Goats for the poor: some keys to successful promotion of goat production among the poor. Small Ruminant Research 77, 221–224.

Desiere, S., Niragira, S., D'Haese, M., 2015. Cow or Goat? Population pressure and livestock keeping in Burundi. Agrekon 54, 23–42.

Gizaw, S., Abebe, A., Bisrat, A., Zewdie, T., Tegegne, A., 2018. Defining smallholders' sheep breeding objectives using farmers trait preferences versus bio-economic modelling. Livestock Science 214, 120–128.

Lê, S., Josse, J., Husson, F., 2008. FactoMineR: an R package for multivariate analysis. Journal of Statistical Software 25, 1–18.

Manirakiza, J., Hatungumukama, G., Thévenon, S., Gautier, M., Besbes, B., Flori, L., Detilleux, J., 2017. Effect of genetic European taurine ancestry on milk yield of Ankole-Holstein crossbred dairy cattle in mixed smallholders system of Burundi highlands. Animal Genetics 48, 544–550.

Ministère de l'intérieur, 2010. Recensement général de la population et de l'habitat du Burundi 2008. Synthèse des résultats définitifs. République du Burundi, Bujumbura, p. 87 (Retrieved 20 October 2019). https://www.usaid.gov/sites/default/files/documents/1866/2008%20Burundi%20Population%20Census_Summary%20of%20Final%20Results.pdf.

Moll, H.A.J., 2005. Costs and benefits of livestock systems and the role of market and non-market relationships. Agricultural Economics 32, 181–193.

Mueller, J.P., Rischkowsky, B., Haile, A., Philipsson, J., Mwai, O., Besbes, B., Valle Zárate, A., Tibbo, M., Mirkena, T., Duguma, G., Sölkner, J., Wurzinger, M., 2015. Community-based livestock breeding programmes: essentials and examples. Journal of Animal Breeding and Genetics 132, 155–168.

Mwebe, R., Ejobi, F., Laker, C.D., 2011. Assessment of the economic viability of goat management systems in goma sub county and mukono town council in Mukono District, Uganda. Tropical Animal Health and Production 43, 825–831.

Nzigidahera, B., 2012. Description du burundi: aspects physiques. Ministere de l'eau, de l'environnement, de l'amenagement du territoire et de l'urbanisme Retrieved 5 August 2020 from. http://bi.chm-cbd.net/biodiversity/presentation-du-burundi/aspects-physiques-du-burundi.

Ogola, T.D.O., Nguyo, W.K., Kosgey, I.S., 2010. Economic contribution and viability of dairy goats: implications for a breeding programme. Tropical Animal Health and Production 42, 875–885.

Peacock, C., 2005. Goats - A pathway out of poverty. Small Ruminant Research 60, 179–186.

Sibhatu, K.T., Qaim, M., 2017. Rural food security, subsistence agriculture and seasonality. PLos-One 12, 1–15.
Taylor, J.E., Adelman, I., 2003. Agricultural household models: genesis, evolution, and extensions. Review of Economics of the Household 1, 33–58.
Tindano, K., Moula, N., Traoré, A., Leroy, P., Antoine-Moussiaux, N., 2017. Assessing the diversity of preferences of suburban smallholder sheep keepers for breeding rams in Ouagadougou, Burkina Faso. Tropical Animal Health and Production 49, 1187–1193.
Toro-Mujica, P., García, A., Aguilar, C., Vera, R., Perea, J., Angón, E., 2015. Economic sustainability of organic dairy sheep systems in central spain. Italian Journal of Animal Science 14, 193–201.
Udo, H.M.J., Steenstra, F.A., 2010. Intensification of smallholder livestock production, is it sustainable? Proceedings of the 5th International seminar on tropical animal production (ISTAP) on Community Empowerment and Tropical Animal Industry, 19–22 October 2010. Yogyakarta, Indonesia, pp. 19–26
Udo, H.M.J., Aklilu, H.A., Phong, L.T., Bosma, R.H., Budisatria, G.S., Patil, B.R., Samdup, T., Bebe, B.O., 2011. Impact of intensification of different types of livestock production in smallholder crop-livestock systems. Livestock Science 139, 22–29.
Verschelde, M., D'Haese, M., Rayp, G., Vandamme, E., 2013. Challenging small-scale farming: A non-parametric analysis of the (inverse) relationship between farm productivity and farm size in Burundi. Agricultural Economics 64, 319–342.
Woldu, T., Markemann, A., Reiber, C., Kassie, G.T., Valle, A., 2016a. Combining revealed and stated preferences to de fi ne goat breeding objectives in Ethiopia. Livestock Science 191, 179–186.
Woldu, T., Markemann, A., Reiber, C., Muth, P.C., Zárate, A.V., 2016b. Optimising contributions of goat farming to household economic success and food security in three production systems in Ethiopia. Journal of Agriculture and Rural Development in the Tropics and Subtropics 117, 73–85.
Wurzinger, M., Sölkner, J., Iñiguez, L., 2011. Important aspects and limitations in considering community-based breeding programs for low-input smallholder livestock systems. Small Ruminant Research 98, 170–175.
Wuta, M., Nyamugata, P., 2012. Management of cattle and goat manure in Wedza smallholder farming area, Zimbabwe. African Journal of Agricultural Research 7, 3853–3859.
Yaekob, L., Kirman, M.A., Birhanu, B., 2017. Participatory identification of breeding objective traits of Woyto-Guji goat in Loma district, Southern Ethiopia. International Journal of Livestock Production 8, 131–135.