Drivers of low-input farmers' perceptions of sustainable ruminant farming practices in the Eastern Cape Province, South Africa

Marandure, T., Bennett, J., Dzama, K., Makombe, G. & Mapiye, C.

Original citation & hyperlink:
Marandure, T, Bennett, J, Dzama, K, Makombe, G & Mapiye, C 2021, 'Drivers of low-input farmers' perceptions of sustainable ruminant farming practices in the Eastern Cape Province, South Africa', Environment, Development and Sustainability, vol. 23, no. 6, pp. 8405-8432.
https://dx.doi.org/10.1007/s10668-020-00973-x

DOI 10.1007/s10668-020-00973-x
ISSN 1387-585X
ESSN 1573-2975

Publisher: Springer

The final publication is available at Springer via http://dx.doi.org/10.1007/s10668-020-00973-x

Drivers of low-input farmers' perceptions of sustainable ruminant farming practices in the Eastern Cape Province, South Africa

Tawanda Marandure[1,2], James Bennett[2], Kennedy Dzama[1], Godswill Makombe[3] and Cletos Mapiye[1]*

[1]*Department of Animal Sciences, Stellenbosch University, P. Bag X1, Matieland 7602, South Africa*

[2]*Centre for Agroecology, Water and Resilience (CAWR), Coventry University, Ryton Gardens, Wolston Lane, Coventry, CV8 3LG, UK*

[3]*Gordon Institute of Business Science, University of Pretoria, 26 Melville Road, Illovo, Johannesburg*

*Corresponding author-: email: cmapiye@sun.ac.za

Abstract

Resolution of the existing disconnect between experts and farmers' insights on sustainable farming requires understanding of the key factors driving farmers' perceptions on the concept. Interviews were conducted with 160 low-input farmers to evaluate the drivers of their perceptions of sustainable ruminant farming practices in Eastern Cape Province, South Africa. It was found that farmers had negative perceptions on rangeland, breeding, livestock security and marketing management practices and positive perceptions on socio-cultural, family health and education practices. The major factors that influenced farmers' perceptions on sustainable ruminant farming practices include location, age, gender and employment status. Full-time, male and peri-urban farmers were more likely to perceive decreases, ($P \leq 0.05$) while the youths had greater probability to perceive increases ($P \leq 0.05$) in ecologically related ruminant farming practices. Male, married, more educated, full-time and rural farmers

were more likely to perceive decreases ($P \leq 0.05$) in economically related ruminant farming practices compared to their counterparts. Young, males and full-time farmers had greater probability to perceive decreases ($P \leq 0.05$), whereas rural farmers were more likely to perceive increases ($P \leq 0.05$) in socially related ruminant farming practices. These key drivers of farmer's perceptions could be used to develop context-specific indicators for sustainability assessment and synchronise experts and farmers insights on sustainable ruminant farming.

Key words: determinants, barriers, perception index, response strategies, sustainable ruminant farming, sustainable livelihoods.

1.0 Introduction

Cattle, sheep and goats have long been providing multiple and diverse roles essential for attaining livelihood, food and nutrition security in Southern Africa (Waters-Bayer and Bayer, 1992; Mapiye et al., 2020a, Molotsi et al., 2020). In South Africa, low-input ruminant farmers are custodians of an estimated 40% of cattle, 12% sheep and 70% goats, which primary rely on communal grazing (Ainslie et al., 2002). Low-input farmers in the context of the current study refer to subsistent ruminant producers who own small plots of land, and predominantly produce for home consumption with erratic sales of a few surpluses (Gwiriri et al., 2019). The system is dominated by elderly men, with women and youth constituting the majority of the labour force (Njuki et al., 2011; Verhart et al., 2015). It is also characterised by low ruminant productivity due to various challenges including poor forage quality and quantity, diseases and parasites, limited access to extension and veterinary personnel among other challenges (Gwaze et al., 2009; Mapiye et al., 2018; Molotsi et al., 2020). Most of the low-input ruminant farmers have limited access to formal markets and often resort to informal marketing which are seasonal and often unreliable (Gwiriri et al., 2019; Molotsi et al., 2020; Monau et al., 2020). The extent of compliance of the system with sustainable farming practices is a matter for debate.

Studies by Atanga et al. (2013) in Ethopia and Marandure et al. (2017) in South Africa revealed that the low-input ruminant farming systems are moderately sustainable. However, low-input ruminant farming in most developing countries is often criticised for inefficient resource use, low economic returns, lack of social security and doubtful propensity for sustainable livelihoods (Moraine et al., 2016; Meissner et al., 2013; Gayatri et al., 2016). Unfortunately, the bulk of methods designed to evaluate the sustainability of the low-input ruminant farming systems are often externally developed and not cognisant of local realities

including multiple objectives, species and outputs of the system, credence attributes and socio-cultural beliefs important to the farmers (Marandure et al., 2017). This is partly attributed to the disconnect between experts and farmers perceptions on sustainable farming (Moraine et al., 2016; Marandure et al., 2017). In general, experts understand sustainability from a technical point of view while low-input farmers understand it from a practical dimension which might not necessarily involve the technicalities of the concept. Consequently, the disconnect exist where experts expect farmers to follow the technical guidelines outlined for sustainability without appreciating that low-input farmers make logical management decisions based on a separate set of parameters including limited access to resources including capital, information, markets, inadequate labour and restrictive climatic conditions (Mapiye et al., 2020a). Establishing farmers' perceptions on sustainable ruminant farming can help to identify and conceptualize drivers of key decisions made at individual farmer level. That will contribute towards resolving the disconnection between farmers and experts.

Farmers' perceptions provides key information necessary for the identification and adoption of sustainable farming practices (Bopp et al., 2019). According to Zeweld et al. (2019) sustainable farming refers to production practices that primarily use locally available resources including farmers' knowledge and skills to enhance productivity for improved household livelihood, food and nutrition security and build resilience of local systems while, maintaining the quality of the environment. The environmental, economic and social aspects of sustainability can be practically measured using a set of appropriately developed indicators as described in various studies (Latruffe et al., 2016; Marandure et al., 2018; Mandarino et al., 2019). Examples of sustainable ruminant farming practices include use of plant and animal genetic resources adapted to local environment, indigenous ethnoveterinary therapies,

local energy resources (e.g., animal manure), local markets and humane animal welfare (Halbrendt et al., 2018; Bopp et al., 2019). Gender equity in control and decision-making about resource use and community-based farmer education and training to build intrinsic motivation within the community are also part of sustainable ruminant farming practices (Marandure et al., 2020). Establishing farmers' perceptions helps to provide basis for encouraging adoption of such sustainable farming practices. Previous studies reported higher per capita harvests, income and assets among adopters of sustainable agriculture practices than non-adopters (Halbrendt et al., 2018; Zeweld et al., 2019).

It is acknowledged that low-input ruminant farmers' perceptions differ with respect to their environmental, economic and socio-cultural circumstances (Oosting et al., 2014;; Mandarino et al., 2019). In that context, identification of the key factors driving low-input farmers' perceptions could be invaluable in further understanding their sustainable farming practices to facilitate the co-development of interventions (Tatlidil et al., 2009). In addition, farmer perceptions and their determinants are important in designing context-specific sustainability evaluation indicators (Moraine et al., 2017). Farmer derived indicators have previously been used to measure sustainability of low-input cattle farming systems (Marandure et al., 2017; Atanga et al., 2013). The current study builds on previous research by Molotsi et al. (2017) that reviewed literature to identify sustainability indicators of relevance to low-input sheep farming in South Africa. No attempt was made by previous studies to understand key factors driving farmers' judgement of sustainable farming practices. In that regard, the objective of the current study was to determine drivers of low-input farmers' perceptions of sustainable ruminant farming practices in the Eastern Cape Province, South Africa. The study also identified major barriers and response strategies to sustainable ruminant farming.

2.0 Materials and methods

2.1 Description of study sites

A survey was conducted in four rural and three peri-urban communities purposefully selected based on farmers' ruminant ownership and distance from the nearest urban centre. In this context three district municipalities namely; Alfred Nzo, OR Tambo and Chris Hani district municipalities of Eastern Cape Province, South Africa were selected. Peri-urban communities were those within a 15 km radius of the nearest town beyond which communities were defined as rural. Extensive literature search could not reveal any definitions of rural and peri-urban communities based on distance from an urban town. The locations of the selected communities are shown in Figure 1. Table 1 provides basic summary data for each community. The study received ethical approval (ANI-2017-1518) from Stellenbosch University Research Committee.

2.2 Farmer selection and questionnaire administration

A total of 160 household heads were randomly selected from the seven communities using extension officers' farmer data bases as sampling frames from which random numbers tables were used for selection. Interviews were conducted with each willing household head using semi-structured questionnaires administered in the local Sesotho (rural communities) and isiXhosa (peri-urban communities) language by trained enumerators. A prototype of the questionnaire was drafted and pre-tested in March 2018 before being revised and administered in October 2018. Pre-testing was done by conducting interviews with farmers in Cradock in the Eastern Cape Province, South Africa using a prototype of the questionnaire to establish relevance of questions and time taken with each respondent.

2.3 Data collection

Data were collected on household demographics, ruminants' livestock herd/flock structures and dynamics. Questions regarding respondents' perceptions of sustainable ruminant farming practices, barriers and response strategies were captured. An example of how the questions were presented to farmers is 'What is your perceived level of change in biomass supply over the past 20 years?' Response were rated using a three-point Likert-type where decreasing = negative change (-1); Constant/ no change = neutral (0) and; increasing = positive change (+1). Follow up questions were framed as 'What are the barriers to sustainable biomass supply?' and 'What response strategies do you suggest for the barriers you mentioned?' These questions were repeated for the selected sustainable ruminant farming practices obtained from literature. These include ecological biomass supply, water management, breeding, health care and soil fertility practices (Lebacq et al., 2013; Moraine et al., 2017). Economic indicators included household income, security management , marketing, income generation and labour supply practices (Franco et al., 2012; Srinivasa Rao et al., 2018). Gender equality, food security, family education, family health, stakeholder engagement, youth engagement, farmer training and socio-cultural practices were the social indicators (Gaviglio et al., 2016; Mandarino et al., 2019). Details of the questions asked are found in the appended questionnaire.

2.4 Statistical analyses

All the data were analysed using the Statistical Analytical Systems (SAS 9.4; 2012). Descriptive analyses of household socio-demographic data were performed by using the PROC FREQ procedure. Ruminant livestock herd/flock structure and dynamics data were analysed using the PROC GLM procedure with location and household head as the fixed and random effects, respectively. Treatment means were generated and separated using the LSMEANS and Tukey's adjustment for multiple comparisons, respectively. The Wilcoxon

rank-sum test was used to rank livestock roles, household income sources and farmers' barriers and response strategies to sustainable ruminant farming using the PROC NPAR1WAY procedure.

For each ruminant farming practice, the mean score value was used as the perception index (PI), using a formula given by Bahta et al. (2016) and expressed as:

$$PI = \frac{Number\ of\ positive\ scores - Number\ of negative\ scores}{Total\ number\ of\ positive\ and\ negative\ scores}$$

Perception index (mean score) values range from -1 = Negative, 0 = Neutral and +1 = Positive. The closer an index is to -1 the more negative the perception for that practice and vice versa.

Socio-economic factors influencing low-input farmers' perceptions on the status of a selected ruminant farming practice were analysed using ordered logistic regression model (Cande and Kleinbaum, 1997; Fullerton, 2009). The status given by low-input ruminant farmers were treated as ordered categorical data and fitted in the ordered logit model:

$$\text{Log}\left(\frac{\Pr(Y \leq m \mid x)}{\Pr(Y < m \mid x)}\right) = \tau_m - x\beta(1 \leq m < M$$

Where, m= category (ordered category: decreasing, no change/constant and increasing); *x*= effect of the determinant on farmers' perception outcomes; τ= cut-off point; β= vector of logit coefficients; τ_m= log odds of being in category *m* or a lower as opposed to a higher category (M) where the ordering of cut points was constrained to $\tau_1 < \tau_2 \ldots < \tau_{M-1}$. Logit coefficient estimates were presented as being at a cut-off point rather than at a lower or

higher category of the ordered outcomes. A category that was lower than the cut-off point was denoted by a negative logit coefficient estimate and vice-versa.

2.5 Description of factors explaining the variation in farmers' perceptions

Key socio-economic factors that influence farmers' perceptions were included based on theoretical and empirical research (Kebebe et al., 2015; Paul et al., 2017; Zeweld et al., 2019). The explanatory variables included in the analysis and their postulated effects on farmers perceptions are described in the subsequent sections.

2.5.1 Location (Rural = 1 and Peri-urban = 0)

Rural farmers are more likely to be reliant on ruminant livestock for their livelihoods than peri-urban farmers who may be exposed to a variety of livelihood options (Tittonell, 2014). As a result of their anticipated reliance on ruminant livestock, rural farmers are postulated to have positive perceptions on sustainable ruminant farming.

2.5.2 Age (Youths <40 years = 1 and Adults >40 years = 0)

Age of the household head can be considered as an indicator of experience in farming. Farmers who are 40 years or above have more experience and resources to invest in ruminant livestock farming and postulated to have positive perceptions on ruminant farming practices (Tatlidil et al., 2009).

2.5.3 Gender (Male = 1 and Female = 0)

In developing countries, women in low-iput farming areas are often excluded from ownership or from critical decision making regarding ruminant livestock (Kristjanson et al., 2010). This is despite that they are left to cater for animals in the absence of the men who often seek off-

farm employment. In this regard, perceptions of women on sustainable ruminant farming are postulated to be negative.

2.5.4 Marital status (Married = 1 and Unmarried = 0)

Emperical evidence suggests that the onus of family responsibility influences married farmers to better adopt new technology than their unmarried counterparts (Rudel et al., 2016; M. Moraine et al., 2017; Marc Moraine et al., 2017). In the same regard, married farmers are postulated to have positive perceptions on the selected sustainable ruminant farming practices compared to their unmarried counterparts.

2.5.5 Education level [(More (>secondary) = 1 and Less (< secondary) = 0)]

Education level of the household head is expected to have a positive influence on the perceptions of ruminant farmers, because of the assumed link between education and knowledge (Gwiriri et al., 2019; Mapiye et al., 2018).

2.5.6 Livestock training (Yes = 1 and No = 0)

Similar to education level, farmers trained in livestock management are assumed to have more knowledge (Marandure et al., 2019) and are postulated to have positive perceptions on the selected sustainable ruminant farming practices.

2.5.7 Employment status (Full-time farmer = 1 and Part-time farmer = 0)

Full-time farmers are engaged with sustainable ruminant farming on daily basis and observe dynamic trends in different aspects of production over time which influence their decision making (Gwiriri et al., 2019; Mapiye et al., 2018). The farming experience gives them the liverage to accurately predict and manage both progressive and degenerating trends in

sustainable ruminant farming practices. In that regard, full-time farmers were postulated to have negative perceptions on the selected sustainable ruminant ruminant farming practices.

3.0 Results

3.1 Socio-economic characteristics of households

Gender, marital status, religion, education level and employment status of the respondents were not associated with location ($P > 0.05$). Seventy percent of the respondents were males and married. Most farmers were Christians (40%) or traditional believers (30%). Education levels of respondents were distributed as, 10% no formal education, 40% primary, 40% secondary and 10% tertiary education. Forty percent of respondents were pensioners, 30% full-time farmers, 20% formally unemployed and 10% part-time farmers. The average age of peri-urban respondents (60.4 ± 2.51) was greater ($P \leq 0.05$) than that of rural respondents (52.6 ± 2.19). Location did not influence ($P > 0.05$) total amount of income earned annually from livestock sales (ZAR4040 ± 857.7; mean ± standard error), social grants (ZAR3397 ± 146.4), salaries (ZAR1268 ± 105.8), pensions (ZAR1549 ± 48.1) and crop sales (ZAR667 ± 270.6). One USD was equivalent to ZAR 15 at the time of the current study.

3.2 Ruminant herd/flock dynamics

Ruminant livestock herd/flock sizes, sales, slaughters, mortality and stock theft statistics in the surveyed communities are presented in Table 2. There were no differences ($P > 0.05$) between the cattle, goats and sheep herd/flock size, sales, slaughters and mortality between rural and peri-urban communities. However, the number of cattle, goats and sheep stolen were greater ($P \leq 0.05$) in rural than peri-urban communities. Communal rangelands were the main source of feed (100% of respondents) followed by crop residues (10%) and bought-in

feed (1%). All the farmers relied on the government extension for animal health, production and marketing information.

3.3 Awareness of sustainable farming practices

All respondents were familiar with sustainable ruminant farming practices. Over 90% of respondents mentioned that they were willing to share information on sustainable farming practices with their neighbouring farmers through the word of mouth while the rest of respondents preferred sharing with their family members. About 40% of respondents from rural and none from the peri-urban communities acknowledged the existence of organizations that promoted principles of sustainable ruminant farming practices.

3.4 Low-input farmers' perceptions and drivers of sustainable ruminant farming practices

Low-input farmers from both rural and peri-urban locations had negative perceptions of all the environmental practices except for water management, which was neutral (Table 3). The most negatively perceived environmental practices were rangeland and breeding management practices. Employment status, age, location and gender influenced ($P \leq 0.05$) farmer perceptions on ruminant production, health care, breeding, rangeland, crop residue and water management practices (Table 4). Full-time as opposed to part-time farmers were more likely ($P \leq 0.05$) to perceive decreases in ruminant production and rangeland management practices. The likelihood of youths to perceive increases in rangeland and crop residue management practices was greater ($P \leq 0.05$) than that of adults. Full-time and peri-urban farmers were more likely ($P \leq 0.05$) to perceive decreases in water management practices than their counterparts. Males had greater ($P \leq 0.05$) likelihood to perceive decrease in animal health care and breeding practices than females. The most prominent barriers to environmental

practices were high disease prevalence (80% of all respondents) and drought (70%; Table 5). The corresponding response strategies suggested, include, regular dipping, vaccination and early treatment of diseases (40% of respondents) and drilling of boreholes and building dams (60%; Table 6).

Farmers perceived all the economic practices as negative (Table 7). Livestock security and marketing management were the most negatively perceived economic practices. Location, age, gender, education level and employment status moderated ($P \leq 0.05$) low-input farmers' perceptions on ruminant livestock security management, labour and income generation practices (Table 4). Young, rural, less educated and part-time farmers had greater ($P \leq 0.05$) likelihood to perceive increases in livestock security management practices in comparison to their counterparts. The probability of married and full-time farmers perceiving decreases in marketing practices was greater ($P \leq 0.05$) compared to that of their counterparts. Rural and more educated farmers were the more likely to perceive decreases in labour practices than peri-urban and less educated farmers. Males were more likely to perceive decreases ($P \leq 0.05$) in income generation practices than females. Major barriers to economic practices were high labour costs (70% of all respondents) and stock theft (70%; Table 7). Motivating family labour (50% of all respondents) and security reinforcement (50%) were mentioned corresponding response strategies (Table 8).

Regarding social practices, low-input ruminant farmers from the rural communities recorded a negative perception index on household food security practices while their peri-urban counterparts recorded a positive perception index (Table 9). Farmers had positive perceptions on family education, health care and socio-cultural practices but had negative perception ratings for women empowerment, stakeholder and youth engagement practices. Socio-

cultural practices had the most positive perceptions while, youth engagement had the most negative perceptions practice related to social sustainability. Farmers' perceptions on social practices were affected ($P \leq 0.05$) by gender, employment status, age and livestock training of the farmer (Table 4). Compared to females, males had greater ($P \leq 0.05$) probability to perceive a decrease in the household food security practices. Rural farmers were more likely to observe increases ($P \leq 0.05$) in the family health care practices than peri-urban farmers. Full-time farmers had greater ($P \leq 0.05$) likelihood to perceive decreases in socio-cultural practices than part-time farmers. The probability of young, male and untrained farmers to perceive a decrease in youth engagement practices was greater ($P \leq 0.05$) than their counterparts. Small herd/flock sizes (100% of respondents) and urban migration of the youths (70%) were the main barriers to social practices (Table 9). Building ruminants herd/flocks (80% of all respondents) and youth involvement in agriculture were the dominant response strategies (Table 10).

4.0 Discussion

The observation that the respondents were familiar with most of the sustainable ruminant farming practices provides hope for its wider adoption and operationalisation in the low-input systems. The sharing of information between neighbours and/or family members is typical of farmers in low-input systems with limited expert advice due poor extension services (Mapiye et al., 2020b). Mapiye et al. (2020b) advocated for use of advanced ICT based methods to widen social networks and enhance farmer to farmer information sharing. The observed low-input farmers' negative perception indices on sustainable environmental practices and the greater likelihood of full-time farmers to perceive decreases in sustainable ruminant production practices is realistic. This may have been driven by farmers' limited capacity and resources to minimise the impact of environmental degradation and frequent occurrence of

severe droughts on ruminant production in the surveyed areas (Hadrich and Jackson, 2014; Nakano et al., 2018; Marandure et al., 2019). This is confirmed by the mention of small herd/flock sizes as a major barrier to ruminant production largely attributed to low fertility levels mainly due to low nutrition, diseases and parasites (Mapiye et al. 2009; Nqeno et al., 2011). The response strategy of building and maintaining larger herds and flocks ties well with the desire of most low-input farmers to fulfil the multiple ruminants functions, and for self-aggrandisement to elevate the status of an individual on the hierarchy of low-input communities (Gwiriri et al., 2019; Marandure et al., 2019).

The perceived decline in rangeland management practices, as reflected by the most negative ratings in the current study, is consistent with the limited resources notion and the common perceptions that rangeland resources in low-input communities are over-utilised and progressively degraded (Wang et al., 2019). Without comprehensive rangeland management strategies, continuous grazing on progressively degraded rangelands exacerbates degradation, and fuel conflicts over scarce rangeland resources (Tschopp et al., 2010). There is, however, some reports suggesting that rangeland ecosystems adapt and become more resilient to heavy stocking and overgrazing than previously believed (El-Kharbotly et al., 2003; Ramoelo et al., 2012). Based on these reports, opportunistic rangeland management practices pursued by low-input ruminant farmers, may not be as ecologically destructive as previously suggested (Hoffmann, 2011; Garibaldi et al., 2017).

The experience gained from decades of male dominance in ruminant farming (Njuki et al., 2011) may have influenced their higher likelihood to perceive decreases in livestock breeding and health care practices compared to their female counterparts. The experience is also positively correlated to perceptions of full-time and trained farmers but negatively associated

with opinions of the youths. The fact that breeding practices were negatively perceived points to the unstructured breeding practiced in the low-input system (Nqeno et al., 2011). Given that the South African government provides regular voluntary animal health care (i.e., deworming, dipping and vaccination) to low-input farmers (Marufu et al., 2011), the propensity to perceive decreasing livestock health care practices might be related to inefficiency of delivery. Various factors influence delivery of government programs including physical accessibility of the area, infrastructure or presence of skilled personnel and transport (Marandure et al., 2020).

Farmers' negative perception indices for all the sustainable economic practices may be related to their limited direct income despite other multiple non-financial benefits of ruminants (Mapiye et al., 2018). The greater propensity to perceive increases in ruminant livestock security practices by young and rural farmers may be a reflection of greater access to information about the government's efforts to reinforce anti-stock theft security on the border with Lesotho (Meissner et al., 2013; Bahta et al. 2016). Low-input ruminant farmers reported being vulnerable to armed thieves that illegally cross the border to steal their livestock thereby, threatening their livelihoods (Ainslie et al., 2002). Individual farmers developed strategies to improve security of their animals through early kraaling, building kraals closer to their homesteads and securing the kraals with chains, locks and security fences (Nevondo et al., 2019). Despite the current livestock security developments, phobia from past losses might have driven the propensity of males, more educated and full-time farmers to perceive decreases in ruminant livestock security practices.

The greater likelihood of married and full-time farmers to perceive decreases in marketing practices could be because of the anxiety generated from experiences of persistent suboptimal

marketing practices (Ndoro etal., 2014). This may have been influenced by a combination of the obligation of family's financial responsibilities and barriers to ruminant marketing such as distant markets, lack of marketing infrastructure, poor marketing information and unfavourable carcass classification systems reported previously (Kocho et al. 2011; Mapiye et al. 2018; Gwiriri et al. 2019). Social capital development including formal organizations membership and having strong networks and relationships with the local community groups is essential on improving marketing of ruminants (Zeweld et al., 2019).

The higher probability of rural farmers to perceive decreases in labour practices may be related to its high cost. Peri-urban farmers may have income opportunities from off-farm employment (Abu Hatab et al., 2019). Low-input farmers, particularly women, are often reluctant to adopt labour intensive practices whose benefits accrue in the long-term (van Wijk et al., 2014). Substantial investments in labour is expendable even with family labour, when there are no immediate benefits (Skaf et al., 2019).

The greater likelihood of males to perceive a decrease in income generation practices maybe linked to their responsibility to fulfil family material requirements through diverse on- and off-farm risk aversion strategies (Hahn et al., 2009). Rural farmers' negative perceptions on food security practices may be linked to their reluctance to slaughter livestock opting for flow-product benefits such as milk and draught power (Marandure et al., 2019). Peri-urban farmers have greater income opportunities and consequently may have greater access to nutritious and safe foods (Abu Hatab et al., 2019) including meat and milk.

The reason for the greater probability of male farmers to perceive decreases in food security practices may be related to declining trends in food availability observed over the years

(Rudel et al., 2016). Barriers to sustainable household food security practices are linked to small herds and flocks (Weiler et al., 2014). The greater propensity of full-time farmers to perceive decreases socio-cultural practices may also be linked to small herd/flock sizes, which may limit them from offering ruminants as part of their culture (Kristjanson et al., 2010; Marandure et al., 2016). The observation that rural farmers were more likely to perceive increases in family health care practices may be linked to the consumption of natural foods, pollutant-free environment and subsidised medical health care offered in government institutions (Oosting et al., 2014). Their peri-urban counterparts may be exposed to unhealthy high energy foods and pollutants from the cities (Marandure et al., 2017).

The negative perceptions of farmers on stakeholder engagement practices may be reflective of unpopular technologies often introduced by development-oriented stakeholders. Senyolo et al. (2018) criticised the approach followed by most rural development organisations as being exclusive and entirely based on the top-down methodologies that lead to development of inappropriate technologies. However, low-input farmers demonstrated their desire to see external organisations integrated into existing government development programs to improve efficiency. Ideally, this could be possible where protocols to be followed by development-oriented stakeholders are stated and supported by policies (Senyolo et al., 2018).

Famers' negative perceptions on youths' engagement in sustainable ruminant farming is reflected by the dominance of adult respondents in the current study and also reported in various studies (Kocho et al. 2011; Mapiye et al. 2018; Gwiriri et al. 2019). Lack of youth engagement practices is taken to indicate absence of dedicated and motivated heirs to advance sustainable ruminant farming in the future (Bernués et al., 2011). The observation that young and married farmers were more likely to perceive decreases in youth engagement

practices may be associated with a lack of interest by youths in ruminants farming which they often consider as dirty, laborious and unrewarding (Swarts and Aliber, 2013). Married farmers might be harbouring expectations of their children's success in ruminant farming and would be more likely to notice limited practices to engage the youths than their unmarried counterparts. Farmers with training in livestock production are more likely to be sensitised by prospects of youth development programs hence, their greater propensity to perceive increases in effective youth engagement practices.

Urban migration of youths which was mentioned among the major barriers to effective youths engagement practices may be fuelled by disgruntled youths who feel that their contributions are limited to providing labour in agricultural activities, while, benefits are retained by the elders (Tatlidil et al., 2009). In this regard, involving the youths and women when making key decisions about ruminant farming revenue and benefits can help to integrate and motivate them (Swarts and Aliber, 2013). Reports of the peri-urban youths engaging in drugs and alcohol may represent missed opportunities to acquire knowledge and skills as well as to accrue relevant experience for the benefit of future food production (Abu Hatab et al., 2019). Exclusion of women in ruminant farming depicts an underutilised but potentially effective human resource capable of augmenting labour and providing the necessary diversity in decision making for more efficient resource use.

Conclusions

Farmers had negative perceptions on biomass supply, water management, breeding, health care, soil fertility practices, household income, security management, marketing, income generation and labour supply practices. Positive perceptions were reported on the social practices including, gender equality, food security, family education, family health,

stakeholder engagement, youth engagement and farmer training. Farmer's perceptions on sustainable ruminant farming practices were mainly influenced by location, age, gender and employment status. On one hand, the perceptions of groups of farmers that were directly involved in daily management of ruminants, such as males, married and full-time farmers closely resembled realistic trends as reflected by empirical studies. On the other hand, knowledgeable groups of farmers, such as the more educated, trained and young farmers recorded pessimistic perceptions that did not always reflect realistic empirically reported trends. However, these key drivers of farmer's perceptions are important in targeting relevant population groups for promoting sustainable ruminant farming practices.

The study discovered critical realities of the local low-input ruminant farming system which ought to be incorporated in sustainability evaluations. Furthermore, the knowledge gained by researchers from interacting with farmers and from studying perceptions is important in resolving the disconnect between experts and farmers perceptions on sustainable ruminant farming practices. The established connection between farmers' perceptions and their drivers could improve understanding of the realities of the low-input ruminant farming systems. That may help policymakers and development agents in framing context-specific indicators to evaluate the sustainability of low-input ruminant farming system. Further research is recommended to integrate the key drivers of farmer's perceptions in sustainability evaluation frameworks of the low-input ruminant farming systems.

Conflict of interest

Authors declare that there is no conflict of interest

Acknowledgements

Authors would like to acknowledge the contribution of farmers and other stakeholders who were involved in the current study. Their information is invaluable in understanding the drivers of farmers of farmers' decision making process.

Funding

The funding contribution of the Department of Science and Technology-National Research Foundation (DST-NRF) Centre of Excellence (CoE) in Food Security (grant number: 140102) is hereby acknowledged.

References

Abu Hatab, A., Cavinato, M.E.R. and Lagerkvist, C.J. (2019). Urbanization, livestock systems and food security in developing countries: A systematic review of the literature. *Food Security*, 94, 129–142

Ainslie, A., Kepe, T., Ntsebeza, L., Ntshona., Z and Turner S. (2002). Cattle ownership and production in the communal areas of the Eastern Cape Province, South Africa. Research Report no. 10. University of the Western Cape, Cape Town, South Africa.

Atanga, N., Treydte, A. and Birner, R. (2013). Assessing the sustainability of different small-scale livestock production systems in the Afar Region, Ethiopia. *Land*, 2, 726–755

Bahta, Y.T., Jordaan, A. and Muyambo, F. (2016). Communal farmers' perception of drought in South Africa: Policy implication for drought risk reduction. *International Journal of Disaster Risk Reduction*, 20, 39–50

Bernués, A., Ruiz, R., Olaizola, A., Villalba, D. and Casasús, I., (2011). Sustainability of pasture-based livestock farming systems in the European Mediterranean context: Synergies and trade-offs. *Livestock Science*, 139, 44–57

Bopp, C., Engler, A., Poortvliet, P.M. and Jara-Rojas, R. (2019). The role of farmers' intrinsic motivation in the effectiveness of policy incentives to promote sustainable agricultural practices. *Journal of Environmental Management*, 244, 320–327

Cande, A.V. and Kleinbaum, D.G. (1997). Regression models for ordinal responses: a review of methods and applications. *International Journal of Epidemiology* 26,1323-1333.

El-Kharbotly, A., Mahgoub, O., Al-Subhi, A. and Al-Halhali, A. (2003). Indigenous grass species with potential for maintaining rangeland and livestock feeding in Oman. *Agriculture, Ecosystems & Environment*, 95, 623–627

Faku, N. and Hebinck, P. (2013). Cattle and rural development in the Eastern Cape, South Africa: the Nguni project revisited, In: Hebinck, P and B. Cousins (eds.), 'In the shadow of policy: everyday practices in South Africa's land and agrarian reform', Johannesburg: Wits University Press, 281–295

Franco, J.A., Gaspar, P. and Mesias, F.J. (2012). Economic analysis of scenarios for the sustainability of extensive livestock farming in Spain under the CAP. *Ecological Economics*, 74, 120–129

Fullerton, A.S. (2009). A conceptual framework for ordered logistic regression models. sociological methods and research. *Sociological Methods and Research* 38(2) 306–347

Galiè, A., Teufel, N., Girard, A.W., Baltenweck, I., Dominguez-Salas, P., Price, M.J., Jones, R., Lukuyu, B., Korir, L., Raskind, I.G., Smith, K. and Yount, K.M. (2019). Women's empowerment, food security and nutrition of pastoral communities in Tanzania. *Global Food Security*, 23, 125–134

Garibaldi, L.A., Gemmill-Herren, B., D'Annolfo, R., Graeub, B.E., Cunningham, S.A. and Breeze, T.D. (2017). Farming approaches for greater biodiversity, livelihoods, and food security *Trends in Ecology and Evolution*, 32, 68–80

Gaviglio, A., Bertocchi, M., Marescotti, M.E., Demartini, E. and Pirani, A. (2016). The social

pillar of sustainability: a quantitative approach at the farm level. *Agricultural and Food Economics*, 4, 1–19

Gayatri, S., Gasso-tortajada, V. and Vaarst, M., (2016). Assessing sustainability of smallholder beef cattle farming in Indonesia: A case study using the FAO SAFA framework. *Journal of Sustainable Development*, 9, 236

Gwaze, F.R.; Chimonyo, M.; Dzama, K. 2009. Communal goat production in Southern Africa: A review. *Tropical. Animal. Health and Production*. 41, 1157–1168.

Gwiriri, L.C., Bennett, J., Mapiye, C., Marandure, T. and Burbi, S. (2019). Constraints to the sustainability of a ‘ systematised ’ approach to livestock marketing amongst smallholder cattle producers in South Africa. *International Journal of Agricultural Sustainability*, 17, 1–16

Hadrich, J.C. and Jackson, J.J. (2014). Livestock emissions regulation with unknown damages and strategic technology adoption. *Applied Economics*, 46:35, 4309–4317

Hahn, M.B., Riederer, A.M. and Foster, S.O. (2009). The livelihood vulnerability index: A pragmatic approach to assessing risks from climate variability and change-A case study in Mozambique. *Global Environmental Change*, 19, 74–88

Halbrendt, J., Gray, S., Chan-Halbrendt, C., Shariq, L. and Tamang, B.B. (2018). Understanding Farmer’s Perception to Environmentally Sustainable Practices for Enhanced Food Security Using Fuzzy Cognitive Mapping In: Sustainable Food Security 2050, (IFAMA: Buenos Aires)

Hoffman, M., Lubell, M. and Hillis, V. (2014). Linking knowledge and action through mental models of sustainable agriculture. *PNAS*, 111, 13016–13021

Hoffmann, I. (2011). Livestock biodiversity and sustainability. *Livestock Science*, 139, 69–79

Kebebe, E.G., Oosting, S.J., Haileslassie, a., Duncan, a. J. and de Boer, I.J.M. (2015). Strategies for improving water use efficiency of livestock production in rain-fed systems

Animal, 9, 908–916

Latruffe, L., Diazabakana, A., Bockstaller, C., Desjeux, Y., Finn, J., Kelly, E., Ryan, M. and Uthes, S. (2016). Measurement of sustainability in agriculture : A review of indicators three sustainability pillars. *Studies in Agricultural Economics*, 118, 123–130

Lebacq, T., Baret, P. V. and Stilmant, D. (2013). Sustainability indicators for livestock farming: A review. *Agronomy for Sustainable Development*, 33, 311–327

Mandarino, R.A., Barbosa, F.A., Lopes, L.B., Telles, V., Florence, E. de A.S. and Bicalho, F.L. (2019). Evaluation of good agricultural practices and sustaintability indicators in livestock systems under tropical conditions. *Agricultural Systems*, 174, 32–38

Mapiye, C., Chimonyo, M. and Dzama, K. (2009). Seasonal dynamics, production potential and efficiency of cattle in the sweet and sour communal rangelands in South Africa *Journal of Arid Environments*, 73, 529–536

Mapiye, O., Makombe, G., Mapiye, C. and Dzama, K. (2018). Limitations and prospects of improving beef cattle production in the emerging sector: A case of Limpopo Province, South Africa. *Tropical Animal Health and Production*, 50, 1711–1725

Mapiye, O., Chikwanha, O. C., Makombe, G., Dzama, K and Mapiye C. (2020a). Livelihoods, food and nutrition security in Southern Africa: What role do indigenous cattle genetic resources play? *Diversity* 12, 74; doi: 10.3390/d12020074

Mapiye, O, Makombe, G, Mapiye, C and Dzama, K. (2020b). Management information sources and communication strategies for commercially-oriented smallholder beef cattle producers in Limpopo province, South Africa. Outlook on Agriculture 49(1) 50–56. https://doi.org/10.1177/0030727019860273.

Marandure, T., Bennett, J., Dzama, K., Gwiriri, L. and Bangani, N. (2019). Envisioning more effective delivery of custom feeding programs using participatory approaches: Lessons from Eastern Cape Province, South Africa. *Outlook on Agriculture*, 48, 157–166

Marandure, T., Bennett, J., Dzama, K., Makombe, G., Gwiriri, L. and Mapiye, C., (2020). Advancing a holistic systems approach for sustainable cattle development programmes in South Africa: insights from sustainability assessments. *Agroecology and Sustainable Food Systems*. In press.

Marandure, T., Makombe, G., Dzama, K., Hoffmann, W. and Mapiye, C. (2018). Towards a system-specific framework for the sustainability evaluation of low-input ruminant meat production systems in developing countries. *Ecological Indicators* 85: 1081–1091

Marandure, T., Mapiye, C., Makombe, G. and Dzama, K. (2017). Indicator-based sustainability assessment of the smallholder beef cattle production system in South Africa. *Agroecology and Sustainable Food Systems*, 41, 3–29

Marandure, T., Mapiye, C., Makombe, G., Nengovhela, B., Strydom, P., Muchenje, V. and Dzama, K. (2016). Determinants and opportunities for commercial marketing of beef cattle raised on communally owned natural pastures in South Africa. *African Journal of Range and Forage Science*, 33, 199–206

Marufu, M.C., Qokweni, L., Chimonyo, M. and Dzama, K. (2011). Relationships between tick counts and coat characteristics in Nguni and Bonsmara cattle reared on semiarid rangelands in South Africa. *Ticks and Tick-borne Diseases*, 2, 172–177

McMichael, A., Powles, J., Butler, C. and Uauy, R. (2007). Food, livestock production, energy, climate change, and health. *The lancet*, 370, 1253–63

Meena, H.R. (2013). Livestock farmers' participation and factors affecting the success of animal health care program in Hill Region. *Journal of. Human Ecolology*. 41, 255–261

Meissner, H.H., Scholtz, M.M. and Engelbrecht, F.A. (2013). Sustainability of the South African livestock sector towards 2050 part 2: Challenges, changes and required implementations. *South African Journal of Animal Sciences*, 43, 298–319

Molotsi, A., Dube, B., Oosting, S., Marandure, T., Mapiye, C., Cloete, S. and Dzama, K.,

(2017). Genetic traits of relevance to sustainability of smallholder sheep farming systems in South Africa. *Sustainability* (Switzerland), 9

Molotsi, A.H. Dube B.and. Cloete, S. W. P. (2020). The current status of indigenous ovine genetic resources in Southern Africa and future sustainable utilisation to improve livelihoods: A review. *Diversity* 12, 14; doi:10.3390/d12010014

Monau, P.. Raphaka, K Zvinorova-Chimboza, I P.and Gondwe T. (2020). Sustainable utilization of indigenous goats in Southern Africa: A review. *Diversity* 12, 20; doi:10.3390/d12010020

Moraine, Marc, Duru, M. and Therond, O. (2017). A social-ecological framework for analyzing and designing integrated crop–livestock systems from farm to territory levels *Renewable Agriculture and Food Systems*, 32, 43–56

Moraine, M., Grimaldi, J., Murgue, C., Duru, M. and Therond, O. (2016). Co-design and assessment of cropping systems for developing crop-livestock integration at the territory level. *Agricultural Systems*, 147, 87–97

Moraine, M., Melac, P., Ryschawy, J., Duru, M. and Therond, O. (2017). A participatory method for the design and integrated assessment of crop-livestock systems in farmers' groups. *Ecological Indicators*, 72, 340–351

Nakano, Y., Tsusaka, T., Aida, T. and Pede, V. (2018). Is farmer-to-farmer extension effective? The impact of training on technology adoption and rice farming productivity in Tanzania. *World Development*, 105, 336–351

Ndoro, J.T., Mudhara, M., Chimonyo, M. (2014). Livestock extension programmes participation and impact on smallholder cattle productivity in Kwazulu-Natal: A propensity score matching approach. *South .African Journal of Agricultural .Extention*, 42, 62–80

Neibergs, J.S., Hudson, T.D., Kruger, C.E. and Hamel-Rieken, K. (2017). Estimating climate

change effects on grazing management and beef cattle production in the Pacific Northwest. *Climatic Change*, 1–13 Njuki, J., & Sanginga, P. C. (2013). Gendered participation in livestock markets. In J. Nkuki & P. C. Sanginga (Eds.), Women, livestock ownership and markets: Bridging the gender gap in Eastern and Southern Africa. London: Routledge.

Nqeno, N., Chimonyo, M. and Mapiye, C., (2011). Farmers' perceptions of the causes of low reproductive performance in cows kept under low-input communal production systems in South Africa. *Tropical Animal Health and Production*, 43, 315–321

Oosting, S.J., Udo, H.M.J. and Viets, T.C., (2014). Development of livestock production in the tropics: farm and farmers' perspectives. *Animal*, 8, 1238–1248

Parsons, D., Nicholson, C.F., Blake, R.W., Ketterings, Q.M., Ramírez-Aviles, L., Fox, D.G., Tedeschi, L.O. and Cherney, J.H. (2011). Development and evaluation of an integrated simulation model for assessing smallholder crop-livestock production in Yucat, Mexico *Agricultural Systems*, 104, 1–12

Partey, S.T., Zougmoré, R.B., Ouédraogo, M. and Campbell, B.M. (2018). Developing climate-smart agriculture to face climate variability in West Africa: Challenges and lessons learnt. *Journal of Cleaner Production*, 187, 285–295

Paul, J., Sierra, J., Causeret, F., Guindé, L. and Blazy, J.M. (2017). Factors affecting the adoption of compost use by farmers in small tropical Caribbean islands. *Journal of Cleaner Production*, 142, 1387–1396

Pham, L. Van and Smith, C. (2014). Drivers of agricultural sustainability in developing countries: A review. *Environment Systems and Decisions*, 34, 326–341

Ramoelo, A., Cho, M., Mathieu, R., Skidmore, A., Schlerf, M. and Heitkönig, I. (2012). Estimating grass nutrients and biomass as an indicator of rangeland (forage) quality and quantity using remote sensing in Savanna ecosystems. *Researchspace*, 1–8

Roland-Holst, D. and Otte, J. (2006). Livestock and livelihoods: Development goals and indicators applied to Senegal

Rosa García, R., Celaya, R., García, U. and Osoro, K., (2012). Goat grazing, its interactions with other herbivores and biodiversity conservation issues *Small Ruminant Research*, 107, 49–64

Rudel, T., Kwon, O.-J., Paul, B., Boval, M., Rao, I., Burbano, D., McGroddy, M., Lerner, A., White, D., Cuchillo, M., Luna, M. and Peters, M. (2016). Do smallholder, mixed crop-livestock livelihoods encourage sustainable agricultural practices? A meta-analysis *Land*, 5, 6

Sala, S., Ciuffo, B. and Nijkamp, P., (2015). A systemic framework for sustainability assessment. *Ecological Economics*, 119, 314–325

Senyolo, M.P., Long, T.B., Blok, V. and Omta, O. (2018). How the characteristics of innovations impact their adoption: An exploration of climate-smart agricultural innovations in South Africa. *Journal of Cleaner Production*, 172, 3825–3840

Skaf, L., Buonocore, E., Dumontet, S., Capone, R. and Franzese, P.P. (2019). Food security and sustainable agriculture in Lebanon: An environmental accounting framework. *Journal of Cleaner Production*, 209, 1025–1032

Srinivasa Rao, C., Kareemulla, K., Krishnan, P., Murthy, G.R.K., Ramesh, P., Ananthan, P.S. and Joshi, P.K. (2018). Agro-ecosystem based sustainability indicators for climate resilient agriculture in India: A conceptual framework. *Ecological Indicators,* 105, 621–633

Swarts, M.B. and Aliber, M. (2013). The “youth and agriculture” problem: implications for rangeland development. *African Journal of Range and Forage Science*, 30, 23–27

Tatlidil, F.F., Boz, I. and Tatlidil, H. (2009). Farmers ’ perception of sustainable agriculture and its determinants : a case study in Kahramanmaras province of Turkey. *Environment,*

Development and Sustainability, 11, 1091–1106

Tittonell, P. (2014). Livelihood strategies, resilience and transformability in African Agroecosystems. *Agricultural Systems*, 126, 3–14

Tschopp, R., Aseffa, A., Schelling, E., Zinsstag, J., Tschopp, R., Aseffa, A., Schelling, E. and Zinsstag, J. (2010). Farmers' perceptions of livestock, agriculture , and natural resources in the rural Ethiopian Highlands. *BioOne*, 30, 381–390

Verhart, N.; van den Wijngaart, A.; Dhamankar, M.; Danielsen, K. (2015). Bringing agriculture and nutrition together using a gender lens; Royal Tropical Institute: Amsterdam, The Netherlands.

van Wijk, M.T., Rufino, M.C., Enahoro, D., Parsons, D., Silvestri, S., Valdivia, R.O. and Herrero, M. (2014). Farm household models to analyse food security in a changing climate: A review. *Global Food Security*, 3, 77–84

Wang, L., Delgado-baquerizo, M., Wang, D., Isbell, F., Liu, Jun, Feng, C. and Liu, Jushan, (2019). Diversifying livestock promotes multidiversity and multifunctionality in managed grasslands *PNAS*, 1–6

Waters-Bayer, A and Bayer, W. (1992). The Role of Livestock in the Rural Economy. *Nomadic Peoples*, 31, 3-18. https://www.jstor.org/stable/43123370

Weiler, V., Udo, H.M.J., Viets, T., Crane, T.A. and De Boer, I.J.M. (2014). Handling multi-functionality of livestock in a life cycle assessment: The case of smallholder dairying in Kenya. *Current Opinion in Environmental Sustainability*, 8, 29–38

Zeweld, W., Van Huylenbroeck, G., Tesfay, G., Azadi, H. and Speelman, S. (2019). Sustainable agricultural practices, environmental risk mitigation and livelihood improvements: Empirical evidence from Northern Ethiopia. *Land Use Policy*, doi: 10.1016/j.landusepol.2019.01.002

Table 1: Respondents and pedo-climatic conditions of studied communities in Eastern Cape Province, South Africa

Location	Community	n	Rainfall (mm)	Mean annual temperature ^{o}C	Distance from nearest town	Altitude (m)	Vegetation species
Rural	Matewu	12	680-815	14.7	23 km from Matatiele	1440-1500	*Themeda species., Heteropogon contortus, Eragrostis spp., Sporobolus africanus, Cynodon dactylon, Digitaria diagonalis*
	Bellford	15	680-815	14.7	21 km from Matatiele		
	Mafube Mission	34	680-815	14.7	20 km from Matatiele		
	Ndakeni	28	680-815	15	24.2 km from Mt Fletcher	900-1 270	
Peri-urban	Ngxalathi	21	600-920	14	3 km from Butterworth	600-1080	*Cymbopogon elionurus, Themeda triandra, Eragrostis spp., Heteropogon contortus, Hyparrhenia hirta, Sporobolus africanus, Aristida junciformis,*
	Gcuwa Mission	17	600-920	14	2.9 km from Butterworth		
	Cegcuwana	30	600-920	14	15 km from Butterworth		

Table 2: Means ± SE for ruminants numbers, sales, slaughters, mortality and theft for rural and peri-urban farming locations in Eastern Cape Province, South Africa

Parameter	Ruminants	Rural	Peri-urban
Numbers	Cattle	12.3±1.30	11.0±1.49
	Goats	26.2±5.38	13.7±6.16
	Sheep	18.5±4.97	31.2±5.68
Sales	Cattle	1.6±2.66	1.5±3.04
	Goats	3.0±0.75	2.6±0.86
	Sheep	2.4±0.39	2.3±0.45
Slaughters	Cattle	1.0±0.13	0.7±0.15
	Goats	2.1±0.35	1.6±0.39
	Sheep	1.6±0.25	1.3±0.29
Mortality	Cattle	1.1±0.23	1.7±0.26
	Goats	1.7±0.26	1.7±0.29
	Sheep	1.8±0.38	2.7±0.44
Theft*	Cattle	5.4^{a}±0.79	1.3^{b}±0.90
	Goats	2.9^{a}±0.72	0.6^{b}±0.83
	Sheep	2.2^{a}±0.56	1.3^{b}±0.64

[ab] Within row means with different superscripts significantly differ

*Theft was not recorded per year but on lifetime memories on farmers' insistence

Table 3: Respondents' perceptions of ecological, economic and social practices for sustainable ruminant farming in the Eastern Cape Province, South Africa

Farming practice		**Rural location**				**Peri-urban location**			**Average PI**
Ecological practices	**n**	**No. of +ve ratings**	**No. of -ve ratings**	**PI**	**n**	**No. of +ve ratings**	**No. of -ve ratings**	**PI**	
Rangeland management practices	56	15	41	-0.46	59	13	46	-0.55	-0.51
Crop residues management practices	61	21	40	-0.31	55	18	37	-0.35	-0.33
Water management practices	66	33	33	0	66	21	45	-0.36	-0.18
Breeding practices	48	13	35	-0.46	57	12	45	-0.58	-0.52
Health care practices	48	22	26	-0.08	64	31	33	-0.03	-0.06
Ruminant production practices	60	21	39	-0.30	58	22	36	-0.24	-0.27
Ecological perception index				-0.27				-0.35	**-0.31**
Economic practices									
Security management practices	55	17	38	-0.38	58	22	36	-0.24	-0.31
Marketing practices	80	26	54	-0.35	61	14	47	-0.54	-0.45
Labour practices	67	29	38	-0.1	66	21	45	-0.36	-0.23
Income generation practices	60	28	32	-0.07	64	31	33	-0.03	-0.05
Economic perception index				-0.29				-0.31	**-0.30**
Social practices									
Food security practices	54	24	30	-0.11	63	34	29	+0.06	-0.03
Family education practices	65	34	31	+0.05	56	32	24	+0.14	+0.10
Family health practices	72	37	35	+0.03	51	29	22	+0.13	+0.08
Socio-cultural practices	89	82	7	+0.84	63	59	4	+0.87	+0.86
Stakeholder engagement	81	38	43	-0.06	64	31	33	-0.03	-0.05
Youth engagement practices	72	19	53	-0.47	57	12	45	-0.58	-0.53
Women empowerment practices	83	34	49	-0.18	58	22	36	-0.27	-0.23
Social perception index				+0.01				+0.05	**+0.03**
Overall perception index							***-0.19***		

Table 4: Maximum likelihood estimates of the influence of socio-demographic characteristics on low-input farmers' perceptions on sustainable ruminant farming in Eastern Cape Province, South Africa.

Practices	**Location rural vs peri-urban**	**Age Youths vs adults**	**Gender Male vs female**	**Marital status Married vs not married**	**Education more vs less**	**Livestock training yes vs no**	**Employment Full-time vs part-time**
Ruminant production practices	0.1796	-0.0811	-0.3335	0.2045	-0.2959	0.00282	-0.565*
Rangeland management practices	-0.2902	0.463*	-0.1269	0.3551	0.2175	0.2416	-0.4157*
Crop residue management practices	0.1370	0.6150*	-0.3354	0.3684	-0.1402	0.0196	-0.2056
Water management practices	-0.970*	0.3066	0.1248	-0.1276	-0.2035	0.2304	-0.4397*
Breeding practices	-0.1908	0.0914	-0.4146*	0.1441	-0.1103	0.3048	-0.2615
Health care practices	0.0834	-0.0405	-0.5526*	0.1488	0.0524	0.4294	-0.2452
security management practices	0.5574*	0.5872*	-0.4233*	0.2583	-0.4443*	0.4433	-0.6726*
Marketing practices	0.0636	0.0429	-0.4373	-0.3284*	-0.0759	0.2648	-0.6243*
Labour practices	-0.3612*	-0.2836	-0.0705	0.0750	-0.3972*	0.1061	0.0294
Income generation practices	0.1301	-0.1143	-0.4384*	-0.0574	-0.2008	0.2030	-0.2376
Food security practices	0.2993	-0.0231	-0.3905*	-0.1911	-0.2590	-0.0471	-0.1557
Family health care practices	0.4556*	0.0620	-0.3060	0.0324	-0.1447	-0.4522	-0.1672
Socio cultural practices	0.4431	0.1193	-0.4796	0.2508	-0.1487	-0.4285	-0.6538*
Youth engagement practices	-0.0681	-0.5189*	-0.6652*	0.3677	0.00810	0.6096*	-0.0123

Logit coefficient of being beyond a cut-off point of the ordered outcomes where ordered outcomes are: -1 = decreasing; 0 = constant; +1 = increasing

Significance level: *P≤0.05

Table 5: Barriers to sustainable ecological practices as reported by low-input farmers in Eastern Cape Province, South Africa

Practice	**Barriers**	**Location (%)**		**Total**
		Rural	**Peri-urban**	**(%)**
Ruminants production practices	Inadequate knowledge	13.4	9.2	22.6
	Low productivity	29.6	25.2	54.8
	Stock theft	19.8	2.8	22.6
Rangeland management practices	Drought	25.9	21.1	50.4
	Poor rangeland management	18.4	16.3	34.7
	Inadequate knowledge	3.4	3.4	6.8
Crop residue management practices	Drought	23.5	22.7	46.2
	Inadequate quantities	15.2	12.9	28.1
	Poor-quality	15.9	9.1	25.0
Water management practices	Unreliable sources	4.8	18.3	23.1
	Dry season shortages	29.8	35.6	65.5
	Distant water points	9.6	1.9	11.5
Breeding practices	Inadequate knowledge	17.9	21.4	39.3
	Poor breeding stock	0	1.4	1.4
	Inadequate infrastructure	37.9	21.4	59.3
Health care practices	High disease prevalence	44.2	32.4	76.6
	Poor health management	11.7	4.5	16.2
	Shortage of veterinary specialists	4.5	2.7	7.2

Table 6: Response strategies to sustainable ecological practices as suggested by low-input farmers in Eastern Cape Province, South Africa

Practice	Response strategy	Location (%)		Total (%)
		Rural	Peri-urban	
Ruminant Production	Building herd/flocks	5.4	4.7	10.1
	Provision of farming resources	31.8	22.3	54.1
	Improved ruminant productivity	16.9	18.9	35.8
Rangeland management practices	Rangeland management training	9.7	3.9	13.6
	Abolishment of rangelands conversions	21.6	41.0	62.6
	Rangeland rehabilitation	15.5	8.4	23.9
Crop residue management practices	Provision of farming resources	33.1	30.3	63.4
	Alternative feed resources	11.3	7.7	19.0
	Supplementary feeding	9.9	7.7	17.6
Water management practices	Drilling boreholes and building dams	42.4	20.5	62.9
	Provision of water tanks	4.0	13.9	17.9
	Even distribution of water points	8.6	10.6	19.2
Breeding practices	Development of community-based breeding plans	12.0	10.0	22.0
	Provision of facilities	18.0	11.3	29.3
	Breeding management training	25.3	23.3	48.6
Health care practices	Provision of veterinarians	13.4	13.4	26.8
	Health management training	14.8	20.4	35.2
	Regular dipping, vaccination and early treatment of diseases	24.7	13.4	38.1

Table 7: Barriers to sustainable economic practice as reported by low-input farmers in Eastern Cape Province, South Africa

Practice	Barriers	Location (%)		Total (%)
		Rural	Peri-urban	
Security management practices	Stock theft	56.0	11.0	66.0
	Predation	19.3	2.8	22.1
	Accidents	4.6	6.4	11.0
Marketing practices	Inadequate marketing channels	27.9	16.3	44.2
	Small herd/flock sizes	17.1	22.5	39.6
	Inadequate marketing information	10.9	5.4	16.3
Labour practices	Costly labour	36.7	34.0	70.7
	Lack of motivation	14.7	7.3	22.0
	Small herd/flock sizes	1.8	5.5	7.3
Income generation practices	Reluctance to sell	6.9	2.6	9.5
	Alternative income sources	2.6	4.3	6.9
	Small herd/flock sizes	50.0	33.6	88.6

Table 8: Response strategies to sustainable economic practices a as suggested by low-input farmers in Eastern Cape Province, South Africa

Practices	Response strategy	Location (%)		Total (%)
		Rural	Peri-urban	
Security management practices	Community-based watch groups	23.5	13.4	36.9
	Security reinforcement	36.8	10.8	47.6
	Early kraaling	6.0	9.4	15.4
	Building herd/flocks	12.4	12.4	24.8
Marketing practices	Marketing management training	34.3	35.0	69.3
	Provision of marketing infrastructure	5.8	0.0	5.8
Labour practices	Motivating family labour	27.3	21.6	48.9
	Construction of grazing camps	15.8	14.4	30.2
	Provision of financial support	10.1	10.8	20.9
Income generation practices	Improving ruminant productivity	25.2	26.7	51.9
	Maintaining larger herds/flocks	8.9	5.9	14.8
	Provision of marketing infrastructure	17.8	15.6	33.4

Table 9: Barriers to sustainable social practices as reported by low-input ruminant farmers in Eastern Cape Province, South Africa

Practice	Barriers	Location (%)		Total (%)
		Rural	Peri-urban	
Food security practices	Small herd/flock sizes	28.8	21.6	50.4
	Reluctance to slaughter for home consumption	8.1	4.0	12.1
	Reluctance to sell	24.3	12.6	36.9
Family education practices	Small herd/flock sizes	4.3	3.2	7.5
	Reaction to emergencies	25.8	12.9	38.7
	Alternative income sources	17.2	36.6	53.8
Family health care practices	small herd/flock sizes	17.8	5.6	23.4
	Reaction to emergencies	21.1	14.5	35.6
	Alternative income sources	13.3	27.8	41.1
Socio-cultural practices	Small herd/flock sizes	75.0	15.0	100
Stakeholder engagement practices	Lack of coordination	4.0	8.0	12.0
	Lack of government support	68.0	0	68.0
	Costly subscriptions	20.0	0	20.0
Youth engagement practices	Urban migration	36.4	32.1	68.5
	Indulgence in drugs and alcohol	7.9	5.0	16.2
	Negative perception of farming	9.3	9.3	7.2
Women empowerment practices	Inadequate livestock knowledge	20.0	20.7	40.7
	Cultural exclusion	24.1	21.4	45.5
	Household chores	9.0	4.8	13.8

Table 10: Response strategies to sustainable social practices associated as suggested by low-input farmers in Eastern Cape Province, South Africa

Practices	Response strategy	Location (%)		Total (%)
		Rural	Peri-urban	
Food security practices	Building herd/flocks	38.7	31.0	69.7
	Slaughtering for home consumption	8.5	9.2	17.7
	Alternative food sources	5.6	7.0	12.6
Family education practices	Assists during emergencies	26.9	25.2	52.1
	Alternative funding sources	6.7	19.3	26.0
	Building herd/flocks	14.3	7.6	21.9
Family health care practices	Assists during emergencies	13.6	21.2	34.8
	Alternative funding sources	18.7	12.7	31.4
	Exploiting free medical health care	17.0	17.0	34.0
Socio-cultural practices	Building herd/flocks	8.4	2.8	11.2
	Partition herd/flocks to different roles	44.1	41.3	85.4
	Purchase animals for ceremonies	1.4	2.1	3.5
Stakeholder engagement practices	Improved government support	43.3	0.0	43.3
	Improved coordination	33.3	6.7	40.0
	Removing affiliation fees	16.7	0.0	16.7
Youth engagement practices	Improving ruminant farming image	23.2	19.2	42.4
	Empowering and motivating the youths	25.2	20.5	45.7
	Youths rehabilitation	6.6	5.3	11.9
Women empowerment	Empowering and motivating women	38.1	35.4	73.5
	Use women farmers as role models	6.8	5.4	12.2
	Abolish cultural exclusion of women	8.8	5.4	14.2

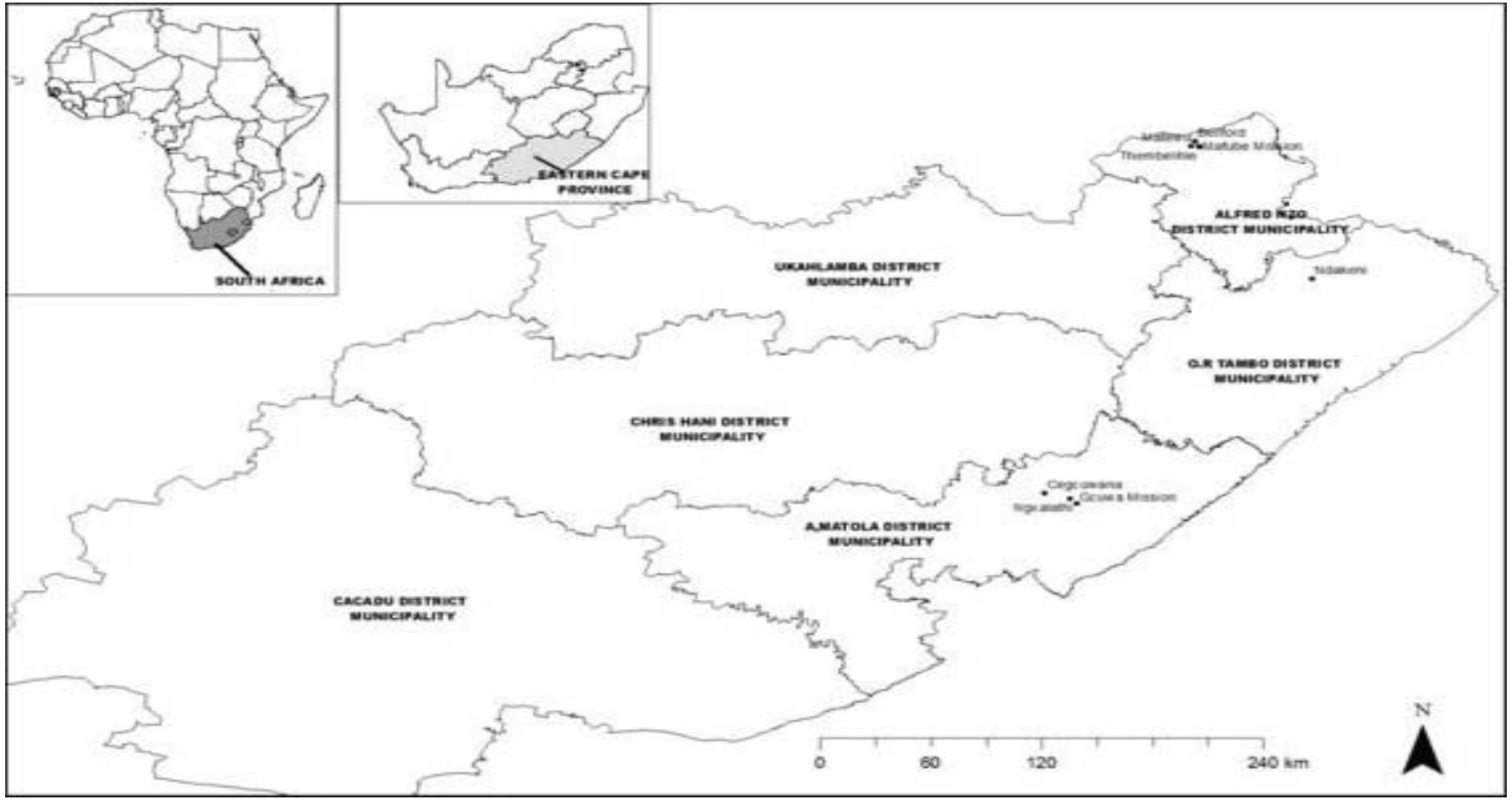

Figure 1: Map showing the study areas in Eastern Cape Province

Appendix 1

Assessing farmers' perceptions on the sustainability of livestock production in South Africa

The study aims to promote more sustainable livestock production practices among farmers and encourage more appropriate developmental interventions from the government or other organizations for the benefit of farmers..

Enumerator:…… Municipality name:……
Community name:…….. Name of respondent:…….....
If you are not the household head, what is your relationship with household head:……

A. HOUSEHOLD DEMOGRAPHICS

1. Age…… **2. Gender** *1=M* ☐ *2=F* ☐

3	**Marital status**	*1= Single*	*2= Married*	*3= Separated*	*4= Divorced*	*5= Widowed*

4	**What is the size of your household?**	Dependants	*1=M*	*2=F*

5	**Religion**	1= *Christianity*	2= *Traditional*	3= *Islam*	*4= Other* (specify)…..……..

6	**Highest level of formal education**				
1=No formal education	*2= Grade 1-3*	*3= Grade 4-7*	*4= Grade 8-12*	*5= Tertiary*	

7	**Do you have any formal training in livestock farming?**	1= *Yes*	2= *No*
8	If yes specify……..……		

9	**Employment status**				
1= Unemployed	*2= Full-time farmer*	*3= Employed off-farm*	*4= Pensioner*	*5= Other* (specify)…...	

10	**Land ownership**	*1= Communal*	*2= Leased*	*3= Private*
4= Cooperative (specify) …….....		*5= Others (specify)* ……		

11	**Land size (ha)**	*1=Total*……...	*2=Arable*……	*3=Grazing*……...

12	**How long have you been farming?**	In general……	On the current land ……..

13	**What are your sources of income and amounts per month?**		
Source of income		**Rank**	**Amount per month or per year**
1= Crop sales			
2= Livestock sales			
3= Salary			
4= Pensions			
5= Social grants			
6= Others (specify)……			

B. LIVESTOCK NUMBERS, OFFTAKE & EXPENDITURE

14	**Which livestock species do you own?** (Rank 1 as the most important species)			
Livestock		**Rank**	**Number**	**Owner**
Cattle				
Goats				
Sheep				

15	**Which livestock breeds do you keep?**				
Livestock	**Breeds**				
Cattle					
Goats					
Sheep					

16	**On average, how many ruminant livestock do you sell, and/or slaughter per year?**		
Livestock	**Sales**	**Slaughters**	

Cattle		
Goats		
Sheep		

17	On average, how many ruminant livestock do you lose through mortality and/or theft per year?		
Livestock		**Mortality**	**Theft**
Cattle			
Goats			
Sheep			

18	On average, what is your total expenditure on ruminant livestock per month?	
Livestock species		**Total expenses**
Cattle		
Goats		
Sheep		

C. SUSTAINABLE AGRICULTURE CONCEPT

19	Are you aware of the sustainable agriculture concept?	*1= Yes*	*2= No**

20	If yes, what do you understand about sustainable agriculture?
.....	
.....	
.....	

**If no, sustainable agriculture aims to improve the socio-economic conditions of farmers by adopting efficient production practices that maintain or improves the natural environment for the benefit of future generations.*

21	Where did you first hear about sustainable agriculture?			*1= Extension officers*
2= Other farmers	*3= Radio/TV*	*4= Print media*	*5= Social media*	*6= Others (specify) …….*

22	How do you embrace the concept of sustainable agriculture?			
1= Highly		*2= Moderately*	*3= Lowly*	*4= None*

23	Who do you normally share sustainable agriculture information with?
……	
……	
……	

24	What are the organizations that promote sustainable agriculture in your area?
……..…	
……	
……	

D. SUSTAINABLE RUMINANTS' LIVESTOCK PRODUCTION

25	How do you describe the sustainability of your ruminant livestock production?		
1= Decreasing		*2= Constant/ No change*	*3= Increasing*

26	If decreasing, what are the major challenges affecting sustainable ruminant livestock production?
……	
……	
……	

27	What strategies do you think should be implemented to minimize the challenge/s you mentioned above?
……..…	
……	
……	

28	How do you describe the sustainability of rangeland biomass supply for your ruminant livestock?	
1= Decreasing	*2= Constant/ No change*	*3= Increasing*

29	If decreasing, what are the major factors limiting the supply of rangeland biomass supply?
……	
……	
……	

30	What management strategies do you think should be implemented to minimize the challenge/s you mentioned above?
……	
……	
……	

31	How do you describe the sustainability of crop residues as feed supply for your ruminant livestock?	
1= Decreasing	*2= Constant/ No change*	*3= Increasing*

32	If decreasing, what are the major factors limiting supply of crop residues for your ruminant livestock?
……	
……	
……	

33	What strategies do you think should be implemented to minimize the challenge/s you mentioned above?
……	
……	
……	

34	What other feed sources do you use for your ruminant livestock?			
1= Planted pastures	*2= Agricultural by-products*	*3= Bought-in feeds*	*4= Industrial by-products*	*5= Others (specify)* ……

35	How do you describe the sustainability of the ruminant livestock feed source/s you mentioned above?	
1= Decreasing	*2= Constant/ No change*	*3= Increasing*

36	If decreasing, what are the major factors limiting feed supply to your ruminant livestock?
……	
……	
……	

37	What strategies do you think should be implemented to minimize the challenge/s you mentioned above?
……	
……	
……	

38	How do you describe the sustainability of water supply for your ruminant livestock?	
1= Decreasing	*2= Constant/ No change*	*3= Increasing*

39	If decreasing, what are the major factors limiting water supply for your ruminant livestock?
……	
……	
……	

40	**What strategies do you think should be implemented to minimize the challenge/s you mentioned above?**

……
……
……

41	**How do you describe the sustainability of your ruminant livestock breeding management practices?**

1= Decreasing	*2= Constant/ No change*	*3= Increasing*

42	**If decreasing, what are the major causes of poor ruminant livestock breeding management practices?**

……
……
……

43	**What strategies do you think should be implemented to minimize the challenge/s you mentioned above?**

……
……
……

44	**How do you describe the sustainability of your ruminant livestock health management practices?**

1= Decreasing	*2= Constant/ No change*	*3= Increasing*

45	**If decreasing, what are the major causes of poor ruminant livestock health management?**

……
……
……

46	**What strategies do you think should be implemented to improve ruminant livestock health management?**

……
……
……

47	**How do you describe the sustainability of your ruminant livestock security management practices?**

1= Decreasing	*2= Constant/ No change*	*3= Increasing*

48	**If decreasing, what are the major causes of poor ruminant security management?**

……
……
……

49	**What management strategies do you think should be implemented to minimise the challenge/s you mentioned above?**

……
……
……

E. ECONOMIC WELFARE

50	**How do you describe the sustainability of your ruminant livestock offtake (i.e., sales and slaughters)?**

1= Decreasing	*2= Constant/ No change*	*3= Increasing*

51	**If decreasing, what are the major challenges limiting your ruminant livestock offtake?**

……
……
……

52	What strategies do you think should be implemented to minimize the challenge/s you mentioned above?

……
……
……

53	How do you describe the sustainability of your ruminant livestock marketing practices?		
1= Decreasing		*2= Constant/ No change*	*3= Increasing*

54	If decreasing, what are the major causes of poor ruminant livestock marketing?

……
……
……
……

55	What strategies do you think should be implemented to minimize the challenge/s you mentioned above?

……
……
……

56	How do you describe the sustainability of labour supply for your ruminant livestock production?		
1= Decreasing		*2= Constant/ No change*	*3= Increasing*

57	If decreasing, what are the major factors limiting labour supply for ruminant livestock production?

……
……
……

58	What strategies do you think should be implemented to minimize the challenge/s you mentioned above?

……
……
……

F. SOCIAL WELL-BEING

59	How do you describe the sustainability of your ruminant livestock's contribution towards household income?		
1= Decreasing		*2= Constant/ No change*	*3= Increasing*

60	If decreasing, what are the major challenges affecting the contribution of ruminant livestock to household income?

……
……

61	What strategies do you think should be implemented to minimize the challenge/s you mentioned above?

……
……
……

62	How do you describe the sustainability of your ruminant livestock's contribution towards household food security?

1= Decreasing	*2= Constant/ No change*	*3= Increasing*

63	**If decreasing, what major challenges are limiting the contribution of ruminant livestock towards household food security?**
…… …… ……	

64	**What strategies do you think should be implemented to minimize the challenge/s you mentioned above?**
…… …… ……	

65	**How do you describe the sustainability of your ruminant livestock's contribution towards your dependants' education?**		
1= Decreasing		*2= Constant/ No change*	*3= Increasing*

66	**If decreasing, what major challenges are limiting the contribution of ruminant livestock towards your dependants' education?**
…… …… ……	

67	**What strategies do you think should be implemented to minimize the challenge/s you mentioned above?**
…… ……	

68	**How do you describe the sustainability of your ruminant livestock's contribution towards family healthcare?**		
1= Decreasing		*2= Constant/ No change*	*3= Increasing*

69	**If decreasing, what are the major challenges limiting the contribution of your ruminant livestock towards family healthcare?**
…… ……	

70	**What strategies do you think should be implemented to minimize the challenge/s you mentioned above?**
…… ……	

71	**How do you describe the sustainability of your ruminant livestock's contribution towards socio-cultural roles?**		
1= Decreasing		*2= Constant/ No change*	*3= Increasing*

72	**If decreasing, what are the major challenges affecting the contribution of ruminant livestock towards socio-cultural roles?**
…… ……	

73	**What strategies do you think should be implemented to minimize the challenge/s you mentioned above?**
…… …… ……	

74	Are you a member of any livestock related organization or cooperative?	1= Yes	2= No
If yes specify ……			

75	If yes, how do you describe the contribution of your organisations and/or cooperatives towards sustainable ruminant livestock production?		
1= High		2= Medium	3= Low

76	If low/medium, what are the major challenges limiting the contribution of organisations and/or cooperatives towards sustainable ruminant livestock production?
……	
……	
……	

77	What strategies do you think should be implemented to minimize the challenge/s you mentioned above?
……	
……	

78	How do you describe the sustainability of youth involvement in ruminant livestock production in your area?		
1= Decreasing		2= Constant/ No change	3= Increasing

79	If decreasing, what are the major challenges affecting the involvement of youths in ruminant livestock production?
……	
……	
……	

80	What strategies do you think should be implemented to minimize the challenge/s you mentioned above?
……	
……	
……	

81	How do you describe the sustainability of women involvement in ruminant livestock production in your area?		
1= Decreasing		2= Constant/ No change	3= Increasing

82	If decreasing, what are the major challenges affecting the involvement of women in ruminant livestock production?
……	
……	
……	

83	What strategies do you think should be implemented to minimize the challenge/s you mentioned above?
……	
……	
……	