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Theoretical and practical considerations in the development of a methodological framework for evaluating sustainability of low-input ruminant farming systems in developing countries

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A R T I C L E I N F O

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A B S T R A C T

The sustainability of low-input ruminant farming systems remains poorly understood and evaluation frameworks that adequately capture their complexity are lacking. The multiple goals of producers, multipurpose roles of ruminants, animal welfare issues, credence goods and services of the system are omitted in existing frameworks. In that context, development of a novel comprehensive framework for evaluating the sustainability of the low-put ruminant farming system is important. The current manuscript, therefore, provides an overview of a systemic process for developing a participatory and interdisciplinary methodological framework to measure sustainability of the low-input ruminant farming system. The proposed framework provides guidance on potentially relevant variables and their subcomponents, and for designing appropriate data collection tools, conducting field measurements and analysing results. The suggested framework captures the complex interrelationships within and between dimensions and indicators of sustainability and apply a system dynamics approach to integrate the indicators into an overall measure of the sustainability of a system.

1. Introduction

Sustainable agriculture is defined as "the efficient production of safe, high quality agricultural products, in a way that protects and improves the natural environment, the social and economic conditions of farmers, their employees and local communities, and safeguards the health and welfare of all farmed species" (Buckwell et al., 2015). Agricultural sustainability at a local level is achieved by practices that simultaneously increase resource-use efficiency or overall system self-sufficiency, while, decreasing environmental degradation and enhancing the social well-being of farmers (Moraine et al., 2017). The existence of practices that simultaneously meet these conditions is a matter of contention for most global agricultural systems, including the low-input ruminant meat production systems (Gomez-Limon and Sanchez-Fernandez, 2010; Röös et al., 2016). In part, the contention originates from a lack of appropriate tools designed to evaluate specific agricultural production systems, given that universal tools are genuinely impractical (Gasparatos and Scolobig, 2012). System-specific evaluations closely reveal local level realities that are often not considered in more generalized national, regional or global level assessments (de Olde et al., 2017). Ideally, the farm or community, as the primary locus for sustainable practice, should logically be prioritized in evaluations (Waas et al., 2014). The increasing demand for sustainability evaluations on the one hand and the diversity of production systems with unique inherent properties on the other, underlines the importance of developing reliable and widely acceptable system-specific protocols for assessment (Ayantunde et al., 2011; Bockstaller et al., 2015; Chand et al., 2015).

The multitude of currently available agricultural sustainability evaluation frameworks predominately focus on cropping and forestry systems at different scales (Häni et al., 2003; Olde et al., 2016; Goswami et al., 2017). The few frameworks dedicated to evaluation of livestock systems are biased towards intensive systems (Olde et al., 2016; Singh et al., 2012; Waas et al., 2014). The same frameworks designed for intensive livestock systems were previously modified and used in the few studies that evaluated low-input livestock production systems (Astier et al., 2012; Atanga et al., 2013; Marandure et al., 2017). Nevertheless,

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the complexity of low-input agricultural systems, including ruminant farming systems, raises questions about how effective any purportedly universal sustainability evaluation framework can possibly be, with some authors suggesting that achieving this is a conundrum (Goswami et al., 2017). For example, the existing sustainability evaluation frameworks do not incorporate multiple goals of producers with multipurpose uses of ruminant livestock, animal welfare issues and credence goods and services the ruminant farming system (Marandure et al., 2017). Furthermore, existing sustainability evaluations frameworks that directly link the use of available resources to farmers' livelihoods are rare (Woodhouse et al., 2001; Goswami et al., 2017). The link ensures food, fibre and fuel supply to the household while optimizing conservation of farm resources and improving low-input ruminant producers' livelihoods on both the short and long terms (Woodhouse et al., 2001). The current paper proposes a conceptual framework for evaluating the sustainability of low-input ruminant farming systems and provide guidelines for its application in developing countries.

2. Complexities in sustainability evaluations of low-input ruminant farming systems

Low-input ruminant farmers operate under a wide variety of challenges spanning the ecological, economic and social aspects of production (Gerber et al., 2015; Mapiye et al., 2018; Gwiriri et al., 2019). The multi-disciplinary nature of the challenges complicates the process of sustainability evaluation of the low-input ruminant farming system. In this regard, Wagner (2013) suggested the necessity for a multi-facets approach involving analysis at the ecological, economic and social platforms to evaluate the sustainability of such complex systems. The approach is, however, complicated by the fact that all the ecological, economic and socio-cultural aspects of sustainability must be simultaneously evaluated (Notenbaert et al., 2017). Practically this is complicated by the interrelationships between the ecological, economic and social components and indicators, including intricate feedback mechanisms (Kragt, 2012). Further complications arise from a lack of production records by most low-input ruminant farmers.

Sustainability evaluations provide basic information that can be used to develop plausible future scenarios and, ultimately, devise appropriate farming system management strategies (Goswami et al., 2017). These evaluations should take into account the complexity of low-input ruminant farming systems, including, the ecological, economic and socio-cultural conditions, and the institutional support services (Goswami et al., 2017). Thus, it is imperative for local level approaches to reflect realistic system attributes required to design more sustainable alternatives (Goswami et al., 2017). It is, however, important not to envisage sustainability as an end point but rather a goal that leads to dynamic state of farming systems (Latruffe et al., 2016). Sustainability is not a fixed state but a process of continuous improvement characterised by a combination of short-term regulation and long-term adaptation to dynamic biophysical and social-economic conditions (Astier et al., 2012). Some typical sustainability evaluation challenges related to low-input ruminant farming systems in developing countries are shown in Fig. 1.

Sustainability evaluations are further complicated by the multiple goals of ruminant farmers and multiple outputs of the low-input ruminant farming system. Low-input ruminant farmers place considerable value on 'flow' animal products such as, provision of milk, manure, fuel and draught power rather than end products like meat, hides/skins and cash (Fao, 2006). Furthermore, ruminants are considered a live bank that can be mobilised in case of emergency, and a source of insurance against environmental disasters and a sign of wealth where one's social status is directly linked to their herd and flock sizes (Swanepoel et al., 2008). As a source of wealth, ruminants are often used as payment for bride price, traditional fines and services rendered by traditional healers (Tembo et al., 2014). Low-input farmers exchange ruminant livestock to symbolize a formal contract of mutual assistance, thereby, strengthening social bonds within communities. In addition, ruminants can also be used as wedding gifts, assets of inheritance and circumcision presents (Nyamushamba et al., 2017; Mapiye et al., 2020). Other socio-cultural roles

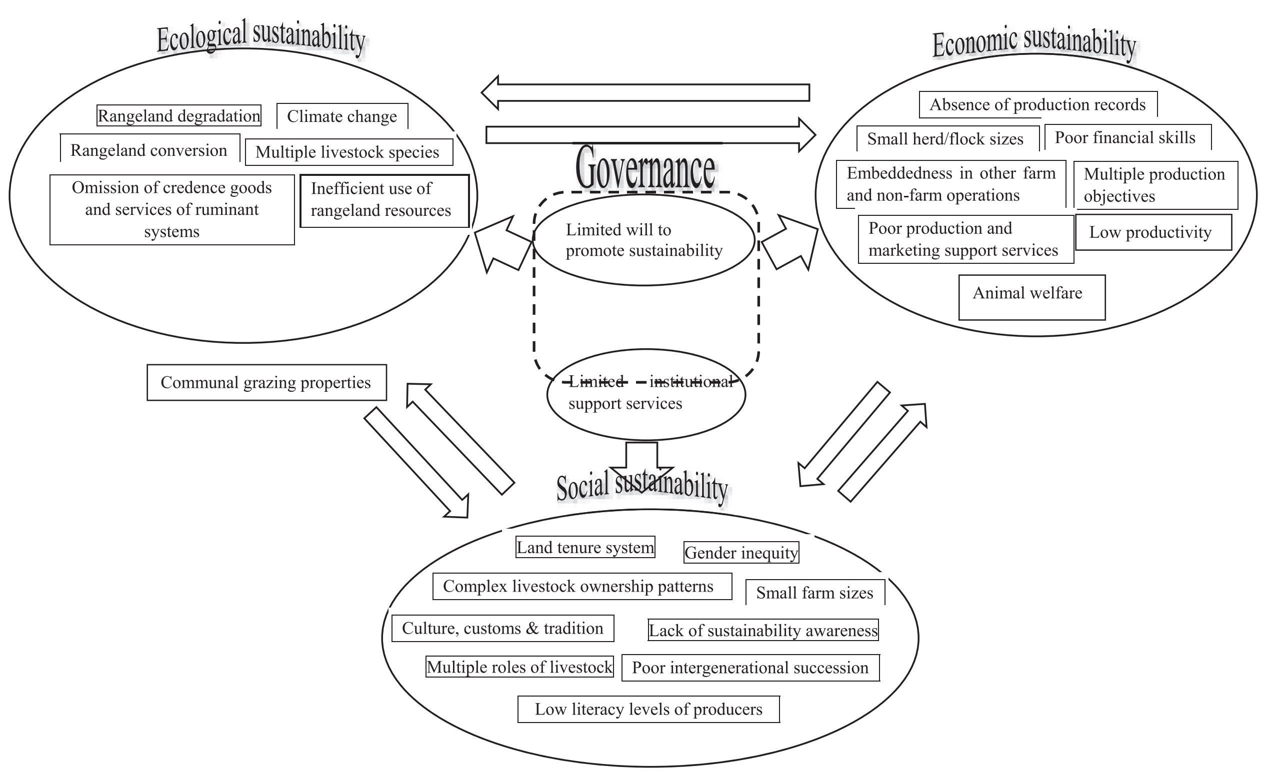

Fig. 1. Complexities surrounding sustainability evaluation of low-input ruminant farming systems in developing countries.

tied to custom beliefs in ancestral or avenging spirit-mediums include their installation, veneration, appeasing as well as exorcism (Mapiye et al., 2009; Mapiye et al., 2020). The benefits represent flow products which differ from end products, in that they generate a regular cash income or ensure availability of other benefits throughout the period that the animal stays on the farm (McDermott et al., 2010). For this reason low-input ruminant farmers keep their animals much longer on the farm compared to market-oriented commercial producers (Fao, 2006). Although some of the roles of ruminants can be directly assigned monetary values based on prevailing market prices and related to the economic pillar of sustainability, other roles such as, strengthening social bonds are difficult to quantify.

Ruminant farmers' multiple production goals are complicated by intricate ownership patterns where one herd/flock may be owned by different members of the household each of whom might have different production goals (Mwacharo et al., 2009). In some cases there maybe joint ownership of one animal by two or more members of the household with contrasting goals (Kristjanson et al., 2010). A lack of decision-making authority over ruminants could be also intricate sustainability evaluation. Women and youths are usually assigned to provide labour but they cannot make key decisions over the same, a privilege that is reserved for male household heads (Bravo-Baumann, 2009). The fact that those who manage ruminants on a daily basis have no key decision making authority which is reserved for men, most of whom are hardly involved in day to day management can complicate sustainability evaluations (Perez et al., 2015). Furthermore, a lack of rewards contributes to the general trend of youth migration to urban cities resulting in lack of intergenerational succession. The impression that youths shun ruminant farming in favour of modern professions may just be confused with a lack of production assets including ownership of livestock and lack of access to benefits with total decision-making authority (Bravo-Baumann, 2009).

Diversity of household income sources presents another form of complexity in sustainability evaluations. Sources of income for a single household can include but are not limited to, social grants, pensions, crops, different livestock species, on-farm and off-farm activities (Bernues et al., 2011). This engagement in a wide variety of livelihood activities by many low-input ruminant farmers is a way to buffer risk in highly variable systems (Gerber et al., 2015). Rural farmers in developing countries are considered to be risk averse (Altieri, 2002) but the extent to which the form of risk preferences constrain them from reaching their productive potential is vaguely understood (de Brauwa and Eozenou, 2014). Designing appropriate risk aversion strategies, therefore, requires adequate understanding of the implications of diverse risk preferences on low-input ruminant farming systems (de Brauwa and Eozenou, 2014).

Ruminant livestock in low-input farming systems are raised on rangelands mainly under continuous grazing management with minimum use of external chemical inputs (Chingala et al., 2017). The rangeland-based production system is associated with unique credence goods and services that are often ignored in many sustainability evaluation frameworks (Moraine et al., 2016). Credence goods and services relate to 'intangible', non-monetary or 'Z-goods' of the low-input ruminant farming system (Umberger et al., 2009). The challenge lies in that these attributes cannot be easily quantified using traditional methodologies to enable their inclusion in sustainability evaluations. Table 3 suggest ways to quantify these 'Z goods' to enable them to be incorporated into sustainability evaluations.

Ecologically related credence goods and services of the low-input ruminant farming system include low carbon and water footprint. Compared to intensive (feedlot) ruminant production, low-input extensive systems are believed to have relatively, low carbon footprint (Herrero et al., 2009). This is partly because low-input ruminant farming escape GHG emissions as a result of external chemical use in grain-feed crop production including massive land clearing and accumulation of manure and slurry dumps (Herrero et al., 2009; Scholtz et al., 2013). In addition, nutrients deposited directly on the rangeland in low-input ruminant farming systems should be used to offset the total GHG emission from the system (Herrero et al., 2009). Valuation of low carbon footprint can be linked to the carbon credit system where a system earns rebates for compliance or are penalised for defiance (Pretty, 2008). Low-input ruminant farming system are also considered to have a low water footprint due to absence of irrigated rangelands or grain feed crops (Doreau et al., 2012). Valuation of water footprint can be linked to prevailing water rates. Sometimes ruminants graze around homesteads providing maintenance of the surroundings in the process (Nyamushamba et al., 2017) and valuation of such attributes can be directly linked to the maintenance cost of the place.

Economically related credence goods and services include perceived healthfulness and food safety (Chingala et al., 2017). Healthfulness of rangeland-fed animal products pertain to human health benefits due to the presence of fatty acids (e.g. vaccenic acid, rumenic acid, omega-3 fatty acids), β-carotene, and α-tocopherol in greater proportions than grain-fed beef (Umberger et al., 2009; Chingala et al., 2017; Mapiye et al., 2011). Food safety relates to the absence of exogenous residual chemicals in food. Some residual chemicals in food has been associated with negative effects on human health including various forms of cancers (Umberger et al., 2009). Both healthfulness and food safety can be allocated an economic value consistent with the premiums that consumers pay for these credence goods and services.

Socially related credence goods and services pertain to animal welfare issues (Broom et al., 2013), contribution to a magnificently pleasant rural landscape (Herrero et al., 2009) and provision of a spiritual and inspirational experiences (Häni et al., 2003). Landscape aesthetics is the enjoyment and pleasure felt through the observation of environmental scenery which contributes to human well-being (Tribot et al., 2018). The congruence between the aesthetic perception of landscapes, ecological value and biodiversity is poorly understood (Tribot et al., 2018). Integration of aesthetic value and ecological components of biodiversity is necessary to understand ecological function at landscape levels. Scores indicated by stakeholders on likert scale can be used to evaluate landscape aesthetic values.

Claims surrounding more natural animal farming, limited handling, and spacious housing practices are the main welfare credence attributes of the low-input farming system. Empirical evidence show that stress-free livestock that are allowed to express their natural behaviour are healthier (Horgan and Gavinelli, 2006), thus more productive in terms of product quantity and quality. Animal welfare issues can be allocated an economic value consistent with premiums that consumers pay when integrating them into sustainability evaluations. The presence of grazing ruminants on the rangeland contributes to a pleasing landscape that can be allocated an economic value based on prevailing tourism rates.

Another core challenge in evaluation is maintaining objectivity and standardizing methodologies in the sustainability evaluation of low-input systems (Waas et al., 2014). System-specific sustainability evaluation frameworks that consider the interrelationships, feedback mechanisms within and between dimensions and indicators could theoretically provide consistency in sustainability evaluation methodologies (Li et al., 2016). Using composite indices to aggregate the indicators is common in many methodologies but is widely criticized for reducing the heterogeneity of indicators representing distinct ecological, economic and social dimensions of sustainability to a single value (Lebacq et al., 2013) which obscures the potential for designing appropriate alternatives (Singh et al., 2012). Other controversies emanate from the reality of maintaining fixed weights of each indicator in light of the variations arising from the frequent and random shifts in ruminant farmers' priorities (Mascarenhas et al., 2015).

Unfortunately, in most sustainability evaluation approaches the operational level of each indicator is compared against the upper threshold levels previously determined without considering the interrelationships between the indicators (Parent et al., 2010; Fadul-Pacheco et al., 2013). Focussing only on upper thresholds presents the risk of giving the misleading impression that operational levels below and improvements beyond the threshold are harmless and of no value, respectively (Marchand et al., 2014). In reality, the operational level of each indicator may hinder or facilitate the overall system depending on its interrelationships with other indicators (Sala et al., 2015). Thus, the threshold value of each indicator should be considered along with its level of confidence and its probability distribution presumed in its definition (Latruffe et al., 2016). The proposed approach to framework development should be able to provide special methodologies to incorporate these ecological and socio-economic complexities in the main sustainability evaluations.

3. General principles of a sustainability evaluation framework

Most sustainability evaluation frameworks have set criteria that guide the indicator selection process (Schader et al., 2016). Indicators are defined as physical and measurable variables that provide quantitative information about some qualitative or non-quantifiable variables (Lebacq et al., 2013). According to Ruth et al. (2015), indicators should be flexible enough to represent the current state as well as dynamic changes over time. As with other methodologies, frameworks are subject to certain scientific, cultural and political/institutional background characterization (Ran et al., 2015). In that context, stakeholder participation becomes pertinent in framework development (Ruth et al., 2015; de Olde et al., 2017; Moraine et al., 2017). The stakeholders may comprise of local ruminant livestock farmers, community leadership (e.g, headmen, chiefs and kings), local government officials (councillors and members of parliament), extension, veterinary and research officers, livestock development project officials, relevant private companies and non-governmental organizations (Marandure et al., 2019). According to Mubita et al. (2017) it is critical to ensure equal participation from all stakeholders as domination of weaker groups of society by the more powerful elite is common in public gatherings.

Low-input ruminant farmers in developing countries have limited awareness of the sustainability concept (Marandure et al., 2017) Since their input in sustainability evaluation is key, the indicator development process can be indirectly informed by farmers' perceptions on challenges and opportunities of their production system. According to Knutson et al. (2011), perception studies assist with giving a measure of the impact of certain variables whose accurate measurement is hindered by lack of relevant data. In addition, perceptions studies gradually build local-based knowledge hubs which are useful in providing relevant data for scientific measurement of the system in future (Meijer et al., 2015). Perception indices have been previously used to estimate the impact of climate change on various aspects of communal farmers livelihoods (Defar et al., 2017). In the current manuscript, perceptions of production challenges and opportunities are proposed to indirectly develop indicators. A perceptions study will also be particularly important to get information from individuals that might been overshadowed by the more dominant local powerful elite during the consultation process (Mubita et al., 2017). Additional indicators will also be derived from the multifunctional roles of ruminant livestock and the credence goods and services of the ruminant production system provided by stakeholders using participatory approaches.

Animal welfare is a pertinent indicator that should be considered in sustainability evaluation of animal production systems prior to stakeholders' consultations as it is the key element for production efficiency and profitability (Mattiello et al., 2019). The Farm Animal Welfare Council (FAWC, 2010) instituted the "Five Freedoms" currently used as a benchmark for meeting animals' needs. These include freedom from hunger and thirst, freedom from discomfort, freedom from pain, injury and disease, freedom from fear and stress, and freedom to express normal behaviour (FAWC, 2010). Thus, an animal in a positive state of welfare is well-nourished, comfortable, healthy, safe and able to express innate behaviour (Mattiello et al., 2019). Animal production systems vary in their potential to provide positive welfare with extensive systems considered to have the propensity for more positive welfare than intensive systems (Waterhouse, 1996; Elliot, 2007). The supply of nutrients, animal health management, the degree of human care and supervision and ability to express natural behaviour are different in the two systems (Elliot, 2007). The subsequent paragraphs describe animal welfare standards of low input rangeland-based (i.e., extensive) ruminant production systems.

Access to adequate nutrition is important in ruminant systems as it guarantees positive animal health, growth and behaviour (Hogan and Phillips, 2008). Nutrition, however, remains one of the most important welfare challenges in low-input ruminant farming systems (Hogan and Phillips, 2008). Animals graze on the rangelands whose vegetation quality and quantity vary with environmental conditions (Niamir-Fuller, 2016). In the rainy season when vegetation biomass is abundant, animals freely select forages with high nutrient content to meet their nutritional requirements (Niamir-Fuller, 2016). In the same season animals have free access to water sources. In the dry season, however, there is rapid deterioration of vegetation quality and quantity, coupled with little or no supplementary feeding, which violate the animal freedom from hunger (Niamir-Fuller, 2016). Animals also travel long distances in search of water whose quality is often poor (Hogan and Phillips, 2008). Animal nutrition should inevitably be included as an indicator when evaluating the sustainability of low-input ruminant production systems. The nutritional status of ruminants can be assessed through body condition scoring of animals or live body weight using either a weigh-band or portable livestock scale.

Under the low-input ruminant farming system, animal comfort is compromised by exposure to environmental stressors such as rain, wind, solar radiation and extreme temperatures as no appropriate shelter is provided during the day or at night (Balaa and Marie, 2006; Rutter, 2014). In cases where animals are sheltered at night, the shelter (i.e., kraal) is made with the goal of providing security from predators rather than comfort to the animals (Mattiello et al., 2019). However, animals under extensive farming systems can choose own shelter during the day, have unlimited access to an enriched environment, and ample space for grazing, resting, exercising and roaming (Madzingira et al., 2018; Mattiello et al., 2019). Overall, positive welfare attributes of housing or the environment entail offering the animal space and requirements for comfort and pleasure associated with feeding, resting and ease of movement, as well as presenting choice and opportunity to express agency in use of the environment (Mattiello et al., 2019). The freedom from discomfort can, therefore, be measured through visual monitoring and scoring of animal's behavioural expressions such as shade-seeking, crowding, restless, lying time and posture, shivering, panting, slipping and falling (Haley et al., 2010; Mattiello et al., 2019).

Ruminants raised under low-input farming systems tend to carry heavy tick and internal parasite loads, may suffer from pain or injuries due to lack of financial resources to pay for medicines, vaccines and veterinary bills (Vaart and Alroe, 2012; Dawkins, 2017; Madzingira et al., 2018). The use of animal breeds selected for high productivity in the low-input production systems has been associated with several production-related conditions that may cause serious animal health and welfare problems (Dawkins, 2017; Mapiye et al., 2019). Rapid modifications made through modern breeding and biotechnology reduces the potential of animals to continuously adapt to their changing environment (Dawkins, 2017). Low-input ruminant systems use adapted indigenous breeds and offer greater opportunities for high welfare standards (Balaa and Marie, 2006; Mapiye et al., 2019). Indigenous tropical animal's genetic or innate nature has been continuously and slowly changing and adapting through evolution making them more suitable for their local environment (Dawkins, 2017). Animal health is, therefore, an important sustainability indicator in the low-input ruminant production system. A positive health condition can be assessed by scoring of behavioural expressions, skin and body damages and incidences of infestation, infections and illness (Mattiello et al., 2019).

Fear-induced stress due poor human-animal interaction is one of the main causes of reduced animal health and productive performance (Zulkifli, 2013). In extensive production systems, negative effects of fear-induced chronic stress may be less likely because of minimal and irregular contact with humans (Hemsworth and Coleman, 2011; Elliot, 2017). However, effects of fear-induced acute stress are likely in situations where animals are in close contact with humans (Hemsworth and Coleman, 2011), especially during handling when performing routine husbandry procedures. Fear-induced acute stress in extensively raised animals is also caused by exposure to predators, novel objects, events and/or environments (Hemsworth and Coleman, 2011). The negative effects of fear-induced stress (Zulkifli, 2013; Elliot, 2017) warrants assessment through scoring of relevant behavioural expressions to ensure positive animal welfare and sustainable production of extensively raised ruminants.

Extensive grazing ruminant farming systems have the potential to allow the animals to express their natural behaviour, maintain health and experience positive emotional states (Madingira et al., 2018; Mattiello et al., 2019). With good management, low-input ruminant systems can offer high standards of animal welfare, providing opportunities for exercise and expression of a wide repertoire of natural behaviours (i.e., foraging, care seeking and giving, reproductive, investigative, eliminative and shelter-seeking; Balaa and Marie, 2006; Mattiello et al., 2019). This freedom can be measured by visual assessment of maladaptive behaviours such as homosexuality, fur/wool biting and licking of objects.

Inevitable environmental indicators include soil biodiversity and vegetation index. Soil biodiversity reflects the variability among living organisms occurring in the soil including bacteria, fungi, protozoa, insects, worms among other invertebrates, and mammals (Orgiazzi et al., 2015). The microorganisms interact with one another in the ecosystem, forming a complex web of biological activity that enhance the metabolic capacity of soils and plays a crucial role in soil health and ecosystem functioning (Menta et al., 2011). It is, therefore, necessary to maintain soil biodiversity to safeguard these functions. Soil organic matter content both a good measure and an important indicator of soil biodiversity.

Given the ambiguity present in the vast literature on sustainability evaluation, a novel comprehensive framework must provide a procedural methodology that overcomes vagueness in favour of transparency, robustness, flexibility and objectivity as the key elements of the framework (Sala et al., 2015). Transparency is reflected in explaining the choices of methodologies, data sources and analytical tools as well as assumptions and uncertainties determining evaluation results (Ruth et al., 2015). Transparency is also aided by ensuring open access to data, indicators used and results of the sustainability evaluation (Ruth et al., 2015). Robustness is reflected by the ability of analytical steps to withstand adverse or rigorous testing while, flexibility is reflected in maintaining relevance through changes in time and space (Sala et al., 2015). The approach to framework development described in this study is specifically restricted to the on-farm or community activities of the low-input ruminant production cycle. The conceptual framework proposed in the current paper incorporates the multifunctionality of ruminants for food, nutrition, income and socio-cultural security of low-input producers and vulnerability reduction strategies. Additionally, the framework considers resource-use and resource conservation in the evaluation framework. The basis for developing the framework is provided by defining the main components and processes of the low-input ruminant farming system in the context of a socio-ecological system.

4. Guidelines on implementing the proposed sustainability evaluation framework

The proposed conceptual framework describes a multi-stage, participatory and iterative process that integrates inputs from stakeholders and key experts from different disciplines with a comprehensive literature review on sustainability principles, thresholds and targets. This, in part, is analogous to approaches previously described by Lovell et al. (2010) and Arushanyan et al. (2017). According to Lovell et al. (2010), the integration of different views helps to identify techniques to incorporate certain realities of low-input ruminant farmers into a new evaluation framework. Moreover, participants involved in the process of designing a conceptual model develop a cognitive ability to decipher the complexity of their system (Marandure et al., 2019). This stimulates knowledge ownership and sharing of innovative ideas and also facilitates scenario setting among stakeholders (Ten-Napel et al., 2011). The process brings together researchers from different professional fields, government officials and famers directly involved with production thereby, allowing them to collaborate on common goals.

The proposed conceptual framework seeks to incorporate the multifunctionality of low-input ruminant livestock (Weiler et al., 2014), animal welfare indicators, the credence goods and services ruminant production systems (Chingala et al., 2017). The following sub-sections describe the main components of the framework as presented in Fig. 2. The description follows a logical order where each step feed information into the next. However, this is too simplistic as the process is not linear but has complex interrelationships with multiple feedback loops and trade-offs within and between the stages. For example, trade-offs exist where pressure on rangeland resources is relieved when an animal is slaughtered or sold yet the benefits of flow-products such as milk, manure, draft power and insurance value are foregone.

4.1. *Definition of system boundaries and production attributes*

The first step of the framework involves a detailed outline of the entire system under evaluation including, spatial and temporal boundaries and general system attributes. This information is largely derived from literature. The review identifies the important production and socio-economic attributes of the system under study, their possible drivers and major constraints. The review also seeks to assist in identifying all the relevant stakeholders who should be engaged at each stage. Comparisons can also be made with other case studies of sustainability evaluations conducted in other communities exhibiting similar attributes to act as benchmarks for the proposed framework (Ruth et al., 2015).

4.2. *Establishing farmers perceptions on sustainability*

The second step should seek to ascertain farmers' goals or targets, farmers' perceptions on sustainability of their farming system as well as challenges, opportunities, credence goods and services and multiple roles of ruminants. Targets are essential in determining end products of the system as well as thresholds which provide guidelines for designing a scoring scale for indicators of sustainability. The challenges and opportunities of the system can be indirectly used to develop relevant sustainability indicators. Famers' perceptions, targets, challenges, opportunities, credence goods and services and multiple roles of ruminants can be determined through focus group discussions with key stakeholders in the communities under study. Ruminant farmers' perceptions are an important indicator of the applicability and utility of the sustainability concept in the communities under study. Perceptions help to understand the general awareness of communities under study of the sustainability concept or sustainable ruminant farming principles (Kebebe et al., 2015). The exercise reveals the extent to which the knowledge of sustainable ruminant farming is expressed or exhibited by members of the community (Zeweld et al., 2019). Likewise, the proportion of producers aware of the sustainability concept and actively applying sustainable ruminant farming practices in their management can be elucidated. Understanding awareness and adoption of the sustainability concept can be useful in post evaluation iteration of the framework as well as in monitoring and evaluation of progress in future. Further determination of the factors influencing those perceptions is crucial in designing appropriate sustainability evaluation tools.

The venue for focus group discussions or meetings with stakeholders can be organised by farmers and community leadership in consultation with stakeholders. By design, the discussions and/or meetings can be conducted using any of the available participatory approaches which enables producers' to freely express their opinions through interactive

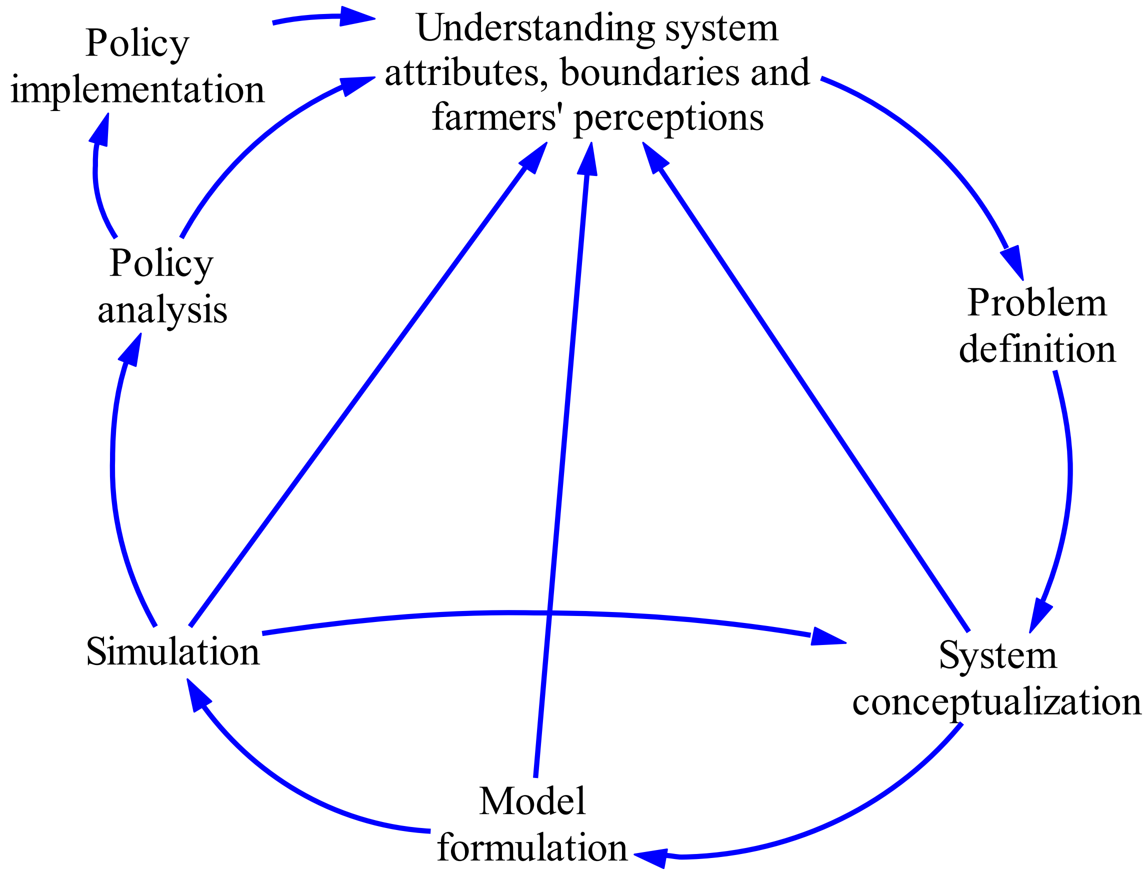

Fig. 2. Iterative steps to developing a system dynamics model (adapted from Sterman, 2000).

discussions (Guijt, 2014). The discussions should be characterised by involvement and free flow of information and knowledge sharing among all stakeholders (Pressentin et al., 2016). It is highly recommended that participants use the language they feel comfortable with in expressing their opinions. The meeting can begin by researchers briefing stakeholders about the objectives of the study prior to the meeting. At the same time, participants can be assured of the confidentiality of all the information that will be shared during the meeting as advised by Sydorovych and Wossink (2008). Participants can then be placed into equal heterogeneous groups with a representative mixture of gender, age and expertise. Each group must be provided with relevant stationery and asked to list their sustainability targets. They can then be led through the different stages to analyse strengths, weaknesses, opportunities and threats (SWOT) of their ruminant farming system in relation to sustainability as described by Sydorovych and Wossink (2008). After completing each stage, one representative from each group should be given an opportunity to share their outcomes presentations (Marandure et al., 2019).

Participants should also be asked to draw up a list of the different roles of ruminants and the credence goods and services of the ruminant farming system using different participatory techniques. The listed roles and credence goods and services can then be allocated scores according to what the participants consider to be the most important to the least. This exercise is necessary to determine the respective importance of various roles of ruminants and the credence goods and services of the ruminant farming system, which can later assist in designing criteria for assessment. de Olde et al. (2017) mentioned the importance of designing criteria for assessment from stakeholders' own experiences of their production system. In the process this also helps to spread awareness of principles of sustainable farming among low-input ruminant farmers (Asadi et al., 2010).

4.3. Development of indicators

Step three involves developing preliminary indicators derived indirectly from farmers' challenges and opportunities and the stakeholders' perceptions. For example, if a key challenge is the presence of undesirable vegetation species then this can be converted to indicators such as species composition or proportion of invasive species. Table 1 illustrates examples of the conversion of hypothetical challenges and opportunities into indicators under a series of different sustainability dimensions. A similar indicator selection procedure was previously described by Moraine et al. (2017). In cases where the indicators developed fail to

Table 1
Examples of challenges that can be used to develop indicators in low-input ruminant farming systems.

Challenge	Indicators	Indicators measurements	Dimension
Rangeland deterioration	Biomass quantity	Biomass weight per hectare	Ecological
	Biomass quality	Biomass nutrient composition	
	Soil quality	Soil nutrient composition	
	Basal cover	Proportion of ground covered by vegetation	
Low livestock offtake	Herd/flock size	Number of animals sold	Economic
Gender disparity	Women involvement in livestock farming	Number of women involved in livestock farming Proportion of women with ultimate decision-making roles in livestock farming	Social

comprehensively represent the system, key experts in the field can be consulted to develop a more balanced set of indicators.

The stakeholders play a leading role in developing reference values and a scoring criteria for the sustainability evaluation indicators as previously reported by Arodudu et al. (2017), Gomez-Limon and Sanchez-Fernandez (2010) and Mascarenhas et al. (2015). Some reference values can also be found in literature, while, others can be developed through consultations with key experts as described by (Marc Moraine et al., 2017). This activity ensures the adequacy and accuracy of data to all the component stages of the framework. The process of developing an appropriate set of indicators is evidently intricate and cumbersome. However, it is critical in defining the comprehensiveness of the process and the conclusions drawn from it (Lebacq et al., 2013; Schader et al., 2014; Mascarenhas et al., 2015). According to Darnhofer et al. (2010) too few indicators may exclude certain aspects of local importance from the evaluation. In addition, important synergies and trade-offs may not be properly taken into account (Schader et al., 2016). On the contrary, consideration of too many indicators complicates data collection and processing leading to redundancies or discord in the conclusions made from the evaluation (Bockstaller et al., 2015). Overall, operational indicators should be comprehensive enough to meet a range of social, economic and ecological conditions of systems being evaluated (Mascarenhas et al., 2015).

4.4. Quantification of indicators

The indicators developed in step four including the multiple functions of ruminants and the credence goods and services of the ruminant faming system will be allocated scores using a scale determined by producers and key sustainability experts. Mazzocchi et al. (2019) mentioned the key elements of multifunctionality as the simultaneous production of multiple commodity and non-commodity system outputs. Non-commodity outputs exhibit the characteristics of externalities or public goods, which are not represented in markets but are voluntarily or involuntarily made available to the entire community (Mazzocchi et al., 2019). Scores are important at this stage to provide standardized values for the different qualitative and quantitative indicators with different units of measurements. The indicators will then be integrated using system dynamics modelling (SDM) approach. The operational levels of some indicators, such as soil organic matter content, biomass quantity and quality, livestock weights and livestock carcass yield may be quantified by different measurements in the absence of existing records. In that case, these may take the form of direct, physical measurements or indirect measurements using remote sensing and other satellite technologies (Lim and Biswas, 2015; Moraine et al., 2017; de Olde et al., 2018).

Multiple functions of ruminant livestock, such as, meat, milk and hides/skins have direct market values that can be directly incorporated into household income (Weiler et al., 2014). Other functions, such as, provision of draught power for crop cultivation or transport of goods could be evaluated indirectly, for example, by using equivalent costs of using a tractor or public transport (Van Asselt et al., 2014). Similarly, provision of manure or fuel could be evaluated by using equivalent value of nutrients (e.g., nitrogen, phosphorus or potassium) or of a unit of energy for cooking or heating, respectively (Van Asselt et al., 2014).

Social functions of ruminants, such as sign of wealth will be allocated scores corresponding to their relative importance to ruminant farmers' livelihoods (Table 2). A likert-type scale can be used to provide guidance during scoring with a range of options to evaluate each social indicator from least to most desirable (Vagias, 2006). Ultimately, multiple functions of ruminants will comprise of those; with a predetermined economic value, those with metric derivative values and those with stakeholder scored values. Similarly, credence goods and services of the low-input ruminant farming systems, such as the perceived healthfulness of the products or ecotourism can be incorporated into the proposed framework using a scoring technique (Table 3).

Table 2
Integration of multiple roles of ruminants in sustainability evaluation of low-input ruminant production systems.

Multiple roles	Method of integration	Sustainability dimension
Reducing bush encroachment	Converted to the cost of clearing bushes	Ecological
Maintaining homestead environment	Converted to cost maintenance cost	
Improves biodiversity	Allocated scores by key experts	
Meat	Use prevailing market prices	Economic
Milk		
Hides/skins		
Horns		
Draught power	Converted to equivalent market value of labour hours provided	
Manure for fertilizer	Converted to market price equivalent for Nitrogen, Phosphorus and Potassium fertilizers	
Dried dung for energy	Converted to market price equivalent for electricity/or paraffin	
Bride price	Converted to the prevailing market value of the animal	
Form of insurance	Converted to the value of monthly premiums for the duration of animal stay on the farm	
Live bank	Converted to prevailing herd/flock market value	
Appeasing ancestral spirits	Converted to prevailing market value of animals	
Gifts or traditional fines	Converted to prevailing market value of animals	
Sign of wealth	Converted to the total value of livestock owned	Social
Strengthening social bonds by sharing animals		

4.5. Integration of indicators

The final step involves integrating all the indicators, taking their interrelationships into consideration using SDM. Fig. 3 presents an example of how the selected ecological, economic and socio-cultural components of the ruminant farming system interact at spatiotemporal scales. The general process of developing a model entails that the outline of the model and definition of its various components is essential as the initial step (Dougill et al., 2010).

Table 3
Integrating credence values of the low-input ruminant farming system in sustainability evaluations.

Credence goods and services	Method of integration	Sustainability dimension
Low carbon footprint	Converted to prevailing carbon credits rates	Ecological
Low water footprint	Converted to prevailing water use rates	
Healthfulness of food products	Scores allocated by consumers and key experts	Economic
Food product safety	Converted to premiums charged for food safety	
High animal welfare	Converted to premiums charged animal products	Social
Provision of spiritual and inspirational experience	Scores allocated by farmers and key experts	
Contribution to a pleasing landscape	Converted to equivalent tourism rates	

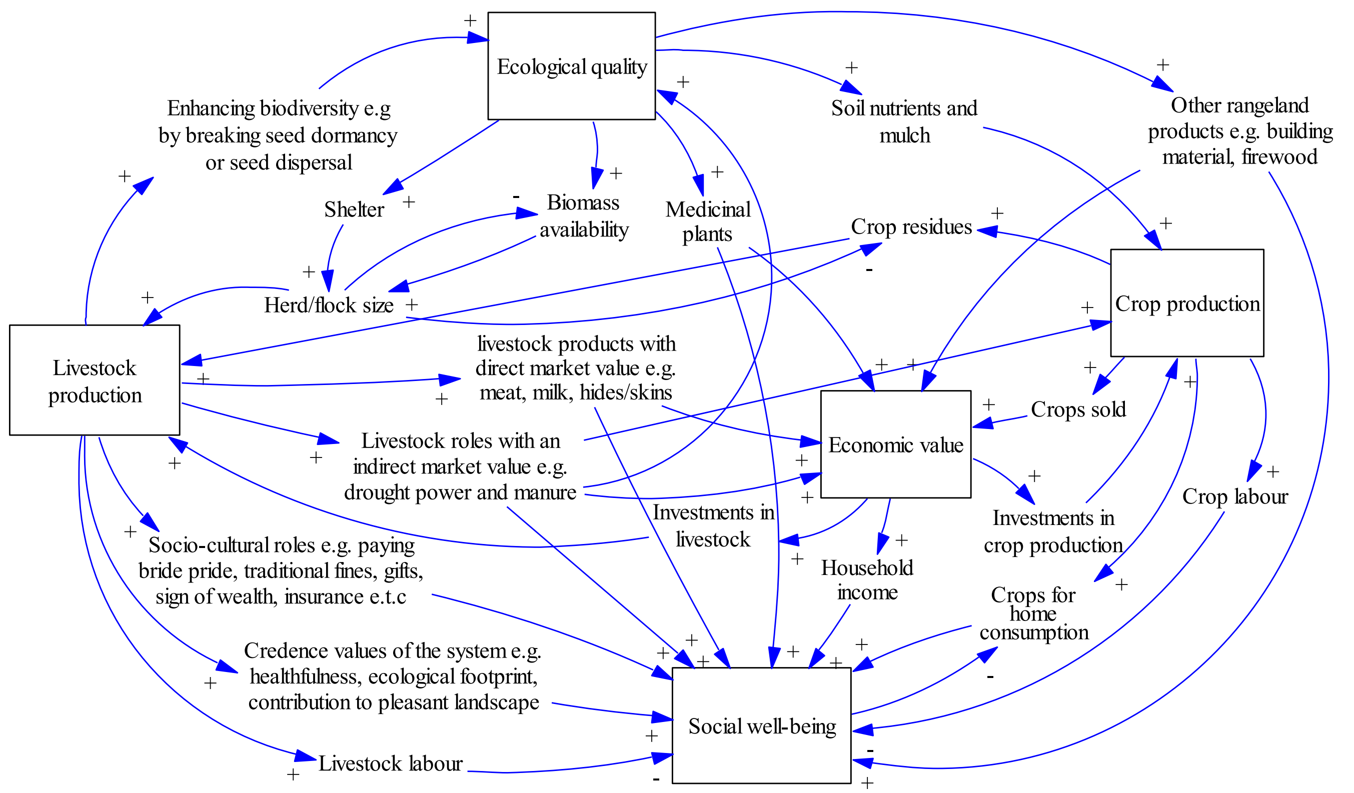

Fig. 3. Interactions between the major biophysical components of the low-input ruminant livestock farming system in developing countries.

Systems dynamics modelling is a computer-aided modelling approach with a foundation in non-linear dynamics theory and feedback mechanisms that can be used to improve understanding of complex systems (Walters et al., 2016). There are several registered SDM software including, Vensim®, Powersim® and Stella®. In addition, SDM integrates scientific knowledge from various disciplines and helps to develop decision support tools that ultimately improves ruminant farming systems (Tendeshi et al., 2011). The approach is informed by the principle that the causal structure of the system rather than specific events determines overall system behaviour (Nicholson, 2007).

Variables used in the models are linked so that an increase in one causes an increase or decrease in another which in turn influences the first variable at a later stage and these links combine to form feedback loops (Tendeshi et al., 2011). This implies that an improvement in one indicator at farm level may reduce the value in other parts of the landscape which may hinder improvement on the first indicator at a later stage. The feedback loops are known as reinforcing if they are positive or balancing if they are negative as determined by the aggregate polarity of each link. Balancing loops are associated with the system memory and resilience, therefore, are more preferred. Thus, systems that exhibit more balancing loops (negative) than reinforcing loops (positive) are more likely to have better sustainability measures than those where reinforcing loops are more dominant.

As a post evaluation strategy, scenarios analyses can be done to predict future dynamic behaviour of some key indicators (Dougill et al., 2010). This process is important to identify or predict key drivers with current and future influence on sustainability of low-input ruminant farming and help to inform on opportunities to adopt and threats to avoid as well as more appropriate policy interventions in the long-term.

Overall, the numerous sustainability evaluation studies conducted to date have proved that every production system is unique within its context and that too many indicators are impractical (Syers et al., 1995; Andrieu et al., 2007; Bockstaller et al., 2015). Low-input ruminant livestock farming systems consist of multiple environmental and socio-economic sub-systems and indicators that exhibit complex behaviour spatiotemporally. Interactions of the sub-systems include reinforcing and balancing feedbacks, nonlinear responses irreversible thresholds, emergent properties and unpredictable results (Martin and Magne, 2015). Most integration methods fail to consider the interrelationships within and between dimensions and indicators, as a result, they only provide a partial picture of the systems' sustainability (Ostrom, 2012).

Understanding the various aspects of ruminant farming including, component interrelationships, linkages and feedback signals is key to building an integrated framework for evaluating sustainability of ruminant farming systems. In this regard, finding variables that are robust under diverse conditions are more important than point estimate accuracy. A common, methodological framework is necessary to facilitate interdisciplinary efforts towards more accurate sustainability evaluation of low-input ruminant systems. It is suggested that the approach to deriving appropriate conceptual frameworks proposed in the current paper be tested in different low-input communities in developing countries to determine its effectiveness. Given the diversity of low-input ruminant farming systems in developing countries, the paper seeks to provide a basis for further analysis and development.

5. Conclusion

The proposed approach to the development of a sustainability evaluation framework for low-input ruminant farming systems comprises of five iterative stages which stakeholders' contributions using participatory approaches. The main steps in the framework's development include description of system physical boundaries and attributes, establishing local stakeholders' perceptions on sustainability, development of indicators, quantification of indicators and integration of indicators. More importantly, appropriate frameworks should incorporate the multiple roles of ruminants, animal welfare and credence goods and services of the system into the main sustainability evaluation framework. They should also consider dynamic interrelationships within and between sustainability components and indicators through integrating indicators using the systems dynamic approach. Finally, it is recommended that the approach outlined be tested on various case studies in different low-input ruminant livestock farmer communities for validation and iteration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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