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Farmer challenge-derived indicators for assessing sustainability of low-input ruminant production systems in sub-Saharan Africa

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ABSTRACT

The process of consulting stakeholders, particularly farmers, in developing appropriate indicators for sustainability evaluation of low-input ruminant systems is often compromised by limited awareness and understanding of the sustainability concept by farmers in developing countries. Insights from farmers' challenges present useful prospects for developing context-specific sustainability evaluation indicators for low-input ruminant systems. In the present review, a meta-analysis was used to develop farmer challenge-derived indicators for the sustainability evaluation of low-input ruminant farming system in sub-Saharan Africa. Key ecological challenges reported were low forage quality, poor soil quality, feed shortages and; economic challenges were low poor marketing structure, high cost of labour, and poor transport network, poor marketing infrastructure; and social challenges were rural to urban migration, lack of animal breeding management and inadequate access to information. The corresponding derived ecological indicators were biomass quality, soil quality, high winds; economic indicators were available marketing infrastructure, labour costs, transport networks; and social indicators were rural to urban migration, animal management training and access to information. The review shows that farmers' challenges can be transformed to indicators for assessing the sustainability of the low-input ruminant farming system in sub-Saharan Africa.

1. Introduction

Improving the sustainability of low-input ruminant farming in developing countries requires the development of an appropriate set of indicators to evaluate and monitor its progress (Mandarino et al., 2019; Munyaneza et al., 2019). Currently, there is no universally accepted set of indicators for assessing the sustainability of low-input ruminant farming systems in developing countries (Atanga et al., 2013; Goswami et al., 2017; Molotsi et al., 2017). Development of indicators is a critical step in designing and implementing farming systems sustainability evaluation tools (Lebacq et al., 2013; Waas et al., 2014; Mascarenhas et al., 2015). Indicators are defined as "physical and measurable variables that provide quantitative information about some non-quantifiable variables" (Bonisoli et al., 2018; Mandarino et al., 2019). They enable efficient evaluation of farming systems by researchers and assist farmers to make decisions at farm-level (Marandure et al., 2018).

The existing agricultural farming systems sustainability indicators have origins in developed countries (Gasparatos and Scolobig, 2012; Schader et al., 2014) and were mostly developed by researchers using traditional top-down or bottom-up approaches (Fraser et al., 2006; Meul et al., 2008; Astier and García-Barrios, 2012; Schader et al., 2016). These indicators often have limited applicability, without prior customization to the low-input farming systems that characterize developing countries (Munyaneza et al., 2019). In addition, the indicator develepment processes have been criticized for the use of traditional approaches often associated with low adoption rates, and targeting specific specialized systems (Marandure et al., 2018). It is, therefore, important to develop context-specific indicators using innovative approaches (Häni et al., 2003) for assessing sustainability and monitor progress of the low-input ruminant farming system in developing countries.

The process of engaging stakeholders using participatory approaches is central to the development of context-specific indicators and their

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reference values (Chand et al., 2015; Schindler et al., 2015; Moraine et al., 2017). Overall, context-specific practice-based indicators are recommended for comprehensive sustainability evaluations (Seghezzo et al., 2016) as opposed to performance-based indicators which are restricted by their requirements for data (Pupphachai and Zuidema, 2017). The development of context-specific practice-based sustainability indicators provides valuable reference points for making management decisions (Bockstaller et al., 2015). The process of engaging primary beneficiaries in the selection of indicators provides an opportunity for community empowerment not provided by conventional top-down approaches (Hoffmann, 2011).

Previous studies used farmer participatory techniques to derive context-specific indicators but realised that both farmers and practioners were more inclined to engage on challenges affecting sustainability of low-input ruminant production systems (Marandure et al., 2017). Marandure et al. (2018), however, highlighted that the relatively low education levels of most low-input farmers, and limited awareness and comprehension of the sustainability concepts by some agricultural practitioners compromise the process of developing farmer-derived indicators. Furthermore, limited access to information among low-input ruminant farmers reduces opportunities for self-familiarization with sustainability principles (Ndoro et al., 2014). Overall, this adversely affects the quality and applicability of the farmer-derived indicators. It is, therefore, important to find an innovative process of developing appropriate indicators for sustainability evaluation of the low-input ruminant farming systems in developing countries (Zahm et al., 2007).

Generally, low-input farmers have valuable knowledge of challenges facing their farming systems (Mutibvu et al., 2012; Gwiriri et al., 2019a, b), which provide useful insights in developing appropriate context-specific practice-based indicators (Halbrendt et al., 2018). Farmers' challenges have been used to determine key factors limiting low-input farming systems (Gowane et al., 2019), and often turn them into opportunities (Mohlatlole et al., 2015). In that context, transforming challenges into indicators presents an opportunity to develop sustainability evaluation tool that use realistic variables, which reflect the context-specific realities of the locals.

Despite diversity of low-input farmer challenges due to varied resources and different production environments, some commonalities do exist. A meta-analysis of various studies can assist to delineate the key challenges facing low-input ruminant farming systems, which can be transformed into sustainability indicators. Combining the results from multiple studies increases statistical power over individual studies to resolve uncertainty between contradictory studies, and improves estimates of the effect size (Rudel et al., 2016). In as much as individual surveys yield location-specific challenges, a meta-analysis review provides a broader long-term effect of prominent challenges (Rao et al., 2008; Ede et al., 2018). In this regard, a meta-analysis present useful prospects for developing context-specific sustainability evaluation indicators for low-input ruminant farming systems. The objective of the current review was, therefore, to develop context-specific indicators for sustainability evaluation of low-input ruminant farming system based on a meta-analysis of farmers' challenges in sub-Saharan Africa.

2. Materials and methods

2.1. Meta-analysis literature search

Peer reviewed publications between the year 1990 and 2020 that investigated the challenges faced by low-input ruminant farmers in sub-Saharan Africa were systematically searched in May 2020 using Google Scholar, ScienceDirect and Scopus as the major electronic databases for academic studies. Initially a broad Boolean search string 'smallholder AND 'farming' AND 'cattle' OR 'goats' OR 'sheep' AND 'challenges' AND 'Africa' was used before subsequently adding OR 'constraints' OR 'limitations'. The preliminary search was refined to 'smallholder' or 'low-input' OR 'resource-constraint' farming systems.

2.2. Selection of meta-analysis studies

Foremost, selected studies were considered provided they fit the scope of the review in terms of the objectives. Studies were primarily selected on the basis that they reported results from interviews conducted with randomly selected low-input ruminant farmers in sub-Saharan Africa, providing quantitative measures to allow direct quantitative comparison across data sets. Individual countries were considered as strata of the overall pool of studies identified, taking the fact that data were collected from different geographic regions into consideration. Titles and available abstracts of all records were examined, and the full text of all potentially relevant studies was retrieved. Forward and backward literature search was further performed on the reference lists of key papers retrieved during the initial search.

2.3. Statistical analysis

The meta-analysis of studies with useable data that investigated the challenges faced by low-input ruminant farmers was performed using the random effects model in Jeffreys's Amazing Statistics Program (JASP) version 0.11.1 (JASP Team, 2019). The following model given by Rao et al. (2008) was used to combine data from multiple surveys into a single estimate:

$$\theta = \frac{\sum_{j=1}^{k}\sum_{i=1}^{nj} w_{ij}x_{ij}}{\sum_{j=1}^{k}\sum_{i=1}^{nj} w_{ij}}$$

where;

$\theta =$ is the pooled estimate from individual-level data;
k is the total number of surveys in the meta-analysis ($k = 1, 2, 3 \ldots 12$);
n_j is the total sample size for the jth survey;
w_{ij} is the revised weight in the combined data for the ith subject from the jth survey and;
x_{ij} is a variable of interest or outcome from the survey for the ith subject from the jth survey.

The effect sizes were used to categorise the impact of each challenge into three classes; low (<0.8), moderate (0.8–1.9) and high (<2.0) following the procedure described by Atanga et al. (2013). Effect sizes provides interpretable values on the magnitude of an effect of a difference between two treatment groups or numerical comparisons or contrast (Geffersa and Agbola, 2019). The impact of challenges provided objective weights to the corresponding indicators. Indicators derived from high, moderate and low impact challenges were allocated weights of three, two and one, respectively. The weight allocation was adapted from a procedure for determining sustainability designed by Atanga et al. (2013). The challenges were allocated to broad ecological, economic and social sustainability dimensions according to Morrison-Saunders et al. (2014). For each sustainability dimension, the challenges were converted to indicators by determining quantifiable variables that best represented each challenge.

3. Results

3.1. Screening of meta-analysis studies

Fig. 1 shows a schematic outline of the study selection process for meta-analysis. The examination of titles and abstracts resulted in the exclusion of 4791 studies out of the 4887 obtained from literature largely because of missing the scope of the intended meta-analysis. A further 63 studies were excluded after full-text examination for not presenting data as percentages of respondents for specific challenges. This was important as the data on challenges were recorded together

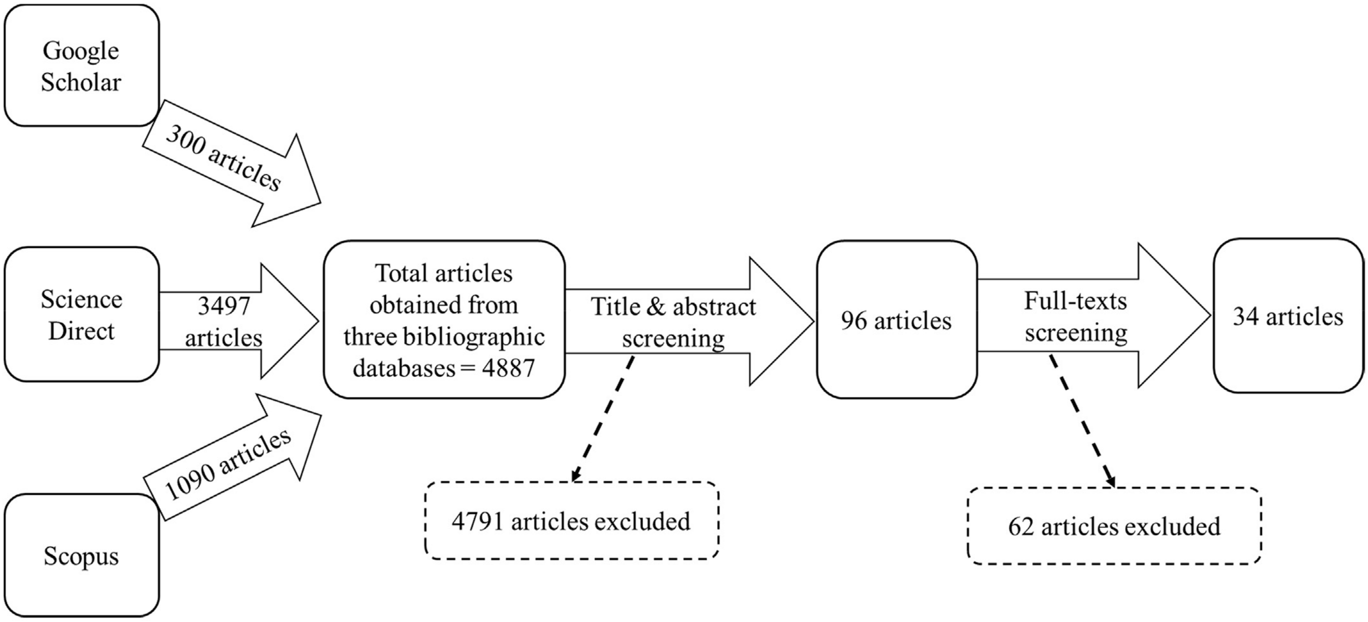

Fig. 1. Outline of the study selection flow diagram.

with the proportion of farmers that acknowledged experiencing that constraint. Ultimately, a total of 34 articles were considered for the current meta-analysis (Fig. 1). The characteristics of the studies included in the meta-analysis are presented in Table 1. Cumulatively, the studies reported interviews held with over 6000 smallholder farmers representing 12 sub-Saharan African countries. The proportion of selected studies by country were; Benin (0.6% of all respondents), Democratic Republic of Congo (2%), Ethiopia (30%), Ghana (8%), Kenya (0.5%), Malawi (4%), Namibia (10%), South Africa (20%), sub-Saharan Africa (8%), Sudan (2%), Tanzania (2%), Zambia (14%) and Zimbabwe (9%). Studies that reported collective statistics for a number of sub-Sarahan countries were represented as such.

Table 1
Characteristics of peer reviewed studies included in the meta-analysis.

Authors		Year	Journal	Country of study	n	(%) of sample
1.	Dossa et al.	2007	Tropical Animal Health & Production	Benin	38	0.6
2.	Maass et al.	2012	Tropical Animal Health & Production	DR Congo	112	2
3.	Didana et al.	2019	African Journal of Science, Technology, Innovation and Development	Ethiopia	200	3
4.	Bishu et al.	2018	Journal of Risk Research	Ethiopia	356	6
5.	Duguma et al.	2012	Global Veterinaria	Ethiopia	78	1
6.	Tschopp et al.	2010	Mountain Research and Development	Ethiopia	148	2
7.	Dugama et al.	2016	Springerplus	Ethiopia	54	0.9
8.	Gebreegziabher & Tadesse	2013	Journal of Risk Management	Ethiopia	304	5
9.	Asravor	2018	African Journal of Economic and Management Studies	Ghana	500	8
10.	Mbdinyo et al.	2018	Tropical Animal Health & Production	Kenya	157	3
11.	Onono et al.	2013	Tropical Animal Health & Production	Kenya	12	0.2
12.	Abdilatif et al.	2018	Tropical Animal Health & Production	Kenya	16	0.3
13.	Tebug et al.	2012	Tropical Animal Health & Production	Malawi	210	4
14.	Hangara et al.	2011	International Journal of Agricultural Sustainability	Namibia	570	1
15.	Togarepi et al.	2016	Livestock Research & Rural Development	Namibia	50	0.8
16.	Mapiye et al.	2009	Livestock Science	South Africa	218	4
17.	Lungu et al.	2018	Small Ruminant Research	South Africa	107	2
18.	Mapiye et al.	2018	Tropical Animal Health & Production	South Africa	62	1
19.	Jari and Fraser	2009	African Journal of Agricultural Research	South Africa	43	0.7
20.	Nkonki-Mandleni	2019	International Journal of Entrepreneurship	South Africa	250	4
21.	Cholo et al.	2018	Agroecology and Sustainable Food Systems	South Africa	76	1
22.	Mapiliyao et al.	2012	Scientific Research Essays	South Africa	72	1
23.	Durawo et al.	2017	Small Ruminant Research	South Africa	195	3
24	Marandure et al	In Press	Environment, Development and Sustainability	South Africa	157	2.5
25.	Opoola et al., 2019	2019	Tropical Animal Health & Production	sub-Saharan Africa	496	8
26.	Tirab & Chimonyo	2016	Tropical Animal Health & Production	Sudan	128	2
27.	Nziku et al.	2017	Animal Production Science	Tanzania	125	2
28.	Chipasha et al.	2017	African Journal of Food, Agriculture, Nutrition and Development	Zambia	110	2
29.	Mumba et al.	2018	Tropical Animal Health & Production	Zambia	699	12
30.	Chinogaramombe et al.	2008	Livestock Research & Rural Development	Zimbabwe	60	1
31.	Mutibvu et al.	2012	Livestock Research & Rural Development	Zimbabwe	60	1
32.	Chatikobo et al.	2013	Preventative Veterinary Medicine	Zimbabwe	294	5
33.	Mhlanga et al.	2018	Small Ruminant Research	Zimbabwe	80	1
34.	Hahlani & Garwi	2014	IOSR Journal of Humanities and Social Science	Zimbabwe	75	1

3.2. *Challenges of low-input farming systems*

The meta-analysis literature review process yielded a total of 45 challenges (Fig. 2). The overall 95% prediction interval for the challenges ranged from 0.0 to 3.0., indicating low impact for most of the challenges reported in the meta-analysis (Fig. 2). Low forage quality was the most frequently mentioned challenge with high effect size., Poor soil quality, feed shortages, poor marketing structure, high cost of labour, poor transport network, poor breeding management and rural to urban migration, in that order were categorised as having moderate impact on low-input ruminant farming (Fig. 2). The remaining challenges were classified as having low impact on low-input ruminant farming. (Fig. 2). Of the 45 challenges identified, 10, 22 and 13 were categorised under the ecological, economic and social dimensions of sustainability, respectively (Table 2).

3.4. *Derivation of challenges to sustainability indicators*

The challenges were converted to indicators by determining variables that best quantify them (Tables 3–5). For example, low rainfall and extreme temperatures challenges were converted to mean annual rainfall and mean seasonal temperatures, respectively (Table 3). Rangeland condition related challenges including degraded rangelands (particularly, bush encroachment) and poor soil quality were converted to their corresponding sustainability indicators namely; bush encroached areas and soil quality (Table 3).

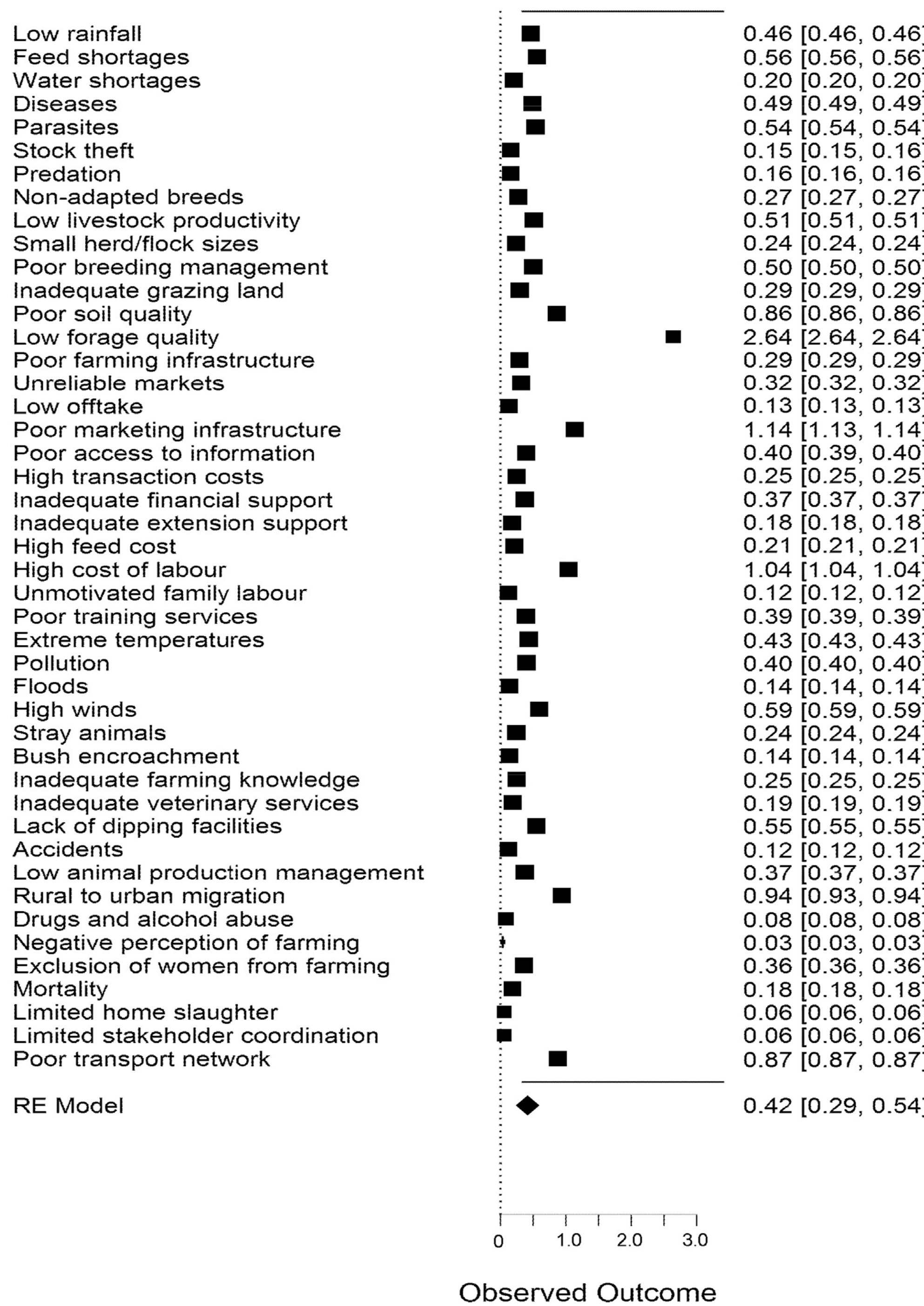

Fig. 2. Forest plot showing effect sizes of challenges of low-input farming systems from a meta-analysis of livestock studies in Africa.

Table 2
Relative impact of challenges recorded in a meta-analysis studies by low-input farmers in Africa.

Ecological challenge	Impact	Economic challenge	Impact	Social challenge	Impact
Low rainfall	Low	Diseases	Low	Poor breeding management	Moderate
Floods	Low	Parasites	Low	Inadequate extension support	Low
Extreme temperatures	Low	Mortality	Low	Inadequate veterinary services	Low
High winds	Low	Stock theft	Low	Inadequate farming knowledge	Low
Pollution	Low	Predation	Low	Poor access to information	Low
Water shortages	Low	Stray animals	Low	Low animal production management	Low
Feed shortages	Moderate	Accidents	Low	Poor training services	Low
Low forage quality	High	Non-adapted breeds	Low	Rural to urban migration	Moderate
Bush encroachment	Low	Low livestock productivity	Low	Drugs and alcohol abuse	Low
Poor soil quality	Moderate	Small herd/flock sizes	Low	Negative perception of farming	Low
		Low offtake	Low	Exclusion of women from farming	Low
		Unreliable markets	Low	Limited home slaughter	Low
		High transaction costs	Low	Inadequate grazing land	Low
		High feed costs	Low		
		High cost of labour	Moderate		
		Unmotivated family labour	Low		
		Inadequate financial support	Low		
		Poor farming infrastructure	Low		
		Poor marketing infrastructure	Moderate		
		Inadequate animal handling facilities	Low		
		Lack of dipping facilities	Low		
		Poor transport network	Moderate		

Table 3
Derivation of ecological sustainability indicators from low-input farming systems challenges in sub-Saharan Africa.

Challenge	Indicator	Indicator measurement
Low rainfall	Rainfall	Amount, distribution, reliability and frequency
		Number of seasons with below average rainfall (mm)
Floods	Floods	Monitoring stream stage, river height and stream or waterway flow rate
Extreme temperatures	Temperature	Temperature records
High winds	High winds	Wind speed records
Feed shortages	Biomass quantity	Biomass amount per unit area
Low forage quality	Biomass quality	Biomass nutrient composition
Bush encroachment	Bush encroached areas	Size of bush encroached areas (ha) and Invasive plant density
	Invasive species	
Poor soil quality	Soil quality/condition	Soil fertility, depth and basal cover/area
Water shortages	Available water	Volume of available water (L)
Environmental pollution	Land quality	Size of polluted land and quantities of land pollutants
	Water quality	Quantity of debris in water bodies
		Concentration of nutrients in water, pH and toxicity levels
	Air quality	Visibility range and air quality index

As presented in Table 4, accidents, stock theft, predation and stray animals challenges were directly considered as indicators without modification. Limited animal handling facilities, inadequate marketing infrastructure, poor transport network and lack of dipping facilities challenges were correspondingly converted to animal handling facilities, available marketing infrastructure, transport networks and available dipping facilities indicators (Table 4). The social challenges reported such as poor breeding management, rangeland management and health management were respectively represented by management training (Table 5). Of the 45 challenges recorded from the meta-analysis review, 13 ecological, 21 economic and 10 social indicators were developed giving a total 44 indicators.

5. Discussion

To the authors' knowledge, the current review is the first to report a meta-analysis of challenges faced by low-input ruminant farmers in sub Saharan Africa. When interpreting the findings of meta-analytical review, it is critical to consider the relative impact of each challenge on low-input ruminant farming systems as reflected by the effect sizes (Mondelaers et al., 2009). The observed variation of meteorological challenges such as floods, high winds, extreme temperatures and low rainfall is reflective the diverse climatic conditions typical of the sub Saharan Africa region (Hoffmann, 2011;Bahta et al., 2016). The observation that rangeland condition and animal production related indicators were the most prominent is consistent with empirical evidence demonstrating the important interrelationships between the two components (McMichael et al., 2007; Shiferaw et al., 2014). Overall, low rainfall and high temperature reduces forage and livestock production (McMichael et al., 2007; Shiferaw et al., 2014).

Given the direct influence of meteorological conditions, especially rainfall and temperature, on forage abundance and quality, it is logical that sustainability evaluation indicators be reflective of this important relationship. In some cases rainfall and temperature are not selected as direct indicators but instead are used to explain the trends of particular variables that they directly influence (McMichael et al., 2007; Shiferaw et al., 2014). In that regard, indicators related to forage productivity, including biodiversity, vegetation abundance and quality, can be considered as proxies for prevailing climatic conditions (Herrero et al., 2009). Empirical evidence reveals gradual decreases in mean annual rainfall and increase in temperatures across sub-saharan Africa over the past three decades (Archer, 2011; Rust and Rust, 2013; Martin and Magne, 2015). Given that low-input ruminant farming is rainfed, decreases in rainfall and increase temperatures can have devastating reparations on forage and animal production in the sub-Saharan region (Archer, 2011; Rust and Rust, 2013; Martin and Magne, 2015).

Absence of diseases and parasites are often placed at the core of ruminant production (Meena, 2013). Livestock mortality can be used as a proxy of the two and was reported as an appropriate indicator in the current study. It is appreciated that mortality is an ambiguous term caused by various factors including accidents (McDermott et al., 2010). However, in the context of the current study mortality is taken to represent animal losses due to diseases and parasites. Though most African governments subsidize livestock vaccination and dipping services to combat prevalent diseases and parasites (Mapiye et al., 2011; Marufu et al., 2011; Ten-Napel et al., 2011), limitations in both facilities and qualified personnel often lead to inadequate delivery of veterinary services (Nakano et al., 2018). In this regard, farmer to veterinary officer ratio and area covered by a state veterinarian were considered as suitable

Table 4
Derivation of economic sustainability indicators from low-input farming systems challenges in sub-Saharan Africa.

Challenge	Indicator	Indicator measurement
Physical accidents	Physical accidents	Number of animals involved in accidents
Disease prevalence	Animal health	Number of animals affected by diseases
Parasitic infestations	Animal health	Number of animals affected by parasites
High mortality rates	Mortality	Number animal deaths
Stock theft	Stock theft	Number of stolen animals
Predation	Predation	Number of animals lost to predators
Straying away animals	Straying away animals	Number of animals astray
Low livestock productivity	Animal performance and offtake	Reproduction efficiency, body weight and condition and growth, mortality and offtake rates
Small herd/flock sizes	Livestock numbers	Number of animals per household
Non-adapted breeds	Animal performance	Reproduction efficiency, body weight and condition and diseases and parasites resistance
Poor farming infrastructure	Available farming infrastructure	Number and types of livestock infrastructure per community
Limited animal handling facilities	Animal handling facilities	Number and types of livestock handling facilities per community
Inadequate marketing infrastructure	Available marketing infrastructure	Number and types of livestock marketing facilities per community
Poor transport network	Transport networks	Number of accessible roads and public vehicles operating a given area
Lack of dipping facilities	Available dipping facilities	Average distance travelled to the nearest dip tank
High feed costs	Feed costs	Cost of feed per kg
High transaction costs	Transaction costs	Transaction costs per animal
High cost of labour	Labour costs	Cost of labour per man hours
Unmotivated family labour	Family members involvement in ruminant farming	Number of family members engaged in ruminant farming
Unreliability of markets	Available and reliable markets	Number of available and reliable markets
Low offtake rates	Livestock offtake	Number of animals sold and/or slaughtered per year
Inadequate financial support	Availability of financial support	Number of available financial institutions

sustainability indicators in the current study (Kocho et al., 2011; Mapiye et al., 2018; Marandure et al., 2019).

The moderate impact of the poor soil quality challenge reported is justified by the common view that most low-input farmers reside in areas with shallow, rocky and infertile soils (Parsons et al., 2011; Segnon et al., 2015; Enahoro et al., 2019). The observation that plant basal cover and soil fertility were considered as appropriate indicators of soil condition is consistent with indicators which signifies the state of agricultural soils reported in previous studies (Gomez-Limon and Sanchez-Fernandez, 2010; Latruffe et al., 2016; Pupphachai and Zuidema, 2017). Ideally the indicators were justified by the fact that rangelands in low-input ruminant farming areas were characterized by shallow, infertile soils with low vegetation cover predisposing them to erosion (Mondelaers et al., 2009).

The challenge of inadequate grazing land mentioned in the current study is consistent with a report by Venter et al. (2018) who reported that 8% of rangelands over South Africa are degraded by woody plant encroachment. The authors suggested a combination of herbivory and fire as strategies to control woody plant encroachment. Alternatively, Mapiye et al. (2011) suggested innovative strategies of formulating livestock diets using invasive woody plant leaves and seeds. With regards to communal rangelands there is a notable disconnect between published

Table 5
Derivation of social sustainability indicators from challenges of low-input farming systems in sub-Saharan Africa.

Challenge	Indicator	Indicator measurement
Poor breeding management	Animal management training program	Number of farmers that received animal management training
Poor health management	Animal management training program	
Inadequate farming knowledge	Animal management training program	
Inadequate extension support	Extension support	Farmer to extension officer ratio and area covered by an extension officer
Inadequate veterinary services	Veterinary support	Farmer to veterinary officer ratio and area covered by an extension officer
Inadequate access to information	Access to information	Number of information sources accessed
Lack of intrinsic family labour motivation	Motivated family labour	Number of family members motivated to provide farming labour
Rural-urban migration	Rural-urban migration	Number of people migrated
Exclusion of women in livestock farming	Women involvement in farming	Number of women involved in or excluded from livestock farming
Drugs and alcohol abuse	Incidences of drugs and alcohol abuse	Number of people consuming drugs and abusing alcohol
Limited home slaughter	Animal slaughters	Number of animals slaughtered for consumption per annum
Limited stakeholder coordination	Existence of stakeholders coordination	Number of stakeholders coordinating farmer activities

farmer challenges and farmers perception of their challenges (Oosting et al., 2014). Local people do not regard degradation of their rangelands as a major challenge, at least in relation to many of the more immediate challenges facing them. This is also reflected by the low impact recorded for the inadequate grazing land challenge in the current study.

The observation that low livestock productivity and inadequate marketing infrastructure were among the common economic challenges outlines the importance of desirable economic performance in low-input systems in sub-Saharan Africa (Sikwela and Mushunje, 2013). Livestock security related indicators observed in the current study, particularly stock theft, predation, accidents and animal straying represent genuine realities of low-input ruminant farming (Atanga et al., 2013; Mapiye et al., 2018). Farmers are reluctant to lose their animals by any means, and low-input ruminant farmers, in particular, are the most vulnerable as it takes them longer to recover from losses (Marandure et al., 2016). Livestock security in most low-input ruminant farming communities is often compromised by lack of fencing, inadequate personnel to monitor animals, inadequate police presence, proximity to national borders and insecure animal housing (Meissner et al., 2013; Dawson et al., 2016; Khapayi and Celliers, 2016). Low-input ruminant farmers usually drive their animals to graze unmonitored in the rangelands during the day and collect them in the evening for kraaling leaving them exposed to various form of losses (Moyo et al., 2008).

The challenges of inadequate animal handling and marketing facilities raised in the current study pronounces the need for support structures to enhance production by farmers. The farming infrastructure-related indicators reported in the current study, such as, animal handling facilities and available marketing infrastructure, represent the importance of adequate farming facilities (Marta-Costa and Costa, 2011). Low-input ruminant farmers prioritise support structures without which their farming efforts can be derailed (Gwiriri et al., 2019a,b). Most low-input ruminant farmers are from remote locations with poor road and transport networks, poor market infrastructure and access to input and financial services (Marandure et al., 2020; Thamaga-Chitja and Morojele, 2014). Any prospects of engaging with formal markets by low-input ruminant farmers are thwarted by these infrastructure-related challenges which often culminate in high production and marketing costs (Mkhabela, 2013; Sikwela and Mushunje, 2013). As a result, low-input farmers resort to informal localised livestock trading (Marandure et al., 2016). Gwiriri et al. (2019a,b) recommended systemisation of the informal livestock markets to allow for more appropriate support.

Given the diversity of socio-cultural preferences across the sub-Saharan African region (Lebacq et al., 2013), it was anticipated that socially-related challenges would be dominant. The fact that the common challenges including inadequate extension support, veterinary services, farming knowledge and access to information, reflects a lack of support services, including farmer training by African governments (Latruffe et al., 2016; Pupphachai and Zuidema, 2017; Marandure et al., 2020). Training in livestock production is critical for capacity building among low-input farmers (Nakano et al., 2018). In the absence of an effective extension service (Mapiye et al., 2018), it is logical for low-input ruminant farmers to express the desire for training to build intrinsic knowledge systems, which helps them become self-sustainable (Nakano et al., 2018). Feder et al. (2004) described agriculture extension and farmer training programmes as key policy instruments used by governments to improve agricultural production. Although, the two instruments have not been proven to be interchangeable (Kezar and Maxey, 2016), it is clear that the absence of one demands the other to fill the knowledge and skills gap (Bennett et al., 2013).

The reason for citing ruminant market and non-market offtake as appropriate indicators highlights farmers' desire for enhanced income which is directly linked to food security at household level (Sikwela and Mushunje, 2013). The reluctance of low-input farmers to slaughter animals for home consumption may be representative of the priority they place on flow animal products such as milk, manure and draft power than on final products like cash and meat (Marandure et al., 2019). Faku and Hebinck (2013), reiterated that low-input farmers are reluctant to lose these life-time benefits by removing animals out of the system through either sales or slaughter (Mapiye et al., 2020). Farmers marketing preferences have led to different strategies of valuing their livestock. For instance, the value of selling ruminants to cover emergency costs such as illness or death, that would normally be covered by insurance, is termed the insurance value of ruminant livestock (Chaminuka et al., 2014). Overall, ruminant farming is considered the core source of food, disposable income, critical socio-cultural functions as well as a major capital reserve used to finance other farm investments in most smallholder areas (Herrero et al., 2014; Mapiye et al., 2020).

Rural to urban migration indicator maybe indicative of youths' negative perceptions of ruminant farming. The indicator was previously used by Atanga et al. (2013) while, Bernues et al. (2011) considered it as lack of generational succession. Rural to urban migration represent the current status of youth exodus to urban areas as they consider farming as dirty and laborious (May et al., 2019). Rural to urban migration may be an indicator of the youths' preference for cleaner, less laborious, and instant high paying city jobs (Swarts and Aliber, 2013). The negative perceptions of farming may also be linked to other family members' frustration about the physical labour they dedicate towards agriculture with no direct remuneration as the benefits accrue to household heads (Gwiriri et al., 2019a). Ultimately, unmotivated family labour may be the driver for rural to urban migration (Mapiye et al., 2019; Marandure et al., 2019). Cultural exclusion of women from livestock farming may be another factor responsible for extinguishing intrinsic motivation among family members (Marandure et al., 2019) and driving rural to urban migration. In some cultures, women are not allowed to get close to livestock kraals or to make any management decisions regarding animals as that is considered men's terrain (Mapiye et al., 2018).

Stakeholders' coordination, which apparently was the derived indicator of lack of coordination among livestock development programs is essential to inspire more focused development efforts (Mapiye et al., 2019; Marandure et al., 2020). Despite the importance and abundance of development efforts in low-input farming areas, stakeholder involvement is not often considered as an indicator for sustainability evaluation of the systems (Lebacq et al., 2013). Development agents are, therefore, urged to take into account the diversity of low-input farmers' sustainability indicators during the design and implementation stages of new technologies (Mascarenhas et al., 2014). This is particularly important under the current circumstances where many developing countries are embarking on active sustainability plans to develop their livestock subsectors either with their own resources or with the assistance of local and/or international donor organizations (Marandure et al., 2020). Overall, researchers and other development professionals should focus on building their human capacity in understanding key factors involved in farmers' perceptions of any intended technology prior to its introduction. It is crucial for low-input ruminant livestock farmers to first evaluate if the introduced technology provides safety for their environment, creates stable and long-term income before they can adopt it (Shilomboleni, 2017; Thanh et al., 2015). Previous studies have identified factors as broad as education level, gender, economic status, knowledge of natural resources, and social responsibility as important influences of the decision making processes in low-input farming communities (Parsons et al., 2011).

The current study does not claim to have presented an exhaustive list of challenges confronted by farmers, neither does it claim that the identified indicators are entirely comprehensive and representative to allow for the best sustainability evaluation of the low-input livestock production system. The authors, however, provide a guideline for alternative development of sustainability indicators, which warrant further assessment for balance and adequacy. Current results provide a baseline for designing an appropriate sustainability evaluation tool, as they indicate important aspects of the low-input ruminant livestock farming system prioritized by farmers in sub-Saharan Africa. The indicators reported in the current study can be quantified in relation to their thresholds and integrated to provide sustainability levels of the low-input livestock production systems in sub-Saharan Africa.

6. Conclusions

The majority of ecologically, economically and socially related common challenges reported in the current review were of low impact to low-input ruminant farming. The major ecological indicators of sustainability developed from the current review were biomass quality, soil quality and high winds, while, available marketing infrastructure, labour costs, transport networks were the key economic indicators. Social indicators of sustainability reported include rural to urban migration, animal management training and access to information. The review was able to demonstrate that it is possible to develop context-specific indicators from farmer challenges. It is recommended to test the set of indicators developed in the current review in a typical sustainability evaluation in the low-input farming system in sub-Saharan Africa. Findings from the current review can help provide valuable information on the extent and magnitude of challenges facing low-input farmers in sub-Saharan Africa. Such information can be used to identify exact factors that need to be targeted by development agencies and low-input farmers to improve their productivity. Furthermore, the information can be useful in influencing policy that will benefit low-input farmers.

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Declaration of competing interest

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