Frontiers in Sustainable Food Systems

TYPE Review
PUBLISHED 29 October 2025
DOI 10.3389/fsufs.2025.1674537

OPEN ACCESS

EDITED BY
Siphe Zantsi,
Agricultural Research Council of South Africa (ARC-SA), South Africa

REVIEWED BY
Mhlangabezi Slayi,
University of Fort Hare, South Africa
Claudia Patricia Alvarez Ochoa,
Universidad de La Salle, Colombia

*CORRESPONDENCE
Zwivhuya Constance Raphalalani
✉ miszwivhu@gmail.com

RECEIVED 28 July 2025
ACCEPTED 08 October 2025
PUBLISHED 29 October 2025

CITATION
Raphalalani ZC, Malatji DP and Chimonyo M (2025) Potential for utilizing indigenous knowledge to sustainably improve reproduction efficiency of cattle in sub-Saharan Africa: a narrative review. *Front. Sustain. Food Syst.* 9:1674537. doi: 10.3389/fsufs.2025.1674537

Potential for utilizing indigenous knowledge to sustainably improve reproduction efficiency of cattle in sub-Saharan Africa: a narrative review

Zwivhuya Constance Raphalalani[1,2]*, Dikeledi Petunia Malatji[1] and Michael Chimonyo[3]

[1]Department of Agriculture and Animal Health, University of South Africa, Florida, South Africa, [2]North West Department of Agriculture and Rural Development, Potchefstroom, South Africa, [3]Faculty of Science, Engineering and Agriculture, University of Venda, Thohoyandou, South Africa

Low-input cattle production systems are characterized by low reproductive efficiency that reduces herd productivity which in turn affects food security. Conventional ways of improving cattle reproduction have been effective but not sustainable in low-input cattle production systems. These interventions follow a top-down approach with procedures based on successes from high-input production systems which have appropriate infrastructure and trained personnel. There are indigenous approaches which farmers in low-input production systems use to manage their herds, set breeding goals, design mating systems and manage reproductive challenges. This narrative review explores the potential of utilizing this indigenous knowledge in integrated strategies to improve cattle reproductive efficiency in sub-Saharan Africa. An extensive review of existing global literature that explored indigenous knowledge on cattle reproductive management as well as closely related integration studies was conducted. It was found that resource-limited farmers select breeding cattle using traits that improve and maintain the herd's survivability and adaptability such as a white coat color being preferred for easy traceability in deep forest and bull body size associated with masculinity. They use indigenous remedies to improve reproductive health such as oral administration of Elephant's root and Velvet Bushwillow to prevent and cure dystocia, treating retained placenta and clearing infections which may cause abortion in cows. Furthermore, farmers select fast growing bulls which indicate their dam's superior mothering ability and heifers with a pelvis that has a wide sloped rump for easier calving. Pregnancy evaluation is mostly visual with udder and abdominal growth which indicate prominent milk production and fetal growth. Challenges that hinder the adoption of these approaches should be addressed and policies that recognize these indigenous strategies should be developed and promoted.

KEYWORDS

low-input, cultural beliefs, food security, conventional knowledge, sustainable

1 Introduction

Due to different production objectives, cattle reproduction efficiency varies by country, management practices and technology used (Perin et al., 2022). Several studies have reported low cattle reproductive efficiency specifically in low input production systems of sub-Saharan Africa (Abin et al., 2018; Olum et al., 2020; Tolasa and Andure, 2021; Nengovhela et al., 2021;

Nkadimeng et al., 2022a; Dauda et al., 2023). This is a major challenge since cattle production has a strategic development role, especially in supporting the achievement of food security (Suganda et al., 2022). Cattle play a unique role of converting low quality forage to high quality protein for human consumption around the world (Zoma-Traoré et al., 2021). Therefore, cattle that are reproductively efficient are fundamental to meeting the high food demand (Diskin and Kenny, 2014) and indigenous requirements. The increasing demand for animal protein can be met by adopting better reproductive strategies and interventions to improve efficiency.

Artificial insemination, in-vitro embryo production, breeding soundness evaluation as well as pregnancy diagnoses techniques have been developed and implemented (Agutu et al., 2023; Mugwabana et al., 2018). Although these interventions are successful in improving cattle reproduction efficiency (Raphalalani et al., 2020; Soumya et al., 2022) and high economic returns (Temesgen et al., 2022; Tadesse et al., 2022), they face challenges of ensuring equitable access to benefits and are unsustainable in low-input production systems. They are costly, require trained personnel as well as sophisticated equipment (Lamb et al., 2016; Mugwabana et al., 2018). These interventions, furthermore, do not consider the indigenous norms and cultural beliefs of low-input cattle producers. The epistemology of this indigenous knowledge (IK) of cattle production is not fully understood (Smith et al., 2017) by intervention developers. The interventions have mostly been focused on the top-down approach and farmers treated as passive followers (Wicaksono et al., 2025). This focus makes it challenging to achieve improved cattle reproduction with adoption of IK (Marandure et al., 2020).

Conventional strategies undoubtedly cannot solve complex production challenges in low input production systems and IK should not be neglected. Low input farmers have had their own way of advancing cattle production prior to the introduction of conventional farming methods (Diko, 2023) and they continue to rely on IK to manage their herd (Malapane et al., 2024). Strategies for improving cattle reproductive efficiency should, ideally, be based on IK. While this knowledge may not always be directly supported by formal evidence, it can be a valuable resource. This can be by offering insight (Melash et al., 2023) and identify potential areas for further studies. Furthermore, IK can contribute to a more holistic approach (Mapiye et al., 2019) of the topic by fostering cultural understanding (Getyengana et al., 2023) without being a substitute for conventional strategies.

Indigenous knowledge is a science that has been tested in the harsh laboratory of survival from practical engagement in everyday life and constantly reinforced by experience, trial and error (Senanayake, 2006). It is cost-effective (Kenasew et al., 2025) and sustainable (Rankoana, 2024) since it has been practiced without the need for relying heavily on external inputs. This knowledge is rarely included in development interventions and not found in public domains (Ncube et al., 2025). Therefore, the aim of this narrative review is to explore the potential of utilizing IK in integrated strategies to improve cattle reproductive efficiency in sub-Saharan Africa. An extensive review of existing literature on indigenous knowledge of cattle reproduction in sub-Saharan Africa as well as closely related integration studies was conducted. Cattle reproduction rates and important constraints to cattle reproductive efficiency in low-input production systems of sub-Saharan Africa are elaborated. Some of the documented indigenous cattle reproductive management practices as well as opportunities for their utilization are discussed.

2 Reproduction rates in low-input production systems

Cattle production systems are diverse, ranging from low-input, pastoral production systems in the arid and semiarid regions to highly intensive production systems (Soumya et al., 2022). A low-input farming system is described as a system which optimizes use of on-farm resources and minimizes the use of production inputs to lower the cost of production (Ibeawuchi et al., 2015). These systems are described as small scale and consist of agro-pastoral, rural landless and peri-urban poor farmers who keep a few cattle as part of a diverse livelihood strategy (Grace et al., 2017). Cattle in these systems are mainly produced with minimal feeding, housing, health and breeding management, as such production tends to be low (Banda and Tanganyika, 2021).

There are recommended reproduction rates set for efficient cattle production (Table 1) and the high input production systems can meet them by utilizing improved management strategies. The costs associated with these improved strategies have been justified through increased income and improved herds (Gicheha et al., 2019). However, in many developing countries which practice low-input farming, much lower reproduction rate has been reported. For example, a 0.8 calf per cow per year (Davis and White, 2020) is expected in high input production system where else a cow in low-input production systems rarely conceive within a year of calving, with calving intervals of between 2 and 3 years (Nengovhela et al., 2021). Nonetheless, in sub-Sahara Africa reproduction rates of less than 50% (Grobler et al., 2010; Nqeno et al., 2010) are frequently reported, despite rural communities benefitting immensely from milk, meat and other services produced using IK with little to no input (Terry et al., 2021).

Age at first calving marks the beginning of a heifer's reproductive life and the earlier this age is reached, the more calves that heifer will produce in its lifetime (Shaanika, 2019). In most low-input production systems, breeding is often uncontrolled and breeding heifers at first opportunity is a norm (Budisatria et al., 2019). Therefore, age at first calving of between 36 to 48 months have been reported (Budisatria et al., 2019; Shaanika, 2019). The ideal calving interval of a cow is expected to be 12 months based on the estimated 285 days gestation and 82 days open (Bareki et al., 2024). Most cows raised in low-input production systems are, however reported to be in the range of 13 to 48 months (Richards et al., 2019; Duro, 2022; Nkadimeng et al., 2022a). Furthermore, the unavoidable period of infertility post-partum where cows do not experience oestrus (Budisatria et al., 2019) usually lasts up to 40 days in high input production systems (Mohammed Ali, 2024). Because this period is affected by the suckling effect, heat stress and nutritional status of the cow, it is usually well managed in high input production systems to ensure that cows return to oestrus in an economically efficient way (Budisatria et al., 2019). In low-input production systems, cows return to estrus after 60 to 84 days post calving (Kamal et al., 2014) which further increases the inter-calving period and reduces reproductive efficiency.

Rearing bulls for draught purposes and social prestige in low-input production system is common, and their selection is usually done after 3 years of age (Aseged et al., 2023) using indigenous selection criteria. For bulls to be considered good enough for mating, it should produce enough progressive motile spermatozoa (McCrindle et al., 2019). McCrindle et al. (2019) reported that, in low-input production systems of South Africa, most bulls had a progressive

TABLE 1 Reproduction rate of cattle in low-input production system and practical recommendations for efficient cattle reproductive efficiency.

Measure	Reproduction rates	Reference	Recommended level	Reference
Age at first calving	36–52 months	Budisatria et al. (2019); Shaanika (2019); Ayele Lombebo (2019)	24 months	Diskin and Kenny (2014)
Calving interval	13–48 months	Richards et al. (2019); Duro (2022); Nkadimeng et al. (2022a)	12 months	Bareki et al. (2024)
Days open	152–253 days	Shaanika (2019); Nkadimeng et al. (2022a)	80–82 days	Washaya et al. (2024)
Oestrus post-calving	60–84 days	Kamal et al. (2014)	30–40 days	Mohammed Ali (2024)
Calving rates	25–60%	Grobler et al. (2010); Delay et al. (2020)	>65%	Grobler et al. (2019)
Bull to cow ratio	1:32–1:38	Grobler et al. (2010)	1:30	Timlin et al. (2021)
Progressive sperm motility	<30%	McCrindle et al. (2019)	>30%	Chenoweth and Mcpherson (2016)

motility which was below the recommended 30% (Chenoweth and Mcpherson, 2016). A bull with low quality semen requires more than one service to get a cow pregnant (McCrindle et al., 2019). Moreover, most farmers in low-input system do not own a bull and rely solely on indigenous bull sharing practices due to shortage of manpower and resources which lead to a high bull to cow ratio of more than 1:38 (Grobler et al., 2010). A ratio of 1:30 is recommended for mature bulls (Timlin et al., 2021). Nonetheless, sharing indigenous bull has an advantage of lowering inbreeding and cutting labor as well as costs of maintenance for these low-input farmers.

3 Constraints to cattle reproduction efficiency

A calf is the sole output of any cattle production system (Diskin and Kenny, 2014). Calving rates in high-input production systems usually exceeds 50% (Grobler et al., 2010). The major factors affecting cattle reproduction in both systems are climate change, nutrition, production goals as well as reproductive inefficiencies. Furthermore, in low-input production system, cultural beliefs which focus on indigenous cattle management also influence cattle reproductive efficiency.

3.1 Climate change

Climatic stressors such as cold, heat, humidity, rain, ice as well as wind can cause chronic stress to cattle because they usually stand outside during most of the year. Of all these climate stressors, heat stress is the most studied. It affects both cattle welfare and fertility (Capela et al., 2025). It reduces fertilization rate and embryo quality and consequently increasing the rate of pregnancy loss (Fernandez-Novo et al., 2020). Incidences of silent estruses increase (Ţogoe and Mincă, 2024) making it difficult to initiate mating. In bulls, heat stress reduces spermatogenesis (Capela et al., 2022) as well as testosterone and spermatozoa quality (Ko, 2024).

Building proper facilities to house dairy cattle and protect them from environmental stressors have been adopted to reduce economic losses and increase herd productivity (Arnott et al., 2017). Selecting beef cattle for physiological traits and high immune response to heat stress has also been suggested for extensive cattle production systems (Cartwright et al., 2023). Applicability and sustainability of these technologies, however, depends on breed, environmental conditions and type of production system used (Ţogoe and Mincă, 2024). Madhusoodan et al. (2019) suggested that cost effective strategies that involve indigenous knowledge have the better success rate among low-input farmers.

3.2 Reproduction inefficiencies

Reproductive efficiency is mainly influenced by age at puberty, age at first conception, duration of post-partum anestrus and total lifetime productivity (Burns et al., 2010). Several reproductive inefficiencies have a significant effect on herd profitability in both high-input (Tanimura et al., 2022) and low-input production systems (Molefe and Mwanza, 2019; Robi et al., 2021). Commonly reported challenges are anestrous, repeat breeding, abortion, vaginal prolapse, dystocia, retained fetal membrane, still births and uterine prolapse (Abdisa, 2018). These challenges reduce fertility, preventing conception, creating problems in the delivery of healthy calves which ultimately lead to postpartum complications and increase inter-calving periods (Deka et al., 2021).

Infectious diseases, shortage of feed, management as well as mechanical issues have been cited as some of the causes of reproductive inefficiency in the low-input production systems (Molefe and Mwanza, 2019; Robi et al., 2021). It is expected that indigenous cattle, which are predominant in low-input production systems, suffer fewer reproductive problems due to their better adaptation to local climatic conditions and high tolerance to various reproductive diseases (Deka et al., 2021). Molefe and Mwanza (2019) reported an increase in likelihood of abortion and retained placenta following veterinary pregnancy diagnosis. In such instances, indigenous methods involving visual examinations of pregnancy (Olmo et al., 2019; Bulcha et al., 2022) may be better alternatives in low-input production systems instead of routine veterinarian examination (Carpenter and Sprott, 2008).

3.3 Inadequate nutrition

The normal function of reproductive system requires energy balance through proper nutritional intake (Nigussie, 2018). These reproduction functions can be inhibited when feed availability is too high or too low and when increased energy demands are not met by compensatory feed intake (Garcia-Garcia, 2012). Reproduction in cattle is energy intensive. Much of the variations in cattle reproductive performances reported in practical production conditions in low and high-input production systems are attributed to energy intake (Bischoff et al., 2012). In low-input farming systems, malnutrition is the main factor causing low calving rates and ultimately resulting in poor body condition and failure of the dam to reconceive (Nowers et al., 2013; Nqeno et al., 2010). On the other hand, feeding excess energy reduces both semen quality and serving capacity of bulls (du Preez et al., 2021). Energy restriction delays the ever-critical onset of puberty. Furthermore, low body condition score reduces pregnancy success in cows throughout their productive lifespan (D'Occhio et al., 2019; Moorey and Biase, 2020). Using a 5-point scale, a score of between 2.5 and 3 is desired for maintaining energy balance and supporting reproduction at herd level (Bell et al., 2018).

3.4 Production goals

In low-input cattle farming systems, production goals are usually influenced by indigenous knowledge, traditional values, economic pressure as well as affordability to improved practices (Fontes et al., 2020; File and Nhamo, 2023). Neighboring herds mix freely due to poor infrastructure and inferior bulls are not castrated which results in uncontrolled breeding (Molefi et al., 2017). As such, uncontrolled breeding (Bulcha et al., 2022) as well as poor reproductive management (Mthi et al., 2020) are some of the major factors affecting reproduction efficiency in low-input production systems.

Contrary to low-input production systems, reproductive management in high-input production systems is mostly influenced by market requirements as well as profit potential (Scholtz and Jordaan, 2025). There is up-to date recording, in most cases computerized to enhance evaluation schemes (Mueller et al., 2015), selection breeding stock (Shah et al., 2021), controlled breeding season (Grobler et al., 2019) as well as strategic supplementation (Hess et al., 2004). Therefore, development strategies should consider the cattle production goals of low-input farmers which will influence how reproductive management of cattle is designed to meet specific cultural, social and household goals.

3.5 Cultural beliefs

Most low-input production systems are practiced by indigenous communities and cattle farming forms part of socio-cultural identity and community expression in addition to sustenance (Dabasso et al., 2022). The role cattle play in these communities range from providing food security and income to fulfilling cultural or religious roles, providing ecosystem services and satisfying their owners' passion and social hierarchy (Busch, 2023). Furthermore, the way cattle are looked after in these communities display the existence of a complex relationship between the farmers and their belief systems (Shava and Masuku, 2019). These belief systems contribute to cattle reproductive efficiency. Some of these cultural practices and beliefs are shown in Table 2.

These inherited cultural management practices and beliefs are less investigated factors influencing cattle reproduction efficiency (Ade and Silas, 2020). Not culling unproductive cows (Nkadimeng et al., 2022b) and keeping old infertile bulls (Mgongo et al., 2014) is common in most low-input production systems. Cows remain in the herd as a symbol of social status for the owners which results in overstocking and underproductive herds. Furthermore, in Zimbabwe, reducing cattle number through culling is seen as being insensitive to traditional expectations (Ndlovu and Mjimba, 2021). Farmers in Benin consider the Legune cattle breed sacred, and they value cultural importance over production (Ahozonlin et al., 2022) which can lead to reproductive traits not being used for selection. Breeding stock selection in most low-input production systems has nothing to do with reproduction but more with social norms (Gudeto et al., 2021; Aseged et al., 2023; Nyamushamba et al., 2017). Staying within these boundaries of conformity is important (Zoma-Traoré et al., 2021). For example, heifers are selected for good physical appearances for their owner's pleasure and social hierarchy in Ethiopia (Gudeto et al., 2021). Some farmers prefer to select their bull for their coat color (Mthi et al., 2020; Aseged et al., 2023). The white coat color of Begaria cattle in Ethiopia is preferred with some tribes citing cultural interest, cattle purity and easily tracing their cattle in deep forests (Aseged et al., 2023).

These are just some of the only documented cultural practices and more of them do exist specifically in sub-Saharan Africa. Most of these beliefs cannot be changed; therefore, working with these communities using indigenous knowledge to develop improvement strategies that preserve them and improve cattle reproduction for food security are required. Careful integration of cultural norms and new development strategies are required so that the interventions could be both beneficial to the communities and sustainable.

TABLE 2 Cultural practices which contribute to cattle reproductive efficiency in low input systems of sub-Saharan Africa.

Country	Practice	Effects	Reference
South Africa	Not culling unproductive cows	Overstocking and underproductive herds	Nkadimeng et al. (2022b)
Kenya	Male dominated decision making	Limit potential reproductive gains	Mutua et al. (2024)
Tanzania	Not culling old and infertile bulls	Reduces conception rate, increases inbreeding, genetic deterioration as well as low overall herd fertility	Mgongo et al. (2014)
Nigeria	Uncontrolled breeding	Increase risk of infertile mating and inbreeding	Gwaza and Yahaya (2018)
Benin	Valuing cultural importance over production as well as considering a breed sacred.	Limited selection for reproductive traits. Reproduction is secondary to ceremonial and cultural functions	Ahozonlin et al. (2022)
Ethiopia	Selecting cattle for owners' preference of physical appearance	Selecting cattle for reproductive traits is limited	Gudeto et al. (2021); Aseged et al. (2023)
Southern Africa	Social capital and bride price	Cattle not optimally bred and kept in the herd for too long	Nyamushamba et al. (2017)

4 Exploiting indigenous knowledge to improve reproduction efficiency

Indigenous knowledge has been undermined because of the prominence given to conventional technology as a superior knowledge (Gashute and Hale, 2023) and the prioritization of economic value over cultural heritage. Exploiting IK of managing herds, setting breeding goals, and designing mating systems within the low-input farming system is of paramount importance (Gudeto et al., 2021). Communities have had their way of advancing agriculture prior to the introduction of modern conventional farming methods (Diko, 2023) and they continue to rely on IK to manage their cattle (Kanuya et al., 2006). Incorporating reproductive management practices used by IK holders in cattle improvement programs could prove effective in improving cattle production in a cost-effective and sustainable way. In many cases, the cattle improvement interventions have prioritized economically driven benefits of cattle production at the expense of environmental and social principles (Marandure et al., 2020).

In low-input production systems, several cattle reproductive management strategies have been utilized effectively without requiring external inputs (Table 3). Most of them are, however, not fully validated and elaborated in literature and therefore cannot effectively be disseminated or integrated into cattle reproductive improvement interventions. There is a need to document indigenous knowledge of cattle reproductive management. One promising example is the non-invasive and inexpensive seed germination cow pregnancy test first reported in Egypt and further studies done in Nigeria and Zambia (Okunlola et al., 2019; Sianangama et al., 2022). This involves collecting a sample of cow urine and adding it to wheat or maize seeds which are evaluated after 5 days for germination. The urine of pregnant cows is thought to inhibit seed germination. Abscisic acid is higher in urine of pregnant cows than in non-pregnant cows (Veena et al., 1997). Most reproductive performance evaluation methods used in low-input farming systems are this simple.

Other visual methods have been utilized to select breeding bulls and heifers as well as evaluate cow mothering ability which have scientific merit. For example, the anatomy and confirmation of the bull are important traits which if not selected properly, may lead to unsoundness as they grow and reduce fertility in the form of low libido as well as being unable to breed (Wolfe, 2018). Farmers using IK to select their bulls know the importance of these traits and select bulls using length of penis envelope, testicle size (Marshall et al., 2016), body size (Ouédraogo et al., 2021), body length as well as strong neck and legs (Aseged et al., 2023). Getu and Misganaw (2015) indicated that cows with large naval flaps as well as well-developed udder with prominent milk veins are docile and good milk yielders. A wide and correctly sloped rump furthermore shows a pelvic structure that allows easier birth and prevents fertility-related challenges (Getu and Misganaw, 2015). Indigenous reproductive evaluation of heifers includes naval flap size, teat size as well as pelvic width (Bulcha et al., 2022). Cow's udder grows in volume during pregnancy due to an increase in number of secretory cells which is stimulated by increasing progesterone and estrogen concentrations (Hartanto et al., 2023). Calf growth which is usually assessed at weaning is the best measure of mothering ability as well as milk yield which represent overall cow productivity (Sapkota et al., 2020).

Across the world, specifically in sub-Saharan Africa, majority of cattle are managed under low-input production systems where cows are bred by natural service which shows how important selecting bull for fertility is (Diskin and Kenny, 2014). A few farmers select bulls and rear them for breeding purposes. Those farmers who do select bulls for breeding purposes usually use body size which is associated with masculinity and docility as important criteria for selection (Gudeto et al., 2021). Body weight which is correlated with body size (Shoimah et al., 2021) at a specific age is the most determinant factor for deciding whether a bull has reached active reproduction or not in Ethiopia (Mohammed Ali, 2024). In low-input production systems of Somalia, a bull is considered fertile when it has large testicles and long length of penis envelope (Marshall et al., 2016). Fast growing bulls are selected in Kenya because they are genetically superior and because it is an indication that their dam had high milk yield trait which will be manifested and useful in the bull's future female calves (Aseged et al., 2023).

Resource-poor farmers in Sub-Saharan Arica tend to select the best cows based on different cost-effective phenotypic characteristics (Gudeto et al., 2021). A heifer is selected in Ethiopia for its long body size which is said to have higher abdominal space for the growing fetus and wide pelvic region for lower incidences of dystocia (Gudeto et al., 2021; Bulcha et al., 2022). The mothering ability of a cow as well as its milk production and calf growth are used to select heifers for future breeding in South Africa (Mthi et al., 2020). These management practices are further discussed in Table 3 with suggestions of practical validation

TABLE 3 Indigenous Knowledge practices of cattle reproduction documented in sub-Saharan Africa.

Reproductive management	Indigenous knowledge practice	Scientific validation	Practical validation approach
Reproductive health	Herbal treatment of retained placenta (Ezeanya-Esiobu et al., 2021)	Not validated	Conducting controlled trials to compare treated and untreated cattle in terms of placenta expulsion time, fertility and complications post treatment. Evaluate safety and efficacy while also respecting the traditional practice (Chakale et al., 2021).
Breeding material selection	Selection of breeding heifers using phenotypical characteristics (Bulcha et al., 2022)	Partially validated (biological plausibility; Adinata et al., 2022)	Correlation studies to measure selected traits versus lifetime productivity (Koirala et al., 2011).
Breeding material selection	Selection of bulls using growth pattern (Aseged et al., 2023)	Partially validated (Aktar et al., 2012)	Progeny testing as well as correlation of bull growth and reproductive performance (Scheepers et al., 2010).
Pregnancy evaluation	Seed gemination using cow urine (Veena et al., 1997)	Validated (Okunlola et al., 2019; Sianangama et al., 2022)	Participatory trials comparing gemination while also documenting traditional preparation, administration, and cultural context of the practice (Appiah, 2020)

approaches which can be used to validate other undocumented indigenous cattle reproductive management practices. They can be useful in developing improved strategies while keeping the distinct feature of indigenous knowledge systems (Gashute and Hale, 2023).

An example of improved strategies would be the parallel use of IK and conventional medicine to control gastrointestinal parasites of goats by smallholder farmers (Ndlela et al., 2022), which shows how complementarity these two practices can be. Ezeanya-Esiobu et al. (2021) reported the use of pounded leaves to speed up the process of placenta and afterbirth discharge as well as treat retained placenta in cows. The recognition that IK is effective at managing animal health challenges is very important (Kamba and Chimonyo, 2022) and provides potential to explore other opportunities for integrated knowledge in improving cattle production such as improving reproductive efficiency. For example, Kamba (2023) highlighted the use of medicinal plants by low-input cattle farmers in South Arica to manipulate reproductive efficiency. These farmers used medicinal plants such as elephant's root and Velvet Bushwillow in preventing and curing dystocia, treating retained placenta, clearing infections that caused abortions and reducing the period between calving and the next estrus. The global beef cattle industry could benefit dearly by not treating these low-input farmers as passive followers and learn to focus on the strength and limitations of both sides.

5 Validation as a constraint to adopting indigenous knowledge

The importance of indigenous knowledge remains more of a formality than reality because practical acknowledgement often falls short (Roue and Nakashima, 2018). This knowledge is often confined to cultural and spiritual domain, undermining its broader significance. There are opinions from the science community that indigenous knowledge is 'junk science' and evidence derived from testing using conventional methods is required before accepting it as a science (De Beer and Van Wyk, 2021). This reflects on the issue of power dynamics where conventional knowledge is regarded as superior science, sets the norm and validates other knowledges while indigenous knowledge is regarded as inferior science (Roue and Nakashima, 2018).

The analysis and validation carry a risk of altering indigenous knowledge and can lead to disempowerment of indigenous knowledge holding communities (De Beer and Van Wyk, 2021). By trying to assess accuracy of such indigenous knowledge from an external view, Chikodzi et al. (2013) noted that a concern may arises because information is being applied and evaluated for purposes that may not be the same from which it was originally created. This is because conventional knowledge process may not fully understand the epistemology of indigenous knowledge (Smith et al., 2017). In most instances, the value of indigenous knowledge is mainly within the community in which it was developed, and its accuracy depends on its applicability not external evaluation (Chikodzi et al., 2013).

Indeed, it is important to validate any process to assess its broader significance. This validation needs to be done in a respectful manner through collaboration and acknowledgement without claiming superiority (Roue and Nakashima, 2018). This validation will assist in recognizing indigenous knowledge of cattle reproduction as vital for addressing cattle reproduction challenges alongside conventional knowledge. This will also address the challenge of policymakers perceiving IK as cultural rather than productive practice (Mapiye et al., 2019). Table 4 demonstrates these challenges as well as suggestions of how validation can be approached in a respectful and collaborative manner.

A study done in Kalosa and Gairo district of Tanzania illustrated co-creation of knowledge between indigenous communities and formal science (Mgongo et al., 2014). Farmers documented their breeding methods such as seasonality, bull usage and separation. They then collected reproductive performance data such as calving rate and compared IK methods from different household. This data was used to link Indigenous knowledge practices with reproductive performances to not only describe but associate them with measurable outcomes. There was comparing and validation of IK practices at the same time. The finding from this study helps in co-creating improved practices that build on what works locally. Similarly to a study done in Ethiopia (Hunde et al., 2024) for community-based breeding program, the farmers and scientist jointly chose the traits which needed to be improved. This led to improvement of the chosen straits because the goals aligned with farmers priority.

TABLE 4 Challenges and potential solutions for validating IK in cattle reproduction.

Challenges	Consequences	Potential solution
Information orally transmitted	Not simple to document and compare which poses a risk of losing meaning and quality (Malapane et al., 2024).	Use of participatory rural appraisal, focus group discussion as well as storytelling (Prajapati et al., 2025). Also, qualitative narrative and on-farm trials can be combined to generate measurable indicators (File and Nhamo, 2023).
Cultural and ethical concern.	Risk of disrespect of spiritual practices and community losing control (Gratani et al., 2011).	Obtaining informed consent (Cooper et al., 2016). Creating benefit sharing agreements and intellectual property recognition (Meyer and Naicker, 2023)
Mismatch with conventional knowledge validation	Standard conventional methods may not take into consideration holistic or seasonal aspects of IK (Kamba and Chimonyo, 2022).	Hybrid indicator development such as combination of animal health and local ecological signs (Lawal-Adebowale, 2020). Forming interdisciplinary teams to co-design protocols (Specht and Crowston, 2022)
Resource and policy limits	Limited funding and institutional support. No policy pathway for integrating IK (Chakale et al., 2021; Van der Merwe et al., 2001).	Integrating IK validation processes into extension and livestock research policy (Masambuka-Kanchewa et al., 2022). Advocate for specially dedicated grants and support partnership.
Intergenerational knowledge gap	Younger community member preferring formal education leading to loss of IK (Malapane et al., 2024)	Support mentorship and youth engagement programs (Sanchez et al., 2023). Extending school curriculum by including IK (Malapane et al., 2024).

6 Way forward on integration of the two knowledge systems

The utilization of IK to improve reproduction of cattle in sub-Saharan Africa should focus on the following with a conceptual diagram of this shown in Figure 1.

1 Understanding local practices for breeding, heat detection, and calf management. This includes recognizing cultural beliefs as well as social norms that guide these practices.
2 Integrating IK with conventional principles such as the consideration of local calving seasons and how they influence breeding strategies. Exploring traditional methods of identifying and treating common reproductive disorders and integrates them with modern veterinary practices. Where applicable a combination of traditional heat detection with artificial insemination to improve breeding efficiency.
3 Community involvement where platforms for farmers to share their knowledge and experiences should be established which will help foster a sense of community and collaborative learning. This can further be used as a platform to document and preserve their IK to ensure its continued relevance and use in future generations.
4 Addressing barrier by promoting collaboration between researchers, extension workers and farmers to ensure that IK is effectively incorporated into breeding programs. Furthermore, access should be provided for essential resources such as quality feed, healthcare and infrastructure to support improved cattle reproductive performance.

7 Conclusion and recommendations

There is IK that exists in the management of cattle reproductive efficiency in low-input farming system across the world. Reports from various countries such as Ethiopia and South Africa show that there is a diversity of IK which include, bull and heifer selection, breeding management, pregnancy diagnosis as well as use of indigenous medicine to manipulate cattle reproductive efficiency. Most of these indigenous cattle reproductive management strategies are not documented and cannot be appreciated and shared effectively. Their complexity should be studied as well as cultural norms and practices that surrounding them. Validation which is required to adopt these practices should be done in a respectful and collaborative manner. Careful consideration of these cultural sensitivities and active engagement with indigenous communities would ensure that their indigenous knowledge is ethically and meaningfully adopted. This equitable partnership is crucial because it will ensure that the unique features that make IK valuable are not lost. This is even more important because culture plays a significant role in cattle production under low-input production systems.

It is, therefore, recommended that participatory research should be conducted with indigenous communities to document and understand exciting knowledge of managing cattle reproduction. This should be done through in-depth interview and focus group discussion with indigenous knowledge holders as well as visually capturing specified reproductive management practices. The documented practices should then be analyzed to identify practices that can be validated, adapted and improved on to address the challenge of cattle reproductive efficiency. Barriers that hinder the adoption of IK should be addressed and policies that recognize these indigenous strategies should be developed and promoted.

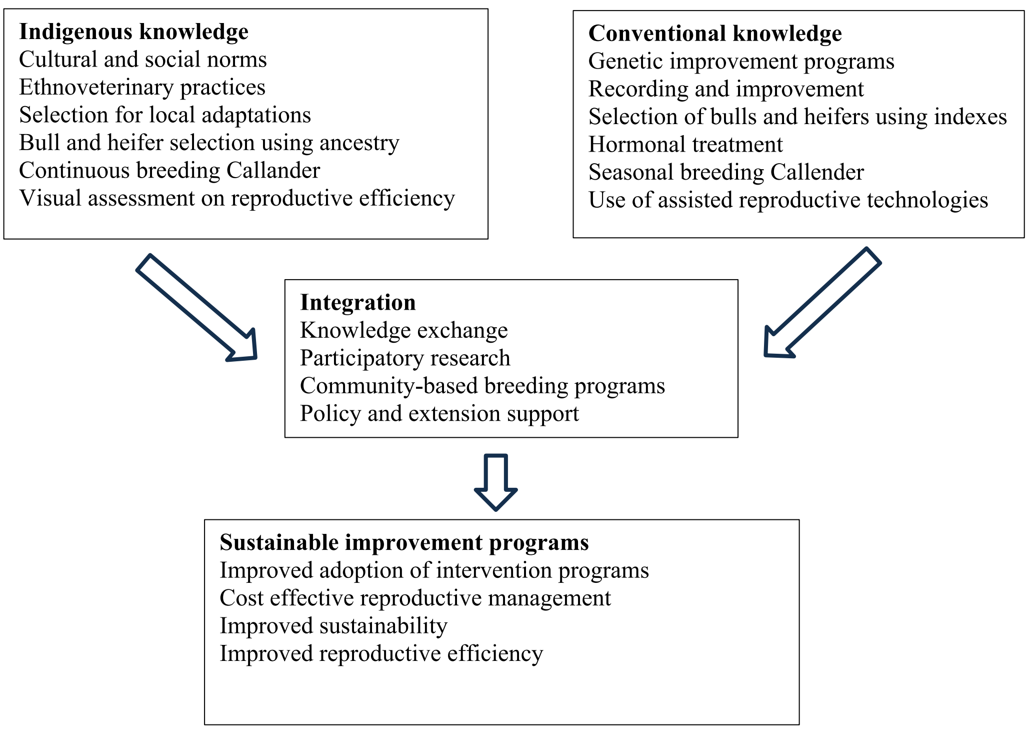

FIGURE 1
Addressing cattle reproduction efficiency through integration.

Author contributions

ZR: Conceptualization, Writing – original draft, Writing – review & editing. DM: Supervision, Writing – original draft, Writing – review & editing. MC: Supervision, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

References

Abdisa, T. (2018). Review on the reproductive health problem of dairy cattle. *J. Dairy Vet. Sci.* 5:655. doi: 10.19080/jdvs.2018.05.555655

Abin, S., Visser, C., and Banga, C. B. (2018). Comparative performance of dairy cows in low-input smallholder and high-input production systems in South Africa. *Trop. Anim. Health Prod.* 50, 1479–1484. doi: 10.1007/s11250-018-1584-9

Ade, A., and Silas, E. (2020). The role of culture in achieving sustainable agriculture in South Africa: examining Zulu cultural views and management practices of livestock and its productivity. *IntechOpen.* doi: 10.5772/intechopen.86759

Adinata, Y., Noor, R. R., Priyanto, R., Cyrilla, L., and Sudrajad, P. (2022). The relationship between frame score, calving interval, and body mass index in Indonesian beef cattle. *J. Hunan Univ. Nat. Sci.* 49, 142–149. doi: 10.55463/issn.1674-2974.49.9.16

Agutu, F. O., Mbuku, S. M., Ondiek, J. O., and Bebe, B. O. (2023). Preferential use of Sahiwal bull calves by beneficiaries of assisted reproductive technologies in southern rangelands of Kenya. *Eur. J. Agric. Food Sci.* 5, 17–24. doi: 10.24018/ejfood.2023.5.3.686

Ahozonlin, M. C., Gbangboche, A. B., and Dossa, L. H. (2022). Current knowledge on the Lagune cattle breed in Benin: a state of the art review. *Ruminants* 2, 271–281. doi: 10.3390/ruminants2020018

Aktar, S., Bhuiyan, A. K. F. H., Saha, N. G., and Hoque, M. A. (2012). Effect of bull performance on progeny early growth and genetic relationships between bull and progeny traits. *Bangladesh J. Animal Sci.* 40, 1–7. doi: 10.3329/bjas.v40i1-2.10620

Appiah, R. (2020). Community-based participatory research in rural African contexts: Ethico-cultural considerations and lessons from Ghana. *Public Health Rev.* 41:145. doi: 10.1186/s40985-020-00145-2

Arnott, G., Ferris, C. P., and O'connell, N. E. (2017). Review: welfare of dairy cows in continuously housed and pasture-based production systems. *Animal* 11, 261–273. doi: 10.1017/S1751731116001336

Aseged, T., Getachew, T., Banerjee, S., Belayhun, T., Melak, A., Engdawork, A., et al. (2023). Production systems and breeding practices of Begaria cattle breed as input for a community-based breeding program. *Heliyon* 9:e21963. doi: 10.1016/j.heliyon.2023.e21963

Ayele Lombebo, W. (2019). Reproductive and productive performances of local cows under farmer's Management in Soro District, Hadiya Zone, Southern Ethiopia. Research & Reviews: Journal of Agriculture and Allied Sciences, Delhi, India.

Banda, L. J., and Tanganyika, J. (2021). Livestock provide more than food in smallholder production systems of developing countries. *Anim. Front.* 11, 7–14. doi: 10.1093/af/vfab001

Bareki, N. P., Kgaswane, S. K., and Kgaswane, M. D. (2024). Evaluation of calving interval of smallholder beef cattle herds in the Dr Kenneth Kaunda District, north West Province, South Africa. *Appl. Anim. Husb. Rural Dev.* 17, 12–17. Available at: https://www.sasas.co.za/wp-content/uploads/2024/03/Bareki-2024-Vol-17-1.pdf (Accessed February 15, 2025).

Bell, M. J., Maak, M., Sorley, M., and Proud, R. (2018). Comparison of methods for monitoring the body condition of dairy cows. *Front. Sustain. Food Syst.* 2:080. doi: 10.3389/fsufs.2018.00080

Bischoff, K., Mercadante, V., and Lamb, G. C. (2012). Management of postpartum anestrus in beef cows. *Edis* 2012, 1–4. doi: 10.32473/edis-an277-2012

Budisatria, I. G. S., Baliarti, E., Satya, T., Widi, M., Ibrahim, A., and Andri, B. (2019). Reproductive management and performances of Aceh cows, local Indonesian cattle kept by farmers in a traditional system. *Am. J. Sustain. Agric.* 13, 20–31. doi: 10.22587/aejsa.2019.13.3.3

Bulcha, G. G., Dewo, O. G., Desta, M. A., and Nwogwugwu, C. P. (2022). Indigenous knowledge of farmers in breeding practice and selection criteria of dairy cows at Chora and Gechi districts of Ethiopia: an implication for genetic improvements. *Vet. Med. Int.* 2022, 1–5. doi: 10.1155/2022/3763724

Burns, B. M., Fordyce, G., and Holroyd, R. G. (2010). A review of factors that impact on the capacity of beef cattle females to conceive, maintain a pregnancy and wean a calf-implications for reproductive efficiency in northern Australia. *Anim. Reprod. Sci.* 122, 1–22. doi: 10.1016/j.anireprosci.2010.04.010

Busch, G. (2023). Social aspects of livestock farming around the globe. *Animal Front.* 13, 3–4. doi: 10.1093/af/vfac080

Capela, L., Leites, I., and Pereira, R. M. L. N. (2025). Heat stress from calving tonmating: mechanisms and impact onncattle fertility. *Animals* 15:1747. doi: 10.3390/ani15121747

Capela, L., Leites, I., Romão, R., Lopes-Da-costa, L., and Pereira, R. M. L. N. (2022). Impact of heat stress on bovine sperm quality and competence. *Animals* 12, 1–11. doi: 10.3390/ani12080975

Carpenter, B. B., and Sprott, L. R. (2008). Determining pregnancy in cattle. *Cereb. Cortex* 24, 1119–1126. Available at: https://hdl.handle.net/1969.1/87072 (Accessed November 17, 2024).

Cartwright, S. L., Schmied, J., Karrow, N., and Mallard, B. A. (2023). Impact of heat stress on dairy cattle and selection strategies for thermotolerance: a review. *Front. Vet. Sci.* 10, 1–13. doi: 10.3389/fvets.2023.1198697

Chakale, M. v., Mwanza, M., and Aremu, A. O. (2021). Ethnoveterinary knowledge and biological evaluation of plants used for mitigating cattle diseases: a critical insight into the trends and patterns in South Africa. *Front. Vet. Sci.* 8:884. doi: 10.3389/fvets.2021.710884

Chenoweth, P. J., and Mcpherson, F. J. (2016). Bull breeding soundness, semen evaluation and cattle productivity. *Anim. Reprod. Sci.* 169, 32–36. doi: 10.1016/j.anireprosci.2016.03.001

Chikodzi, D., Murwendo, T., and Simba, F. M. (2013). Reliability of indigenous knowledge in monitoring and mapping groundwater fluctuations in Zimbabwe. *Int. J. Dev. Sustain.* 3, 231–241. Available at: https://isdsnet.com/ijds-v3n1-15.pdf (Accessed July 15, 2025).

Cooper, T. L., Kirino, Y., Alonso, S., Lindahl, J., and Grace, D. (2016). Towards better-informed consent: research with livestock-keepers and informal traders in East Africa. *Prev. Vet. Med.* 128, 135–141. doi: 10.1016/j.prevetmed.2016.04.008

D'Occhio, M. J., Baruselli, P. S., and Campanile, G. (2019). Influence of nutrition, body condition, and metabolic status on reproduction in female beef cattle: a review. *Theriogenology* 125, 277–284. doi: 10.1016/j.theriogenology.2018.11.010

Dabasso, B. G., Makokha, A. O., Onyango, A. N., and Mathara, J. M. (2022). Beyond nutrition: social–cultural values of meat and meat products among the Borana people of northern Kenya. *J. Ethn. Foods* 9:160-5. doi: 10.1186/s42779-022-00160-5

Dauda, A., Okon, B., Joseph Henry, A., and Nggada Jibrin, D. (2023). Reproductive performance and Management of Three Breeds of cattle under major constraints in extensive management. *Farm Animal Health Nutrition* 2, 30–34. doi: 10.58803/fahn.v2i2.13

Davis, T. C., and White, R. R. (2020). Breeding animals to feed people: the many roles of animal reproduction in ensuring global food security. *Theriogenology* 150, 27–33. doi: 10.1016/j.theriogenology.2020.01.041

De Beer, J., and Van Wyk, B. E. (2021). Indigenous knowledge systems and western science: the conundrum of validation. *Indilinga* 20, 170–193.

Deka, R. P., Magnusson, U., Grace, D., Randolph, T. F., Shome, R., and Lindahl, J. F. (2021). Estimates of the economic cost caused by five major reproductive problems in dairy animals in Assam and Bihar, India. *Animals* 11:116. doi: 10.3390/ani11113116

Delay, N. D., Thumbi, S. M., Vanderford, J., and Otiang, E. (2020). Linking calving intervals to milk production and household nutrition in Kenya. Cham, Switzerland: Springer Nature, 309–325.

Diko, M. (2023). Advancing agriculture through indigenous knowledge systems (IKS) in south African indigenous or black communities. *Int. J. Res. Business Soc. Sci. (2147–4478)* 12, 267–277. doi: 10.20525/ijrbs.v12i2.2333

Diskin, M. G., and Kenny, D. A. (2014). Optimising reproductive performance of beef cows and replacement heifers. *Animal* 8, 27–39. doi: 10.1017/S175173111400086X

du Preez, A. M., Webb, E. C., and van Niekerk, W. A. (2021). Effects of different feeding systems on growth, fat accumulation and semen quality of merino-type sheep. *S. Afr. J. Anim. Sci.* 51, 566–577. doi: 10.4314/sajas.v51i5.3

Duro, E. S. (2022). Cattle breeding practice of the community and evaluation of artificial cattle breeding practice of the community and evaluation of artificial insemination (AI) after estrus synchronization in Wondo Genet District, Sidama National Regional State. *Int. J. Livest. Res* 12, 1–13. Available at: https://ijlr.org/ojs_journal/index.php/ijlr/article/view/114 (Accessed February 15, 2025).

Ezeanya-Esiobu, C., Oguamanam, C., and Ndungutse, V. (2021). Indigenous knowledge and vocational education: marginalisation of traditional medicinal treatments in Rwandan TVET animal health courses. *Afr. J. Inf. Commun.* 27, 1–23. doi: 10.23962/10539/31372

Fernandez-Novo, A., Pérez-Garnelo, S. S., Villagrá, A., Pérez-Villalobos, N., and Astiz, S. (2020). The effect of stress on reproduction and reproductive technologies in beef cattle—a review. *Animals* 10, 1–23. doi: 10.3390/ani10112096

File, D. J. M. B., and Nhamo, G. (2023). Farmers' choice for indigenous practices and implications for climate-smart agriculture in northern Ghana. *Heliyon* 9:e22162. doi: 10.1016/j.heliyon.2023.e22162

Fontes, P. L. P., Oosthuizen, N., and Lamb, G. C. (2020). Reproductive management of beef cattle. Amsterdam, Netherlands: Elsevier, 57–73.

Garcia-Garcia, R. M. (2012). Integrative control of energy balance and reproduction in females. *ISRN Vet. Sci.* 2012, 1–13. doi: 10.5402/2012/121389

Gashute, T. S., and Hale, T. K. (2023). The role of permaculture in the integration of indigenous and modern agricultural knowledge: evidence from Konso, Ethiopia. *Sustain. Dev.* 31, 1781–1789. doi: 10.1002/sd.2483

Getu, A., and Misganaw, G. (2015). The role of conformational traits on dairy cattle production and their longevities. Wuhan, Hubei Province: Scientific Research Publishing, 1–9.

Getyengana, K., Kamba, E. T., Mkwanazi, M. v., Ndlela, S. Z., Mwale, M., and Chimonyo, M. (2023). Factors influencing the integration of indigenous and conventional knowledge of water security for livestock. *Trop. Anim. Health Prod.* 55:529. doi: 10.1007/s11250-023-03529-z

Gicheha, M. G., Akidiva, I. C., and Cheruiyot, R. Y. (2019). Genetic and economic efficiency of integrating reproductive technologies in cattle breeding programme in Kenya. *Trop. Anim. Health Prod.* 51, 473–475. doi: 10.1007/s11250-018-1689-1

Grace, D., Lindahl, J., Wanyoike, F., Bett, B., Randolph, T., and Rich, K. M. (2017). Poor livestock keepers: ecosystem – poverty – health interactions. *Philos. Trans. R. Soc. Lond. Ser. B Biol. Sci.* 372:166. doi: 10.1098/rstb.2016.0166

Gratani, M., Butler, J. R. A., Royee, F., Valentine, P., Burrows, D., Canendo, W. I., et al. (2011). Is validation of indigenous ecological knowledge a disrespectful process? A case study of traditional fishing poisons and invasive fish management from the wet tropics, Australia. *Ecol. Soc.* 16:16. doi: 10.5751/ES-04249-160325

Grobler, S. M., Scholtz, M. M., Neser, F. W. C., Greyling, J. P. C., and Morey, L. (2019). Effect of controlled breeding on performance of beef cattle in central bushveld bioregion. *S. Afr. J. Anim. Sci.* 49, 1013–1020. doi: 10.4314/SAJAS.V49I6.5

Grobler, S. M., Scholtz, M. M., Seshoka, M. M., and Theunissen, A. (2010). The negative effect of heat stress on fertility of extensive beef cattle in South Africa. Pretoria, Gauteng Province: Agricultural Research Council.

Gudeto, A., Mirkena, T., and Kebede, T. (2021). Traditional cattle breeding practices and rate of inbreeding in the mid rift valley of Oromia. *Ethiopia. Int. J. Vet. Sci. Res.* 7, 77–82. doi: 10.17352/ijvsr.000084

Gwaza, D. S., and Yahaya, A. (2018). Effect of interaction between economic driving force, value chain intervention, communal crisis and uncontrolled breeding on genetic resource abundance of the Nigerian savannah muturu cattle. *J. Res. Reports Genet.* 2, 29–37. Available at: https://isdsnet.com/ijds-v3n1-15.pdf (Accessed October 13, 2025).

Hartanto, R., Ranggano, C. P., Prayitno, E., and Prima, A. (2023). Udder volume and teat size of Friesian Holstein dairy cows from post-weaning calves to pregnant heifers. *IOP Conference Series: Earth Environ. Sci.* 1246:2060. doi: 10.1088/1755-1315/1246/1/012060

Hess, B. W., Lake, S. L., and Scholljegerdes, E. J. (2004). Nutritional controls of beef cow reproduction, vol. 1 Oxford, United Kingdom: Oxford University Press, 3684.

Hunde, D., Tadesse, Y., Tadesse, M., Abegaz, S., and Getachew, T. (2024). Community-based breeding programs can realize sustainable genetic gain and economic benefits in tropical dairy cattle systems. *Front. Genet.* 15:709. doi: 10.3389/fgene.2024.1106709

Ibeawuchi, I. I., Obiefuna, J. C., and Iwuanyanwu, U. P. (2015). Low external input agricultural farming system for the increase in productivity of resource poor farmers. *J. Biol.* 5, 109–117. Available at: https://www.iiste.org/Journals/index.php/JBAH/article/view/19548/1990 (Accessed July 24, 2025).

Kamal, M., Bhuiyan, M. U., Parveen, N., Momont, H. W., and Shamsuddin, M. (2014). Risk factors for postpartum anestrus in crossbred cows in Bangladesh. Ankara, Turkey: Scientific and Technological Research Council of Turkey, 38.

Kamba, E. T. (2023). Utilizing indigenous knowledge to sustain cattle during droughts. Thesis. University of KwaZulu Natal.

Kamba, E. T., and Chimonyo, M. (2022). Exploitation of indigenous knowledge to control gastrointestinal nematodes in cattle during droughts, 1–18.

Kanuya, N. L., Matiko, M. K., Kessy, B. M., Mgongo, F. O., Ropstad, E., and Reksen, O. (2006). A study on reproductive performance and related factors of zebu cows in pastoral herds in a semi-arid area of Tanzania. *Theriogenology* 65, 1859–1874. doi: 10.1016/j.theriogenology.2005.10.016

Kenasew, A. S., Tesfaye, Y. M., Langana, B. B., and Masha, M. K. (2025). A study on indigenous knowledge on animal disease and medicinal plants used in animal disease management in Benatsemay Woreda, south Omo zone, southern Ethiopia. *Vet. Med. Int.* 2025:667. doi: 10.1155/vmi/9951667

Ko, S. H. (2024). Effects of heat stress-induced sex hormone dysregulation on reproduction and growth in male adolescents and beneficial foods. *Nutrients* 16:032. doi: 10.3390/nu16173032

Koirala, B., Alam, M. Z., and Bhuiyan, A. K. F. H. (2011). Give to AgEcon search study on morphometric, productive and reproductive traits of native cattle at Sylhet district. *J. Bangladesh Agril. Univ* 9, 85–89. doi: 10.3329/jbau.v9i1.8749

Lamb, G. C., Mercadante, V. R. G., Henry, D. D., Fontes, P. L. P., Dahlen, C. R., Larson, J. E., et al. (2016). Invited review: advantages of current and future reproductive technologies for beef cattle production. *Prof. Anim. Sci.* 32, 162–171. doi: 10.15232/pas.2015-01455

Lawal-Adebowale, A. O. (2020). Farm animals' health Behaviours: an essential communicative signal for farmers' veterinary care and sustainable production. *IntechOpen*. 25–49. doi: 10.5772/intechopen.89738

Madhusoodan, A. P., Sejian, V., Rashamol, V. P., Savitha, S. T., Bagath, M., Krishnan, G., et al. (2019). Resilient capacity of cattle to environmental challenges – an updated review. *J. Anim. Behav. Biometeorol.* 7, 104–118. doi: 10.31893/2318-1265jabb.v7n3p104-118

Malapane, O. L., Musakwa, W., and Chanza, N. (2024). Indigenous agricultural practices employed by the Vhavenda community in the Musina local municipality to promote sustainable environmental management. *Heliyon* 10:e33713. doi: 10.1016/j.heliyon.2024.e33713

Mapiye, C., Chikwanha, O. C., Chimonyo, M., and Dzama, K. (2019). Strategies for sustainable use of indigenous cattle genetic resources in southern Africa. *Diversity (Basel)* 11:214. doi: 10.3390/d11110214

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. *Agroecol. Sustain. Food Syst.* 44, 827–858. doi: 10.1080/21683565.2020.1716130

Marshall, K., Mtimet, N., Wanyoike, F., Ndiwa, N., Ghebremariam, H., Mugunieri, L., et al. (2016). Traditional livestock breeding practices of men and women Somali pastoralists: trait preferences and selection of breeding animals. *J. Anim. Breed. Genet.* 133, 534–547. doi: 10.1111/jbg.12223

Masambuka-Kanchewa, F., Lamm, A., and Qu, S. (2022). Exploring the impact of agricultural policies on the documentation and sharing of indigenous knowledge in sub-Saharan Africa. *J. Agricultural Extension Rural Develop.* 14, 173–182. doi: 10.5897/JAERD2022.1331

McCrindle, C. M. E., Maime, M. J., Botha, E. A., Webb, E. C., and Smuts, M. P. (2019). Scrotal tick damage as a cause of infertility in communal bulls in Moretele, South Africa. *J. S. Afr. Vet. Assoc.* 90, 1–7. doi: 10.4102/jsava.v90i0.1966

Melash, A. A., Bogale, A. A., Migbaru, A. T., Chakilu, G. G., Percze, A., Ábrahám, É. B., et al. (2023). Indigenous agricultural knowledge: a neglected human based resource for sustainable crop protection and production. *Heliyon* 9:e12978. doi: 10.1016/j.heliyon.2023.e12978

Meyer, C., and Naicker, K. (2023). Collective intellectual property of indigenous peoples and local communities: exploring power asymmetries in the rooibos geographical indication and industry-wide benefit-sharing agreement. *Res. Policy* 52:851. doi: 10.1016/j.respol.2023.104851

Mgongo, F. O. K., Matiko, M. K., Batamuzi, E. K., Wambura, R. M., Karimuribo, E. D., Mpanduji, D. G., et al. (2014). Pastoral indigenous breeding practices and their impact on cattle reproduction performance: the case of Kilosa and Gairo districts. *Livest. Res.*

Rural. Dev. 26:76. Available at: https://www.lrrd.org/lrrd26/4/mgon26076.htm (Accessed February 10, 2025).

Mohammed Ali, T. (2024). A review on underestimated; but pertinent challenges of cattle breeding: the Ethiopia perspective. *J. Appl. Anim. Res.* 52, 1–9. doi: 10.1080/09712119.2024.2375246

Molefe, K., and Mwanza, M. (2019). Cattle production management practices predisposing animals to the incidences of reproductive failures in small scale farming. *J. Agric. Sci. Technol. A* 9, 182–192. doi: 10.17265/2161-6256/2019.03.006

Molefi, S. H., Mbajiorgu, C. A., and Antwi, M. A. (2017). Management practices and constraints of beef cattle production in communal areas of Mpumalanga province. *South Africa. Indian J. Anim. Res.* 51, 187–192. doi: 10.18805/ijar.11325

Moorey, S. E., and Biase, F. H. (2020). Beef heifer fertility: importance of management practices and technological advancements. *J. Anim. Sci. Biotechnol.* 11, 1–12. doi: 10.1186/s40104-020-00503-9

Mthi, S., Nyangiwe, N., Thubela, T., Nyalambisa, N., Madyibi, Z., and Yawa, M. (2020). Cattle production and breeding practice in communal farming system in the eastern Cape Province, South Africa. *Appl. Anim. Husb. Rural Dev.* 13, 42–54. Available at: https://www.sasas.co.za/AAH&RD/cattle-production-and-breeding-practice-in-communal-farming-system-in-the-eastern-cape-province-south-africa/ (Accessed January 4, 2024).

Mueller, J. P., Rischkowsky, B., Haile, A., Philipsson, J., Mwai, O., Besbes, B., et al. (2015). Community-based livestock breeding programmes: essentials and examples. *J. Anim. Breed. Genet.* 132, 155–168. doi: 10.1111/jbg.12136

Mugwabana, T. J., Muchenje, V., Nengovhela, N. B., Nephawe Khathutshelo, A., and Nedambale, T. L. (2018). Challenges with the implementation and adoption of assisted reproductive technologies under communal farming system. *J. Vet. Med. Anim. Health.* 10, 237–244. doi: 10.5897/jvmah2018.0707

Mutua, E., Namatovu, J., Campbell, Z. A., Tumusiime, D., Ouma, E., and Bett, B. (2024). A qualitative study on the effects of intra-household decision-making patterns on utilization of preventive and curative veterinary practices in communities affected by Rift Valley fever in Kenya and Uganda. *Gend. Technol. Dev.* 28, 323–342. doi: 10.1080/09718524.2024.2354104

Ncube, I., Chigwada, J., Ngulube, P., and Maluleka, J. R. (2025). Government support for indigenous knowledge for sustainability in southern Africa. *South African J. Info. Manag.* 27:a1901. doi: 10.4102/sajim.v27i1.1901

Ndlela, S. Z., Mkwanazi, M. V., and Chimonyo, M. (2022). Factors affecting utilisation of indigenous knowledge to control gastrointestinal nematodes in goats. *Agri* 11, 1–10. doi: 10.3390/agriculture11020160

Ndlovu, T., and Mjimba, V. (2021). Drought risk-reduction and gender dynamics in communal cattle farming in southern Zimbabwe. *Int. J. Disaster Risk Reduct.* 58:102203. doi: 10.1016/j.ijdrr.2021.102203

Nengovhela, N. B., Mugwabana, T. J., Nephawe, K. A., and Nedambale, T. L. (2021). Accessibility to reproductive technologies by low-income beef farmers in South Africa. *Front. Vet. Sci.* 8, 1–13. doi: 10.3389/fvets.2021.611182

Nigussie, T. (2018). A review on the role of energy balance on reproduction of dairy cow. *J. Dairy Res. Technol.* 1, 1–9. doi: 10.24966/drt-9315/100003

Nkadimeng, M., van Marle-Köster, E., Nengovhela, N. B., and Linah, M. M. (2022a). Understanding beef cattle production practices and associated factors constraining performance: a survey of smallholder farmers in South Africa. *J. Agric. Rural. Dev. Trop. Subtrop.* 123, 131–145. doi: 10.17170/kobra-202204216054

Nkadimeng, M., Van Marle-Köster, E., Nengovhela, N. B., Ramukhithi, F. V., Mphaphathi, M. L., Rust, J. M., et al. (2022b). Assessing reproductive performance to establish benchmarks for small- holder beef cattle herds in South Africa. *Animals* 12:3003. doi: 10.3390/ani12213003

Nowers, C. B., Nobumba, L. M., and Welgemoed, J. (2013). Reproduction and production potential of communal cattle on sourveld in the eastern Cape Province, South Africa. *Appl. Anim. Husb. Rural Dev.* 6, 48–54. Available at: https://www.sasas.co.za/AAH&RD/reproduction-and-production-potential-of-communal-cattle-on-sourveld-in-the-eastern-cape-province-south-africa/ (Accessed April 13, 2023).

Nqeno, N., Chimonyo, M., Mapiye, C., and Marufu, M. C. (2010). Ovarian activity, conception and pregnancy patterns of cows in the semiarid communal rangelands in the eastern Cape Province of South Africa. *Anim. Reprod. Sci.* 118, 140–147. doi: 10.1016/j.anireprosci.2009.07.006

Nyamushamba, G. B., Mapiye, C., Tada, O., Halimani, T. E., and Muchenje, V. (2017). Conservation of indigenous cattle genetic resources in southern Africa's smallholder areas: turning threats into opportunities—a review. *Asian Australas. J. Anim. Sci.* 30, 603–621. doi: 10.5713/ajas.16.0024

Okunlola, O. O., Olorunnisomo, O. A., Alalade, J. A., Oyinlola, O. O., Amusa, H. O., Adebisi, I. A., et al. (2019). Maize seed germination inhibition test for pregnancy diagnosis in zebu cows. *Niger. J. Anim. Prod.* 46, 1–7. doi: 10.51791/njap.v46i3.864

Olmo, L., Reichel, M. P., Nampanya, S., Khounsy, S., Wahl, L. C., Clark, B. A., et al. (2019). Risk factors for neospora caninum, bovine viral diarrhoea virus, and leptospira interrogans serovar hardjo infection in smallholder cattle and buffalo in Lao PDR. *PLoS One* 14, 1–25. doi: 10.1371/journal.pone.0220335

Olum, M. O., Mungube, E. O., Nakami, W. N., and Kidali, J. A. (2020). A cross-sectional study on infertility and its causes in small holder dairy cattle in selected counties of Kenya. International. *J. Vet. Sci.* 9, 534–539. doi: 10.37422/ijvs/20.079

Ouédraogo, D., Soudré, A., Yougbaré, B., Ouédraogo-Koné, S., Zoma-Traoré, B., Khayatzadeh, N., et al. (2021). Genetic improvement of local cattle breeds in West Africa: a review of breeding programs. *Sustain.* 13, 1–16. doi: 10.3390/su13042125

Perin, L., Dumas, P., and Vigne, M. (2022). Representing cattle farming around the world: a conceptual and holistic framework for environmental and economic impact assessment. *Ruminants* 2, 360–381. doi: 10.3390/ruminants2040025

Prajapati, C. S., Priya, N. K., Bishnoi, S., Vishwakarma, S. K., Buvaneswari, K., Shastri, S., et al. (2025). The role of participatory approaches in modern agricultural extension: bridging knowledge gaps for sustainable farming practices. *J. Experimental Agricul. Int.* 47, 204–222. doi: 10.9734/jeai/2025/v47i23281

Rankoana, S. A. (2024). A review of cultural factors influencing sustainable cattle production "A review of cultural factors influencing sustainable cattle production." Available online at: www.isdsnet.com/ijds (Accessed September 22, 2025).

Raphalalani, Z. C., Nedambale, T. L., Nengovhela, N. B., and Nephawe, K. A. (2020). An investigation of factors influencing synchronization response, conception and calving rate of communal cows in Limpopo Province, South Africa. *Appl. Anim. Husb. Rural Dev*. 13, 13–22. Available at: https://www.sasas.co.za/AAH&RD/an-investigation-of-factors-influencing-synchronization-response-conception-and-calving-rate-of-communal-cows-in-limpopo-province-south-africa/ (Accessed February 3, 2025).

Richards, S., Vanleeuwen, J., Peter, S. G., Wichtel, J., Kamunde, C., Uehlinger, F., et al. (2019). Impact of mineral feeding on reproductive efficiency on smallholder dairy farms in Kenya. *Livest. Res. Rural. Dev.* 31:80. Available at: https://www.lrrd.org/lrrd31/6/srich31080.html (Accessed September 15, 2025).

Robi, D. T., Gelalcha, B. D., and Deresa, F. B. (2021). Knowledge and perception of community about causes of cattle abortion and case-control study of brucellosis as cause of abortion in Jimma zone, Ethiopia. *Vet. Med. Sci.* 7, 2240–2249. doi: 10.1002/vms3.600

Roue, M., and Nakashima, D. (2018). Indigenous and local knowledge and science: from validation to knowledge coproduction. *Int. Encycl. Anthropol.* 54:4. doi: 10.1002/9781118924396.wbiea2215

Sanchez, J., Maiden, J., Barton, E., Walters, L., Quinn, D., and Lim, D. (2023). Factors that sustain indigenous youth mentoring programs: A qualitative systematic review. *BMC Public Health.* 23:429. doi: 10.1186/s12889-023-15253-2

Sapkota, D., Kelly, A. K., Crosson, P., White, R. R., and Mcgee, M. (2020). Quantification of cow milk yield and pre-weaning calf growth response in temperate pasture-based beef suckler systems: a meta-analysis. *Livest. Sci.* 241:104222. doi: 10.1016/j.livsci.2020.104222

Scheepers, S. M., Annandale, C. H., and Webb, E. C. (2010). Relationship between production characteristics and breeding potential of 25-month old extensively managed Bonsmara bulls. *S. Afr. J. Anim. Sci.* 40, 163–172. doi: 10.4314/sajas.v40i3.1

Scholtz, M. M., and Jordaan, F. J. (2025). Applied Animal Husbandry & Rural Development. Available online at: www.sasas.co.za/aahrd/ (Accessed September 27, 2025).

Senanayake, S. G. J. N. (2006). Indigenous knowledge as a key to sustainable development. *J. Agric. Sci. Sri Lanka* 2, 87–94. doi: 10.4038/jas.v2i1.8117

Shaanika, A. N. (2019). Effects of non-genetic factors on beef production in a communal system in Botswana. South Africa: Msc (Agric) University of Pretoria.

Shah, N., Sethi, M., and Kumar, P. (2021). Selection of heifers and breeding bulls for reducing calving difficulties in the first Calvers: An overview. India: Indian Journal of Veterinary Sciences and Biotechnology.

Shava, S., and Masuku, S. (2019). Living currency: the multiple roles of livestock in livelihood sustenance and exchange in the context of rural indigenous communities in southern Africa. S.A. *J. Environ. Educ.* 35, 1–13. doi: 10.4314/sajee.v35i1.16

Shoimah, U. S., Dakhlan, A., Sulastri, and Hamdani, M. D. I. (2021). Use of body measurements to predict live body weight of Simmental bull in Lembang artificial insemination center, West Java. *IOP Conf. Ser. Earth Environ. Sci.* 888:8. doi: 10.1088/1755-1315/888/1/012030

Sianangama, P. C., Mtonga, M., Harrison, S. J., and Abigaba, R. (2022). The potential of seed germination inhibition test for early pregnancy detection and improved reproductive efficiency of cattle in Zambia. *Online J. Anim. Feed Res.* 12, 356–362. doi: 10.51227/ojafr.2022.47

Smith, B. M., Basu, P. C., Chatterjee, A., Chatterjee, S., Dey, U. K., Dicks, L. V., et al. (2017). Collating and validating indigenous and local knowledge to apply multiple knowledge systems to an environmental challenge: a case-study of pollinators in India. *Biol. Conserv.* 211, 20–28. doi: 10.1016/j.biocon.2017.04.032

Soumya, N. P., Mondal, S., and Singh, R. L. (2022). Introduction. *Emerg. Issues Clim. Smart Livest. prod. Biol. tools tech.*, 1–17. doi: 10.1016/B978-0-12-822265-2.00014-4

Specht, A., and Crowston, K. (2022). Interdisciplinary collaboration from diverse science teams can produce significant outcomes. *PLoS One* 17:8043. doi: 10.1371/journal.pone.0278043

Suganda, A., Salman, D., Baba, S., and Fahmid, I. M. (2022). Cattle corporation village program as small-scale farmer group empowerment to support national beef self-sufficiency. *IOP Conf. Ser. Earth Environ. Sci.* 1114:2041. doi: 10.1088/1755-1315/1114/1/012041

Tadesse, B., Reda, A. A., Kassaw, N. T., and Tadeg, W. (2022). Success rate of artificial insemination, reproductive performance and economic impact of failure of first service insemination: a retrospective study. *BMC Vet. Res.* 18:226. doi: 10.1186/s12917-022-03325-1

Tanimura, K., Uematsu, M., Kitahara, G., Osawa, T., and Sasaki, Y. (2022). Longitudinal effect of repeat breeding in Japanese black beef cattle at a low parity on subsequent fertility in commercial cow–calf operations. *Theriogenology* 189, 177–182. doi: 10.1016/j.theriogenology.2022.05.016

Temesgen, M. Y., Alemayehu, A., Id, A., and Gizaw, T. T. (2022). Factors affecting calving to conception interval (days open) in dairy cows located at 1–15. *PLoS One* 17:e0264029. doi: 10.1371/journal.pone.0264029

Terry, S. A., Basarab, J. A., Guan, L. L., and McAllister, T. A. (2021). Strategies to improve the efficiency of beef cattle production. *Can. J. Anim. Sci.* 101, 1–19. doi: 10.1139/cjas-2020-0022

Timlin, C. L., Dias, N. W., Hungerford, L., Redifer, T., Currin, J. F., and Mercadante, V. R. G. (2021). A retrospective analysis of bull:cow ratio effects on pregnancy rates of beef cows previously enrolled in fixed-time artificial insemination protocols. *Transl. Anim. Sci.* 5, 1–9. doi: 10.1093/tas/txab129

Ţogoe, D., and Mincă, N. A. (2024). The impact of heat stress on the physiological, productive, and reproductive status of dairy cows. *Agriculture* 14:241. doi: 10.3390/agriculture14081241

Tolasa, B. I., and Andure, E. O. (2021). Age at first service and calving, calving interval, open days, and number of services per conception of dairy cows under small holder in Siltie zone, Ethiopia. *NBSP*. doi: 10.21203/rs.3.rs-408706/v1

Van der Merwe, D., Swan, G. E., and Botha, C. J. (2001). Use of ethnoveterinary medicinal plants in cattle by Setswana-speaking people in the Madikwe area of the north West Province of South Africa. *J. S. Afr. Vet. Assoc.* 72, 189–196. doi: 10.4102/jsava.v72i4.651

Veena, T., Narendranath, R., and Sarma, P. V. (1997). The reliability of ancient Egyptian pregnancy diagnosis for cows/buffaloes. *Adv. Contracept. Deliv. Syst.* 113, 49–53.

Washaya, S., Mudzengi, C. P., Gobvu, V., Mafigu, T., and Mutore, R. (2024). Postpartum anoestrus in extensively managed beef cows. *Theriogenology—Recent Advances in the Field*, 1–15. doi: 10.5772/intechopen.112200

Wicaksono, A., Steeneveld, W., van Werven, T., Hogeveen, H., and van den Borne, B. H. P. (2025). Knowledge, attitude and behaviour of farmers towards the use of reproductive hormones in dairy cattle. *Animal* 19:101470. doi: 10.1016/j.animal.2025.101470

Wolfe, D. F. (2018). Review: Abnormalities of the bull – Occurrence, diagnosis and treatment of abnormalities of the bull, including structural soundness. *Animal* 12, s148–s157. doi: 10.1017/S1751731118000939

Zoma-Traoré, B., Ouédraogo-Koné, S., Soudré, A., Ouédraogo, D., Yougbaré, B., Traoré, A., et al. (2021). Values and beliefs that shape cattle breeding in southwestern Burkina Faso. *Hum. Ecol.* 49, 429–441. doi: 10.1007/s10745-021-00240-1