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The contribution of indigenous multipurpose trees found in Southern Africa to increased livestock production and climate change adaptation: a review

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Feed shortages during the dry season remain a critical challenge for livestock production in Southern Africa, where ruminant farming supports livelihoods and food security. This review assesses the role of indigenous multipurpose trees (MPTs) in enhancing ruminant livestock production during the dry season and climate change adaptation. Using PRISMA 2020 guidelines, the review systematically analyzed 41 ethnobotanical studies and 19 *in vivo* trials, identifying key gaps in prior reviews regarding quantitative ethnobotanical metrics, regional coverage, and climate adaptation mechanisms. The review identified 122 plant species from 34 botanical families and 78 genera browsed by ruminants, with *Dichrostachys cinerea* and *Colophospermum mopane* emerging as the most frequently cited species. These MPTs provide essential ecosystem services, including medicine, food, construction materials, firewood, and ethnoveterinary uses, while also contributing to climate resilience through shade, windbreaks, and insect repellent properties. The findings demonstrate that integrating these trees into livestock diets improves body weight, milk and meat production, and reduces methane emissions. Despite their potential, invasive species like *D. cinerea* require careful management. We recommend adopting non-invasive, high-value species such as *Acacia erioloba, Sclerocarya birrea, Boscia albitrunca,* and *C. mopane* into silvopastoral systems to mitigate feed shortages and enhance climate resilience. Future efforts should focus on domestication, conservation, and policy support to optimize their use in sustainable livestock production.

KEYWORDS

browse, climate change adaptation, feed shortages, indigenous multipurpose trees, livestock production, Southern Africa

1 Introduction

1.1 Background

Arid and semi-arid regions cover approximately 41% of the Earth's land surface, supporting over 2 billion people, many of whom rely on livestock production for their livelihoods (FAO, 2019). These regions are characterized by limited rainfall, high temperatures, and frequent droughts, making crop production challenging and necessitating a heavy reliance on rangeland-based livestock systems (IPCC, 2022). However, climate change is exacerbating feed scarcity, reducing pasture productivity, and threatening food security in these vulnerable ecosystems (Balehegn et al., 2020).

Southern Africa, where dry lands constitute 84% of the land area (224 million hectares), faces similar challenges (Sheppard C. et al., 2020). About 190 million people live in the region, half in rural areas, with livestock playing a crucial role in livelihoods and food security (FAO, 2022a). Ruminant production comprising 27.3 million sheep, 36.0 million cattle, and 36.1 million goats relies heavily on natural pastures, yet seasonal feed shortages lead to weight loss (up to 15%), reduced milk yields, and increased methane emissions due to poor forage quality (Cooke et al., 2023). With 104 million people food insecure, including 22 million undernourished, improving livestock nutrition through sustainable feed alternatives is critical (FAO, 2022b).

Rangeland grazing is the primary feed source for ruminant livestock production in Southern Africa. Two major animal nutrition challenges are faced due to the seasonal feed gap. The natural pastures and crop residues that are available to animals during the dry season are typically fibrous and lacking in the majority of vital nutrients, such as protein, energy, minerals, and vitamins (Cooke et al., 2023; Lamega et al., 2021). In a six-year study of rangeland pasture productivity in southern Mozambique, Muir and Alage (2001) found that the mean dry matter yield at the end of the rainy season was 5,209 g ha^{-1}, whereas at the end of the dry season, it was 3,822 g ha^{-1}. Likewise, Mphinyane et al. (2015) found that biomass availability in Botswana was only 178 g/m^2 at the end of the dry season but 513 g/m^2 at the end of the wet season. During the dry season in southern Ethiopia, natural pasture's crude protein (CP) and *in vitro* dry matter digestibility (IVDMD) decreased by 28 and 5%, respectively (Abebe et al., 2012).

In response, there is growing global interest in sustainable livestock feeding strategies that leverage drought-resistant fodder trees and shrubs to bridge seasonal feed gaps, enhance animal nutrition, and mitigate environmental degradation. Indigenous woody fodder trees offer a promising solution, providing high-protein fodder (5.84–28.98% CP), essential minerals, and year-round biomass (Babiker and Abdulla, 2015). Several authors in sub-Saharan Africa have documented the use of woody fodder to feed livestock, particularly during the dry season (Simbaya et al., 2020; Franzel et al., 2014; Balehegn et al., 2015a). Studies in sub-Saharan Africa highlight their role in reducing methane emissions by 20%, enhancing weight gain, and supporting dairy production (Chakeredza et al., 2007; Murgueitio et al., 2011). Despite this, large-scale adoption remains limited due to deforestation, land-use conflicts, and poor domestication efforts (Mapiye et al., 2011). Additionally, indigenous knowledge on species selection based on biological, cultural, and socioeconomic factors is often overlooked in scientific interventions (Balehegn et al., 2015b). In southern Africa, efforts have been taken to domesticate, enhance, and introduce Miombo trees into agroforestry systems (Akinnifesi et al., 2006).

1.2 Comparison with previous relevant review papers in Southern Africa

This review addressed 6 unresolved gaps from earlier works through PRISMA-guided analysis of 122 species across 10 countries, as shown in Supplementary Table 1: (1) Quantitative Ethnobotany: Prior reviews lacked RFC/FC metrics to rank species by cultural importance. (2) Invasiveness-Climate Trade-offs: No earlier study systematically evaluated invasive but high-RFC species (e.g., *A. karroo*). (3) Regional Coverage: Most focused on single countries (e.g., Zimbabwe), missing cross-border comparisons. (4) Integrated Analysis: Combined Ethnobotany (RFC), nutrition (*in vivo*), and invasiveness. (5) Phenology-Climate Links: Deciduous vs. evergreen traits were previously ignored in fodder availability models. (6) Novel Metrics: First use of Jaccard Index to compare species overlap between countries.

The review paper systematically addresses indigenous knowledge (IK) through ethnobotanical surveys, quantitative metrics, and comparative analysis of species utilization. Indigenous Knowledge was assessed by studying ethnobotanical surveys (questionnaires, interviews, field observations) from studies across Southern Africa to document: 1. Species selection: identified plant species browsed by ruminants, ranked by Frequency of Citation (FC) and Relative Frequency of Citation (RFC); 2. Cultural and socioeconomic factors: Other uses or Ecosystem services; 3. Phenological traits: deciduous vs. evergreen species (affecting dry-season fodder availability); and Invasiveness: highlighted conflicts (e.g., *D. cinerea* is invasive but highly utilized).

1.3 Research questions

This study aimed to identify culturally important multipurpose trees browsed by ruminant livestock in Southern Africa and assess their contributions to livestock productivity, climate change adaptation, and whether they are suitable for adoption into silvopastoral systems without affecting ecological biodiversity. Specifically, we addressed: (i) Which multipurpose tree species are preferentially browsed by ruminants?, (ii) What additional socio-economic or ecological uses (e.g., medicine, fuelwood) do these trees provide?, (iii) Which species are most frequently represented across studies?, (iv) Which plant families (e.g., Fabaceae, Anacardiaceae) are most common among utilized trees?, (vi) How do these trees enhance climate resilience (e.g., drought tolerance)?, (vii) Which culturally significant species are invasive (e.g., *D. cinerea*)?, and (viii) What are the phenological traits (deciduous, semi-deciduous, evergreen) of key species, and how do these traits influence year-round forage availability?

2 Materials and methods

2.1 Study area

This review focuses on 10 Southern African countries: Angola, Zambia, Mozambique, Namibia, Botswana, Zimbabwe, Malawi, Eswatini, Lesotho, and South Africa (Figure 1). The region experiences a bimodal climate characterized by two distinct seasons: a hot, wet season (October/November to March/April) and a cold, dry season (mid-April to September/October) (Cooke et al., 2023; Reason, 2017). Annual precipitation ranges from <100 mm in arid zones (e.g., Namib Desert) to >1,000 mm in eastern high-rainfall regions (Malawi, Mozambique) (Reason, 2017). Most rainfall occurs during the wet

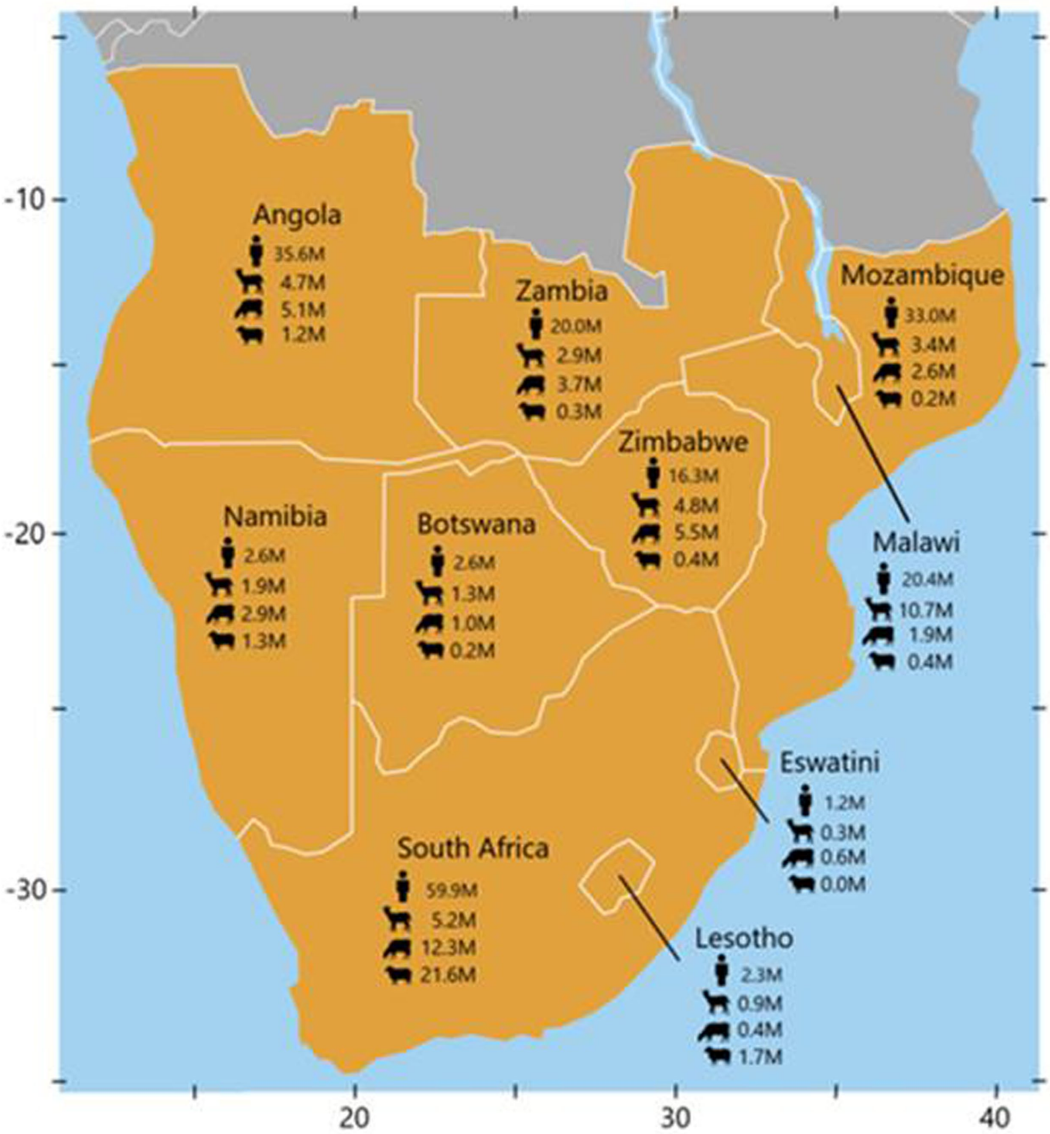

FIGURE 1
Map of countries in Southern Africa considered in this review paper. Countries in grey were not considered part of Southern Africa. Adopted from Cooke et al. (2023).

season, while the dry season is marked by drought (0–50 mm monthly). Mean annual temperatures vary from 18°C in high-altitude areas (e.g., Lesotho) to >30°C in lowland deserts (Namibia, Botswana) (Cooke et al., 2023). The region's rangelands are ecologically diverse. Savannas constitute grasslands with scattered trees, particularly *Acacia* spp. (e.g., *Acacia tortilis*, *A. nigrescens*) (Bond et al., 2003). Common grasses include *Themeda triandra* and *Cenchrus ciliaris*. The arid or desert zones are dominated by succulent flora (*Aloe* spp., *Euphorbia* spp.) and drought-resistant shrubs (*Salsola* spp., *Stipagrostis* grasses). The Mopane Woodlands are dominated by *C. mopane*, a key browse species for livestock in clay-rich soils. The Miombo Woodlands in Eastern regions feature mixed deciduous (*Brachystegia* spp., *Julbernardia* spp.) and evergreen species (*Uapaca* spp.), providing critical dry-season fodder (De Cauwer et al., 2018). The region supports diverse livestock adapted to seasonal forage variability. Indigenous cattle breeds (e.g., Nguni, Tuli) and crossbreeds dominate, relying on grasses during wet seasons and browse species in dry periods. Hardy small ruminants (e.g., Boer goats, Damara sheep) thrive on mixed browse and succulent plants in arid zones (Cooke et al., 2023).

2.2 Review methods

This review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021). A thorough online literature search was done to collect data from June 2024 to November 2024. The identification of multipurpose trees used in ruminant livestock production in Southern Africa was restricted in respecting the following inclusion criteria: (1) only ethnobotanical survey articles carried out in Southern Africa were considered; (2) articles with trees browsed by ruminant livestock; (3) only articles that were written in English or that had English translations were considered. Key search words used were "Ethnobotanical survey OR study OR observation" AND "browse trees" OR "forage trees" OR "fodder trees" AND "ruminant livestock" OR "cattle" OR "sheep" OR "goats" AND "Southern Africa" OR "Zimbabwe" OR "Zambia" OR "South Africa" OR "Botswana" OR "Namibia" OR "Lesotho" OR "Angola" OR "Malawi" OR "Mozambique" OR "Eswatini" OR "Swaziland."

The second part of the study was restricted to respecting the following inclusion criteria: (1) for determining contribution to livestock productivity, only *in vivo* empirical studies carried out in Southern Africa on the most cited species were considered. Key search words were "Tree species, e.g., *Acacia karroo*" AND *in vivo* AND ruminant livestock AND invasiveness in Southern Africa AND leaf phenology. Data was collected from search engines such as Scopus, Google Scholar, National Center for Biotechnology Information (NCBI), Science Direct, Research Gate, Springer Link, and Taylor and Francis Online.

2.3 Data extraction

This study systematically compiled and analyzed four primary categories of data from 41 ethnobotanical researches: (i) General study characteristics, including authors, publication dates, and the total number of studies reviewed, to contextualize the temporal and academic scope of the research; (ii) Geographic data, documenting the country of origin for each study to identify regional patterns in fodder tree utilization; (iii) Browsed plant attributes, encompassing scientific names (e.g., *Acacia karroo*), local and common names, plant family (e.g., Fabaceae), and (iv) Multifunctional uses, particularly the roles of cited species in climate change adaptation (e.g., drought resilience). The 41 research studies comprised 16 ground survey data, 14 questionnaire survey data, five experimental articles, four theses, one book chapter, and one book.

The second part of the study used 19 *in vivo* empirical research papers to determine the contribution of the most cited browse species to livestock productivity in Southern Africa. The researchers also determined the phenology (deciduous, semi-deciduous, or evergreen) and invasive status for adoption suitability into silvopastoral systems. This structured approach enabled a holistic evaluation of culturally significant trees, bridging ecological, nutritional, and socio-economic dimensions to inform sustainable livestock and agroforestry practices in Southern Africa.

2.4 Data analysis

To ascertain the local significance of woody plant species browsed by ruminant livestock in Southern Africa, quantitative ethnobotanical data analysis was used to calculate the frequency of citation (FC), relative frequency of citation (RFC), and family importance value (FIV) (Maroyi, 2022; Chinomona et al., 2024). The methods used for analyses were according to modifications by Mpofu et al. (2022).

2.4.1 Browse tree frequency of citation (FC)

Frequency of Citation (FC) is the number of times a specific browse tree was mentioned in a study. It is the number of times a plant has been mentioned in various studies. It indicates the frequency of mentioning of a single botanical species by studies. It is the number of times a plant was reported by different studies. FC was computed in this way:

FC = (Number of times a particular species was mentioned)/(total number of times that all species were mentioned) × 100

2.4.2 Browse tree relative frequency of citation (RFC)

The RFC scale ranges from zero, where no citations are found to support the essentiality of the browse tree, to one where all citations do support the importance of the browse tree. By dividing the FC by the total number of citations (N), the RFC was calculated.

2.4.3 Family importance value

The Family Importance Value indicates the local significance of the families of browse trees commonly utilized by ruminant livestock in Southern Africa. A high FIV value suggests that the families featured plants that were commonly referenced in ethnobotanical research as being browsed by ruminants in Southern Africa, whereas a low FIV value suggests that the families contained few browse trees. It was calculated by dividing the number of plant species in each family by the total number of plant species found in this study (Mpofu et al., 2022).

$$\mathrm{FIV} = \left[\mathrm{FC}\left(\mathrm{family}\right) / \mathrm{N}\right]$$

2.4.4 Comparative analysis

The Jaccard Index (JI) was used to calculate similarities in terms of plant species between countries with the most cited plant species, which were South Africa, Namibia, Angola, Zimbabwe, and Botswana (Mpofu et al., 2022). The JI was calculated as follows:

JI = C/(A + B − C), where A is the number of plant species recorded in country A, B is the number of plant species recorded in country B, and C is the number of plant species common to A and B (Jaccard, 1902).

3 Results

3.1 Plant species browsed by ruminant livestock in Southern Africa

The data that was used in this review is shown in Appendix 1, which was retrieved from ethnobotanical surveys carried out in Southern Africa. A total of 41 ethnobotanical studies on plants browsed by ruminant livestock were used to gather the data. One hundred and twenty-two plants belonging to 34 botanical families and 78 plant genera have been documented to be browsed by ruminant livestock in Southern Africa.

3.2 Country of study

The studies used in this review were conducted in South Africa, Botswana, Namibia, Zimbabwe, Angola, and Lesotho. There were no studies published from Mozambique, Eswatini, Zambia, or Malawi. The highest number of studies was from South Africa (18), followed by Zimbabwe (eight), Namibia (seven), Botswana (five), and Angola had only two studies, as shown in Figure 2. Forty-six different plant species were cited to be browsed by ruminants in South Africa and Angola, 31 in Namibia, 30 in Zimbabwe, 25 in Botswana, and one plant was mentioned in Lesotho (Figure 3).

3.3 Browse tree frequency of citation (FC) and relative frequency of citation (RFC)

Supplementary Table 2 presents a comprehensive quantitative analysis of plant species used for fodder in Southern Africa, calculated through two key metrics: FC and RFC. The Frequency of Citation (FC) score was used to identify plants that were mentioned the most in ethnobotanical surveys to be commonly browsed by ruminant livestock in Southern Africa. The Relative Frequency of Citation is represented by a range from zero (no citations, indicating that the plant is not commonly browsed by ruminant livestock in Southern Africa) to one (where all the citations consider the plant to be commonly browsed by ruminant livestock). The results reveal a clear hierarchy of ethnobotanical importance among 122 plant species. The most commonly browsed plants by ruminant livestock with an RFC ≥ 0.15 were *D. cinerea* (FC 12, RFC 0.29), *C. mopane* (FC 11, RFC 0.27), *A. karroo*, *S. birrea* (FC 8, RFC 0.20), *A. tortilis* (FC seven, RFC 0.17), *A. erioloba, B. albitrunca*, and *O. ficus indica* (FC 6, RFC 0.15) confirming their status as a keystone fodder resources. Thirty-four plant species were moderately cited to be commonly browsed with an RFC of 0.05 to 0.14, and 80 plants were least cited with an RFC of 0.02. It was also noted that plants with the highest FC value also had a high RFC value.

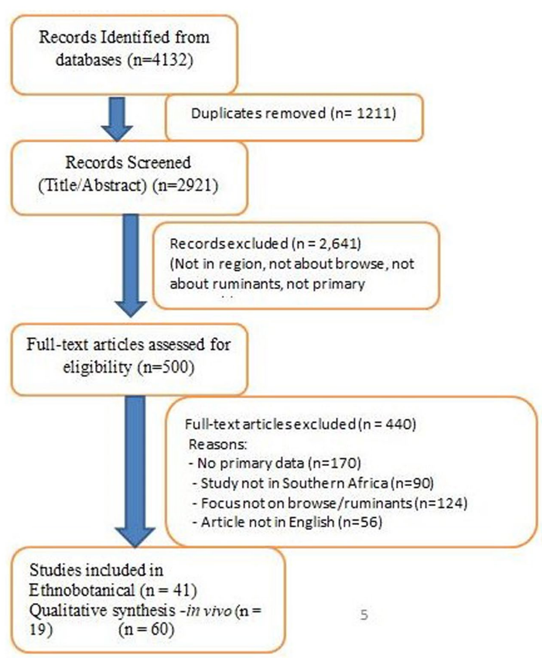

FIGURE 2
PRISMA 2020 flow diagram of the study selection process.

3.4 Diversity of plants providing ruminant feed from rangelands in Southern Africa (families, genera, species)

The four most represented genera with 4 to 14 species were Acacia, Grewia, Combretum, and Ficus; 12 genera had moderate representation of 2 to 3 species; and 62 plant genera had low representation of one plant species, as shown in Supplementary Table 3.

Fabaceae was the most represented botanical family with 39 plants (FIV 0.32, 32%), Malvaceae 11 plants (FIV 0.09, 9%), and Combretaceae 10 plants (FIV 0.08, 8%). Thirteen families were moderately represented, having 2 to 6 plant species and an FIV of 0.02 to 0.05. Eighteen families had the lowest number of plant species of 1 and an FIV of 0.01. The FIV enhances our understanding of biodiversity and informs conservation strategies. This research indicated how different botanical families contribute to ecosystem functions and showed that most browse trees in Southern Africa belong to the Fabaceae, Malvaceae, and Combretaceae families (Supplementary Table 4).

3.5 Country comparative analysis (Jaccard index JI)

The Jaccard index was used to measure the similarity in plant species used by different countries. This was computed between Angola, South Africa, Zimbabwe, Botswana, and Namibia, which had the highest number of plant species cited, as displayed in Supplementary Table 5. The highest similarity in plants browsed by ruminants was between Zimbabwe and South Africa, with a JI of 0.19 and 12 common plant species. The 12 common plant species were *C. mopane*, *D. cinerea*, *B. albitrunca*, *A. karroo*, *A. tortilis*, *A. digitata*, *G. flavescens*, *O. ficus-indica*, *Combretum apiculatum*, *Ficus sycomorus*, *Acacia albida*, and *Moringa oleifera*. The second highest similarity was between Zimbabwe and Namibia, with eight common plants, and between Botswana and Zimbabwe, with seven common plants and a JI of 0.15. The two plant species that are common between the 5 countries in Southern Africa are *D. cinerea* and *C. mopane*.

3.6 Contribution of common browse trees to climate change adaptation

Ecosystem services are often divided into four groups: (1) providing services, (2) regulatory services, (3) supporting services, and (4) cultural services (Sileshi et al., 2007). A total of 9 provisioning services (medicinal, food, construction, fuel wood, ethnoveterinary, cosmetics, fish traps, oils), three regulating services (shade, insect repellent, wind breaks), and three cultural services (rituals, ornamental, handicrafts) were reported to be provided by browse trees in Southern Africa. Medicines (33.6%), food (23%), construction (17.2%), fuel wood (13.1%), and ethnoveterinary (4.9%) were among the provisioning services provided by the majority of species reported in this review. Trees can assist communities to withstand the effects of climate change by providing ESs such as food, fuel wood, fodder, wind break, shade, and revenue, as well as improved soil productivity, insect protection, and disease resistance (Rao et al., 2007; Mulatu and Hunde, 2019).

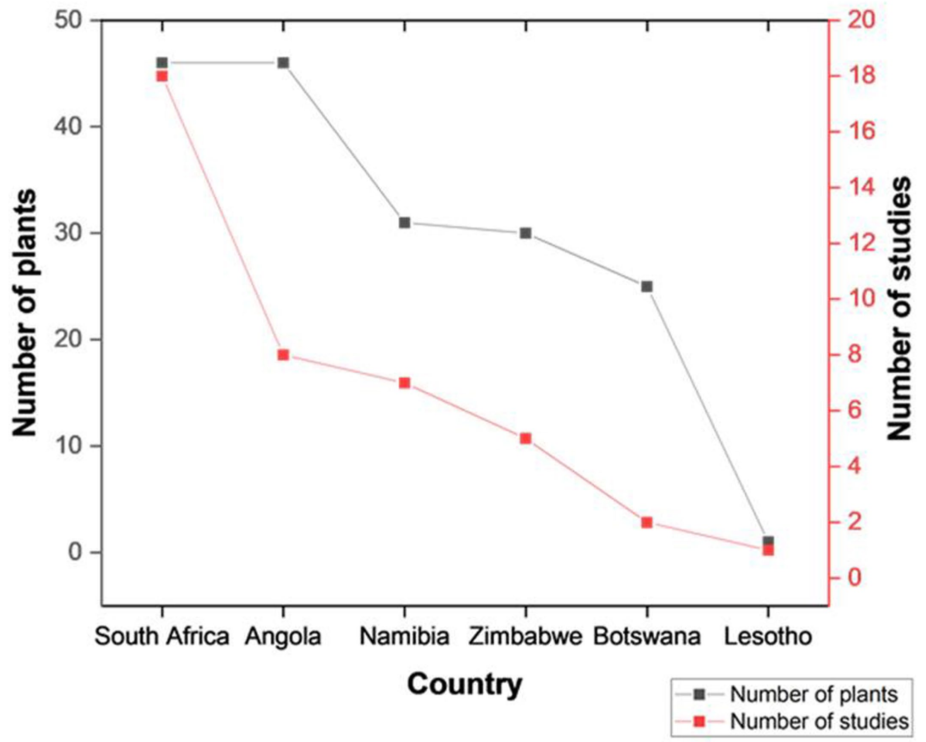

FIGURE 3
The figure shows results on the countries in Southern Africa cited in the study against the number of plant species mentioned to be browsed by ruminant livestock and the number of studies that published the work from each country.

Supplementary Table 6 presents a comprehensive analysis of how browse plant species across Southern Africa serve as critical climate change adaptation resources through five key mechanisms. The other uses or ESs provided by plants commonly browsed by livestock in Southern Africa that contribute to climate change adaptation are medicine, food, ethnoveterinary, shade, insect repellent, and windbreak. Medicinal applications constitute the primary adaptation strategy, with 41 plants like *D. cinerea* and *S. birrea* used to treat climate-sensitive diseases while often providing secondary fodder value. Food security functions form the second largest category, featuring drought-resilient food sources such as *A. digitata* and *C. mopane* that sustain communities during climate shocks. The analysis identifies three specialized adaptation niches: (1) 10 shade-providing species, including *A. erioloba* that mitigate microclimate warming, (2) six ethnoveterinary species like *S. birrea* that enhance livestock climate resilience, and (3) two singleton adaptations—*A. digitata* as a biopesticide and *A. mearnsii* for erosion control. The results demonstrate significant overlap in species functions, with 26 plants (50%) serving multiple adaptation roles. *Acacia karroo* and *S. birrea* provide the highest number of adaptation roles (four), followed by *A. digitata*, *B. albitrunca*, *C. mopane*, and *M. oleifera,* providing three roles, and 20 plants serve dual roles.

3.7 Contribution of common browse trees to livestock productivity

The data on the contribution of the eight most cited browse plant species with an RFC ≥ 0.15 is shown in Supplementary Table 7, which was retrieved from *in vivo* studies carried out in Southern Africa (South Africa, Namibia, Zimbabwe, Botswana, and Malawi). A total of 19 *in vivo* research papers were used to gather the data. There was no research published that tested the effect of *B. albitrunca* on livestock productivity in Southern Africa. Findings show that indigenous browse plants can enhance livestock productivity while addressing climate challenges through improved feed efficiency, improved growth performance, reduced methane emissions, drought resilience, and cost-effective protein alternatives. *Acacia tortilis* and *A. karroo* lowered methane emissions in ruminants. Indigenous plants (e.g., Opuntia, Acacia pods, *S. birrea* seed cakes) reduced feed costs while maintaining productivity by effectively replacing expensive protein sources like soya bean meal.

3.8 Invasiveness and leaf phenology of the most represented browse species in Southern Africa

Knowing which species are invasive allows for better grazing management of rangelands to prevent ruminant livestock from selectively browsing these plants and exacerbating biodiversity loss. The results displayed in Supplementary Table 6 show that the three commonly browsed trees are considered invasive in Southern Africa, and five browse trees are not invasive. The table shows that amongst the eight most cited browse trees, there are five evergreen plants, two deciduous plants, and one semi-deciduous plant.

3.8.1 Impact of phenological traits on year-round forage availability

1. Evergreen Species (*A. erioloba*, *A. karroo*, *A. tortilis*, *B. albitrunca*, *O. ficus-indica*).

They provide continuous browse throughout the year, making them critical dry-season fodder when deciduous species shed leaves.

2. Semi-deciduous (*C. mopane*)

Forage Availability: Partial leaf retention (50–70%) in the dry season.

3. Deciduous species (*D. cinerea*, *S. birrea*)

Forage Availability: Seasonal (wet season) with key exceptions: *D. cinerea* pods persist 2–3 months after leaf fall (Smith et al., 2005) and *S. birrea* fruits/nuts available 4–5 months post-leaf shedding. Their disadvantages are that complete leaf loss for 3–5 months creates forage gaps and heavy browsing delays spring leaf flush (Shikangalah et al., 2022).

4 Discussion

4.1 Country comparative analysis

South Africa had the highest number of studies, probably because of its high investment in Research and Development, approximately 0.8% of its GDP (Chagwiza et al., 2024). This is followed by Botswana 0.5% GDP, Zimbabwe 0.4% GDP, and Namibia, Zambia, Lesotho, and Eswatini have a low investment of 0.3% GDP in Research and Development. Also, research by Yalley et al. (2023) showed that South Africa publishes more research papers compared to other African countries. The same trend was reported by Cooke et al. (2023), they noted that there was little literature published from Angola, Lesotho, and Eswatini.

The highest similarity in plants browsed by ruminants was between Zimbabwe and South Africa. In ecological studies, a high JI might mean that two communities or habitats support similar species, which probably may indicate similarity in environmental conditions (Webb, 2000). It might also mean that there is a similarity in how trees are utilized in different countries and that there is an overlap in traditional knowledge. The low similarity between some countries in Southern Africa might have been an effect of climate change and land use transformations, which might have affected the distribution of species and biological diversity (Kapuka et al., 2022; Warszawski et al., 2013). This would have been caused by drought-induced mortality and contraction, invasion by other species, and reduced species expansion due to thermal limitations (Robinson et al., 2020; Anderegg et al., 2019).

4.2 Quantitative analysis of browse plant species in Southern Africa (FC and RFC)

The quantitative results align with qualitative research on Southern African fodder systems, where drought-resistant species like *D. cinerea*, *C. mopane*, *S. birrea*, *B. albitrunca*, and Acacias dominate pastoral rangelands (Mudzengi et al., 2017). Plant species like *D. cinerea* and *A. karroo* are widely distributed and abundant in Southern Africa as they are considered invasive species in this region (Shikangalah et al., 2022; Hansford, 2015). The high citation of *C. mopane* reflects its ecological dominance in mopane woodlands and importance for both fodder and mopane worm production.

The 80 browse species with the least representation were only mentioned once, probably suggesting either highly localized use or underutilized resources or knowledge gaps needing documentation. The other reason might be that they had been affected by climate change and did not adapt well to the high temperatures currently being experienced in Southern Africa. A study by Kapuka et al. (2022) assessed how eight species' distributions in Southern African countries were affected by climate change. It was reported that the baseline suitability range of *C. mopane* was least affected by climate change. Salem and Smith (2008) reported that *A. tortilis*, *Acacia cyanophylla*, and *D. cinerea* are commonly browsed by ruminant livestock in semi-arid and arid tropics because they have palatable leaves and fruits. In South Africa, *C. mopane* is commonly utilized by ruminants, and *Z. mucronata* and *Maerua angolensis* are the least browsed species (Kujoana et al., 2022). The results are similar to a report from a study in Ethiopia, which reported *A. tortilis*, *A. nilotica*, and *Ziziphus* sp. to be important indigenous tree species that are used as sources of fodder (Mulatu and Hunde, 2019). The results showed a strong citation for native species over introduced ones (e.g., *Moringa oleifera* at RFC 0.07), emphasizing the adaptation of indigenous flora to local feeding systems.

A high RFC value was probably because *D. cinerea* and *C. mopane* are well adapted to arid and semi-arid environments in Southern Africa (Trytsman et al., 2023). Wetland/riverine species (e.g., *Ficus sycomorus*, *Hyphaene petersiana*) had lower RFC, possibly due to restricted habitats. It was noted that though some of these plants had different FC values, they had the same RFC value, meaning that in terms of cultural importance, they had the same value, such as *A. karroo*, *S. birrea*, *A. tortilis*, *A. erioloba*, *B. albitrunca*, and *O. ficus-indica*. The results provide empirical support for prioritizing *D. cinerea*, *C. mopane,* and key Acacias in fodder interventions while highlighting the need to conserve ethnobotanical knowledge of lesser-used species.

4.3 Diversity of browse plant species in Southern Africa (genera and FIV)

Acacia, Grewia, Combretum, and Ficus genera had a high representation of browse species, probably because these genera have adapted well to the semi-arid and arid climatic environment and poor or degraded soils common in Southern Africa (Trytsman et al., 2023). These genera have been reported to keep their leaves longer, making them a dependable source of fodder during dry seasons. Acacia was the most prominent genus with species such as *A. karroo* and *A. tortilis,* which are widely documented as key forage species for goats and cattle due to their drought tolerance and nutritional value (Mapiye et al., 2009; Brown et al., 2016). The Acacia genus is reported to be most widely distributed throughout the semi-arid and arid regions of Sub-Saharan Africa (Brown et al., 2016; Barnes et al., 1996). In the Acacia genus, *A. karroo* was the most represented plant commonly browsed by ruminant livestock in Southern Africa. The results were similar to what was reported by Brown et al. (2016), that *A. karroo* is the most widespread among acacias in Southern Africa. The browse species is abundant in communal rangelands with evergreen foliage. The moderate representation of Opuntia, including *O. ficus-indica*, aligns with research demonstrating its value as drought-resilient fodder that reduces feed costs (Zeeman, 2005; Shiningavamwe, 2009). The 62 single-species genera included high-value but underutilized taxa like *S. birrea* and *C. mopane*, whose pods and leaves are protein-rich.

Fabaceae was the most important family (highest FIV) due to its high species diversity and citations. The overwhelming dominance of Fabaceae aligns precisely with Mapiye et al. (2009)'s nutritional analyses, which identified this family as critical for livestock due to its nitrogen-fixing capacity and high leaf protein content (18–22% CP). Several Fabaceae species have been reported to have a high protein content and are palatable, making them valuable forage (Lebeloane et al., 2024; Jamala et al., 2013). The Fabaceae family is the third largest family of flowering plants (Doyle, 1994). This highlights the need for careful management of trees in the Fabaceae family to ensure sustainability while supporting both livestock performance and biodiversity. In addition, Fabaceae, Malvaceae, and Combretaceae species have been reported to be well adapted to arid and semi-arid environments in Southern Africa, providing forage during dry periods (Trytsman et al., 2023). Bennett (2011) indicated that plants belonging to Fabaceae, Apiaceae, Malvaceae, Lamiaceae, Myrtaceae, and Poaceae families are important to human livelihoods. The mid-range FIV families (Moraceae, Bignoniaceae, Euphorbiaceae) exhibit patterns matching Shackleton et al. (2000)'s ethnobotanical studies in communal lands, where Ficus and Euphorbia genera serve as emergency fodder during droughts. Families like Cactaceae (*Opuntia*) and Capparaceae (*Boscia*) have lower FIV but provide critical dry-season fodder. Top families require sustainable management policies due to heavy utilization pressure. Rare families with high-potential species (e.g., Moringaceae) merit further agronomic evaluation.

4.4 Ecosystem services of browse plant species and their contribution to climate change adaptation

The results were similar to a report by Maroyi (2022), who reported browse trees in South Africa to provide 12 provisioning services (cash income, construction materials, culinary herbs, ethnoveterinary medicines, fiber, firewood, fodder, food, herbal medicines, leaf gel, thatching materials, and wine production), nine regulating services (air purification, animal enclosure, erosion control, green manure, insect control, live fencing, shading, windbreak, and water purification), and five cultural services (aesthetic, circumcision ritual, handicrafts, spiritual, social cohesion, and integration).

Medicines, food, construction, firewood, and ethnoveterinary were among the provisioning services provided by the majority of species reported in this review, with medicine as the most important provisioning service. Medicines, foods, firewood, and construction materials were the provisioning services provided by the majority of browse species. However, some scholars have argued that food provisioning is important ESs for the livelihoods of people in rural subsistence economies (Zaldivar et al., 2002; Reed et al., 2017). Sileshi et al. (2007) reported that 80% of rural communities in Southern Africa rely on medicinal plants for the majority of their medicinal requirements, and more than 90% rely on firewood for energy needs. The cultural and regulating services had fewer plant species compared to provisioning services. The results are similar to earlier research, which highlighted that the most significant ESs provided by plants were medicine, food, firewood, fiber, building supplies, and fodder (Maroyi, 2022; Sandhu et al., 2010).

These research findings are important because ESs are the basis for livelihoods in rural communities. This expands our understanding of the uses and values of plant resources and how these services influence local support for natural resource management initiatives in Southern Africa. The rangelands in Southern Africa are an important source of construction materials such as poles. This is probably because some of the plant species available have been reported to possess attributes such as strength and strong fibre that is resistant to peeling and splitting (Kalaba et al., 2010). Five multipurpose browse trees that provided five Ecosystem Services included *D. cinerea*, *M. oliefera*, *S. birrea*, and *Albizia adianthifolia*.

Climate change has brought about the outbreak of diseases and some new variants, which have led to resistance to conventional medicines being used. Species such as *D. cinerea* and *S. birrea* appear particularly valuable, matching observations by Moiketsi et al. (2023) and Viol (2013) regarding their antimicrobial properties in changing disease environments. More than 80% of rural communities in Southern Africa rely on medicinal plants for disease treatment (Garrity, 2004). The ethnoveterinary applications of *S. birrea* align with Akoto et al. (2020) records of its anthelmintic properties for climate-stressed livestock.

The food-security species reflect documented climate adaptation strategies where drought-resistant trees provide "famine foods" during crop failures (Chinomona et al., 2024). *Adansonia digitata* stands out, with its nutrient-dense fruits serving as documented drought-period sustenance, while *C. mopane* offers both edible insects (mopane worms) and livestock browse. It has been reported that the Miombo forests of Southern Africa provide indigenous fruits during times of famine and hunger (Akinnifesi et al., 2006; Chinomona et al., 2024). Communities also benefit from selling wild fruits. The gathering of native fruits accounts for 5.5–6.5% of household income and creates employment in Southern Africa (Akinnifesi et al., 2008). The most widely marketed indigenous fruits in the Eco-region are *Uapaca kirkiana*, *Azanza garckeana*, *S. birrea*, and *Strychnos cocculoides* (Sheppard J. P. et al., 2020).

Browse trees in Southern Africa provide shade, which aids in climate change adaptation. A study from Kenya's semi-arid regions reported that the temperature of the soil beneath the *A. digitata* and *A. tortilis* trees at a depth of 5–10 cm was found to be 6°C lower than that of the open areas (Belsky et al., 1993). In the Sahel, where soil temperatures usually exceed 50 to 60°C, *A. albida* trees were reported to reduce soil temperature at a depth of 2 cm by 5 to 10°C, enhancing crop production (Vandenbeldt and Williams, 1992). In addition to lowering soil temperatures, shade provided by trees lowers water requirements by lowering evapotranspiration in vegetation and also improves animal comfort by reducing heat stress (Pezo et al., 2024). Sida et al. (2018) reported *A. albida* to aid in climate change adaptation by providing microclimate regulation services through reducing daytime temperatures to drop by 6°C when compared to open fields.

This review reported *Acacia mearnsii* to provide windbreak services. Windbreaks are important in climate change adaptation because they can affect local microclimates by moderating temperatures, reducing wind speeds, and increasing humidity. This helps shield livestock and crops from harsh weather events such as high wind speeds and frost in the face of climate change. In addition, windbreaks contribute to the preservation of soil fertility and health by minimizing wind erosion. Natural insecticides derived from plants can help control insects without the use of chemical insecticides. This ES is important to adapt to climate change since it can alter the insect dynamics, potentially increasing infestations and resistance. *Adansonia digitata* was cited as the only browse tree used as an insect repellent.

The data particularly support the "safety-net" hypothesis (Paumgarten and Shackleton, 2011), where certain species (*D. cinerea, A. digitata*) provide simultaneous medicinal, nutritional, and ecological benefits, a critical adaptation strategy given climate change's compound impacts. This multifunctionality suggests traditional ecological knowledge strategically utilizes keystone species for integrated climate adaptation, where a single plant may simultaneously address health, nutritional, and environmental challenges exacerbated by climate change. However, the limited representation of erosion-control species (only *A. mearnsii*) suggests potential underutilization of this function compared to West African systems (Lamers et al., 1994), possibly indicating region-specific knowledge gaps. These species exemplify nature-based solutions for climate adaptation, aligning with Intergovernmental Panel on Climate Change (IPCC) recommendations for agroforestry and ecosystem-based adaptation (EbA) (Matocha et al., 2012).

4.5 Effect of browse tree species on ruminant livestock productivity

Acacia karroo leaves significantly improved nutrient digestibility and weight gain in goats, likely due to their high protein and mineral content. Multiple Acacia species (*A. karroo*, *A. tortilis*) demonstrated significant methane reduction ($p < 0.05$) in goat diets, highlighting their potential for climate-smart livestock production. This might have been due to tannins that modify rumen fermentation and improve feed efficiency, leading to less fermentable material in the gut. Given the global emphasis on reducing livestock greenhouse gas emissions, these findings support the use of indigenous plants as sustainable feed additives. The methane-reduction effects of Acacia spp. observed (25–30% decrease), exceed the 15–20% reductions reported for Leucaena in comparable Mexican systems (Hernández et al., 2022), suggesting regional species may offer superior environmental benefits. *Opuntia ficus-indica* cladodes reduced feed costs (36% inclusion) while maintaining sheep performance, likely due to high water and carbohydrate content. Increased water intake and wet feces indicate high moisture retention, which could be beneficial in arid regions but may require management adjustments to prevent excessive wetting. *Dichrostachys cinerea* pods improved milk production in goats, leading to better kid survival, a crucial benefit in smallholder farming systems where kid mortality is high.

4.6 Invasiveness and leaf phenology of browse plant species

It is important to understand the leaf phenology of the most represented browse species in Southern Africa, as it influences the availability of forage throughout the year and the nutritional quality of forage. This enables better planning for feed supply. Evergreen species such as *A. erioloba*, *A. karroo*, *A. tortilis*, *B. albitrunca*, and *O. ficus-indica* provide critical browse during drought periods due to their continuous foliage retention. This aligns with Mudzengi et al. (2017), who found that *A. karroo* maintains 18–22% crude protein year-round, making it indispensable in arid zones. However, invasive evergreens like *A. karroo* and *O. ficus-indica* pose ecological trade-offs, as they often outcompete native grasses (Hansford, 2015). Maroyi (2019) notes that *B. albitrunca* is particularly drought-resilient due to deep taproots accessing groundwater, corroborating its high forage value in water-limited regions. A key limitation, however, is that some evergreens (e.g., *A. tortilis*) increase leaf tannins by up to 40% during dry months, reducing palatability (Ngwa et al., 2002). This suggests that while evergreens buffer against forage shortages, their nutritional quality may fluctuate seasonally.

Colophospermum mopane, the only semi-deciduous species reviewed, exhibits adaptive leaf retention (50–70%) in dry seasons, particularly in riparian zones (Teshirogi et al., 2017). This partial defoliation reduces water loss while sustaining some forage availability, a trait highlighted by Sinthumule (2024) as critical under climate change. However, its leaves accumulate flavonoids in drought, lowering digestibility (Makhado, 2020).

Deciduous species like *D. cinerea* and *S. birrea* provide high-quality wet-season browse but contribute little during leaf-shedding periods. *Dichrostachys cinerea* partially mitigates this through persistent pods (12–14% crude protein), which sustain goats for 2–3 post-leaf fall months (Smith et al., 2005). Similarly, *S. birrea* fruits and nuts extend forage utility into early dry seasons, though regional studies report 3–5 month gaps in leaf availability (Shackleton et al., 2002). Overbrowsing exacerbates these gaps by delaying spring leaf flush, as observed in Namibia's *D. cinerea* woodlands (Shikangalah et al., 2022). These findings echo Franzel et al. (2014), who emphasized deciduous species' seasonal limitations in East African agroforestry systems.

The phenological diversity of these species offers a buffer against climate variability. Evergreens ensure baseline dry-season fodder, while deciduous species provide peak wet-season nutrition. Semi-deciduous *C. mopane* bridges these extremes, though its nutritional decline during drought warrants careful management. Regional studies support silvopastoral systems blending evergreen and deciduous species; for example, Namibian farms combining *A. erioloba* (evergreen) and *S. birrea* (deciduous) reported 23% higher livestock survival rates in droughts (Kasale, 2013). However, invasive evergreens like *A. karroo* require controlled utilization to prevent ecological damage (Trytsman et al., 2023).

The results revealed that 38% of the most commonly browsed species are classified as invasive, with all invasive species being evergreen except for *D. cinerea*. This aligns with findings by Givnish (2002) showing that evergreen species often exhibit higher invasive potential due to their year-round competitive advantage. Notably, all invasive species are either evergreen or deciduous, with no semi-deciduous species showing invasiveness, suggesting phenological strategy may influence invasion success. The ecological implications are significant, as invasive evergreens like *A. karroo* and *O. ficus-indica* may alter water budgets and fire regimes (Milton and Dean, 2010), while the non-invasive status of ecologically important species like

C. mopane (semi-deciduous) and *S. birrea* (deciduous) confirms their balanced role in native ecosystems (Chikuruwo, 2016).

These findings underscore the need for targeted management of invasive evergreens while protecting the phenological diversity of native species that support ecosystem functioning across seasonal cycles. These results suggest potential links between phenological strategies and invasion potential in Southern African ecosystems, with evergreen species generally showing higher invasiveness risk. The data provides valuable insights for ecological management, highlighting species requiring control measures (invasive evergreens) and those important for conservation (native deciduous and semi-deciduous species). The absence of invasive semi-deciduous species may indicate that this phenological strategy confers a lower competitive advantage in invasion scenarios.

4.7 Research gaps

The review provided a comprehensive synthesis of indigenous multipurpose trees (MPTs) in Southern Africa, but certain methodological constraints and regional disparities affected the robustness and generalizability of findings. The review depended on 41 ethnobotanical surveys, but these may not represent all Southern African communities equally. There was an underrepresentation of oral IK, as many Indigenous Knowledge Systems (IKS) are transmitted orally and may not be captured in formal studies. Language barriers as only English-language studies were included, excluding Portuguese (Angola, Mozambique) and local language records. High RFC species (e.g., *Dichrostachys cinerea*) are culturally prominent but may not always be the most nutritious (e.g., tannins reducing digestibility). There was a lack of weighting as RFC treats all citations equally, but some studies had larger sample sizes or deeper ethnobotanical engagement. There was no comparison between pastoralist preferences versus agro-pastoralist species. For example, pastoralists (e.g., Namibia's Damara) favor drought-resistant species (*A. erioloba*) and agro-pastoralists (e.g., Zimbabwe) integrate fodder trees with crops (*Ficus sycomorus*). There were Geographic biases where no data were reported from Mozambique, Eswatini, Zambia, and Malawi. Nutritional evaluation gap of important browse species, as no *in vivo* research has been carried out in Southern Africa to evaluate the contribution of *B. albitrunca* to livestock productivity. There is a need for further studies on species-specific nutritional profiles, methane reduction mechanisms, and climate resilience. Cross-cultural IK studies comparing species preferences across ethnic groups (e.g., Vhavenda vs. Tsonga knowledge).

5 Conclusion

It is concluded that they are many plant species (122) from 34 botanical families and 78 genera that are browsed by ruminant livestock in Southern Africa. This review highlighted the critical role of indigenous multipurpose trees (MPTs) in addressing feed shortages, enhancing livestock productivity, and supporting climate change adaptation in Southern Africa. Key species such as *D. cinerea*, *C. mopane*, *S. birrea*, and *A. karroo* provide high-quality forage during dry seasons while delivering additional ecosystem services, including medicinal uses, food security, and microclimate regulation. Their integration into ruminant diets improves weight gain, milk production, and feed efficiency while reducing methane emissions making them valuable for both smallholder and commercial farming systems. However, the invasiveness of some species, such as *D. cinerea* and *A. karroo*, necessitates careful management to prevent ecological disruption. Non-invasive, high-value trees like *S. birrea*, *A. erioloba*, and *B. albitrunca* should be prioritized for silvopastoral systems due to their adaptability and multiple benefits. To maximize their potential, future efforts should focus on: (1) Participatory domestication and conservation—Promoting the cultivation of drought-resistant MPTs to ensure sustainable availability, (2) Policy Support—Encouraging agroforestry initiatives and habitat protection for key plant species, and (3) Farmer Training—Educating livestock producers on optimal feed formulations and sustainable grazing practices. By integrating indigenous MPTs into livestock production systems, Southern Africa can enhance food security, mitigate climate impacts, and restore degraded rangelands, ensuring long-term agricultural sustainability.

Author contributions

MM: Writing – original draft, Funding acquisition, Formal analysis, Project administration. PM: Writing – review & editing. LT: Writing – review & editing, Supervision. DC: Writing – review & editing, Supervision. JM: Supervision, Writing – review & editing. SC: Supervision, Writing – review & editing.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2025.1636284/full#supplementary-material

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