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Review Article

Contribution of Climate-Smart Forage and Fodder Production for Sustainable Livestock Production and Environment: Lessons and Challenges from Ethiopia

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Sustainable farm animal raising is dependent on the production of sufficient quantities and quality of forages and fodder, especially in dry regions. Improved forage and feed species are an option for these aspects because adequate feed resources enhance soil health and carbon, generate income, and reduce emissions. Therefore, the purpose of this review paper was to investigate the role of climate-smart forage production in sustaining farm animal production and maintaining the environment in arid and semiarid regions. Seasonal fluctuations in feed supply cause temporal scarcity in Ethiopia, with more acute gaps in dry periods, particularly in drought-prone regions. To address these problems in the country, improve forages to strengthen farm productivity, climate change resilience, and environmental sustainability, particularly in arid and semiarid areas. The country has a long history and is of some exemplary practices in indigenous improved forage production, but the input of improved forage to the total biomass production in feed resources is still low due to many factors like scarcity of land and water for irrigation, lack of awareness, forage seed, and policy recommendations. Despite the potential profits of feed and forage grasses and legumes, the availability of species adapted to a wide range of situations in actual use in the livestock sector has been insufficient. Therefore, it is strongly suggested that climate-resilient forage species be popularized to sustain livestock production and the environment, particularly in the country's arid and semiarid regions.

1. Introduction

Ethiopia is a growing human population country resulting in an increased demand for agricultural products, especially livestock products to satisfy human demand [1]. Dryland livestock production will play an increasing role in feeding the world's growing population because it covers 40% of the global area and represents 75% of Ethiopia's landmass [2]. Pastoralism and agropastoralism mostly found in arid and semiarid regions are the predominant production systems in Ethiopia, accounting for an estimated 15% of the population and occupying more than 60% of the country's drylands [3, 4]. Besides, it produces 34% of national red meat, 38% of total milk, and 21% of cow milk. In general, the livestock sector, which is based in PAP areas, donates 12–16% of its GDP and 30–35% of its agricultural GDP [5]. However, periodic shortages of feed both in quantity and quality by pastoralist and agropastoral societies are with key encounters with livestock production in the country [6].

Grazing land and searching for plant species are the most significant food and feed resources in pastoral and agropastoral areas [7], while crop residue, better quality grasslands, and processed feeds have restricted participation in the country's feed resources [8]. Due to increasing cropping land, natural grazing land has been shrinking and decreasing pasture productivity [9] and crop residues have high fiber content, but low digestibility and intake, making them unsuitable for high animal productivity [10]. This, combined with recurring drought and the spread of hostile species, has resulted in a significant disaster in livestock productivity and the livelihood of communities [11]. Improved forages and pastures which are climate-resilient options have been one of the main approaches to addressing feed scarcity [12, 13]. The use of improved and cultivated forages combined with genetically improved animals provides benefits such as increased feed conversion efficiency [14], increased livestock productivity, and reduced emissions, which would help as a basis for achieving food and nutrition security, as well as a climate-resilient green economy to climate change [15].

Ethiopia has a suitable climate and a wide variety of native forage species. Forage development strategies have been introduced and popularized for about five decades in the country's crop-livestock production systems [16, 17]. Improved and climate-resilient grass and legume forage species that grow in Ethiopia include buffel grass, desho grass, Rhodes grass, elephant grass, *Phalaris* grasses from grass forage species, axillaris, green leaf, lablab, cowpea, vetch, alfalfa, and white clover among legume forage species and *Leucaena*, *Sesbania*, pigeon pea, and tree lucerne from tree and shrub legumes [8, 18–20].

Most improved and climate-resilient grass and legume species were recently selected and evaluated in various parts of the country for sustainable animal raising and environmental management [14, 19, 21–29]. Improved fodder and forage production are the options for better feeding in climate-changing scenarios because they increase efficiency with minimal efforts, benefit the degraded environment, reduce food competition, increase climate adaptation capacity, and reduce vulnerability to recurrent climate change and drought [29]. Improved forage practices also play a significant role in the three pillars of climate-smart agriculture that protect the ability of pasturelands to sequester carbon dioxide, ensure vegetative cover and prevent soil erosion, and reduce methane emissions from ruminant animals. Therefore, the purpose of this document was to examine the role that climate-smart forage production plays in sustaining livestock production and the environment in Ethiopia's semiarid and arid regions under climate-changing scenarios.

2. Methodology

This review's framework was based on new research to identify knowledge gaps in the global literature [30, 31]. The final review paper is based on the analysis and application of selected journal articles, books, short pieces, and numerous reports from various researchers, institutions, and organizations. For this review, the literature search concentrated on the current 2000 publications to discover information on climate-smart forage and fodder for livestock productivity and the environment. Climate, intelligent forage, feed, livestock productivity and environment, adaptability, response to climate change, global warming, resilience, feed, animals, dry, arid, and semiarid habitats were used as search phrases. Scopus, PubMed, Web of Science, AGRIS (agris.org), Research Gate (https://www.researchgate.net), Science, and others were used. Finally, more than 100 articles were referred to produce the final assessment of the role of climate-smart forage and feed production for livestock productivity and the environment under climate change.

3. Livestock Production Systems and Their Importance in Sustainable Livestock Production

Ethiopia has the largest livestock population in Africa, with 70.3 million cattle, 42.9 million sheep, 52.5 million goats, 8.2 million camels, and 49 million chickens in 2021 [32]. Most livestock production systems and practices in Ethiopia are traditional with native breeds. Productivity is hampered by several factors, such as poor genetics, poor reproduction rate, poor food quality and availability, high prevalence of disease, parasite barriers, and scarce access to products and inputs [33]. In the region, three management systems predominate intensive, mixed crop-livestock, and pastoral/agropastoral management. Pastoral and agropastoral livestock production is Ethiopia's second most dominant system, in the country's southern and eastern lowlands. These systems can be categorized as extensive livestock management systems with low input and output [34].

Furthermore, the global population is rapidly increasing, as is industrial activity all around the entire globe. The growing economic activity entails increased global emissions, which results in international problems such as global warming and climate change [35, 36]. Mixed farming systems occupy more than a quarter of the world's land area. Another fifth of the world's arable land is used to grow grains for livestock feed, primarily for industrial systems [37]. Animal agriculture is a critical sector that encourages socioeconomic development in developing countries, employing approximately 600 million smallholder farmers [38]. Demand for livestock production has increased in developing and transitional economies due to dietary changes toward higher meat consumption accompanied by economic growth [39]. Because of their own steadily rising household consumption, increasing urbanization, increased incomes, and dietary changes, developing parts of the world will be suppliers of livestock products for their markets [40]. Furthermore, livestock will become highly significant in sub-Saharan Africa, particularly in Ethiopia, as demand for animal-sourced food is anticipated to rise because of overpopulation, increased incomes, and urbanization. Low- and middle-income consumers will consume 107 million tons more meat and 5.5 million tons more milk by 2050, with an annual per capita consumption of 26 kg and 64 L, respectively [41, 42]. Livestock is an important asset to people's livelihoods in most semiarid environments, where natural resources cannot be used directly for human consumption [43].

Thus, sustainable livestock production is crucial in developing countries because it improves nutrition, economic and environmental stewardship, and sociocultural needs, and is critical to achieving most of the Sustainable Development Goals. Livestock farming makes a significant contribution to sustainability by using degraded land for food production, transforming energy and protein sources that humans cannot use into highly nutritious animal-sourced food, and reducing environmental pollution with agro-industry by-products while creating wealth and promoting the livelihoods of millions of people around the world [44]. Moving toward sustainable intensification of livestock production is a possibility, which could reduce the negative effects on the environment and even provide essential ecosystem services on farms, such as improved soil health, carbon sequestration, and increased biodiversity. The use of cultivated forages, many of which have been improved through selection or breeding and include grasses, legumes, and trees, is recommended as a key component of the evolution of sustainable agriculture in integrated cropping-tree-livestock systems [13].

4. Challenges and Constraints of Livestock Feed Resource

Livestock is critical to incomes, livelihoods, nutrition, food security, and resilience in much of East Africa. The seasonality of feeds and water means that people and livestock must move to areas of concentration of these resources, which is increasingly leading to conflict, overgrazing, and degradation of rangelands in East Africa [45]. There are several types of livestock feed and fodder resources in Ethiopia, the common of which are subject to seasonal availability, particularly in dry areas. Ethiopian livestock feed resources were classified as pasture land, crop residues after grazing, improved pasture, pasture trees and browse, and agroindustrial by-products [46]. In pastoral and agro-pastoral livestock production systems, rangeland grazing and browsing (foliage and pods of trees and shrubs) are the primary sources of feed while cropping residues, stubble grazing, and conserved forages are used on occasion. Seasonal monitoring of forage and water resources is a frequent practice for dealing with seasonal feed and water shortages. Pastoral herds depend on emergency feeding from highland feed during exposure to severe drought. However, the production of forages irrigated along river basins is increasing. Seasonal fluctuations in forage availability and quality, invasive plant encroachment, scarce livestock mobility, land-use changes, recurring droughts, damaged customary institutions, and a lack of infrastructure investment in rangeland betterment are one of the main challenges influencing livestock feed production and pastoral livestock farming. The opportunity for customary cropping approaches that depend on movement has also decreased because of crop increment and other changes in land use, as well as rising population pressure [47].

Feeding both in terms of quantity and quality is a major bottleneck for livestock production in Ethiopia. Feed resources can be classified as natural pasture, crop residue, improved forage, and agroindustrial by-products of which the first two contribute the largest share (Figure 1). Currently, with the rapid increase in human population and the increasing demand for food, grazing lands are steadily shrinking, being converted to arable lands, and are restricted to areas of little value [8]. Forage grasses are a crucial source

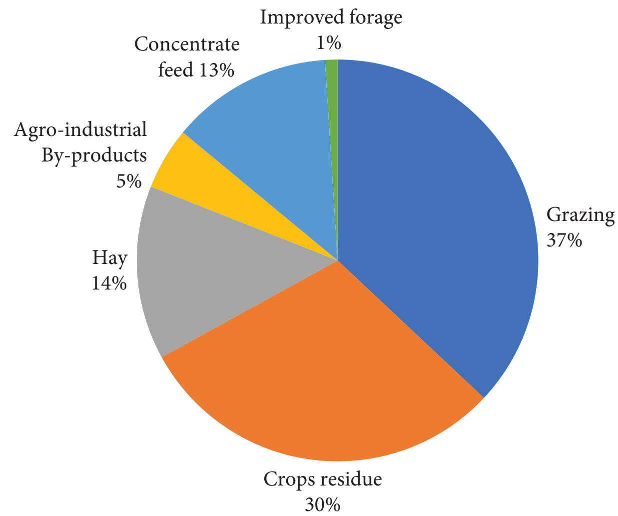

Figure 1: The proportion of animal feed resources in Ethiopia [48].

of food for animals, particularly ruminant animals. They provide a source of feed during both the wet and dry seasons, however escalating climate change could threaten the availability of fodder, especially in East Africa, including Ethiopia [49].

Poor feed quality and quantity, environmental deterioration, excessive grazing, border conflicts, drought, and a lack of seed and planting supplies continue to be obstacles to the development of Ethiopia's livestock industry. Most of the grazing land in Ethiopia's arid and semiarid regions is communal, and its availability is highly seasonal because of rainfall patterns and overgrazing. Natural pasture is the only source of livestock feed, accounting for more than 80% of all livestock feed [50]. They are owned by the community and include a variety of grasses, legumes, and shrubs. Numerous factors, including poor management, a short growing season, little rainfall and frequent droughts, shrub invasion, the extinction of more palatable and high-quality grass species, overgrazing, and soil nutrient depletion, have an impact on lowland grasslands [51]. Especially in pastoral and agro-pastoral systems, grazing land is disappearing steadily due to population pressure, land degradation, and conversion to arable land. It is significant to note that some farmer groups are beginning to implement initiatives to improve communal lands using various management techniques, such as sowing improved species (Rhodes grass), stopping grazing, or practicing controlled grazing, and producing hay and seeds [21].

Furthermore, seasonal variation in rainfall affects the availability of feed resources, particularly in arid and semiarid regions. Compared to the long dry season, feed is available in greater quantity and quality in some areas during the rainy season and the early dry season [52]. Insufficient grazing resources can identify the dry season. So, while crop residues and purchased feed have increased, the use of communal grazing lands, private pastures, and forest areas as feed resources has decreased. Even though the use of agroindustrial by-products has increased, many farmers in some regions of the country cannot easily access, afford, or use them [53]. In Ethiopia's arid and semiarid regions, drought and climatic variability have significantly hampered the availability and utilization of feed resources. Therefore, food scarcity is a significant problem in most of Ethiopia's highland regions from December to February, but less so from October to November. Furthermore, pastures and crop residues are typically scarce and inadequate quality during the dry season [54].

Climate change, particularly drought, reduces pasture and crop production. Droughts caused by climate change reduce livestock productivity and their contribution to food security, along with household and national incomes [47]. Furthermore, changes in rainfall patterns, elevated CO_2 levels, and extreme weather events negatively affect the growth, distribution, and nutritional value of the main forage species [55]. Climate change affects the quantity and quality of feed available for livestock production; the specific effects vary depending on the farming system and geographical location. Rising temperatures, floods, and other unpredictable weather conditions, as well as an increase in the emergence and spread of pests and diseases, can seriously harm food and feed crops [56, 57]. Temperatures higher than a species' optimal are harmful to plant growth and development at all stages. Elevated carbon dioxide levels are expected to stimulate plant growth while still reducing forage quality by increasing the content of lignin and reducing nutritive value [58]. Increased availability and use of improved forage and forage seed, as well as the incorporation of forages into localized feeding strategies, will allow livestock farmers to cope more successfully with climate change [56, 59]. Recently, rather than establishing sustainable seed systems or livestock growers' capacity for forage production and use, efforts to support livestock growers in adopting forages have primarily focused on promoting technology [60]. In general, population pressure on cropland development, seasonality in feed supply, and lack of understanding of feed preservation require alternative methods of feeding, conservation, and utilization. Ethiopian livestock and grain output can be sustained if dramatic modifications in livestock and land management systems are implemented. This will require a more efficient integration of livestock and cropping systems, improved genetics, and a shift toward more intensive feeding systems, with a greater emphasis on cut-and-carry feeding, forage production in the midlands and highlands, and rational grazing, particularly in the lowlands.

5. Climate-Smart Agriculture as a Solution to Feed and Forage Production

The sustainability of the livestock sector in sub-Saharan Africa is threatened by a lack of quantity and quality of feed and feed. Global warming further exacerbates food availability and quality. Improved forages and feed, such as *Brachiaria* grass, have been recommended as an approach for reducing feed crisis, particularly in drier agroecological zones [61]. Forage-based animal genetic makeup and application, combined with the use of climate-smart forage feeding systems, will result in enhanced farm productivity, that provide farmers at all phases of progress with an economic encouragement to endorse and maintain more ecologically and economically cost-effective farming methods [62]. Climate-smart research, innovation, and practices will support the creation of a production systems strategy aimed at changing the livestock sector and advancing advancement forward toward the sustainable development targets of poverty, hunger, global warming, and environmental improvement [63].

In addition, livestock farmers can better adapt to climate change by spreading the availability and utilization of improved forage and forage seeds, as well as integrating forages into regional feeding techniques. Resilient to stress forage grasses and legumes provide feed for livestock during drought or waterlogging [64]. In crop-livestock systems, drought-adapted forage legumes can provide high-quality feed during the dry season [65]. Supporting livestock keepers to make better use of the resources already available and integrating forages into a feeding strategy that includes crop residues and agricultural by-products can help reduce feed shortages and inflated costs. In addition, the production of climate-smart forage and feed is crucial to the sustainable improvement of livestock production and productivity, maintaining degraded land, improving soil health, and reducing greenhouse gas emissions (Figure 2).

Climate-smart agriculture (CSA) tackles the dangers that climate change poses to agricultural production. A three-pillared approach to ensuring food security and sustainable development is obtained: increasing agricultural productivity (crops, livestock, and fisheries) and income; improving resilience or adaptation of livelihoods and ecosystems to climate extremes; and lowering and removing GHG emissions from the atmosphere [11]. Climate-smart agriculture refers to agricultural techniques or practices that contribute to the achievement of these pillars. However, different techniques regularly act differently throughout the three pillars, requiring their integration in an integrated CSA approach to complement and maximize their gains [67].

The importance of climate-smart pasture production is evident in addressing the consequences of climate change and variability, particularly drought and floods, and reducing the economic impacts caused by previous droughts and floods [68]. The role of improved forage production in the three pillars of climate change differed significantly and described in Figure 3.

5.1. Adaptation of Improved Forage Species in Ethiopia.

The adaptation of a crop is determined by the climatic and edaphic conditions of a specific area [71]. In many tropical areas, forage species have grown in specific types of soil. For example, buffelgrass (*Cenchrus ciliaris*) is well-adapted to fertile and dry soil but not suitable for waterlogging areas [72], whereas *Brachiaria* grass is well-adapted to acidic and infertile soil [73]. Thus, forage development strategies have been created to meet the requirements of both farm households and specialized large forage production

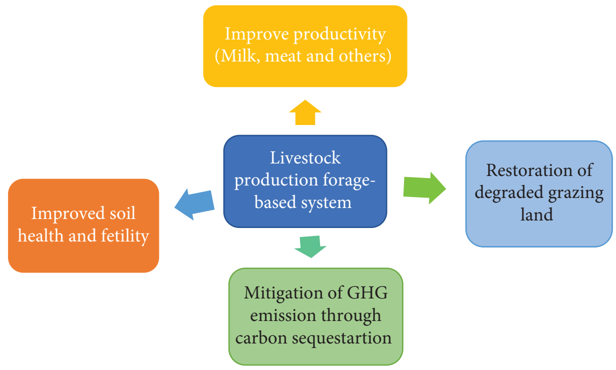

Figure 2: Role of forage-based livestock production in smart ways [66].

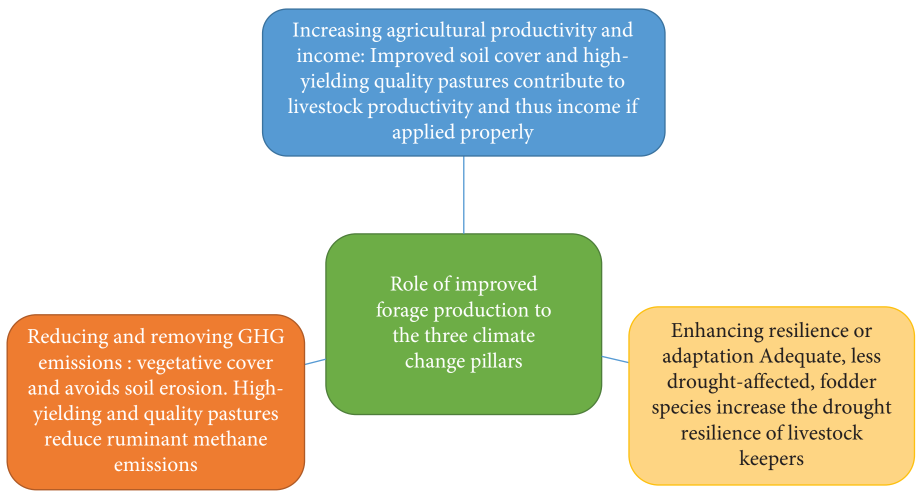

Figure 3: Role of improved forage production in the three pillars of CSA [67, 69, 70].

companies, and suited species for each strategic plan have been suggested for Ethiopia's numerous agroecologies [74]. Options such as the integration of food and forage crops are ideal for small farmers facing land scarcity. In areas with poor soil fertility and degradation, forage plants can be planted in soil bands, soil management structures, hedges, and alley crops. High-yielding and high-quality forage crops, on the other hand, such as alfalfa, elephant grass, cowpea, lablab, vetch, and others, are suitable in very well-intensive production systems with better production inputs and irrigation to supply quality feed for high-yielding livestock [75].

5.2. Forage Production and Productivity in a Different Ecology. Many studies have been carried out to test and evaluate forage species' ability to adapt and perform in different ecological zones [70]. Government ranches, state farms, farmer demonstration plots, and dairy and fattening operations have all cultivated and used improved pastures and forages. The most prominent forage plants are those grown as additional animal feed to help dairy cows produce more milk and meat. Oats, vetch, fodder beet, elephant grass, siratro, *Desmodium*, Rhodes grass, lucerne, *Phalaris*, *Trifolium*, *Sesbania*, *Leucaena*, and tree lucerne are examples of typical forage species. Improved pasture and forage grasses can produce 6 to 8 tons of dry matter per hectare, while tree legumes can produce 10 to 12 tons (Table 1). There has been a limited introduction of improved pastures and forages because of land scarcity and farming focused on crop production (IRLI, [55]). Much native forage species produce little, which limits their value for livestock productivity and animal nutrition. The adoption of forage crops has been hampered by a lack of technical understanding and awareness [84]. Forage crops that are grown annually are more productive and need less maintenance than perennials. Techniques for processing seeds, such as threshing, drying, and cleaning, are challenging for most perennial species and require specialized knowledge and skills. Most perennial forage grasses and legumes produce 1–4 quintiles of seeds per hectare of seed production [51]. The increased cultivation of improved forages and their processing through innovative technologies would help bridge the gap between the availability and demand for feed in Ethiopia, especially during dry periods and emergencies. The inclusion of improved cultivated forages also improves feed quality, which reduces methane emissions per unit of livestock product from ruminants [13, 25, 85]. Regardless of farm size, many Ethiopian farmers taken part in enhanced forage production. Desho grass (*Pennisetum pedicellatum*) (71.38%)

Table 1: List of forage species that are best for Ethiopia's lowland agroecologies.

Forage species	Adaptation (altitudes)	Nutritional contents (%)			
Perennial grass species		DM	CP	CF	GE
Bracharia grass (*Brachiaria brizantha*)	Low to high altitude	31.5	10.4	33.5	18.2
Napier grass (*Pennisetum purpureum*)	Low to mid altitude	17.9	9.7	36.1	17.4
Desho grass (*Pennisetum pedicellate*)	Low to mid altitude	31.5	6.3	40.9	18.1
Buffelgrass (*Cenchrus ciliaris*)	Low to mid altitude	30.1	7.1	40.2	18.3
Rhodes grass (*Chloris gayana*)	Low to mid altitude	24.9	9	36.9	18.3
Annual legumes species					
Alfalfa (*Medicago sativa* L.)	High to low altitude	96.6	18.3	28.6	18.0
Lablab (*Lablab purpureus*)	Mid to low altitude	22.1	18.4	28.2	18.2
Cowpea (*Vigna unguiculata*)	High to low altitude	20.9	18.1	24.1	18.1
Green leaf desmodium (*Desmodium interim*)	Mid to low altitude	24.2	15.5	30.6	18.9
Silver leaf desmodium (*Desmodium uncinatum*)	Mid to low altitude	25.7	15.1	32.1	18.6

DM: dry matter; CP: crude protein; CF: crude fiber; GE: gross energy. Source: [76–83].

and elephant grass (*Pennisetum purpureum*) (42.63%) are the most widely developed forages in the country, particularly in southern Ethiopia, for the prevention of feed, cash, and soil erosion [16].

6. Forage Research Development and Strategies in Ethiopia

Ethiopian forage development began with the introduction of improved feed species [86]. The national and international institutions conducting forage research in Ethiopia are universities' research in agriculture, EIAR, ILRI, and other national and internal research centres are the main national and international organizations engaged in forage development. They support research in agriculture, agro-pastoralism, and pastoralism through agricultural technologies that are competitive in the market. However, the main shortcomings of forage research in Ethiopia include inadequate collaboration and coordination within and between national and international research centres, the requirement for stronger links between forage and animal nutrition research, and the absence of efficient models to bring research (i.e., new seed varieties) to the farmer: route to market, distribution network, and training in best agronomic practices, as well as a lack of knowledge on forage crop production and utmost care [21]. The Ethiopian government has the primary goal of development and a catalyst for change in its growth and transformation plan. The main intervention in this plan is to improve the quality and supply of feed, with cultivated forage production as the primary goal. The national Climate Resilient Green Economy (CRGE) strategy focuses on lowering greenhouse gas emissions from livestock through improved feeding and increased productivity [87]. The main plan of action is to support crossbred animals and improve feeding through forage cultivation. In a similar vein, livestock development has been planned in the Livestock Master Plan (LMP) primarily with increased access to cultivated forage production [5].

In Ethiopia, there are many techniques for integrating forage crops into crop-livestock farming systems. The manner of integration used in a particular farming system is mostly decided by the type of feed crops, food crops, soil type, rainfall pattern, and other social and economic considerations. Cropping systems are spreading and strengthening to feed growing human populations and compensate for declining productivity caused by soil degradation and inadequate husbandry. Adopting solutions that combine livestock and cropping systems can boost crop yields while increasing the quantity and quality of fodder for ruminant animals. Due to their ability to fix nitrogen, forage legumes are widely used to increase soil nitrogen available for food crops. Furthermore, multipurpose browsing trees and shrubs enhance the availability of fuel wood supplies to agricultural households, reducing the need to use dung as fuel and increasing the availability of dung for use as fertilizer. In general, better forage legumes and browse species supply a sustainable source of protein, increasing the productivity of ruminant animals [88–91].

7. Adoption of Improved Forage Technology

Research on forage crops was formally started as a national program when the Institute of Agricultural Research (IAR) was established in the mid-1960s. At this time, a wide range of tropical and temperate pasture and fodder species were introduced from various parts of the world with the support of the FAO, ILRI, EARI, Universities, and other governmental and nongovernmental organizations. For instance, ILRI has developed and recommended about 50 well-adapted forage crops together with proper production packages for the different agroecologies. However, the adoption of this improved material has been limited [91]. The adoption of new agricultural technologies depends on the capital, willingness, and educational status of the users; the availability of land and technology; and other factors. In Ethiopia, different studies were conducted on the evaluation of improved forage species in various parts of the country; however, the distribution was limited to a specific place [92–94]. In the country, the adoption of improved and cultivation of forage production and use is low due to several factors [70]. Melesse et al., [95] reported that most livestock producers did not plant improved forage, and only a small area of land was distributed for forage development. Capital and technology limitations could challenge the poor practice of improving forage development. In general, land scarcity, forage seed, lack of awareness, and training on how to cultivate and use improved forage, and capital limitations are the main challenges to improving forage development in Ethiopia [75]. Furthermore, research and development efforts for agriculture and pastures were more focused on species/variety screening, adaptation, and biomass production, and less attention was paid to use. There were limited studies on farm feeding and animal response to prove the impact on productivity. This has resulted in a lack of compelling evidence that shows the benefits of forage production and use. Furthermore, poor market linkage for animal products could discourage investment in improved intermediate feed products, and forage seed is another intermediate in the livestock value chain [75].

8. Improved Forage and Fodder Production and Their Implications for Sustainable Livestock Production and the Environment

The livestock sector in Ethiopia is characterized by low productivity due to insufficient availability of affordable high-quality animal feed all year, with especially acute gaps in the country's drought-prone regions. Cultivated forage-based diets are critical to meeting animal feed requirements while reducing GHG emissions [96–98]. In growing animals, diets having more than 85% cultivated forages can support a daily body weight gain of up to 1 kg. The costs from farm animals can be up to 15 times cheaper than those of conventional feed supplies. Diets based on pelleted cultivated forages reduce feeding costs by four times during a 100-day drought period, fattening expenses by 2.3 times, and feed costs for milk production by four times. In the fattening sector, the use of grown forages might cut methane emissions by $165 to USD 240 for every 1000 kg of body weight growth. The abatement value for the dairy sector would vary from $1350 to USD 2400 per million litres of milk produced. The value of methane reductions for the 120-day drought period would be between $5500 and USD 11,400 per 1000 animals [25]. The main long-term prospects for improved forage cultivation and utilization in Ethiopia include urban development, income growth, farmland expansion, rising populations, crop intensification, and irrigation expansion [99]. The current situation shows rising demands for livestock products and growing interest in commercial livestock production, which leads to increased demand for productivity-enhancing inputs. Currently, there is a significant disparity between actual and potential levels of livestock productivity. The supply of feed has becomes a critical issue. The reduction of traditional grazing areas has resulted in a decrease in the availability of feed from natural pastures. Furthermore, agroindustrial by-products and other concentrate feeds are scarce and expensive. As a result, there is increased demand for alternative, affordable, and high-quality feed resources, and improved forage production could fill this gap significantly [100].

Commercial fodder production can supply livestock feed in urban and periurban intensive landless ruminant production systems, land-constrained smallholder farms in rural areas, drought relief interventions, and export to neighboring countries. Smallholder commercial fodder production diversifies and increases farm income (through the sale of fodder and fodder seed), while also intensifying smallholder livestock production [75]. In addition to advancing food security, livelihood opportunities, economic growth, and environmental policy aims, cultivated forages such as grasses and perennial herb legumes, as well as browse trees and shrubs, offer hope for Ethiopia's livestock. As the livestock industry becomes more commercialized and forage demand and business opportunities in the subsector increase, there will be an increase in demand for high-quality feed [28]. The benefits of cultivated forages include the ability to use a variety of species and practice recommended for specific locations and production systems as a source of high-quality feed [16, 29], the ease of production close to dwellings and farmyards, including inaccessible areas, the possibility of integrating forage production with food crops to improve soil management, the relatively low cost of production, and environmental and natural resource management benefits [91]. With prevalent drought and degradation of natural resources, including grazing lands, and critical feed shortages in Ethiopia, forage crops play critical roles [91]: in delivering quality feed close to the household, particularly in areas where other feed sources, such as concentrates, are scarce, and combining the main goals of improved conservation and productivity enhancement by introducing perennials and leguminous crops more widely in the farming system [101, 102].

9. Conclusion

More than a third of Ethiopia's agricultural GDP comes from the livestock industry, but productivity is low due to a persistent lack of affordable, high-quality animal feed. Prioritizing improved forage that can be integrated into land use and farming systems and improved feeding systems are options to address challenges related to feeding quantity and quality. Despite limited land, scarce resources, high-cost forage seed, lack of training and awareness among farmers, crop-dominated farming systems, and inadequate extension services, the growth of improved forage plants was not widely adopted at the farmer level. With a focus on high yield, good nutritional quality, enhanced disease resistance, reduced GHG emissions, and improved stress tolerance in the face of climate change, use modern molecular genetics to choose productive and resilient perennial forage varieties to help farmers now and breed new varieties for the future. Additionally, it is recommended to keep research and extension on best practices to improve livestock production using high-quality and high-yielding conserved forages that are adapted to the agroecological conditions of the specific regions, given the threat of climate change and the predicted effects on forage production in the future.

Data Availability

The work is a review that depends on published articles from different databases like Scopus, PubMed, and other search engines.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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