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REVIEW

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# An overview of the status, productivity and determinants of improved forage technology adoption in Ethiopia: a review

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## Abstract

In Ethiopia, the adoption of improved forage technology is low despite the fact that improved technology adoption can play a pivotal role in boosting livestock production and productivity in general and the dairy sub-sector in particular, thereby contributing to poverty reduction and food and nutrition security. This low adoption of improved forage technology is constrained by various socioeconomic, institutional, and biophysical factors. We conducted a literature search on the reputable journal database by searching for "improved forage technology", "determinants of forage technology", "adoption", "status of forage production in Ethiopia", and "forage production limitations". Moreover, we conducted a literature search on key national-level research institutions, the Ethiopian Society of Animal Production Proceedings, the Central Statistics Agency (CSA) of Ethiopia, and conference proceedings and abstracts of societies and other relevant databases related to our keywords. This review article, therefore, highlights important issues that potentially constrain farmers` improved forage technology adoption and implementation in Ethiopia. Previous empirical study findings, analyzing the determinants of forage production technology adoption underscored that economic, technological, sociocultural, demographic, and institutional factors are the most important determinants of improved forage technology adoption and diffusion. Generally, to intensify the likelihood of the adoption of improved forage technologies, policymakers and concerned stakeholders should focus on strengthening the research-extension-farmers (R-E-F) linkage, adult education, and capacity building, coaching farmers to access improved forage seeds, information on forage husbandry and feeding, strengthening extension systems as well as capabilities which can improve the livelihoods of smallholder dairy farmers. Finally, the technology developer should incorporate the needs and perceptions of farmers through technology design and development; and consider the key demand and supply side during technology development, which enhances the adoption of the technology more easily. Therefore, our empirical review highlights the importance of addressing the aforementioned technology adoption constraints to improve the adoption and diffusion of improved forage technologies. This in turn, would help to improve the livelihoods of rural smallholder dairy farmers.

**Keywords** Adoption, Determinant, Ethiopia, Improved technology, Forage

## Background

Ethiopia's livestock population is estimated to be 59.5 million cattle, 30.7 million sheep, 30.2 million goats, 8.4 million donkeys, 2.2 million horses, 0.4 million mules, 1.2 million camels, 59.5 million chickens, and 5.9 million beehives (CSA 2016/17). The country's varied agro-climatic situation makes it ideal for the production of

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a wide range of livestock (Asresie and Zemedu 2015). Despite their large number and status, their productivity is low due to a lack of feed of sufficient quantity and quality to meet the annual demand for livestock population that the country owes (Yadessa et al. 2016).

Livestock feed in Ethiopia is almost entirely generated from natural pasture and crop residues, with some urban and peri-urban market-oriented livestock producers using agro-industry by-products as supplementary feeds. Previous data, some 3 decades ago showed that natural pasture accounts for approximately 53% of Ethiopia's total land area (Gebrehiwot and Tadesse 1985).

Currently, the Ethiopian population has at least tripled what it used to be 30 years ago necessitating the expansion of arable cropping at the expense of available grazing land to feed the ever-increasing population (Feyissa et al. 2015). Furthermore, increased urbanization and the use of arable land for housing, recreation, and industrial development displace a significant amount of grazing lands. Consequently, grazing lands are reduced significantly, and the potential for expanding and/or retaining available grazing areas is limited, as the best pasture lands are lost to cultivated land expansion, investment, and urbanization, resulting in critical feed shortages (Feyissa et al. 2015).

In the highland crop-livestock mixed farming system where about 80% of both the human and livestock population of the country are concentrated, the area of available grazing lands has been estimated to be only about 5.7 million hectares (Abera 2006). Furthermore, the available grazing lands are highly fragmented and limited to areas where conditions are adverse for cropping due to topographic, edaphic, and climatic limitations. These marginal environments also impose further limitations on the yield and quality of the pasture. Crop residues also form the other main constituent of roughage feed resources, particularly during the dry season. However, crop residue quality is generally regarded as unsatisfactory to support significant weight gain and productivity in animals. A rough estimate of the available feed in various parts of the country shows a deficit of approximately 35% of the maintenance requirement, which can rise to 70% in dry seasons, such as when there is a prolonged drought as well as erratic rainfall (Feyissa et al. 2022). Suggesting increasing livestock production and productivity requires a simultaneous increase in feed production using improved/cultivated forage crops in addition to natural pasture and crop residues. Improved forage crops serve a variety of functions and play an important role in farmers' livelihoods, owing to their positive effects on livestock production and contribution to economic and environmental sustainability. Besides the production of a large amount of better-quality forage, they have several other benefits in the farming system including improvement of soil fertility through biological N-fixation or when used as mulch (legumes), erosion control when established as conservation structures, fuel wood supply, bee forage and control of weeds, pests, and diseases when integrated into crop rotation as break crops. Generally, the use of improved forage crops is an important step in supporting and improving livestock productivity while maintaining environmental sustainability in agrarian societies like Ethiopia (Feyissa et al. 2022).

Adoption and usage of improved forage technologies were supposed to be the remedial measure and means of upgrading the output of the livestock sector and easing the limitation of feed scarcity (Bashe et al. 2018). However, the amount of available forage is not satisfactory to feed the existing livestock population even during years of good rainy periods (Gashu et al. 2014) for reasons related to the land shortage, free grazing, input shortage, poor extension service, and attitude and skill gap among forage producers (Endalew et al. 2016). Moreover, despite many years of forage research and extension efforts made in the country, improved forage crop use has been very low, and their potential contribution to alleviating the country's critical feed shortage problem remains unsolved. Smallholder farmers' low adoption of cultivated forage crops can be attributed to a variety of factors (Feyissa et al. 2015). Therefore, this review paper provides insights into improved/cultivated forage research and development efforts that have been made so far, as well as determinants for improved forage technology adoption in Ethiopia.

## Methodology

We conducted a literature search on the Web of the Science database by searching for "improved forage technology adoption", determinants of forage technology adoption", the status of forage production in Ethiopia, and major forage production constraints in Ethiopia. Moreover, we conducted a literature search on key national-level research institutions, the Ethiopian Society of Animal Production Proceedings, the Central Statistics Agency (CSA) of Ethiopia, and conference proceedings and abstracts of societies and other relevant databases related to our keywords.

### The major livestock feed resources in Ethiopia

The total annual biomass potentially available for animal feeding in Ethiopia is 144.5 million tonnes, with a Metabolizable Energy (ME) and (CP) crude protein content of 890 × 109 MJ (*million joules)* and 7.5 million tons, respectively (FAO 2017). The total annual potential availability of forage [in million tons of dry matter (DM)] is approximately 110, which includes 5.8 million tons of stubble

biomass, 57 million tons of grazing forage, and 46.9 million tonnes of crop residues (primarily straw and stover) (FAO 2017). Hay and crop residues, combined with natural grass, account for more than 90 percent of livestock diets in all regions, while the use of improved forages accounts for 0.35 percent, except in the Harari region, where it is 1.68 percent. (FAO 2017).

### The livestock feed resources available during the dry period in Ethiopia

Crop residues such as straws, stovers, sugarcane tops, bagasse, grass hay, pulse and cereal milling by-products (brans), and oilseed cakes are commonly used to overcome feed shortages during drought-prone periods. The diagram below (Fig. 1) depicts their availability in Ethiopia. Crop residue availability in Benishangul-Gemuz and Gambela (the regions with positive feed balance) is 931.6 and 44.3 (both as × 103 tonnes), respectively, while pasture grass availability is much higher: 2 874.9 and 1 820.5 (both as × 103 tonnes). Sugarcane tops and bagasse, which are abundant in Southern Nations Nationalities and Peoples Region (SNNPR), Amhara, and Oromia, are two other biomasses that could be used for feed production. The annual availability of sugarcane tops and bagasse (both in × 103 tons) in SNNPR is 110.2 and 123.4, respectively, compared to 42.9 and 48.1 in Oromia and 22.9 and 25.5 in Amhara, respectively. These biomasses, specifically a mixture of bagasse, sugarcane tops, grass hay, and cereal straws in varying proportions depending on availability, can be used to prepare densified complete feed blocks for emergencies.

### The development of improved forage research in Ethiopia

Ethiopian forage research dates back to the establishment of agricultural colleges such as Alemaya College of Agriculture (now Haremaya University) and Ambo College (now Ambo University). However, with the establishment of the Institute of Agricultural Research (IAR) in the mid-1960s, forage research was formally established as a national program (Mengistu and Assefa 2012). Other governmental and non-governmental organizations, particularly the Arsi Rural Development Unit (ARDU)/Chilalo Agricultural Development Unit (CADU) and the International Livestock Research Institute (ILRI), played crucial roles in assisting national forage research and development efforts.

ARDU, founded in Asela in 1967, is credited with pioneering livestock research and development in the Arsi highlands. The project introduced various temperate and tropical forage species and made significant contributions to IAR's national forage and pasture research (Arsi Highlands) in addition to its development efforts in promoting improved forage crops and crossbred heifers in its mandate area. Forage research efforts have primarily focused on germplasm introduction/collection, evaluation, and selection of promising species for various agro-ecologies, forage agronomic studies, micro-seed multiplication, on-farm demonstrations, and user promotion over the last four to five decades (Feyissa et al. 2015).

### The status of improved forage varieties released for different agro-ecologies

Over the past four decades, a marvelous effort has been made on forage improvement. As a result, several useful forage crops have been selected for different agroecological zones of the country (Fig. 2). The ultimate objective of improved forage introduction, collection, and evaluation is to release superior species/varieties/cultivars for wider utilization mainly as a source of feed and natural resource conservation in the farming system within appropriate agro-ecology (Mengistu et al. 2016). However, forage research works have progressed without a formal variety

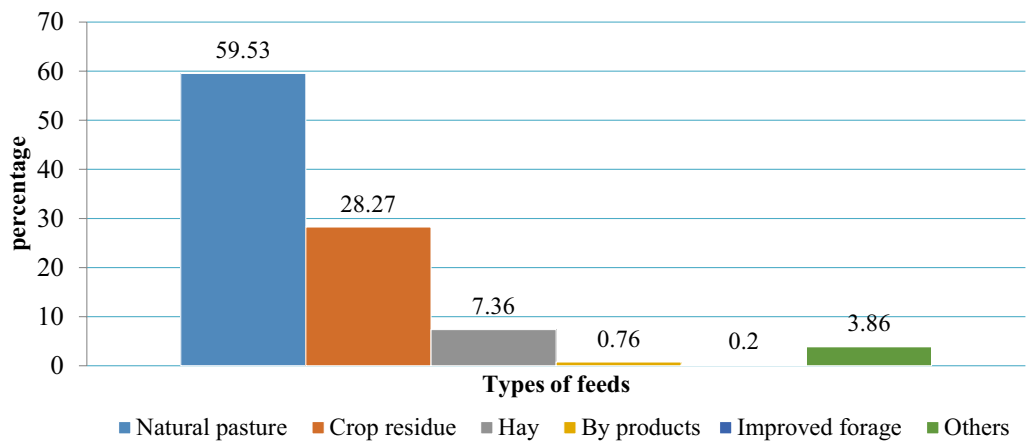


**Fig. 1** Bar graph showing major livestock feed sources and their contribution in Ethiopia. *Source*: Adapted from (Yilma et al. 2011)

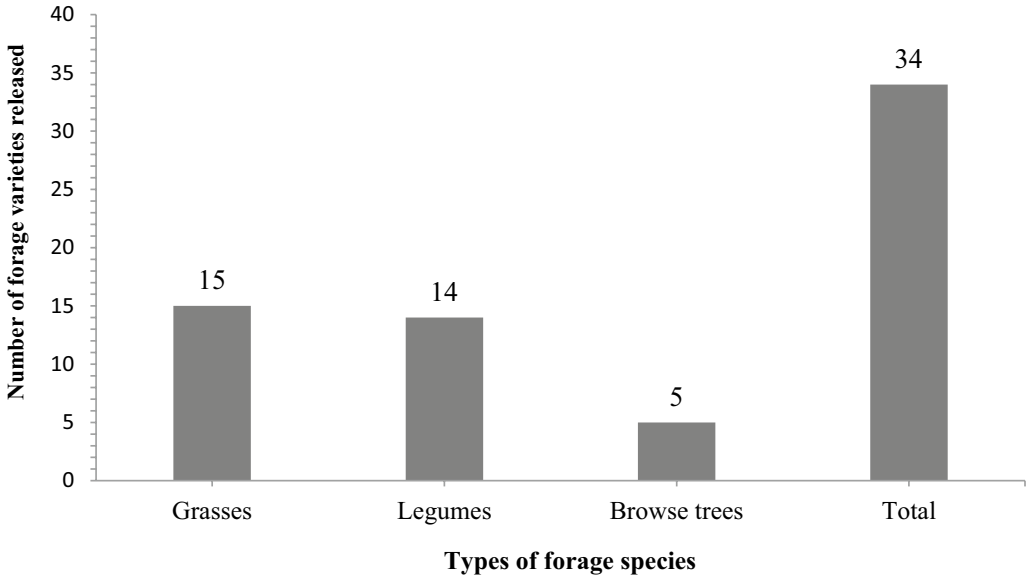


**Fig. 2** Number of released forage crops to different types of agro-ecology in Ethiopia. *Source*: (Holetta Agricultural Research Center progress report 2017/18 varieties)

release mechanism for quite a long period in Ethiopia. Regardless of this, various promising forage species/varieties have been promoted via different livestock development projects like the Fourth Livestock Development Project (FLDP) and are being developed and utilized under varying scales in different parts of the country. Despite the absence of a formal variety release mechanism in the past, many forage species/varieties/cultivars were informally promoted and fairly accepted by end users (ex-state farms, private farms, and smallholder farmers) that were registered in the crop variety register book of the Ministry of Agriculture (MoA) (Mengistu et al. 2016).

### Productivity of improved fodder crops in comparison to natural pasture

According to research findings of Feyissa et al. (2022), improved fodder species have higher herbage yield potential than natural pastures. Improved grass yield potential typically ranges from 8.0 to 15.0 tons DM per ha per year, with a mean of around 13.0 tons/ha. Yields of herbaceous legumes range from 6.0 to 10.0 tons DM/ha, with an average of 8.0 tons DM/ha. Tree legume productivity ranges from 9.0 to 13.0 tons DM/ha, with a mean of around 10.5 tons DM/ha (Feyissa et al. 2022). These yield potentials were calculated using rain-fed conditions and a single cut per year. Multiple cuts and potential herbage yields could be much higher than the figures shown above if forage evaluation work had been supported by supplementary irrigations, especially for perennial forage species. In general, improved fodder crop productivity per unit area is approximately threefold of seasonally rested and continuously grazed natural pastures (Fig 3). Aside from productivity, most improved forage crops are nutritionally superior to natural pasture and crop residues, and they have long growing seasons, which helps to extend the green feed period and could provide useful nutrients, especially in rural areas where Agro-Industrial By-Products are scarce. Furthermore, when grown as part of integrated natural resource conservation, improved fodder crops particularly legumes, can supplement crop production by maintaining soil fertility through N2 fixation and accumulation, enables to maintain ecology of the land by preventing soil fauna and degradation (Feyissa et al. 2022).

### Factors influencing improved forage technology adoption in Ethiopia

Despite many years of forage research, development, and extension efforts, several factors influence the likelihood of improved forage technology adoption. Farmers are very slow to adopt and use improved forages (Mekonnen et al. 2013). Keeping other variables constant, land scarcity, lack of improved forage seed/planting material, lack of awareness, and poor extension services were the most restrictive bottlenecks that hindered forage technology adoption (Bassa et al. 2016; Assefa et al. 2015; Salo et al. 2017; Tesfaye and Melaku 2017).

Similarly, the sex of household head, farm size, and farm income had a negative impact on improved forage technology adoption in Debrelibanose district, North Shewa, Oromia region, Ethiopia (Tesfaye and Gutema

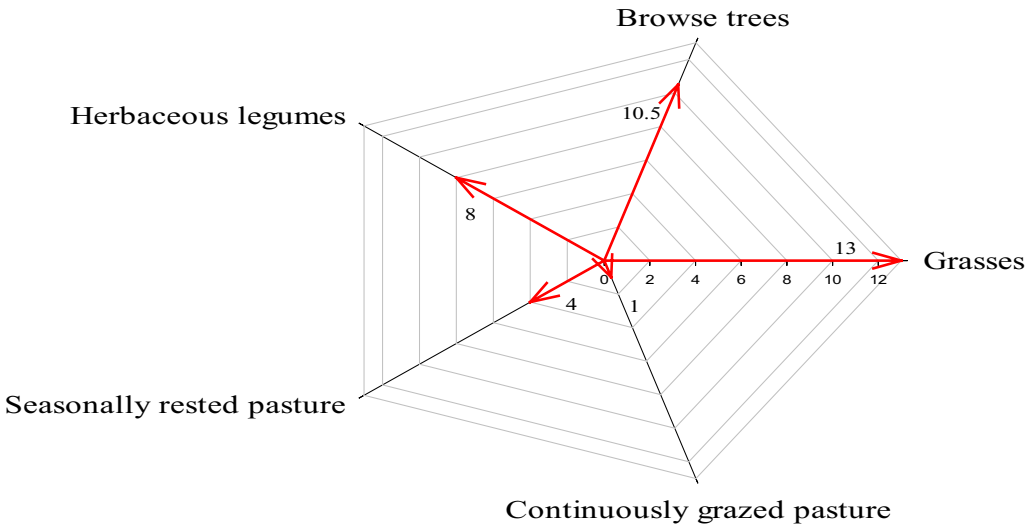


**Fig. 3** Axes in red represent forage dry matter productivity (tons/ha). *Source*: (Ministry of Agriculture and Natural Resource, crop variety register issue no.19, 2016)

2022). According to Bashe et al. (2018) the most important factors influencing improved forage technology adoption in Wolaita zone, SNNPR of Ethiopia were family size, farm size, topography, and distance from farmers' homes (residence) to farmers' training centers. Limited capacity development and extension systems for forage technology packages also played a significant role in the area (Bassa et al. 2016).

### Conceptual framework of factors influencing improved forage technology adoption

Improved forage technology adoption could be influenced by many factors viz., demographic, social, economic, institutional, and technological factors are the most cited factors which influence improved forage technology adoption (Fig. 4). The most determinate variables included in this review are the age of household head, family size, tropical livestock unit (TLU), land allocation, shortage of capital, improved cattle ownership, educational status, and access to extension, training and market as well as a shortage of inputs. Some variables affect the probability of adopting the technologies more than other factors in specific areas and on specific technologies. If the technology is very complex and difficult to operate and apply, the farmers can not voluntarily accept rather they prefer divisible technologies like high-yielding varieties and fertilizer (Mignouna et al. 2011).

### Socioeconomic and institutional factors

Different authors of empirical research on forage production technology adoption in different areas classify the factors into different variables and interpret the significant effect of each variable. Depending on the existing literature, these factors are classified as (i) demographic factors that include age, family size, etc., (ii) socio-economic factors which include education level, size of the farm, etc., (iii) institutional factors like extension services, access to training, field day, inputs, etc., and (iv) technological-related factors can be the expansion of innovation, improved seed, and adoption of technology.

### Demographic factors

#### *Age of household heads*

According to (Tesfaye and Gutema 2022) study conducted in the Debrelibanose district in Ethiopia shows that the age of the household head positively and significantly affects the likelihood of improved forage technology adoption. A plausible explanation for this is that older households might have a better awareness of the benefits of new agricultural technologies from their life experiences. In addition, older households may have larger farm sizes and are better endowed with different assets which help them to adopt more agricultural technology. Similarly, a result endorsed by (Admassie and Ayele 2010) found that age has a positive effect on agricultural technology adoption.

#### *Education*

Education is one of the critical socio-economic factors influencing the decision to adopt new technology and improve household income. Farmers with higher educational backgrounds have a better chance of accessing information and comprehending the benefits of improved agricultural technologies. This is because

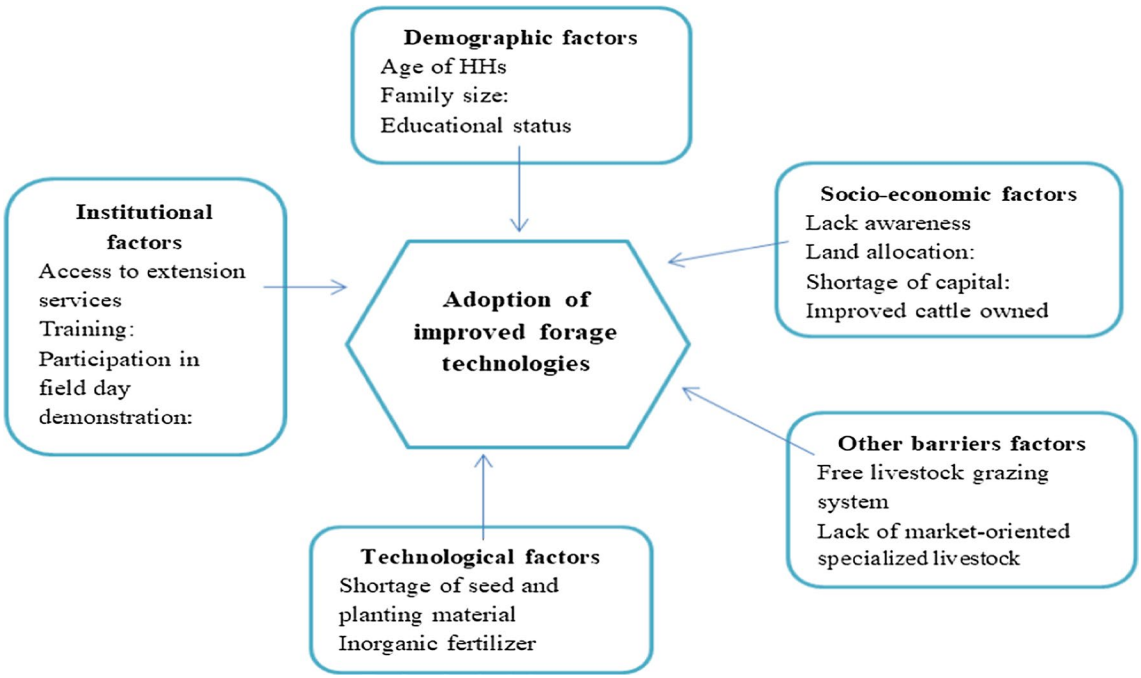


**Fig. 4** Conceptual framework illustrated from various sources

liberated household heads are more likely to see the benefits of technology and contribute to greater innovation and invention. As a result, the findings of (Tesfaye and Gutema 2022) depicted that improved forage technology uptake can be increased through better education attainment among farmers. Similarly, (Bassa et al. 2016) found that literate farmers are far more likely to adopt improved technologies than illiterate farmers.

#### *Household size*

Household size and characteristics are directly related to supply and demand conditions for basic human needs such as food, shelter, health, and educational facilities, which in turn influence improved forage technology adoption either directly or indirectly (Tesfaye and Melaku 2017). The fact that the number of adult males in the family had a positive effect on the likelihood of adopting improved forages was unsurprising, given that improved practices are labor intensive, and households with more family labor units are in a better position to adopt forage technologies than households with fewer family labor units (Abebe et al. 2018; Beshir 2014; Bashe et al. 2018).

### Socio-economic factors

#### *Lack of knowledge*

Lack of knowledge is one of the main limitations identified as a bottleneck for improved forage technology adoption (Assefa et al. 2015; Tesfaye and Melaku 2017). Farmers' knowledge of improved forages and forage seed production practices is very low (Bassa et al. 2016). They do not use their land effectively for forage production in the borders, terraces, and homesteads due to a lack of information and a knowledge gap on improved forage utilization and production (Emuru 2015). Few farmers allocate land for forage farming, possibly due to a lack of awareness (Yadessa et al. 2016; Shiferaw et al. 2018).

#### *Land allocation*

Land is the most important resource because it serves as the foundation for all economic activities, especially in the rural and agricultural sectors. The most pressing issue for improved forage production is a lack of land (Tesfaye and Melaku 2017; Teklay 2017). Due to an information and knowledge gap on improved forages, the same problem has been identified as the most limiting factor in encouraging forage production in various parts of the country (Endalew et al. 2016; Mengistu and Alene 2016). Similarly, (Yadessa et al. 2016; Shiferaw et al. 2018) found that few farmers assign land for forage farming, possibly due to a lack of knowledge, implying that access to training had a significant and positive effect on forage technology adoption. It is not surprising that increasing farmers' knowledge of newly released and adapted forage technologies, as well as how to use them, increases forage adoption (Abebe et al. 2018). As a result, it is likely to encourage improved forage adoption through education

among farmers with large land holdings (Bashe et al. 2018).

#### *Shortage of capital*

Access to credit for purchasing different inputs plays a crucial role in developing and adopting of new technologies and improved feed resources, especially in low-income households (Tesfaye and Melaku 2017). Moreover, land shortage, input shortage, and the lack of money to cover the higher prices of developing improved forage varieties raised a reason for the farmers (Endalew et al. 2016; Assefa et al. 2015). The high price of forage seed is also considered as a factor in forage production (Mengistu et al. 2017). The cash income of the families showed a positive connection with forage adoption, as families with high cash income showed a higher chance of being adopters. A possible clarification for the positive effect of cash income on forage adoption is that families with additional cash can purchase feed from the marketplace, allowing extra land to be allocated to forage crop production rather than food crops (Abebe et al. 2018). One of the reasons for inadequate forage production is the limited financial incentives or the return is not immediate since the production of improved forage crops did not link with productive animals (Endalew et al. 2016).

#### *Improved cattle ownership*

According to the findings of (Tesfaye and Gutema 2022; Birhanu et al. 2017) households that owned improved cattle had a higher likelihood of adopting improved forage technology. The findings revealed that Adopter households with improved cattle were more likely to adopt improved forage than counterpart households with local cattle only in the study area. The reason for this positive effect was that improved forage and improved cattle are inextricably linked, and thus their availability could increase the area under cultivation and the likelihood of adoption.

### Institutional factors

#### *Access to extension services*

An agricultural extension service was also another institutional variable that significantly influences the likelihood of improved forage technology adoption. This suggests that the frequency of extension visits increase rural households' access to information (Tesfaye and Gutema 2022). It indicates that those households having more contact with development agents are more likely to adopt improved forage compared to households with no or little extension services. In line with this finding, studies by (Beshir 2014; Kinuthia 2017) confirmed that access to extension service positively and significantly influenced the probability of improved forage technology adoption.

Poor extension services were other causes for the adoption of improved forages which desires to be improved (Assefa et al. 2015; Salo et al. 2017). Similarly, (Abebe et al. 2018) found that increased access to extension services is associated with increased forage adoption. In the same vein, (Sinyolo et al. 2014) reported that farmers with access to extension services have better access to updated information, which increases their likelihood of adopting new forage technologies.

In addition to the inadequate extension service, the extension service by its nature in Ethiopia is a crop skewed extension system. Livestock production in general and forage development in particular, have not been adequately addressed in the national agricultural extension system yet the contribution of the livestock sector to food security is vast. Improved forage technology has been promoted sporadically through various externally funded livestock development projects (Feyissa et al. 2022). Externally funded projects usually have a fixed and often limited duration and scope, which may not be sufficient for the smallholder farmers to buy into the interventions and take them up in a sustainable manner (Goduscheit 2022; Franssen et al. 2018). Moreover, most of the projects had no proper phase-out strategies that ensure sustainability through the incorporation of the development initiatives into the government development programs (Franssen et al. 2018). As a result, most of the project initiatives in promoting improved forage technologies into the farming system have been subject to total collapse after phasing out of the projects. Although the extension system structurally accommodates livestock production, the actual service is crop biased in terms of input supply and technical support, while the livestock aspect has remained subordinate. This is further exacerbated by a blanket extension approach followed throughout irrespective of the potential suitability of different areas for different enterprises (Feyissa et al. 2022).

#### *Access to training service*

Training is one of the extension events where farmers get practical skill and technical information for new technology updates from different government and non-government sources. Accordingly, (Tesfaye and Gutema 2022) confirmed that participation in training positively and significantly influenced the probability of adoption of improved forage technologies in the Debrelibanose district, Ethiopia. This could be explained by the fact that farmers who get training gain better knowledge on improved forage development practices than non-trained ones which can help them to extend their production and

productivity. Similarly, the findings of (Kedir 2017) indicated that training was positively related to the adoption of improved forage technology. It is not astonishing that increasing the knowledge of farmers regarding newly released and adapted forage technologies and viewing them in what way to use them, improves the probability of forage adoption (Abebe et al. 2018). However, (Assefa et al. 2015), reported that about 37.5% of the interviewed households had access to training on improved forage development, use, and utilization, whereas the remaining 63.5% were not addressed. As a result, it is likely to encourage improved forage technology adoption among farmers with large land holdings (Bashe et al. 2018).

#### *Participation in field day demonstration*

Farmers can acquire new knowledge and experience by participating in demonstration activities, which may enable them to increase agricultural production and productivity. (Tesfaye and Gutema 2022) outlined that participation in field day demonstrations positively and significantly influenced the likelihood of adopting improved forage. This suggests that the demonstration approach is one of the important approaches to transferring practical knowledge on agricultural production and technologies to farmers. When farmers conduct a new practice, they can weigh the advantages and disadvantages of the new technology and this can facilitate adoption and help them to implement the new technology properly. This result shows that farmers who participate in demonstration activities are more likely to adopt new and improved technology than others. This suggests that wider demonstration would speed up the adoption of agricultural packages and hence calls for the development of the existing limited demonstration practices. Similar results were reported by (Belay 2003; Bezabih 2012; Kedir 2017). These studies indicated that the demonstration and dissemination of information through field day and demonstration activities might facilitate the adoption of improved varieties and other new agricultural technologies.

#### *Lack of coordination among stakeholders*

Another reason for farmers' poor distribution, production, and utilization of forage technology is a lack of integration among research organizations, governmental and non-governmental organizations, and farmers. There is a huge gap between research and extension services due to a lack of coordination. Researchers did not receive a sufficient response, which could have helped them to design their research actions based on farmer preferences. As a result, most plans are proposed in response to locally perceived problems (Endalew et al. 2016; Kebede et al. 2016). It was also found that linking forage technologies with a variety of value chain issues in livestock enterprises was essential for farmers' positive adoption of forage technologies.

#### *Marketing challenges*

The lack of private sector participation in forage seed production and supply is also a major constraint that has resulted in the absence of forage seed marketing (Gebreselassie 2019). The existing forage seed market is highly fragmented, with weak links between suppliers and buyers and a general lack of market information (Tekalign 2014). Furthermore, the findings of the study by (Bassa et al. 2016) revealed that there is no direct marketing link between traders and farmers. There are no forage seed dealers either. Some of the challenges for forage seed marketing include low forage seed production, poor quality forage seed, poor seed management (handling and storage), fluctuating forage seed demand, a lack of a quality control system, and a lack of working capital.

#### *Distances to the market and development agents' office*

The distance of the household's residence from the main road, market centers, or demonstration place is another important factor influencing the adoption of technology. The closer the household is to market centers and/or roads the better it would be to access information about technology and prices and hence is positively related to technology adoption. Different studies' results indicated that distance from the market has a significant and negative effect on the farmers' decision to adopt agricultural technology (Admassie and Ayele 2010; Hagos and Zemed 2015). Similarly, Farmers closer to the Development Agents office have better access to information on improved practices and other extension services as well as to supply of forage seeds (Abebe et al. 2018). However, contrary to the expected, finding by (Tesfaye and Gutema 2022) market distance positively and significantly determines the probability of adoption of improved forage technology in the Debrelibanose district in the north Shewa zone. A possible explanation for this contradicting result would be those households far from the market (the town in this case) might have better extension service providers and be able to adopt different technologies.

### Technological factors

#### *Shortage of seed and planting materials*

Inadequate forage seed research and dependable forage seed production, processing, and distribution schemes resulted in shortage of reliable supply of forage seed/planting materials (Tesfaye and Melaku 2017). Besides, loosening information on the national demand for forage seeds, as well as poorly developed seed marketing systems, limits forage seed production and

development (Feyissa et al. 2022). Ethiopia is hampered by high cost and low availability of seed for the recommended varieties. Farmers rarely collect or use seeds from their own farms or from their neighbors, as they still expect the forage/tree seedlings or seeds from projects, government and non-governmental organizations (Mapiye et al. 2006).

The scarcity of seed and seedling material, especially in dairy farming and fattening areas, limits the tremendous development of improved pasture and forage growth (Mengistu et al. 2017). This is consistent with statements made by (Bassa et al. 2016). Likewise, lack of input (seeds/seedlings) is a factor in the adoption of improved forages, as evidenced by research conducted (Yadessa et al. 2016). According to (Beshir 2014), improved forage seeds cover only 1.3% of the total cultivated land in Ethiopia's Northeast Highlands. In some areas, lack of forage seed sources may be causing a large number of farmers to face insufficient forage planting material. Hence, quality seed or vegetative planting material of desired forage crop for a given agroecology is critical for the improvement of livestock production under rural households' context (Bassa et al. 2016).

### Additional barriers to the adoption of improved forage technologies

#### *Free livestock grazing system*

Free grazing is another constraint in the mixed farming system in the adoption and utilization of improved forage crops by smallholder farmers, especially following crop harvest, particularly in the country's central highlands, where livestock population is not proportional to land ownership and the area is densely populated (Endalew et al. 2016; Hassen et al. 2010). Free grazing has become a challenge for the survival of forage plants (Mengistu and Alene 2016). As compared to grass type improved forage crops legume crops have poor persistence (particularly under continuous grazing), low tolerance to poorly drained soils and low soil fertility (Kebede et al. 2016). Most forage species are perennials once they are established well can persist and provide continuous feed supply for more than 5 years with good management once they are well established. However, the prevailing free livestock grazing systems limit the development and utilization of these forages by smallholder farmers. The prolonged dry season and the lack of irrigation setups also impose further limitations on the development and proper management of perennial forage crops (Feyissa et al. 2022).

#### *Lack of market-oriented specialized livestock production to catalyze forage development*

Livestock production in Ethiopia is in the hands of smallholder farmers mainly based on low-producing indigenous breeds with limited market-oriented livestock production systems (Hurrissa and Eshetu 2003). Farmers` main livestock production objective is also to produce draft oxen for their farming occupation, while livestock products (milk, beef, etc.) are often considered as byproducts of draught. The other factor is associated with the socioeconomic situations of farmers, who operate under high transaction costs and have difficulties in connecting to markets; as their animal production is predominantly linked to domestic needs with only limited market orientation and lack of specialization in livestock production. In such a system, where the primary purpose of livestock keeping is to support crop production, livestock is unlikely to be a competitive enterprise to catalyze forage development. Moreover, all the prime land is devoted to food crops and farmers have a low affinity to allocate land, labor, and capital for fodder development, and livestock is supposed to depend on the crop byproducts and degraded grazing lands as the major source of feed (Feyissa et al. 2022). Moreover, the use of feed from commercial sources is scarce because of inadequate feed supply and inefficient marketing systems (Dejene et al. 2014).

## Conclusions

This review addresses the major determinants of improved forage technology adoption that likely influence the livestock sector of the country and the agriculture sector as well. Improved forage crops are very significant to maximizing and sustaining the productivity of livestock in diverse scenarios. Many forage crops by their nature have multi-purpose uses other than their primary significance as livestock feed. In addition, improved forage crops also served as a soil and water conservation role and natural restoration of degraded lands, used in keeping the ecological balance of the ecosystem by fixing nitrogen. They are also shelters for livestock, especially in dry seasons. The adoption of improved forage technologies supports farmers to exploit and sustain the output of livestock. However, smallholder farmers in Ethiopia do not extensively adopt improved forage technologies due to a variety of reasons, including land scarcity, a lack of input/forage seed and planting materials, a lack of capital, a lack of awareness or technical know-how, poor extension services, free grazing, poor coordination among stakeholders, and a lack of support from governmental and non-governmental organizations. Furthermore, extension services for forage technology diffusion,

technical support, and follow-up remain insufficient; all of these factors contribute significantly to farmers' low adoption of forage crops and their complete package Therefore, this review paper compiles such relevant information on the status of forage technology and its major adoption bottlenecks to bring insights together made by various studies so far in one piece of paper to enable policymakers, practitioners, extension agents, and other stakeholders to exploit the livestock sector for better livelihoods and food security to smallholder farmers in Ethiopia.

Additional recommendations for future improvement of improved forage technology adoption by smallholder farmers in the country arise from this review are:

1. Research efforts should be directed towards inclusive forage technology adoption from demand and supply sides rather than developing technologies without participating the end users
2. The extension system should be capable enough to demonstrate, popularize and make accessible the improved forage technologies to smallholder farmers and other beneficiaries.
3. Food security is the primary agenda of the Ethiopian government and the livestock sector is expected to play a pivotal role in the food and nutrition security of millions` livelihoods. Hence, the government authorities, research institutions, policymakers and all stakeholders should take a comprehensive forage technology adoption action through awareness creation, improved forage technology development, dissemination, and popularization to outshine the livestock sector by enhancing access and affordability of improved forage crop technologies.
4. Formulating and updating the existing policy guidelines and strategies regardless of livestock production, export, and marketing would also be very imperative to improve the livestock sector and thereby increase the contribution of livestock to food and nutrition security to the country.

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**Author contributions**
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Not applicable.

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