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Bridging the Ruminant Productivity Gap in Eastern Africa: Practical Considerations

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Abstract: In this study, we address key challenges in enhancing ruminant productivity across Ethiopia, Tanzania, Kenya, Uganda, Rwanda, and Burundi in eastern Africa. A critical focus is on improving access to forage seeds essential for cattle systems. Key factors such as ruminant population, feed deficits, and governmental priorities are examined. The primary challenge lies in inadequate access to affordable forage seeds, compounded by reluctance to invest in perceived expensive elite varieties. Many farmers rely on outdated planting materials, lacking purity and vigor. To overcome these barriers, our analysis stresses the urgency of transitioning to recently improved seed varieties through rigorous selection and breeding. Promoting domestic seed production within Africa is crucial to mitigate high import costs and logistical complexities like variety registration. A coordinated regional approach to seed production could enhance economic viability and foster widespread adoption of improved forages. Such initiatives align with governmental agendas for sector development, offering triple benefits: increased productivity, environmental gains through reduced methane emissions, and regional economic growth.

Keywords: market potential; feed deficit; cultivated forages; ruminants; food security; seed systems

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Highlights

- Governments prioritize forages to boost livestock productivity and sustainability
- East Africa faces a 40% annual feed deficit, impacting food security and livelihoods
- Cultivated forage seed requirement: 95,605 tons for 10% adoption over 10 years
- 2M hectares and 1.5M farmers are needed to close the forage deficit in the region
- Regional forage seed market could reach US$877 billion over 10 years

1. Introduction

Livestock farming is essential in Africa, where most producers are small-scale farmers who rely on their animals for income, nutrition, insurance, and savings (Felis, 2020; Bahta & Malope, 2014; FAO, 2018). The continent is projected to experience a significant rise in demand for animal-sourced foods (ASF), with milk consumption expected to increase from 30 liters to 64 liters per capita annually by 2050, and meat consumption from 14 kg to 26 kg (Paul et al., 2021; Little et al., 2014; Njuki and Mburu, 2013; Moritz, 2013). In East Africa, livestock supports millions of livelihoods by providing food, income, and employment (East African Community, 2022), and the region counts on Africa's largest cattle herd and is the main exporter of cattle on the continent (DAI, 2023).

When it comes to feeding these large numbers of livestock, mixed feed baskets are the main source of animal nutrition and feed makes up approximately 60-70% of the overall production costs (Maina et al., 2022; Strauch and Stockton, 2017). Literature is abundant with information on the limitations in the quality and quantity of livestock feed, its impact on animal productivity in Africa, and the influence of climate change on feed production (e.g., de Oto et al., 2019; Paul et al., 2020). This issue has persisted for several decades and remains prevalent across most sub-Saharan African countries. Despite the existence of technologies, such as adapted forages that could potentially

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address these gaps, the intentional cultivation of forages has lagged (Flórez et al., 2024; Ahumuza et al., 2022; Dey, 2021). Furthermore, business models for seed distribution that could stimulate market demand for quality cultivated forages and increase technology access are underdeveloped and lead to high shares of labor-intense vegetative propagation through splits (Flórez et al., 2024; Creemers and Opinya, 2022).

Mixed farming and pastoral systems, both of which strongly rely on ruminants, are widespread but lack strategies to bridge feed deficits, leading to animal losses in severe cases, a situation strongly aggravated by climate change. Notably, forage cultivation is limited in mixed systems (Fuglie et al., 2021), and pastoral areas depend on natural grasses without large-scale conservation efforts for the dry seasons. In some countries, like Rwanda, livestock populations continue to grow despite these challenges, adding pressure to the production systems (Habiyaremye et al., 2021).

To put the low levels of cultivation into perspective, Ethiopia, Tanzania, Kenya, Uganda, Rwanda, and Burundi together have a cultivated forage area of about 1.5 million hectares, compared to Colombia's 8.9 million hectares, which is 5.8 times higher despite eastern Africa having significantly more agricultural land compared to Colombia (273 million vs. 42.7 million hectares) (Fuglie et al., 2021). The reasons for low forage cultivation are diverse and include limited land availability due to competition with food crops, lack of seeds and planting materials (Flórez et al., 2024), high seed prices and unwillingness to pay for improved forage seeds (Osiemo et al., 2024; Flórez et al., 2024), adverse weather conditions, lack of skills and technology (Flórez et al., 2024; Creemers and Alvarez-Aranguiz, 2019; Maina et al., 2022; Fuglie et al., 2021), and other socio-cultural factors.

Addressing these key bottlenecks is essential. For instance, integrating forages into mixed systems at a maximum of 33% could support sustainable food production (Dey et al., 2022). In addition, mitigation strategies are urgently needed to address adverse climatic conditions and contribute to greenhouse gas (GHG) emission reduction. Cultivated forages can help in carbon sequestration, reduce methane emissions per unit of animal product, and in general, sustainably increase meat and milk productivity (Rao et al., 2015; Karimi et al., 2022; Paul et al., 2020; Maina et al., 2020; Schiek et al., 2018). Some forages, like certain *Urochloa* species, possess Biological Nitrification Inhibition (BNI) properties that reduce nitrate denitrification to nitrous oxide, a potent GHG (Arango et al., 2013). Cultivated forages can alleviate land pressure by boosting productivity per hectare, thereby helping to prevent the encroachment of agricultural expansion into vital ecosystems like forests and protected areas (Cohn et al., 2014; Edwards et al., 2021). In addition to their mitigation potential, improved forages also enhance system adaptation to adverse climatic conditions, such as severe droughts or waterlogging, thereby increasing resilience (Macedo Pezzopane et al., 2019; Naranjo Ramírez et al., 2014; Montagnini et al., 2013;).

The shortage of forage seeds and limited access to them could be addressed through local seed production initiatives. This would lower seed costs compared to imports, making them more affordable for farmers and reducing their reluctance to invest in them (Osiemo et al., 2024). For example, *Urochloa* seeds cost US$40-50 per kilo in Kenya (Flórez et al., 2024) compared to about US$15-30 in Latin America, where most of the seeds are being produced. A conducive policy environment that fosters access to forage seeds through efficient variety registration processes is key for further seed sector development and stronger private seed sector involvement (Flórez et al., 2024). Local seed production business models can also boost income generation and diversification, thereby improving the livelihoods of people in rural areas and contributing to reducing migration of youth to cities (Narjes Sanchez et al., 2021).

Against this background, this article aims at providing evidence for improving access to forage seeds for ruminant systems in several East African countries, specifically Ethiopia, Tanzania, Kenya, Uganda, Rwanda, and Burundi. Drawing on existing literature, we address the following research questions: (i) What governmental plans exist to promote the livestock sector in the region, and how are forage seeds integrated into these plans? (ii) What is the current cultivated forage dry matter deficit in the region, and how many forage seeds are needed to close this gap? (iii) How much land and how many farmers would be required to implement the adoption of forage cultivation? (iv) Can vegetative propagation through splits be a viable alternative to seeds in addressing the forage deficit? (v) What is the estimated economic value of the forage seed market, and how much value could forage crops generate over time? (vi) What would be necessary to develop a functioning regional forage seed system and ensure widespread forage adoption?

We begin by examining the governmental priorities for the livestock sector in the studied countries to identify future goals and needs. Next, we calculate the annual feed demand for ruminant livestock and the existing feed deficit. Following this, we select two forage grasses—*Urochloa* hybrids and *Megathyrsus maximus*—and two forage legumes—*Lablab purpureus* and *Vigna unguiculata* (cowpea)—chosen for their adaptability to the predominantly tropical agroclimatic conditions of these countries, their provision of essential nutrients for ruminants, and the availability of their seeds. We then calculate the quantity of forage seeds needed to bridge the estimated feed deficit. Afterward, we estimate the land area required to cultivate these forages, the number of farmers needed for adoption, the economic value of this potential forage seed market, and the value that forage crop adoption could generate over a 10-year period. Finally, we outline the steps necessary to develop a functional forage seed system to support widespread adoption.

This article is structured as follows: Section two highlights the materials and methods applied in each section, Section three provides a combined results and discussion section in which we answer the research questions, and Section four provides concluding remarks and recommendations.

2. Materials and Methods

First, we examined the most recent governmental plans, such as Livestock Master Plans, across the six countries under analysis. Using qualitative content analysis, we summarized these plans, highlighting key aspects relevant to future development.

Second, we reviewed recent scientific and grey literature to gather data on total ruminant populations (including cattle, sheep, goats, and camels), Tropical Livestock Units (TLU), annual feed demand, and annual feed deficit (see Table 4). Using this data and following the methodology outlined by Dey et al. (2022), we estimated the portion of the annual feed deficit that could be addressed by the selected forage grasses and legumes (referred to as the annual cultivated forage deficit) for each country using the following equation:

$$ACF_{\mathrm{Def}} = AFD\ RS\ CFS \quad (1)$$

where ACF_{Def} is the annual cultivated forage deficit per country in tons of dry matter and AFD is the total annual feed deficit per country in tons of dry matter. RS is the share of roughages of the total diet, which is estimated to be 70% (30% concentrates) (Dey et al., 2022). CFS is the share of RS accounting for recommended cultivated forage inclusion and is 33% (Dey et al., 2022).

Third and prior to estimating the amount of forage seeds needed to bridge the projected feed deficits, we selected two forage grasses and two forage legumes that (i) are adaptable to the (largely tropical) agroclimatic conditions of the countries, (ii) supply key nutrients required by ruminants, i.e., metabolizable energy and crude protein, and (iii) have seed availability in the region, either through the seed private sector or other sources (e.g., informal seed system, development projects, governmental programs). The selected grass species are *Urochloa* hybrids and *Megathyrsus maximus*, and the selected legume species are *Lablab purpureus* and *Vigna unguiculata* (cowpea) both of which in some cases are used for human food and can also do well in relatively marginal areas. Their attributes, such as growth type, seed rate, days to first cut, days to regrowth cutting, days to cutting after sowing, and potential yields, were extracted from Dey et al. (2022).

Fourth, we estimated the amount of forage seeds required for the four selected species to address the identified ACF_{Def}. For this purpose, we calculated different scenarios:

- Scenario 1: Where 100% of the identified ACF_{Def} is covered in the first year by simultaneously planting the two grass species at 35% each and the two legume species at 15% each. This scenario considers a 10-year evaluation horizon, the annual seed requirements for reseeding the legumes, and regeneration seed for the grasses for the last three years at 100%.

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- Scenario 2: Where 10% of the identified ACF_{Def} is covered in the first year by simultaneously planting the two grass species at 35% each and the two legume species at 15% each. We projected a 10% annual increase in covering the ACF_{Def} and a lifespan of 7 years for the perennial grasses (Jank et al., 2014). For the two longer-term perennial grasses (*Megathyrsus maximus*, *Urochloa* hybrids), we included annual regeneration seed in the calculation after year 7 at 100%. The projected horizon for our calculations is 10 years.

The following equations were estimated for Scenario 1:

$$AFSR = AFSR_U + AFSR_M + AFSR_L + AFSR_V \quad (2)$$

where $AFSR$ is the annual forage seed requirement of a country (in tons), $AFSR_U$ is the annual forage seed requirement for *Urochloa* hybrids (in tons), $AFSR_M$ is the annual forage seed requirement for *Megathyrsus maximus* (in tons), $AFSR_L$ is the annual forage seed requirement for *Lablab purpureus* (in tons), and $AFSR_V$ is the annual forage seed requirement for *Vigna unguiculata* (in tons).

$$AFSR_U = AFSR_{UG} + AFSR_{URS} = \left(\frac{(ACFDef\ U_{area})}{U_{yield}} U_{SR}\right) + \left(\frac{(ACFDef\ U_{area})}{U_{yield}} U_{SR} \frac{RS}{EH}\right) \quad (3)$$

$$AFSR_M = AFSR_{MG} + AFSR_{MRS} = \left(\frac{(ACFDef\ M_{area})}{M_{yield}} M_{SR}\right) + \left(\frac{(ACFDef\ M_{area})}{M_{yield}} M_{SR} \frac{RS}{EH}\right) \quad (4)$$

$$AFSR_L = \left(\frac{(ACFDef\ L_{area})}{L_{yield}} L_{SR}\right) EH \quad (5)$$

$$AFSR_V = \left(\frac{(ACFDef\ V_{area})}{V_{yield}} V_{SR}\right) EH \quad (6)$$

where $AFSR_{UG}$ is the general annual forage seed requirement for *Urochloa* hybrids, $AFSR_{URS}$ is the forage seed requirement for *Urochloa* hybrids for regeneration purposes, $AFSR_{MG}$ is the general annual forage seed requirement for *Megathyrsus maximus*, $AFSR_{MRS}$ is the forage seed requirement for *Megathyrsus maximus* for regeneration purposes, ACF_{Def} is the total annual cultivated forage deficit of a country (in t), U_{area} is the share of area that could be covered with *Urochloa* hybrids (35%), U_{SR} is the *Urochloa* hybrid seed rate (in t ha^{-1}), U_{yield} is the *Urochloa* hybrid yield (in t ha^{-1}), M_{area} is the share of area that could be covered with *Megathyrsus maximus* (35%), M_{SR} is the *Megathyrsus maximus* seed rate (in t ha^{-1}), M_{yield} is the *Megathyrsus maximus* yield (in t ha-1), L_{area} is the share of area that could be covered with *Lablab purpureus* (15%), L_{SR} is the *Lablab purpureus* seed rate (in t ha^{-1}), L_{yield} is the *Lablab purpureus* yield (in t ha-1), V_{area} is the share of area that could be covered with *Vigna unguiculata* (15%), V_{SR} is the *Vigna unguiculata* seed rate (in t ha^{-1}), V_{yield} is the *Vigna unguiculata* yield (in t ha-1), RS is the number of years in which regeneration seed is being used (3 years), and EH is the evaluation horizon (10 years).

For Scenario 2, we broke down $AFSR_U$ and $AFSR_M$ by year by multiplying $AFSR_{UG}$ and $AFSR_{UG}$ by 10% to reflect the projected adoption rate and their perennial character. For the inclusion of regeneration seed, for the years 8, 9, and 10, we divided $AFSR_{URS}$ and $AFSR_{URS}$ by RS and added the respective values to the $AFSR_{UG}$ and $AFSR_{UG}$ for years 8, 9, and 10. To reflect the annual seeding of the selected legumes, we divided $AFSR_L$ and $AFSR_V$ by EH and then multiplied it by the respective year of analysis.

Fifth, we estimated the amount of land that would be required for the adoption of the suggested cultivated forages as well as the number of farmers that would be needed. For this, we estimated the following equations:

$$LR = \frac{FSR_U}{U_{SR}} + \frac{FSR_M}{M_{SR}} + \frac{FSR_L}{L_{SR}} + \frac{FSR_L}{V_{SR}} \quad (7)$$

$$FR = \frac{LR}{AFS} \quad (8)$$

where LR is the amount of land required in the adoption process (in ha), FSR_U, FSR_M, FSR_L, FSR_V are the total forage seed requirements (in tons) for *Urochloa* hybrids, *Megathyrsus maximus*, *Lablab purpureus*, and *Vigna unguiculata*, U_{SR}, M_{SR}, L_{SR}, V_{SR} are the seed rates (in tons ha^{-1}) for *Urochloa*

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hybrids, *Megathyrsus maximus*, *Lablab purpureus*, and *Vigna unguiculata*, FR is the total number farmers needed in the adoption process, and AFS is the average farm size (in hectares) per country.

Sixth, we estimated both the total and annual economic values of the cultivated forage seed market, applying two scenarios. For Scenario 1, we used current seed prices to reflect the current situation. For Scenario 2, we applied reduced seed prices by 25% to reflect a scenario in which a) some of the seed is produced locally and b) economies of scale apply due to higher seed purchases. The following equation was calculated:

$$EV = FSR_U P_U + FSR_M P_M + FSR_L P_L + FSR_V P_V \quad (9)$$

where EV is the economic value of the forage seed market in US$, and P_U, P_M, P_L, P_V are the average seed prices (in 2023 US$) for *Urochloa* hybrids, *Megathyrsus maximus*, *Lablab purpureus*, and *Vigna unguiculata*.

Seventh, we estimated the potential cultivated forage value in 2015 US$ according to the method described by Fuglie et al. (2021). We applied a forage price equivalent to 18% of the global maize price (as leading feed grain). The global average maize price was consulted with FAO for 2014-2016 (US$201 t^{-1}) and the resulting average forage price was US$36 per ton dry matter (in 2015 US$). For this, we estimated the following equation:

$$FCV = \left((LR_U\, U_{yield}) + (LR_M\, M_{yield}) + (LR_L\, L_{yield}) + (LR_V\, V_{yield}) +\right) p\, EH \quad (10)$$

where FCV refers to the cultivated forage crop value (in 2015 US$), LR_U, LR_M, LR_L, LR_V to the estimated area to be cultivated with *Urochloa* hybrids, *Megathyrsus maximus*, *Lablab purpureus*, and *Vigna unguiculata* (ha), U_{yield}, M_{yield}, L_{yield}, V_{yield} to the forage dry matter yield for *Urochloa* hybrids, *Megathyrsus maximus*, *Lablab purpureus*, and *Vigna unguiculata* (t ha^{-1} y^{-1}), and p to the average forage price per ton of dry matter (in 2015 US$).

Table 1 provides an overview of the data used for each variable and some general characteristics of the forage species; Table 2 provides an overview of the applied seed prices.

Table 1. Data used for each variable and some characteristics of the forage species.

Characteristic	**Forage** *Urochloa hybrid*	*Megathyrsus maximus*	*Lablab purpureus*	*Vigna unguiculata*
Share of forage deficit to cover (%)	35	35	15	15
Seed rate (t ha^{-1})	0.008	0.003	0.02	0.02
Yield (dry matter t ha^{-1})	17	20	8	8
Growth type	Perennial	Perennial	Annual	Annual
Days to first cut	90	75-90	n.a.	n.a.
Days to regrowth cutting	30-45	30-45	n.a.	n.a.
Days to cutting after sowing	n.a.	n.a.	90	70-90
Lifespan (years)	8	8	1	1
Adoption rate (%)	10	10	10	10
Regeneration seed	100% after year 7	100% after year 7	n.a.	n.a.

Source: based on Dey et al. (2022)

Table 2. Seed prices for the studied forage grasses and legumes.

Country	*Urochloa hybrids* (cv. Mulato II)		*Megathyrsus maximus* (cv. Mombasa)		*Lablab purpureus*		*Vigna unguiculata*	
	Current price (US$ t^{-1})	Reduced price** (US$ t^{-1})	Current price (US$ t^{-1})	Reduced price** (US$ t^{-1})	Current price (US$ t^{-1})	Reduced price** (US$ t^{-1})	Current price (US$ t^{-1})	Reduced price** (US$ t^{-1})
Ethiopia	50,460	37,845	48,670	36,503	6,245*	4,684*	9,426	7,070

Tanzania	50,460	37,845	48,670	36,503	6,245*	4,684*	4,378	3,284
Kenya	43,660	32,745	48,670	36,503	2,291	1,718	1,975	1,481
Uganda	50,460	37,845	48,670	36,503	10,199	7,649	1,485	1,113
Rwanda	50,460	37,845	48,670	36,503	6,245*	4,684*	4,442	3,332
Burundi	50,460	37,845	48,670	36,503	6,245*	4,684*	2,719	2,040

Notes: all prices in 2023 US$; *no price available, the average price was built for Kenya and Uganda and applied to the countries with no information on prices; **reduced price by 25% to reflect a scenario in which a) some of the seed is produced locally and b) economies of scale apply due to higher seed purchases.

Sources: Agroduka Limited (2024a, 2024b); Simlaw Seeds (2024a, 2024b); Robran Mall (2024); Greenspoon (2024); Selina Wamucii (2024a, 2024b, 2024c, 2024d, 2024e).

3. Results and Discussion

3.1. Governmental Plans for the Livestock Sector in the Studied Countries

Table 1 summarizes the governmental plans for the livestock sector in the studied countries. It highlights that governments in the region aim to increase the sector's contribution to their Gross Domestic Products, while emphasizing the need for sustainably boosting livestock productivity with a commercial focus and prioritizing environmental stewardship in some cases. Likewise, emphasis is put on the role of feeding improvements to reach the planned aims, which corresponds to the strong contribution of feed to the overall production cost (Maina et al., 2022; Strauch & Stockton, 2017) and its enormous potential for climate change mitigation and adaptation (Rao et al., 2015). Governments in the studied countries are increasingly prioritizing the use of forages in their livestock policies, recognizing their critical role in improving livestock productivity and sustainability. Through policies that promote forage cultivation, seed system development, and farmer training, these countries are addressing the persistent challenges of feed shortages and low livestock productivity. The emphasis on forages is a clear indication that sustainable livestock development in East Africa depends on improved feed resources, with far-reaching implications for food security, rural livelihoods, and economic growth.

Table 3. Governmental plans for the livestock sector.

Country	Focus and aspirations
Ethiopia	The Ethiopian government plans to quadruple milk production by 2031 by enhancing the productivity of dairy cows, camels, and goats. This goal is a key focus of the government's ten-year strategic plan for the dairy sector. The plan aims to address significant challenges related to genetics, technology, feeding, health, marketing of inputs and outputs, value addition, product quality, and consumer safety (Legese et al., 2023). Ethiopia's Livestock Master Plan (Shapiro et al., 2015) emphasizes the importance of forages in improving livestock productivity. The plan addresses forage shortages, particularly during dry periods, by promoting the cultivation of improved forage varieties and better pasture management. The government supports research and development of high-yielding forage crops and the integration of forage production into mixed farming systems. Additionally, there are efforts to enhance the dissemination of forage technologies and improve farmers' access to quality seeds. By prioritizing forages, Ethiopia aims to boost livestock productivity and support the livelihoods of pastoral and agro-pastoral communities.
Tanzania	By 2025, the livestock sector is expected to be largely commercial, modern, and sustainable, leveraging improved and highly productive livestock to ensure food security, boost household and national income, and support environmental conservation (Ministry of Livestock Development Tanzania, 2006).

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	Both Tanzania's National Livestock Policy (Ministry of Livestock Development Tanzania, 2006) and Livestock Sector Transformation Plan (Ministry of Livestock and Fisheries Tanzania, 2022) prioritize the development and use of forages to modernize the livestock sector. The policy emphasizes the need for improved forage resources and sustainable feed management practices. The government promotes the cultivation of high-quality forage crops and supports research on forage technologies. Additionally, there are initiatives to enhance the availability of forage seeds and improve pasture management. By focusing on forages, Tanzania seeks to address feed scarcity, increase livestock productivity, and contribute to the overall development of the sector.
Kenya	Kenya's Livestock Policy (Ministry of Agriculture, Livestock, Fisheries and Cooperatives Kenya, 2020) aims to harness livestock resources to enhance food and nutrition security and improve livelihoods while protecting the environment. This objective will be met through several measures, including improved management of livestock, feed, and rangeland resources, as well as promoting social inclusion and environmental resilience. Interventions in livestock nutrition, feeds, and feeding will involve various measures focused on roughage and concentrate feed resources. These measures will ensure the availability of adequate forage resources by enhancing the productivity and utilization of diverse roughage materials. Forages are thus a key component in improving livestock productivity and sustainability. The plan advocates for the development of improved forage varieties and the adoption of better forage management practices. The government supports the cultivation of forage crops, the use of high-quality feed supplements, and the establishment of forage banks to ensure availability during dry periods. Furthermore, there are initiatives to educate farmers on effective forage management through extension services. By prioritizing forages, Kenya aims to enhance livestock performance and support pastoral and agro-pastoral livelihoods.
Uganda	Uganda's National Animal Feeds Policy (Ministry of Agriculture, Animal Industry and Fisheries Uganda, 2005) aims to address challenges in the livestock sector by improving the quality, availability, and affordability of animal feeds. This policy, first introduced in 2005, aligns with Uganda's broader agricultural development strategy, particularly its Plan for the Modernization of Agriculture. The policy seeks to ensure optimal use of local feed resources, which would improve livestock productivity and increase the supply of animal products. The recent Animal Feeds Act (The Republic of Uganda, 2024) builds on this policy by introducing more stringent regulations for the production, sale, and transportation of animal feeds. It mandates licensing for all stakeholders involved in these activities and seeks to control the quality of animal feeds by regulating imports and exports. The Act also includes provisions for penalties for non-compliance, especially in cases involving counterfeit or low-quality feeds, which have been problematic in the sector. Additionally, inspectors will be empowered to ensure that feeds meet safety and nutritional standards. This policy and its legislative updates are expected to enhance Uganda's livestock productivity by improving feed quality, reducing animal diseases linked to poor nutrition, and ultimately supporting the country's growing livestock sector Uganda's Livestock Sector Prioritization under the Agriculture Sector Strategic Plan (ASSP) (Ministry of Agriculture, Animal Industry and Fisheries Uganda, 2016) recognizes the role of forages in enhancing livestock productivity. The plan includes strategies to boost forage production through the development of improved forage varieties and the promotion of sustainable forage management practices. The government supports research and development in forage technologies and encourages private sector involvement in forage production. Additionally, efforts are made to improve the distribution of forage seeds and enhance farmers' knowledge of

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	forage cultivation. By prioritizing forages, Uganda aims to address feed shortages and support smallholder farmers.
Rwanda	Rwanda's 5th Strategic Plan for Agricultural Transformation (PSTA5) highlights the crucial role of the livestock sector in the country's economic growth and development from 2024 to 2030. The Rwandan government has established several targets for the sector, including boosting milk production from 785 million liters in 2018 to 1.5 billion liters by 2024, and expanding the national herd size from 1.5 million to 2.5 million (FAO, 2024). Rwanda's National Livestock Policy and Livestock Master Plan (Shapiro et al., 2017) emphasize the importance of forages in increasing livestock productivity and sustainability. The plans focus on improving forage resources and management practices, including the cultivation of high-quality forage crops and the development of forage technologies. The government also supports integrated approaches that combine forage production with other agricultural activities to maximize resource use. By prioritizing forages, Rwanda aims to enhance livestock performance and contribute to food security and rural development.
Burundi	Burundi's National Plan for Development (PND, 2018) focuses on enhancing productivity, encouraging private sector investment, and strengthening the capabilities of public and private institutions. Burundi's National Agricultural Investment Plan (Ministere de L'Agriculture et de L'Elevage Burundi, 2011) places a strong emphasis on increasing livestock productivity through improved feeding systems, including the use of cultivated forages. The plan highlights the need for expanding forage cultivation to reduce the country's dependence on natural pastures, which are often overgrazed and degraded.

3.2. Annual Ruminant Feed Demand, Feed Deficit, and Cultivated Forage Deficit in the Region

The annual ruminant feed demand is determined by the total ruminant population of a country, the equivalent number of Tropical Livestock Units (TLU), and the animals' requirements for body maintenance, growth, production, and reproduction. The annual feed deficit is calculated as the difference between annual feed demand and the available feed resources. Table 4 presents these indicators for the six countries studied, showing a total regional annual feed demand of 353 million tons of dry matter and a significant regional annual feed deficit of nearly 40% of this amount, which equates to 136 million tons of dry matter.

Table 4. Annual feed demand, feed deficit, and cultivated forage deficit in the selected countries.

Country	Ruminant population	Tropical Livestock Units (TLU)	Dry matter deficit (%)	Annual feed demand (dry matter t y^{-1})	Annual feed deficit (dry matter t y^{-1})	Annual cultivated forage deficit (dry matter t y^{-1})
Ethiopia	156,968,403	64,524,901	21.6	176,636,918	38,153,574	8,813,476
Tanzania	66,900,000	27,030,000	72.3	73,994,625	53,498,114	12,358,064
Kenya	69,481,459	23,455,031	60	64,208,147	38,524,888	8,899,249
Uganda	32,461,107	12,126,138	13	33,195,304	4,315,389	996,855
Rwanda	4,758,591	1,199,288	42	3,283,051	1,378,881	318,522
Burundi	2,673,929	621,212	35	1,755,316	614,361	141,917

Notes: Ruminants include cattle, sheep, goats, and camels. 1 TLU = 250kg
Sources: FAO (2018); Federal Democratic of Ethiopia (2022); The United Republic of Tanzania (2021); FAO & IGAD (2019); Mary et al. (2016); Bacigale et al. (2018).

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This situation is concerning because ruminants, particularly cattle, are vital for food security, combating hunger and poverty, and supporting the livelihoods of millions in the region (Junca et al., 2023). Additionally, dryland cattle holders, who typically have a limited number of Tropical Livestock Units (TLU) per capita, are highly vulnerable to external shocks like climate change (de Haan, 2016). Such shocks can rapidly threaten their livelihoods and exacerbate the regional feed deficit.

In the region, farms often lack adequate land for grazing, leading to widespread reliance on cut-and-carry forages and stall feeding (Schiek et al., 2018). Forage is generally scarce and of low quality, a problem that intensifies during dry seasons and is further aggravated by climate change, thus impacting food security over time (Paul et al., 2020; de Oto et al., 2019). This issue has been notably evident in 2022 in Kenya, Ethiopia, and Somalia (WFP, 2022). Table 4 also indicates that the regional annual cultivated forage deficit exceeds 31 million tons of dry matter, with Tanzania, Kenya, and Ethiopia having the highest deficits.

This scenario underscores the urgent need to address the forage gap to enhance regional food security and reduce poverty. One potential solution is to increase the availability and accessibility of forage seeds, particularly as demand currently exceeds supply (Flórez et al., 2024). The following section will estimate the forage seed requirements for the studied countries to address the cultivated forage deficit.

3.3. Annual Forage Seed Requirements for Bridging the Regional Cultivated Forage Deficit

According to Table 5, for Scenario 1, which assumes a 100% adoption rate, the regional Annual Forage Seed Requirement (AFSR) for the adoption year would be 22,612 tons. This figure does not account for the additional forage seeds needed for annual legume replacement or regeneration seeds for perennial forage grasses. Including these additional requirements, the total regional Forage Seed Requirement (FSR) for Scenario 1 amounts to 166,543 tons over a 10-year period. The highest seed requirements would be in Tanzania (8,863 tons in the adoption year; 65,280 tons over 10 years), followed by Kenya (6,383 tons; 47,009 tons), Ethiopia (6,321 tons; 46,556 tons), Uganda (715 tons; 5,266 tons), Rwanda (228 tons; 1,683 tons), and Burundi (102 tons; 750 tons). However, this scenario appears highly unrealistic given the current low seed availability in the region, high seed prices, and the generally underdeveloped seed systems (Flórez et al., 2024; Junca Paredes et al., 2023; Creemers et al., 2021; Creemers and Alvarez-Aranguiz, 2019; Tekalign, 2014; Dey et al., 2022; Dey, 2021).

Scenario 2 offers a more realistic estimate by applying a 10% adoption rate, which would allow the cultivated forage deficit to be gradually addressed over 10 years. Under this scenario, the total regional FSR would be 95,605 tons. The distribution of this requirement is as follows: Tanzania would need 37,474 tons, Kenya 26,986 tons, Ethiopia 26,726 tons, Uganda 3,023 tons, Rwanda 966 tons, and Burundi 430 tons. The Annual Forage Seed Requirement AFSR for the adoption year totals 2,261 tons at the regional level. Although this is still a significant amount, it is more manageable compared to the 22,612 tons required under Scenario 1, considering the current limitations in the seed sector.

Table 5. Estimated annual forage seed requirement to bridge the roughage dry matter gap in Ethiopia, Tanzania, Kenya, Uganda, Rwanda, and Burundi using selected forages.

Country	Forages	Scenario 1: 100% adoption rate, AFSR (t/y1) / FSR (t/10y)	Scenario 2: 10% adoption rate, AFSR for 10 years (t)									
			Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	FSR (t/10y)
Ethiopia	*Megathyrsus maximus*	463 / 463	46	46	46	46	46	46	46	46	46	46	**463**
	Urochloa hybrids	1,452 / 1,452	145	145	145	145	145	145	145	145	145	145	**1,452**
	Vigna unguiculata	2,203 / 22,030	220	441	661	881	1,102	1,322	1,542	1,763	1,983	2	**12,119**

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	Lablab purpureus	2,203 / 22,030	220	441	661	881	1,102	1,322	1,542	1,763	1,983	2	**12,119**
	Regeneration seed *M. maximus*	0 / 139	-	-	-	-	-	-	-	46	46	46	**139**
	Regeneration seed Urochloa hybrids	0 / 436	-	-	-	-	-	-	-	145	145	145	**436**
	Total	**6,321 / 46,556**	632	1,073	1,514	1,954	2,395	2,836	3,276	3,908	4,349	4,790	**26,726**
Tanzania	*Megathyrsus maximus*	649 / 649	65	65	65	65	65	65	65	65	65	65	**649**
	Urochloa hybrids	2,035 / 2,035	204	204	204	204	204	204	204	204	204	204	**2,035**
	Vigna unguiculata	3,090 / 30,900	309	618	927	1,236	1,545	1,854	2,163	2,472	2,781	3,090	**3,090**
	Lablab purpureus	3,090 / 30,900	309	618	927	1,236	1,545	1,854	2,163	2,472	2,781	3,090	**3,090**
	Regeneration seed *M. maximus*	0 / 195	-	-	-	-	-	-	-	65	65	65	**195**
	Regeneration seed Urochloa hybrids	0 / 611	-	-	-	-	-	-	-	204	204	204	**611**
	Total	**8,863 / 65,280**	886	1,504	2,122	2,740	3,358	3,976	4,594	5,480	6,098	6,716	**37,474**
Kenya	*Megathyrsus maximus*	467 / 467	47	47	47	47	47	47	47	47	47	47	**467**
	Urochloa hybrids	1,466 / 1,466	147	147	147	147	147	147	147	147	147	147	**1,466**
	Vigna unguiculata	2,225 / 22,250	223	445	667	890	1,112	1,335	1,557	1,780	2,002	2,225	**12,236**
	Lablab purpureus	2,225 / 22,250	223	445	667	890	1,112	1,335	1,557	1,780	2,002	2,225	**12,236**
	Regeneration seed *M. maximus*	0 / 140	-	-	-	-	-	-	-	47	47	47	**140**
	Regeneration seed Urochloa hybrids	0 / 440	-	-	-	-	-	-	-	147	147	147	**440**
	Total	**6,383 / 47,009**	638	1,083	1,528	1,973	2,418	2,863	3,308	3,946	4,391	4,836	**26,986**
Uganda	*Megathyrsus maximus*	52 / 52	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	**52**
	Urochloa hybrids	164 / 164	16	16	16	16	16	16	16	16	16	16	**164**
	Vigna unguiculata	249 / 2,490	25	50	75	100	125	150	174	199	224	249	**1,371**
	Lablab purpureus	249 / 2,490	25	50	75	100	125	150	174	199	224	249	**1,371**
	Regeneration seed *M. maximus*	0 / 16	-	-	-	-	-	-	-	5.2	5.2	5.2	**16**
	Regeneration seed Urochloa hybrids	0 / 49	-	-	-	-	-	-	-	16	16	16	**49**
	Total	**715 / 5,266**	72	121	171	221	271	321	371	442	492	542	**3,023**
Rwanda	*Megathyrsus maximus*	17 / 17	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	**17**
	Urochloa hybrids	53 / 53	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	**53**
	Vigna unguiculata	80 / 800	8	16	24	32	40	48	56	64	72	80	**438**
	Lablab purpureus	80 / 800	8	16	24	32	40	48	56	64	72	80	**438**
	Regeneration seed *M. maximus*	0 / 6	-	-	-	-	-	-	-	2	2	2	**5**
	Regeneration seed Urochloa hybrids	0 / 15	-	-	-	-	-	-	-	5	5	5	**16**
	Total	**228 / 1,683**	23	39	55	71	87	103	118	141	157	173	**966**
Burundi	*Megathyrsus maximus*	7 / 7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	**7**
	Urochloa hybrids	23 / 23	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	**23**
	Vigna unguiculata	36 / 360	4	7	11	14	18	21	25	28	32	36	**195**
	Lablab purpureus	36 / 360	4	7	11	14	18	21	25	28	32	36	**195**
	Regeneration seed *M. maximus*	0 / 2	-	-	-	-	-	-	-	0.7	0.7	0.7	**2**
	Regeneration seed Urochloa hybrids	0 / 7	-	-	-	-	-	-	-	2.3	2.3	2.3	**7**
	Total	**102 / 750**	10	17	24	32	39	46	53	63	70	77	**430**

Grand Total	**22,612 / 166,543**	**2,261**	**3,838**	**5,414**	**6,990**	**8,566**	**10,143**	**11,720**	**13,981**	**15,557**	**17,134**	**95,605**

3.4. Land and farmers required in the forage adoption process

As shown in Table 6, addressing the cultivated forage deficit in the region would require nearly 2 million hectares of land across the six countries, with the majority needed in Tanzania (779,648 hectares), Kenya (561,438 hectares), and Ethiopia (556,027 hectares). Although a gradual adoption scenario with a 10% adoption rate would not require all this land at once, the annual land requirement would still be around 200,000 hectares.

Given the production pressures faced by farmers in the region, along with the strong competition for land between livestock farming and crop production (Mekuria et al., 2018; Alemu et al., 2015; Eleni et al., 2013), and the increasing impacts of climate change, this target might be ambitious. Burkart (2024) highlights this challenge by noting that *Urochloa* hybrid adoption in Africa between 2005 and 2023 covered only 30,141 hectares, including vegetative propagation. Additionally, while some authors like Flórez et al. (2024), Junca Paredes et al. (2023), and Burkart (2023) describe the forage seed market in the region as emerging with significant potential, Creemers and Opinya (2022) characterize the Ugandan forage seed market as small.

Table 6. Land required for the cultivation of forages to close the forage deficit in the region.

Forage	Ethiopia (ha)	Tanzania (ha)	Kenya (ha)	Uganda (ha)	Rwanda (ha)	Burundi (ha)	Total (ha)
Megathyrsus maximus	154,236	216,266	155,737	17,445	5,574	2,484	551,741
Urochloa hybrids	181,454	254,431	183,220	20,523	6,558	2,922	649,108
Vigna unguiculata	110,168	154,476	111,241	12,461	3,982	1,774	394,101
Lablab purpureus	110,168	154,476	111,241	12,461	3,982	1,774	394,101
Total (ha)	**556,027**	**779,648**	**561,438**	**62,890**	**20,095**	**8,953**	**1,989,051**

Notes: Based on Dey et al. (2022), the following seed rates were applied: *Megathyrsus maximus* 3kg/ha; *Urochloa* hybrids 8kg/ha; *Vigna unguiculata* and *Lablab purpureus* 20kg/ha

Based on average farm sizes in the studied countries, our analysis indicates that closing the forage deficit would require the participation of approximately 1.5 million farmers, with the majority located in Kenya (652,835), Tanzania (412,512), and Ethiopia (397,162) (see Table 7). In a gradual adoption scenario with a 10% adoption rate, this would translate to over 150,000 farmers annually adopting the recommended forage technologies.

Reaching this number of adopters may be challenging due to several factors. Farmers are typically risk-averse, forage seeds are expensive and often difficult to access, willingness to pay is low, and there is limited technical assistance for technology adoption (Flórez et al., 2024; Osiemo et al., 2024; Tekalign, 2014). For example, Urochloa hybrids were adopted by approximately 65,000 farmers in Africa between 2005 and 2023, including vegetative propagation (Burkart, 2024). Furthermore, Ahumuza et al. (2022) and Dey (2021) reported low adoption rates for forage seeds in Uganda and Ethiopia, respectively. The African Seed Access Index highlights that forage seeds are notably absent from focus areas, which are predominantly centered on food crops like maize (TASAI, 2024). Flórez et al. (2024) noted a strong demand for improved forage seeds in East Africa but limited access, mainly due to availability and high prices. In Ethiopia, Tekalign (2014) identified an underdeveloped and informal forage seed system unable to meet the growing demand, while Creemers et al. (2021) reported limited seed availability in Kenya. Similarly, Ahumuza et al. (2022) emphasized the need for improved seed dissemination in Uganda. These observations align with our findings, indicating that while there is significant demand for cultivated forage seeds, issues of accessibility (price and availability) are major barriers to higher adoption rates.

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Table 7. Estimated number of farmers required to be involved in the adoption process.

Country	Average farm size (ha)	Number of farms (total)	Number of farms (annual, 10% adoption rate)
Ethiopia	1.4	397,162	39,716
Tanzania	1.89	412,512	41,251
Kenya	0.86	652,835	65,284
Uganda	1.51	41,649	4,165
Rwanda	0.72	27,910	2,791
Burundi	0.5	17,907	1,791
Total		**1,549,974**	**154,998**

Note: For this analysis, we estimated that each farm is led by a single farmer.
Sources: Average farm sizes were consulted from the Family Farming Knowledge Platform of FAO (2024) for Ethiopia, Tanzania, Kenya, and Uganda; for Rwanda, we used Ngango and Hong (2022); for Burundi we used information provided by the Ministry of Agriculture and Livestock Burundi (2012).

3.5. The Role of Vegetative Propagation in the Forage Adoption Process

Not all cultivated forages on farmers' fields come from purchased seed. In Sub-Saharan Africa, it is common for farmers to sell, purchase, or distribute vegetative material in the form of splits, largely due to high seed prices and limited seed availability (Flórez et al., 2024). A conservative estimate for the split-to-seed ratio in the study region is 3:1, meaning that for every plant sown from purchased seed, three additional plants are propagated vegetatively (S. Mwendia, P. Karimi, M. Peters, personal communication). This highlights the significant role of vegetative propagation in the current adoption of cultivated forages. Burkart (2024) also noted that over 22,000 hectares of the total 30,000 hectares of *Urochloa* hybrid adoption in Africa by 2023 were derived from vegetative material.

However, vegetative propagation has its drawbacks. It requires substantial labor and often involves additional transportation, especially when converting large areas with splits, which significantly increases costs. For example, Tiley (1959, 1969) reported that cultivating a single hectare of *Cenchrus purpureus* (Napier grass), an example that could apply to *Megathyrsus maximus* and *Urochloa* hybrids, with vegetative material required 20,000 splits. This material weighs about 10 tons (transportation cost), must be sourced from an area of 1,000 m^2 (land requirement), and involves approximately 445-1,000 man-hours for sourcing, transportation, and planting (labor cost). For large-scale adoption, such as the 2 million hectares proposed, relying solely on vegetative propagation seems impractical. Instead, the primary source of planting material should be seeds, with vegetative propagation serving as a supplementary method to support the adoption process.

3.6. Estimated Value of the Regional Forage Seed Market and Potential Forage Crop Value Generation

The development of seed systems largely depends on the willingness of seed companies, particularly when aiming for large-scale adoption. These companies seek to maximize profits and thus require economic incentives to enter a market. Additionally, markets must be of a sufficient size to be profitable.

Table 8 provides an overview of the estimated forage seed market value for the studied countries. The data indicates that the regional seed market holds significant potential, even with a conservative adoption rate of 10%. At current seed prices, this market is valued at approximately US\$877 million over 10 years. Even if seed prices were reduced by 25%, the market value would remain substantial at around US\$658 million.

Table 8. Estimated seed market value for the selected countries.

Country	Scenario	Seed market value (in millions 2023 US$)				
		*Megathyrsus maximus**	*Urochloa* hybrids*	*Vigna unguiculata*	*Lablab purpureus*	Total
Ethiopia	1a / 1b	29.28 / 21.96	95.22 / 71.42	207.69 / 155.77	137.60 / 103.20	**469.79 / 352.34**

	2a / 2b	29.28 / 21.96	95.22 / 71.42	114.23 / 85.67	75.68 / 56.76	**314.41 / 235.81**
Tanzania	1a / 1b	41.05 / 30.79	133.52 / 100.14	135.26 / 101.45	192.94 / 144.70	**502.78 / 377.08**
	2a / 2b	41.05 / 30.79	133.52 / 100.14	74.40 / 55.80	106.12 / 79.59	**355.08 / 266.31**
Kenya	1a / 1b	29.56 / 22.17	83.19 / 62.40	43.94 / 32.95	50.96 / 38.22	**207.66 / 155.74**
	2a / 2b	29.56 / 22.17	83.19 / 62.40	24.16 / 18.12	28.03 / 21.02	**164.95 / 123.71**
Uganda	1a / 1b	3.31 / 2.48	10.77 / 8.08	3.70 / 2.77	25.42 / 19.06	**43.20 / 32.40**
	2a / 2b	3.31 / 2.48	10.77 / 8.08	2.03 / 1.53	13.98 / 10.48	**30.10 / 22.57**
Rwanda	1a / 1b	1.06 / 0.79	3.44 / 2.58	3.54 / 2.65	4.97 / 3.73	**13.01 / 9.76**
	2a / 2b	1.06 / 0.79	3.44 / 2.58	1.95 / 1.46	2.74 / 2.05	**9.18 / 6.89**
Burundi	1a / 1b	0.47 / 0.35	1.53 / 1.15	0.96 / 0.72	2.22 / 1.66	**5.19 / 3.89**
	2a / 2b	0.47 / 0.35	1.53 / 1.15	0.53 / 0.40	1.22 / 0.91	**3.75 / 2.82**
Total	**1a / 1b**	**104.73 / 78.55**	**327.68 / 245.76**	**395.09 / 296.32**	**414.11 / 310.58**	**1,241.62 / 931.21**
	2a / 2b	**104.73 / 78.55**	**327.68 / 245.76**	**217.30 / 162.98**	**227.76 / 170.82**	**877.47 / 658.11**

Notes: Scenario 1a: 100% adoption rate, 10 years evaluation horizon, current seed prices; Scenario 1b: 100% adoption rate, 10 years evaluation horizon, reduced seed prices by 25%; Scenario 2a: 10% adoption rate, 10 years evaluation horizon, current seed prices; Scenario 2b: 10% adoption rate, 10 years evaluation horizon, reduced seed prices by 25%. *Regeneration seed included.

Table 9 details the estimated value of cultivated forages that could be generated over 10 years. At the regional level, this value ranges from US$5.6 billion to US$10.2 billion, depending on the adoption rate. This equates to annual values of between US$560 million and US$1.02 billion. Tanzania, Kenya, and Ethiopia are expected to contribute the highest values. The two grass species being analyzed account for the largest share of the total estimated values.

The potential forage crop value would make a substantial contribution to the estimated US$63 billion annual value of cultivated forage crops in the developing world, as reported by Fuglie et al. (2021). Specifically, for *Urochloa* hybrids, the potential annual forage crop value in the studied region would be between US$219 million and US$397 million. This would also significantly add to the estimated annual forage crop value of US$1.14 billion for *Urochloa* hybrids already adopted in the global tropics (Burkart, 2024).

Table 9. Estimated cultivated forage crop value for the selected countries.

Country	Scenario	Estimated cultivated forage crop value (in millions 2015 US$)				
		*Megathyrsus maximus**	*Urochloa* hybrids*	*Vigna unguiculata*	*Lablab purpureus*	Total
Ethiopia	1 / 2	1,110 / 611	1,110 / 611	317 / 175	317 / 175	**2,856 / 1,571**
Tanzania	1 / 2	1,557 / 856	1,557 / 856	445 / 245	445 / 245	**4,004 / 2,202**
Kenya	1 / 2	1,121 / 617	1,121 / 617	320 / 167	320 / 167	**2,883 / 1,586**
Uganda	1 / 2	126 / 69	126 / 69	36 / 20	36 / 20	**323 / 178**
Rwanda	1 / 2	40 / 22	40 / 22	11 / 6	11 / 6	**103 / 57**
Burundi	1 / 2	18 / 10	18 / 10	5 / 3	5 / 3	**46 / 25**
Total	**1 / 2**	3,972 / 2,185	3,972 / 2,185	1,134 / 616	1,134 / 616	**10,215 / 5,619**

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Notes: Scenario 1: 100% adoption rate, 10 years evaluation horizon; Scenario 2: 10% adoption rate, 10 years evaluation horizon.

3.7. Developing the Forage Seed Market and Ensuring Forage Adoption

A recent position paper by the Intergovernmental Authority on Development (IGAD, 2022), which includes eight member states—Djibouti, Ethiopia, Kenya, Somalia, South Sudan, Sudan, Uganda, and Eritrea—emphasizes the need to focus on forage seed value chain development and demand creation, given the region's large livestock population and the livelihoods tied to livestock. This recognition highlights the critical importance of ensuring forage seed availability. One key aspect is the registration of forage varieties in individual countries, which is essential to encourage private sector involvement and to tap into the region's market potential. However, registering forage varieties can be a time-consuming process, often involving significant bureaucracy (Flórez et al., 2024; Creemers and Alvarez-Aranguiz, 2019; Mwendia et al., 2020; Creemers and Opinya, 2022; Maina et al., 2022; Dey et al., 2022; Creemers et al., 2021).

A more efficient approach would involve leveraging regional trade blocs to expedite the registration process. For instance, under COMESA (Common Market for Eastern and Southern Africa), a forage variety registered in two member countries can be accepted in a third member country without undergoing lengthy and resource-intensive national performance trials (COMESA and ACTESA, 2014). Extending this approach to other trade blocs, such as the East African Community (EAC), IGAD, or the Southern African Development Community (SADC), could present a significant opportunity for the easier movement of developed forage varieties across borders. Given the overlapping memberships of many countries in these trade blocs, such harmonization would facilitate smoother regional trade and agricultural integration. Table 10 gives an overview of the membership of several African countries in regional trade blocs.

Table 10. Membership of African countries in the regional trade blocs COMESA, IGAD, EAC, SADC.

Country	COMESA	IGAD	EAC	SADC	Total memberships
Angola				■	1
Botswana				■	1
Burundi	■		■		2
Comoros	■			■	2
Djibouti	■	■			2
Democratic Republic of Congo	■		■	■	3
Egypt	■				1
Eritrea	■	■			2
Eswatini	■			■	2
Ethiopia	■	■			2
Kenya	■	■	■		3
Lesotho				■	1
Libya	■				1
Madagascar	■			■	2
Malawi	■			■	2
Mauritius	■			■	2
Mozambique				■	1
Namibia				■	1
Rwanda	■		■		2
Seychelles	■			■	2

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Somalia	■	■	■		3
South Africa				■	1
South Sudan		■	■		2
Sudan	■	■			2
Tanzania			■	■	2
Tunisia	■				1
Uganda	■	■	■		3
Zambia	■			■	2
Zimbabwe	■			■	2
Total member countries	**21**	**8**	**8**	**16**	

Note: Shaded cells indicate membership

To lower seed costs, boosting production within the continent and targeting regional markets is a promising strategy. This involves identifying the most suitable locations for such production. For some forage species, achieving synchronized flowering and seed setting requires longer photoperiods (Hare et al., 2015). Zambia has been suggested as a suitable location due to its longer day lengths and strong ties to regional trade blocs like COMESA and SADC, which together encompass 37 member countries, providing enhanced market linkages. Additionally, Zambia's well-established seed production sector, particularly for maize, a staple food in the region, and the involvement of numerous private companies in its production and marketing (Smale et al., 2015) make it a strategic choice.

Once seeds are registered in a country, establishing effective distribution logistics is crucial, which remains a challenge in the current forage seed system (Flórez et al., 2024; Creemers and Opinya, 2022). Distribution models involving seed companies and producer associations could address issues related to bulk seed purchases, distribution in rural areas, and providing essential information for successful technology adoption. Livestock producers in the region often lack knowledge about forage cultivation (Flórez et al., 2024; Creemers and Alvarez-Aranguiz, 2019; Maina et al., 2022; Fuglie et al., 2021), which can lead to poor adoption outcomes and technology rejection. Collaboration on technical assistance and extension among stakeholders—such as seed companies, public entities, NGOs, and producer associations—could bridge this knowledge gap and support effective technology adoption.

However, establishing a functional seed system alone will not guarantee widespread adoption of cultivated forages. Existing modest adoption rates are influenced by a complex interplay of social, economic, political, cultural, and environmental factors, including risk aversion, labor availability, access to inputs and credit, land tenure, regulatory frameworks, market dynamics, and gender dynamics. Addressing these complexities requires a comprehensive strategy that considers the multifaceted influences on adoption, which is essential for designing effective approaches to promote the large-scale use of forage innovations.

4. Conclusions and Recommendations

The livestock sector across East Africa is recognized as a key contributor to economic growth and rural livelihoods, with governments in the region focusing on improving productivity and sustainability through various initiatives and policies. These efforts increasingly prioritize the use of forages due to their potential to enhance livestock production and mitigate environmental impacts. However, the region faces significant challenges, notably the vast feed and cultivated forage deficits, which threaten food security and economic stability.

Efforts to close the feed gap reveal that over 40% of feed demand remains unmet, exacerbated by climate change and limited land availability, especially in smallholder farming systems. This critical shortage underscores the urgency of increasing forage cultivation and seed availability, although the current seed systems are underdeveloped and characterized by lacking accessibility – a result of limited seed availability and high prices.

Closing the cultivated forage feed gap over 10 years seems to be an ambitious endeavor since challenges related to land requirements, farmer participation, and access to inputs persist. Vegetative propagation remains a supplementary but costly method, emphasizing the need for a robust seed system to scale up forage adoption.

Despite these significant hurdles, the forage seed market holds considerable economic potential, with an estimated seed value of up to US$877 million over 10 years at a slow adoption rate of 10%, which could lead to significant economic gains in terms of forage crop values. To realize this potential, governments and private entities must work together to improve seed systems, lower costs, and streamline registration processes, particularly by leveraging regional trade blocs.

For widespread adoption, addressing socio-economic barriers, including risk aversion, access to credit, and gender dynamics, will be crucial. A comprehensive, multi-stakeholder approach is necessary to build an inclusive and sustainable forage seed market that supports the region's livestock sector, food security, and rural development goals.

From this, we propose the following recommendations:

- Enhance feed and forage policy integration: Governments should enhance the integration of feed and forage policies with broader livestock sector strategies. This includes aligning forage production initiatives with overall livestock productivity and environmental sustainability goals. They should also emphasize the adoption of sustainable forage management practices to improve feed quality and availability. Likewise, policies that balance economic, environmental, and social objectives in forage production should be developed.
- Address feed and forage deficits: Strategies to significantly boost the availability of forage seeds should be developed. This could involve supporting seed production initiatives, reducing seed prices, and improving seed distribution channels. Investments in research to develop high-yielding and climate-resilient forage varieties is essential. Collaboration with international research organizations can help accelerate the development of suitable forage crops for the region.
- Improve seed systems and distribution: Regional trade blocs such as COMESA and EAC should be used to streamline the registration and movement of forage varieties across borders. This can reduce bureaucratic delays and enhance seed accessibility. Efficient seed distribution models that involve seed companies and producer associations should be developed to improve access to seeds in rural areas. Logistics and supply chain solutions to ensure timely delivery of forage seeds should be established.
- Support of farmers and land use: Comprehensive training and extension services to farmers on forage cultivation and management are essential. This should include practical advice on the use of forage technologies and addressing common challenges in forage production. Innovative land management practices should be explored to maximize the use of available land for forage cultivation. Policies that mitigate competition between livestock and crop production and promote sustainable land use planning should be developed.
- Enhance market incentives: Economic incentives for seed companies to enter and invest in the forage seed market should be created. This could involve subsidies, tax breaks, or public-private partnerships to support the development of the seed industry. The forage seed value chain should be developed by encouraging private sector involvement, improving market infrastructure, and fostering demand creation for forage crops.
- Address adoption barriers: Barriers related to high seed prices and limited seed availability should be addressed. This could involve subsidies or financial support mechanisms (e.g., credits) for farmers adopting improved forage varieties. Likewise, social, economic, and environmental factors that influence adoption rates must be addressed, e.g., through developing targeted interventions to overcome risk aversion, labor constraints, and other barriers to successful technology adoption.
- Monitor and evaluate adoption: Robust monitoring and evaluation systems to track progress in forage adoption, seed distribution, and impact on livestock productivity should be established. Data derived from such systems can be used to refine strategies and make evidence-based adjustments to policies and programs.

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