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Research Article

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Prospects of Selected Improved Forages under Various Agroecologies and Soil Conditions in the Tropics

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ABSTRACT
The projected rise in the global population—from 7.7 to 9.7 billion by 2050—will substantially increase the demand for livestock products, especially in sub-Saharan Africa, where the population is expected to double. Livestock production in the region remains constrained by feed scarcity, as most systems depend on natural pastures, crop residues, and traditional forages of low nutritive quality. Climate change, disease pressure, and competition for arable land have further exacerbated feed deficits, limiting productivity and resilience. In response, improved forage species such as *Urochloa* (syn. *Brachiaria*) and *Megathyrsus* (syn. *Panicum*) have been promoted as climate-smart alternatives due to their adaptability, drought tolerance, and high biomass yields. However, adoption has been uneven, and performance often declines when introduced into smallholder systems characterized by diverse agroecological and socio-economic conditions. This review examines the adaptability and productivity of *Urochloa* and *Megathyrsus* across different tropical agroecologies and soil types, emphasizing their role in sustainable livestock production. It highlights the importance of participatory research to bridge the gap between experimental results and on-farm realities, ensuring that improved forages contribute effectively to feed security and climate-resilient agriculture in sub-Saharan Africa.

Keywords: Soil Conditions, Forage Production, Selected Species, Various Agroecologies

An overview

The global human population is projected to rise from 7.7 billion to 9.7 billion by 2050, with sub-Saharan Africa's population expected to double within the same period [1]. This demographic shift will drive a sharp increase in demand for livestock products, particularly milk and meat, which are critical sources of dietary protein. Livestock production also contributes significantly to household income, employment, and agricultural GDP in Africa [2].

Currently, livestock production in sub-Saharan Africa faces persistent constraints due to feed scarcity. The sector relies heavily on natural pastures, crop residues, and homegrown fodder, which are strongly affected by seasonality and rainfall variability [3,4]. In Kenya, for example, communal grazing, maize stover, and Napier grass are the main feed resources [5,6]. While these resources are widely used, they are often inadequate during dry seasons and of low nutritive quality. Furthermore, the spread of Napier head smut disease and the prioritization of food crops such as maize have reduced the availability and productivity of traditional forages [7-9]. The continued reliance on low-quality residues such as maize stover and sorghum stalks ultimately constrains livestock productivity [10].

To address this feed deficit, improved forage species such as *Urochloa* (syn. *Brachiaria*) and *Megathyrsus* (syn. *Panicum*) have been introduced as climate-smart alternatives. These grasses are recognized for their adaptability to diverse agroecologies, high dry matter yields, and tolerance to stresses such as drought

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and low soil fertility [11]-13. *Urochloa* species, for instance, are highly resilient in acidic soils and have strong tillering ability, while *Megathyrsus* maximus cultivars such as Mombasa and Tanzania are valued for their high biomass production and vigorous regrowth [14,15].

Despite their potential, adoption of improved forages has been uneven. Performance often falls short when technologies are transferred from research stations to smallholder farms due to agroecological and socio-economic variability (Giller et al., 2011; Vanlauwe et al., 2019). Understanding how improved forages interact with site-specific factors such as soil fertility, rainfall, and farmer management practices is therefore critical for scaling their use. This review explores the prospects of *Urochloa* and *Megathyrsus* under diverse tropical agroecologies and soil conditions, highlighting their adaptability, production potential, and the role of participatory research in overcoming adoption barriers.

Agroecologies and Forage Production

Agroecology refers to the interaction between crops, livestock, environment, and farming practices within a defined ecological and socio-economic context [16]. It considers biophysical factors such as climate, soils, topography, and biodiversity, as well as human dimensions like resource access, farming knowledge, and land-use history [17]. Agroecological zones are often categorized based on altitude, rainfall, temperature, and growing season length, which collectively shape the suitability and productivity of different forage species [18].

The success of forage grasses such as *Urochloa* and *Megathyrsus spp* is largely determined by their adaptability to these varied agroecological conditions. Their ability to establish, persist, and yield under different combinations of soil fertility, rainfall, and temperature is critical in scaling up fodder production across diverse farming systems [19]. *Urochloa* spp are especially noted for their adaptability to low-fertility, acidic soils and their tolerance to drought-prone environments. These traits make them ideal for humid and sub-humid tropical agroecological zones where soil degradation and variable rainfall are common [20].

On the other hand, Megathyrsus maximus, particularly the Mombasa and Tanzania cultivars, thrives in well-drained, fertile soils and can perform optimally in areas receiving more than 1000 mm of rainfall annually. These grasses grow best in tropical lowland and mid-altitude zones with moderate-to-high temperatures and a long growing season [21]. Their robust root systems and high tillering capacity contribute to strong regrowth, making them suitable for cut-and-carry systems as well as rotational grazing setups [22].

Although both genera have shown promise across multiple agroecological zones in sub-Saharan Africa, including western Kenya, much of the existing data comes from controlled research environments. There is limited literature on their performance under real-world farmer-managed conditions, where factors like soil variability, rainfall inconsistency, and management practices heavily influence outcomes. As such, further studies are needed to validate their agroecological fit and productivity under diverse, farming systems. Understanding and leveraging the agroecological adaptability of improved forages is not only essential for livestock feed security but also aligns with broader goals of climate resilience and sustainable intensification in mixed crop-livestock systems.

Selected Species of Improved Forage Varieties

Forage alternatives such as genus *Urochloa* syn. *Brachiaria* and *Megathyrus* syn Panicum have been introduced as alternatives to napier and the low-quality crop residues. Breeding and selecting *Urochloa* spp for instance, has aided in introducing superior genotypes with adaptive characteristics [11]. The *Urochloa* spp are considered climate smart, highly adaptive to multiple agro ecological zones and low fertile soils [12]. In addition, the tillering capability of *Urochloa* species allows their survival in drought conditions and the accumulation of high dry matter content [6]. Species of *Megathyrsus* are also considered alternatives of napier due to their high yielding nature and vibrant regrowth after cutting [14].

However, these improved forage species have not performed as expected when released to farmers. Most improved pasture technologies are tested and developed mainly on research stations, in the confinements of homogeneous, researcher-controlled environments with little consideration of heterogeneity that is in in farmer's environments [23]. Established that heterogeneity of socio-economic and agro-ecological production environments on smallholder farmers has a direct impact on crop production [24]. In forage systems, site-specific studies in various agro ecologies evaluate how key environmental factors including declining soil fertility, erratic rainfall, and local microclimates directly impact forage establishment, regrowth rates, and total biomass yields [25]. For example, species such as *Urochloa* may perform well in acidic, low-nutrient soils, while *Megathyrsus* typically requires well-drained, fertile conditions to reach optimal productivity [26]. By integrating these ecological and agroecology enables researchers to select forage species that are not only biologically compatible with local conditions but also viable under the practical realities of smallholder farming systems [27].

However, research including that of forage agronomy, has often overemphasized and focused on single factors while ignoring important aspects of variability especially those of soil, climate, and management [28]. This explains why technologies do not perform as well as expected when they are introduced to farmers [29]. Heterogeneity minimizes technology performance especially in on-farm setups therefore discouraging and limiting success of adoption by farmers [30].

Several research methods have been developed to address on-farm heterogeneity. Participatory on-farm research is one such method that was developed to address the variability. Often this type of study will prioritize setting up research in the typical farmer environment in a need to evaluate performance of technology once it is released to the farmer [31]. Consequently, research is deviating from on-station trials to practical ways of using multiple locations and hands on involvement of farmers in research [32]. As opposed to traditional agronomy that applies principles of minimising variability by excluding factors not within the treatment, on-farm and participatory trials are set up in farmer's environment hence enabling them to evaluate the technologies and learn during research [29]. In addition, data is derived from multiple environments and used to make advisory and tailored recommendations to small scale farmers.

Urochloa grass belongs to the Poaceae family which are C4 plants and are regarded to be perennial crops [33]. They perform better than other species of grasses in acidic soils [34] . All species of *Urochloa* can either be propagated using seeds or cuttings. While propagating through cuttings is easy, it becomes impractical to do so in large scale [35].

The continuous studying of cytological behavior and mode of reproduction of *Urochloa* grasses has spearheaded activities of improving and coming up with cultivars that are superior and better in biomass production, nutritional quality, and improved resistance to pest and diseases [36,37]. In the *Urochloa* genus, cultivars, and hybrids such as Xaraes, Mulato II, and Cayman have demonstrated varied adaptability and resilience. Xaraes (*Urochloa brizantha* cv. Xaraes) has shown dry matter yields ranging between 8.78 t/ha and 13.95 t/ha under different cutting regimes in Cameroon [38]. Mulato II, a hybrid Urochloa, is a hardy perennial with medium height (80–100 cm) and high leafiness. It produces between 14 and 17 t/ha of dry matter per year on acid soils pH 4.7 [39]. A study by portrayed the potential of improved forage varieties from *Urochloa* and *Megathyrsus* to increase productivity compared to local germplasm [40].

It is anticipated that promotion of such improved germplasm of forages will have a direct impact on livestock feed production in Kenya. *Megathyrsus spp* is a C4 Plant occurring naturally and is native to East Africa although other types are found all over the world [41]. This grass has the potential to grow up to 1-2m especially in areas receiving rainfall, of more than 1000mm per year. Additionally, it thrives well in soils that are well drained and fertile [42]. Propagation can be done using seeds or cuttings with the seeds mostly planted 2-3 cm depth [8].

Among the *Megathyrsus maximus* cultivars, Mombasa and Tanzania are widely recognized for their high biomass production potential. Mombasa grass, is a tall, leafy grass, reported to produce between 15–20 t/ha dry matter per year on poor soils in Thailand, with dry matter yields 28%–40% more than that of Tanzania guinea grass [21]. It is suitable for cut-and-carry systems, with cutting intervals of 40–45 days during the wet season when plants reach 60–80 cm in height. Selection of these species of grasses has been associated with improved production. reported an increase in yield by 10-80% when genetically advantaged crops coupled with appropriate agronomic management practices were used in China [43]. The increase in production encourages adoption of new varieties of fodder technologies when introduced to farmers.

On-Farm Heterogeneity

Livestock keeping originally relied on natural pastures that were majorly rain fed. However, over the years, due to drastic climate change, availability of natural grasses has declined which has necessitated cultivation of forages artificially to feed animals [44]. In North America, South America and some parts of Asian tropics and subtropics, efforts have been made to enhance availability of fodder through artificial production. The decline in rainfall has affected production of crops including those that are used as livestock feeds [45]. The scenario is worsened during periods of prolonged droughts whereby production of these animal feeds such as forage maize, fodder sorghum is decreased by a significant percentage [46]. Studied how seasonal changes in rainfall affects forage production in South-eastern Australia and found a huge relationship between declined productions in yields of fodder maize, and ryegrass [47]. Notably there were positive responses to dry matter production in all the locations that the study was carried out clearly indicating the importance of precipitation in forage production.

While Latin America is known to devote huge tracks of land to produce pasture in a bid to support their thriving livestock production sector, studies have indicated looming danger of climate change. Fluctuation in rainfall has continuously threatened pasture production in the region [48-50]. The region relies on a delicate balance of soil nutrients, reliable rainfall, and superior pasture species to sustain livestock feed production [51,52]. In addition, to the changes in precipitation, disastrous natural phenomenon such as hurricanes have also negatively influenced both native and introduced species of forage [53]. With the increased climatic changes experienced over the years, farmers are encouraged to adapt forage genotypes that are more climate resilience and can withstand prolonged dry conditions.

Like Asia, European and Latin America, Global south countries experience seasonal changes characterized with wet and dry periods hence the fluctuating amounts of rainfall received in certain times of the year [54,55]. This seasonal changes in rainfall have been the main cause of low production of livestock feed during drier times of the year. East Africa is no exception in experiencing radical rainfall changes over the years [56,57]. Most of the region experiences bimodal inter seasonal rainfall patterns whereby long rains are in March to May and short rains from October to December but in the recent past, precipitation has become more erratic, leading to some prolonged dry conditions during certain times of the year [58,59]. Consequently, fodder during drier months is scarce with little to feed livestock [60,61].

Constraints of unpredictable and unreliable rainfall prompted researchers to introduce climate smart forages that could withstand climate variability [13]. Genotypes from *Urochloa* were specifically selected, tested and later introduced to farmers due to their ability to tolerate low soil fertility and low rainfall [62-64]. Studies by in western and eastern Kenya reported an increase of livestock feed by 31.6% which is generated from the adoption of improved *Urochloa* grasses [65]. Evidently, there is limited information on the effect that variable climatic changes have on improved forages in context of *Urochloa* and *Megathyrsus* grasses. Although these forages are reported to adapt well in multiple agro ecological zones, more studies are required with specific interest to their performance and production potential in western Kenya under on-farm conditions.

Soil Fertility and its Effects on Forage Yields

Utilizing nitrogen-based fertilizers is key in promoting root development and photosynthesis [66]. In early research, studied the effect that potassium application has on alfalfa grass. It was illustrated that fertilizing was both necessary and profitable if the total exchangeable potassium was less than 40mols/kg per acre [67]. It was further noted that alfalfa yield did not increase if potassium was added to a soil containing more than 80mols/kg exchangeable potash per acre.

Vanlauwe carried out studies in sub-Saharan Africa on the use of local and hybrid maize varieties which has often been utilised as silage [68]. There was extra grain yield in hybrids compared to local varieties. He further illustrated the essence of mixing fertilizer with either compost or manure which resulted to higher dry matter accumulation compared to sole fertilizer application. Long-term pasture trials in New Zealand found that stopping fertilizer use led to an increase in weeds and low-fertility grasses. Although production declined in a curvilinear pattern after fertilizer was withdrawn, it remained significantly higher even after 20 years than in plots that had never received fertilizer [69].

It is key to prepare seed beds before planting forages and occasionally replenish nutrients by applying fertilizer and manure, managing of pest and diseases to maximize fodder production [70]. Whose study focused on interactions between fertilizer application and variety selection in western Kenya reported an 88% increase in yield [71]. This was attributed to fertilizer application which also influenced an increase in 100 seed weight by 14%. The study therefore recommended nitrogen-based fertilizer as a way of increasing yields in maize which can be used to make silage.

Experiences from East Africa, Kenya soils, which mainly comprise of Acrisols and Ferrasols have undergone a lot of weathering over the years [72,73]. Moreover, the continuous cultivation of crops without replenishing nutrients in the soils has resulted to deficiently in key soil nutrients such as Nitrogen and Phosphorous [74]. This condition has led to the drastic reduction in production potential of crops. Maize, a staple food, and fodder crop in the region, produces less than 0.5 t/ha per cropping [75,76].

While efforts are geared towards improving, status of these soils, on-farm heterogeneity of soil fertility within the region is limiting with essential minerals such nitrogen phosphorous. Status of soils fertility is influenced by varying factors such as soil types, climatic factors and cropping patterns which must all be put in consideration during recommendations studied nutrients level of soils among farmers in Kakamega who are adjacent to the tropical forest and illustrated that these soils were most limited in nitrogen and phosphorous [77]. He further reported low levels of phosphorous in farmers within the region that are not keen in using inorganic fertilizer to replenish soil nutrients.

Providing fodder crops with essential nutrients such as nitrogen, phosphorous, potassium, calcium, magnesium, sulphur, molybdenum, manganese, and zinc is key in ensuring production of high-quality fodder [78]. Studies on the role of phosphorus found that pasture production generally increases with increase in the availability of P [79,80]. Low fertility has however continued to be associated synonymously with sandy soils which are often described to have a pH less than 5.5 and extraordinarily little organic matter of less than 2%. Studies [81]. Established lowered production in such soils. However, noted sandy soils required increased application of Potassium and Sulphur to increase production in a bid to match production to that of other soil types [82].

Studies in Laikipia, Kenya by observed that nitrogen levels had a positive influence on the biomass production of pasture but soil organic Matter (SOM) and biomass above ground of biomass of grasses had a negative relationship [83]. Inadequate moisture in the soil may have constrained the mineralization of SOM therefore limiting its effectiveness [15]. Studies on the impact of soil heterogeneity in western Kenya have focused mainly on food crops, particularly maize. Demonstrated significant differences between maize produced on-farm and that produced under research management. The differences were further demonstrated by applying fertilizers containing Nitrogen Phosphorous and potassium and all had positive effect on yields across all locations [84]. With growing interest in dairy production in the region, research that focuses on on-farm variability of soil and its effects on productivity of forages merits study.

Among these, nitrogen plays a central role in promoting vegetative growth and dry matter accumulation in grasses. Studies have consistently shown that nitrogen application significantly increases forage yields across different species, particularly in C4 grasses such as *Urochloa* and *Megathyrsus spp* (Da Costa Leite et al., 2019).

The physical and chemical properties of soils including pH, organic matter content, texture, and cation exchange capacity also influence nutrient availability and forage productivity. Acidic soils, common in many parts of sub-Saharan Africa, often limit phosphorus availability and reduce microbial activity, which negatively impacts forage establishment and yield [85]. Sandy soils, for example, tend to be low in organic matter (<2%) and essential nutrients, with poor water retention, resulting in reduced forage productivity unless supplemented with targeted fertilization and organic inputs [86].

Scaling Forages

Research has long relied on carrying out on station trials in a controlled environment that are managed by scientists at every step [87]. Although this has previously worked, success of agricultural technology interventions is slowly adopted by farmers. Farmers, who are most times the end users, tend to have varying and completely different context compared to those tested (Liu et al., 2018). Often, these technologies will be subjected to completely different environments regarding soil fertility, agronomic management, and climatic factors.

As a result, it has become incredibly important to involve farmers at every step of the research to ensure they have maximum input and participation during the research process. It is important to involve farmers in the early stages of research enabling them to be part of the objective setting, qualitative management of trials and ultimately making autonomous decisions (Rose et al., 2018). Studies have found that technologies produced through farmer participation produced different results compared to conventional methods. Furthermore, farmer participation was found to reduce bias in recommendation of technologies [88].

These research methods however completely disregarded on-farm variability, inclusive of soil fertility, rainfall, on-farm resources used in management of farms even within the same community [23]. The agenda to ensure technologies reach farmers was entirely left to extension whose main agenda was to push the experimental findings to many farmers as possible in the hopes of adoption [89]. Unfortunately, these technologies did not perform as well in farmers' environments as they had in research stations.

The foregoing reason necessitated the introduction of methods studying farmers systems and the use of participatory research methods which ensures farmers are involved in technology development from the onset [90]. Instead of farmers getting recommendations based on experiments, they are involved in research from the onset through on-farm trials thus facilitating the scaling up of agronomy research. The introduction and the use of participatory research is a sure way of bridging the gap between scientific research and the reality that is in the farmers' setup [91]. This paradigm change may, in future if adapted, necessitate the introduction and use of research designs that cater for studies carried in multi locations. Such designs are suited for variability that is presented on-farm [92-97].

Conclusion

Improved forages such as *Urochloa* and *Megathyrsus* spp. offer significant potential to address the livestock feed deficit in the tropics, particularly in sub-Saharan Africa where population is increasing. Their adaptability to diverse agroecologies, resilience to drought, and potential for high biomass yields position them as promising alternatives to traditional feed resources. However, the performance of these forages under farmer-managed conditions remains variable due to soil fertility constraints, erratic rainfall, and management differences.

On-farm heterogeneity continues to be the most critical barrier to scaling, as technologies optimized in research stations rarely translate directly to smallholder contexts. Participatory research approaches, such as mother-baby trials, provide a pathway for aligning scientific innovations with farmer realities, thereby enhancing adoption. Yet, more empirical data are required to assess genotype × environment interactions under diverse soil and climatic conditions.

Future research should therefore prioritize: (i) multi-location trials with farmer participation to capture real-world variability, (ii) integrated nutrient management strategies tailored to resource-constrained smallholders, and (iii) seed system strengthening to ensure availability of improved germplasm. By combining ecological adaptability with socially embedded scaling pathways, improved forages can significantly contribute to climate resilience, livestock productivity, and food security in the tropics.

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