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Tracing the benefits of ILRI germplasm distributions: *Medicago sativa, Sesbania sesban* and *Pennisetum purpureum*

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Abstract

Forage diversity plays an important role in the livelihoods of millions of smallholder livestock keepers and in the nourishment of the world population. Land degradation, agricultural expansion and climate change pose serious threats to forage diversity, necessitating ardent diversity conservation efforts. The International Livestock Research Institute (ILRI) is a leading institution in the conservation of forage genetic diversity. This study investigates the impacts of use of three popular species sourced from the ILRI genebank: *Medicago sativa (Alfalfa), Sesbania sesban (Sesbania)* and *Pennisetum purpureum (Napier).* The study also sought to understand the traits farmers prefer when selecting forage. Village-level survey data confirm that farmer preferences are key determinants of fodder adoption. Soil fertility improvement, soil erosion control, and crop protection were identified as the main secondary benefits linked to the adoption of *Sesbania sesban* and *Medicago sativa* in Ethiopia. In Kenya, soil erosion control was the main benefit attributed to the two Napier cultivars(Kakamega 1 & 2). Findings from secondary data demonstrated the critical role of genebank accessions in evaluation trials as well as in the mitigation of serious agricultural challenges.

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Contents

1. Introduction

Now more than ever before, the conservation of forage genetic diversity is a subject matter of great importance for economic development, particularly in poorer regions of the world. This concern is motivated by the important recognition of the role that forage availability and diversity play in the livelihood strategy of an estimated 1 billion poor, smallholder livestock rearers and their households (Herrero et al. 2013). This is especially the case in dryland ecosystems where livestock rearing is the predominant livelihood venture for low income rural people (Fikru et al. 2016). Income, nourishment, traction, manure production and insurance are just some of the crucial benefits that livestock ownership delivers to this demographic (Enahoro et al. 2018). Moreover, on a macroeconomic frontier, it is estimated that livestock contribute to approximately 40% of the global agricultural Gross Domestic Product (GDP) (Ferner et al. 2018).

Unrelenting pressure from drivers of change especially underscore the imperative urgency for conservation. The demand for livestock products, and consequently forages, is anticipated to significantly increase with the advancing structural transformation of economies (Barrett et al. 2017). Moreover, increasing climate change variability underscores the need to have adapted forages that can function in ever-changing ecosystems (Gamoun, Belgacem, and Louhaichi 2018). The importance of diversity notwithstanding, population increases exert continuous pressure on natural resources, leading to the conversion of marginal tracts of land to agricultural use and contributing to the loss of forage diversity (Ponsens et al. 2010). The continued assurance of forage availability and quality, in the context of the aforementioned pressures, is contingent on the existence of a diverse genetic reservoir of forages.

Cognizant of the critical role that forage genetic diversity plays for humankind, the genebank of the International Livestock Research Institute (ILRI) holds approximately 18,643 accessions in its conservation portfolio, 17,387 of which constitute forages (www.Genesys-Pgr.Org n.d.).These accessions represent over 1,400 species of diverse forage plant types such as legumes, grasses and browse fodder. The genebank has been of great utility to many countries, most notably Ethiopia and Kenya, who rank first and second as recipients of the forage germplasm given their vibrant livestock sectors. Concerning distributions in Ethiopia, *Medicago sativa* (alfalfa) takes the lead as the most distributed legume accession (Accession Number 6984) whereas *Sesbania sesban* (Sesbania) takes the lead in the browse category (Accession Number 10865) (Table 1). In the case of Kenya, *Pennisetum purpureum* (Napier) takes the lead as the most distributed species in the grass category (Table 2).

The demand for *Medicago sativa* and *Sesbania sesban* is motivated by the recognition that poor feed quality (herein low protein content) is a significant contributor to poor livestock productivity not only in Ethiopia but also in many countries situated in the tropics(Salem et al. 2006). *Medicago sativa* has often been referred to as the "queen of forages" given that it has the highest yield of protein per unit area among all forage grains and legumes (Bacenetti et al. 2018). Similarly, *Sesbania sesban* has been heavily promoted in Ethiopia as an affordable fodder source that can supplement the low protein basal diets. The browse fodder ranks very highly in the protein hierarchy among the fodder tree options amenable to the tropics (Franzel et al. 2014). In the case of Kenya, the demand for Napier grass is fuelled by its dominance in the intensive and semi-intensive dairy farming systems (Wamalwa et al. 2017).

The demand for these species as well as others from the ILRI genebank is fuelled by the recognition that the genebank strives to preserve germplasm to the preferred standard, a measure that guarantees high quality germplasm albeit at significant financial cost (Koo, Pardey, and Wright 2003). The continued support of genebank operations, such as ILRI and others, is anchored on the existence of an up-to-date portfolio of evidence on genebank impacts. Yet, there is a paucity of evidence documenting the impacts attributable to ILRI's genebank conservation efforts. This study aims to contribute to this evidence in several ways. First, we perform a detailed analysis of the distribution data (1984-2017) to identify major trends in germplasm distribution. Secondly, CGIAR genebanks have often been referred to as the "genebanks of the poor" given their affiliation and devotion to smallholder agriculture (Koo, Pardey, and Wright 2003). In this regard, we seek to gain an understanding of farmer-preferred traits of forages, which can serve as an important foundation for setting priorities in conservation and encouraging widespread adoption (Peters et al. 2003). Thirdly, to the best of our knowledge, this study is one of few if any that has attempted to systematically investigate genebank benefits arising from the direct utilization of ILRI germplasm.

Our contribution to the literature is threefold. First, we analyse patterns in distribution data for the period 1984-2017. Second, we apply a quantitative approach to understand farmer preferred traits of three aforementioned species: *Medicago sativa*, *Sesbania sesban* and *Pennisetum purpureum.* Third, we apply a mixed methods approach to understand the benefits of the three species for smallholder farmers in Ethiopia and Kenya. The rest of the paper is organized as follows: Section 2 presents the context; Section 3 outlines the data and methods used in the study: Section 4 presents the results; Section 5 presents the discussion; finally, Section 6 concludes.

2. Context

Ethiopia and Kenya dominate forage germplasm requests from ILRI's collection. Ethiopia enjoys a vibrant livestock sector whose performance is almost unparalleled within Africa. The country has the highest population of livestock in Africa standing at approximately 52 million cattle (Mbate 2016). From a macroeconomic perspective, the sector is a significant revenue earner. Livestock and livestock product exports are estimated to have earned the country approximately USD 131.1 million dollars, contributing to approximately 4% of the Gross Domestic Product (GDP) in Ethiopia (Brautigam, Weis, and Tang 2018). From a microeconomic perspective, the sector serves as a key source of livelihood for millions of people, directly engaging an estimated 65% of the population (Jibat, Mourits, and Hogeveen 2016).

Kenya has a huge dairy industry with an estimated output of 4.8 million tonnes of milk, of which 4.6 million tonnes are from cattle. The dairy cattle population stands at 12.8 million, comprising of 3.5 million exotic cattle and 9.3 million indigenous cows (Makau et al. 2018). Similar to Ethiopia, the sector plays a major role on both a macroeconomic and microeconomic scale. The sector contributes approximately 14% to the agricultural Gross Domestic Product (GDP) in Kenya. On a microeconomic scale, the sector is a direct source of livelihood for approximately 1.8 million smallholder farmers who account for 80% of milk output (Wetende, Olago, and Ogara 2018).Kenya has the highest milk consumption per capita in the developing world (Kiambi et al. 2018).

The demand for livestock products in Sub-Saharan Africa is anticipated to increase, providing ample opportunities for growth in the livestock sectors of many developing countries, including Kenya and Ethiopia (Ferner et al. 2018).The anticipated demand is attributed largely to an increasing population, urbanization and affluence (Kebebe 2019). Enhanced livestock productivity can enable developing economies to capitalize on transformative opportunities. That said, however, the enhancement of livestock productivity in these countries is hampered by a number of factors. Key among them is sub-optimal nutrition (Franzel et al. 2014). Indeed, poor feed quality has been identified as one of the factors limiting livestock productivity in Ethiopia— a challenge that is exacerbated during the dry season (Birhanu, Girma, and Puskur 2017). Livestock are ordinarily fed on a combination of crop residues and natural pastures whose combined crude protein content is very low (Oosting et al. 2011). Poor feed quality not only compromises production but also has a bearing on livestock mortality (Mayberry et al. 2018).In the case of Kenya, sub-optimal nutrition has been partly fuelled by the devastating Napier Grass Stunt Disease (NGSD). NGSD has adversely affected feed availability and quality, by virtue of its prime position as the dominant forage within intensive and semi-intensive dairy farming systems in East and Central Africa (Wamalwa et al. 2017). The disease is caused by phytoplasma, a single cell-wall bacterium, and transmitted by an infected insect vector identified as *maiestas banda* (Kawube et al. 2015). Physical symptoms observed on infected Napier plants include yellow leaves, stunted growth and necrosis (Kawube et al. 2015). The virulence of the disease has been experienced most in western Kenya where it is estimated that farmers have lost between 40 and 90% of their crop. Crop losses have in turn forced farmers to sell their livestock, reduce their herd or purchase feeds from markets (Wamalwa et al. 2017).

The ILRI genebank has played an important role in addressing the challenges facing the livestock sector in these countries. The genebank has distributed high protein forages such as *Medicago sativa* and *Sesbania sesban* in Ethiopia in order to address concerns of poor feed quality. Forage legumes and fodder trees, by virtue of their protein content, can significantly ameliorate livestock productivity outcomes for smallholders (Kiptot, Franzel, and Degrande 2014). In Kenya, the genebank was instrumental in the development of Kakamega 1 and Kakamega 2, Napier cultivars that were developed with materials from the ILRI genebank to combat Head Smut disease affecting Napier grass (Mwendia et al. 2007). The genebank has also played an important role in availing germplasm to research institutions seeking to identify accessions that are resistant to NGSD. This is important given that the virulence and prevalence of the disease has been partly attributed to the narrowing of Napier genetic base (Kawube et al. 2015). These examples illustrate the multiple pathways through which the ILRI genebank has played an active role in the amelioration of livestock productivity in Kenya and Ethiopia. The commitment of the genebank to conservation assures the availability of a genetic diversity from which valuable genotypes can be identified for the purpose of breeding varieties that are high-yielding, disease resistant, nutritive and climate-smart (Hanson and Maass 1997).

3. Data and Methods

3.1 Research design

The three research objectives were to: 1) analyze distribution data from the genebank and identify three widely distributed species that have a clear attribution to the ILRI genebank, 2) understand farmer-preferred traits of the selected species, and 3) investigate impacts of use associated with germplasm of the three species that were distributed by ILRI. Quantitative techniques were applied to investigate objectives one and two. A mixture of quantitative and qualitative techniques was applied to address objective three.

3.2 Data sources

Two data sources were consulted in addressing study objectives: 1) distribution data from the ILRI genebank, and 2) data from a village level survey conducted by ILRI in Kenya and Ethiopia.

3.2.1 Distributions from the ILRI genebank

The meticulous records kept by the ILRI genebank detail the distribution of germplasm from the 1984 through 2017. The distribution data chronicles germplasm requests from and distributions to diverse users such as national programmes, national genebanks, universities, non-governmental organization, private/commercial institutions, and CGIAR centers' research institutions. Individual farmers feature rarely in this data. Farmers make up a small proportion of requestors given that genebanks do not usually target end users as only a small number of seeds are distributed.

Each germplasm request was accompanied by a request number, accession number, lot number, genus, species, plant type category, institution name, country, and in some cases use purpose.

3.2.2 Forage use survey data (ILRI)

The forage impact study was a joint effort by the Feed and Forage Development and the Policy, Institutions and Livelihoods programs of ILRI. The village level survey was conducted in Kenya and Ethiopia between the months of May and September of 2015. The objective of the survey was to assess the impact of improved fodder material from the ILRI genebank and other organizations in Kenya and Ethiopia. In Kenya, the survey was implemented in 12 counties: Murang'a, Nyamira, Kakamega, Bungoma, Uasin Gishu, Trans Nzoia, Nandi, Homa Bay, Kisii, Kilifi, Kiambu and Nyandarua. A total of 180 villages were sampled from the 12 counties. Counties were purposively selected based on the significance of dairy activity and germplasm distribution records that fodder material originating from ILRI or other institutions had been dispensed. In Ethiopia, a total of 180 woredas (districts) were selected in the four regions of Oromiya (63 woredas), Amhara (54 woredas), Tigray (27 woredas), and Southern Nations and Nationalities and People's (SNNP, 36 woredas). The survey regions in Ethiopia were selected based on the agro-ecosystem and on records that improved fodder material had previously been distributed in these regions. A semi-structured questionnaire was used to guide the Focus Group Discussions (FGDs)in each of the surveyed villages.

Focus group sizes typically ranged from 5 to 15 participants per session. The total number of participants in the FGD was 2,569; 1477 in Ethiopia and 1,092 in Kenya. The survey sought to assemble information about the village situation; hence, overall knowledge regarding the village (population structure, land use patterns, forage practices) was the main criterion for FGD participation. Data on individual households or persons was not collected. Participants were village elders and livestock/forage experts. Age, wealth and gender were not considered as characteristics. Enumerators were conversant with the local language and hence were able to translate the interview questions for the purposes of clarity and consistency. Moreover, enumerators were trained as a group prior to the data collection excursion to ensure consistency in the interviewing process. The questionnaire captured detailed information at the village level under several different modules including but not limited to forage production, forage benefits, forage diseases, forage climate, livestock production, milk production and milk prices.

3.3 Data analysis

A mixed-methods approach, comprising of quantitative and qualitative techniques, was employed to analyze the data. The summary statistics featured a decade chronology of frequencies in germplasm requests per species, plant type, and number of accessions. The findings from the summary statistics were triangulated with findings from the impact survey and consultation with key genebank staff (concerning attribution) to select the species of focus for this study. *Medicago sativa* and *Sesbania sesban* were selected to assess germplasm impacts in Ethiopia whereas *Pennisetum purpureum (*Kakamega 1 and Kakamega 2) was selected for the Kenya case study. The choice of *Medicago sativa* and *Sesbania sesban* reflected the fact that the species dominated distributions over the time period. While it is evident that *Pennisetum purpureum* has not consistently featured as a prominent species, the selection of this species reflected the fact that two cultivars, Kakamega 1 and Kakamega 2, were developed using ILRI germplasm.

Quantitative analysis was also used to investigate farmer-preferred traits for the selected species. We assessed impacts based on two indicators: adoption by villages (percentage of villages where at least one farmer is known to have adopted the species under consideration) and benefits derived from distributed germplasm as explained by FGD participants. Secondary literature documenting the use of ILRI accessions was examined in order to understand the diverse pathways through which distributed germplasm has influenced research. The resulting information was then corroborated with findings from the forage survey and the distribution data.

4. Results

4.1 Germplasm distribution in Ethiopia from 1984 through 2017

Table 1 presents the top ten most requested accessions in Ethiopia. Legumes dominate the first three positions with Accession Number 6984 (*Medicago sativa*) in first position and *Desmodium intortum (Accession Number 104)* and *Desmodium uncinatum* (Accession Number 6765) taking the second and third positions. *Sesbania sesban* leads the browse category, with Accession Number 10865 being the most requested accession. Table 3 presents the 10 most requested species distributed over the time period of 1984 through 2017. We observe that legumes dominate with *Vigna unguiculata, Lablab purpureus* and *Medicago sativa* taking the first, second and third positions, respectively. Browses feature prominently in the top 10 most requested category, accounting for almost half of the most requested plant type. *Cajanus cajan* followed by *Sesbania sesban* lead the browse category in the fourth and fifth position, whilst *Cytisus proliferus* and *Leucaena leucocephala* rank in eighth and ninth position. Apparently, grasses do not feature much in the request category. *Chloris gayana* is the only grass in the top ten most requested category. Table 4 categorizes this information by decade. *Medicago sativa* maintains its leading position with the legume featuring prominently in three of the four time periods and dominating the first and the third decade. *Cajanus cajan* features prominently in the first three decades. *Sesbani asesban, Vigna unguiculate* and *Avena sativa* are also heavily requested in two of the four decades.

4.2 Germplasm distribution trends in Kenya: 1984-2017

Table 5 represents the most requested accessions. Accessions of *Sesbania sesban* feature prominently in this list. Accession Number 10865 of *Sesbania sesban* was the most requested accession for the period spanning 1984-2017. The species also occupies the second and fourth positions under Accession Numbers 15019 and 15036, respectively. Table 5 presents a summary of the 10 most requested species in Kenya for the period 1984-2017. Browses and legumes feature prominently in the list with each of these plant types accounting for 40% of each request. *Sesbania sesban* is the most requested species, whilst other browses, *Cytisus proliferus*, *Sesbania bispinosa* and *Leucaena leucocephala* rank as the seventh, ninth and tenth most requested species, respectively. *Lablab purpureus* leads the legume category as the second most requested species, whilst and *Medicago sativa* come in sixth and eighth positions, respectively. Although grasses feature sparsely overall, *Pennisetum purpureum* and *Cenchrus ciliaris* rank highly in the list with the former being the third most requested species and the latter ranking fifth. Table 6 presents a summary of the five most requested species in Kenya by decade. *Sesbania sesban* ranks as the most requested species in the first two decades. *Pennisetum purpureum* dominates the third decade, whilst *Lablab purpureus* dominates the last time frame.

4.3 Impact and assessment of farmer-preferred traits

Table 7 presents the status of fodder adoption by village or woreda. *Sesbania sesban* leads in terms of numbers of survey locations (villages or woredas) where adoption has been observed in Ethiopia as well as in both countries overall. Adoption of the multi-purpose fodder tree stands at 152 woredas out of the 180 sampled villages in Ethiopia. The adoption of *Medicago sativa* significantly lags behind that of *Sesbania sesban* at 52 out of the 180 sampled woredas. In Kenya, the adoption of Kakamega 1 appears to supersede that of Kakamega 2, with the adoption of the former standing at 22 villages compared with the latter's adoption standing at 11 villages. We use the data on fodder benefits perceived by FGD participants to gain an understanding of farmer-preferred traits that inform germplasm selection. Table 8 presents the data on the benefits derived from the adoption of *Sesbania sesban.* The benefits associated with *Sesbania sesban* are stated to be multiple, consistent with the documented benefits of leguminous trees and their recognition as Multi-Purpose Trees (MPTs). The main benefits associated with adoption of *Sesbania sesban* are soil erosion control, soil fertility improvement and crop protection. This should not be surprising given that the deep-rooted structure of leguminous trees and their ability to fix atmospheric nitrogen render them important allies in erosion control and fertility management. Other well-known benefits, though marginally mentioned, include shading, fencing and wood. Table 9 presents benefits reported for *Medicago sativa*. Similar to *Sesbania sesban*, soil erosion control, fertility improvement and crop protection rank as three main benefits associated with the cultivation of the species. The benefits associated with the cultivation of Kakamega 1 are presented in Table 10. The main benefit associated with the cultivation of this Napier is erosion control. Other associated benefits, such as soil fertility improvement, push-pull technology and crop protection received marginal mention. Finally, Table 11 presents the benefits associated with the cultivation of Kakamega 2. Erosion control featured as the main benefit while soil fertility improvement came in a distant second followed closely by mulching, push-pull technology and sources of income. We deduce that erosion control and soil fertility improvement are recognized as valuable traits by smallholder farmers, who often rely on multiple integrated solutions to address multi-dimensional agricultural challenges. This is crucial in terms of future efforts at mitigation and adaptation to climate change.

5. Discussion

5.1 Germplasm demand in Ethiopia: 1984-2017.

The extensive utilization of *Sesbania sesban* in Ethiopia that is documented in the results of the forage use survey and its prominence in germplasm requests is corroborated by evidence reported in the literature on fodder trees. The multi-purpose exotic tree was introduced into Ethiopia in the 1990s and was thereafter extensively promoted by numerous non-governmental organizations as a supplement to low quality basal diets consisting of grass and crop residues (Oosting et al. 2011; Mekoya et al. 2009). ILRI has in its possession some of the best accessions of *Sesbania sesban*. These accessions have been identified as superior commercial cultivars based on their adaptability, agronomic performance and ability to withstand numerous cuttings. Accession Numbers 15036, 15019 and 10865 have been the most widely distributed cultivars from the ILRI collection (Oosting et al. 2011).This information complements the findings from the genebank distribution data that identify Accession Number 10865 as the fifth most requested accession for the whole period. Moreover, Accession Numbers 15036 and 15019 were prominent during the second decade (1994-2003) ranking fourth among the most requested accessions.

The demand for *Sesbania* accessions has also been galvanized by extensive research that has assessed fodder tree suitability with respect to agronomic performance, agroecological adaptability, nutritive value, digestibility and live weight gain (Wiegand et al. 1995; Manaye, Tolera, and Zewdu 2009; Hossain and Becker 2002; Mekoya et al. 2009; Melaku, Peters, and Tegegne 2003; Soliva et al. 2008). Evaluation is important for identification of fodders that can enhance livestock productivity as well as in mitigating large-scale undesirable effects (such as toxicity in some fodders) that would severely constrain adoption.

The significant demand expressed for *Medicago sativa* is not surprising given the primary nutritional constraint to livestock productivity in tropical areas, which is quality diets rich in protein. *Medicago sativa*, a perennial dry tolerant legume, is one of the most cultivated forages in the world. Cultivation of this crop spans approximately 32 million hectares as of 2009 (Yu et al. 2018; Rafińska et al. 2017). Fodder yields are estimated to range between 2000-3000 kg/hectare (Bacenetti et al. 2018; Rafińska et al. 2017). The species has sometimes been referred to as “the queen of forages” given that it has the highest yield of protein per unit area among all forages and grain legumes.

5.2 Germplasm demand in Kenya: 1984-2017

The prominence of legumes and browse fodder in Kenya's demand pattern is not surprising given that Kenya's dairy sector, like many other countries in tropical areas, must contend with challenges of feed scarcity and quality that impose limitations on livestock productivity (Shikuku et al. 2017). Browse fodder is a superior source of protein that can greatly supplement the basal diet of crop residues and natural pastures that in themselves do not adequately provide for livestock's nitrogen needs. Browse fodder nutritive content does not vary significantly across seasons compared to grasses, a very important consideration given that feed scarcity and quality are problems that are especially exacerbated during the dry season (Pamo et al. 2006). Moreover, browse fodder has been heavily promoted in Kenya and other countries in East Africa, mainly through projects run by the International Centre for Research in Agroforestry (ICRAF) headquartered in Nairobi. Similarly, the demand for legumes is fueled by the fact that they are high in crude protein which is important in supplementing their low nitrogen basal diets (Belete et al. 2019).

The prominence of *Pennisetum purpureum* corresponds to the dominance of Napier in Kenya's dairy context. The appeal of the grass lies in the fact that it is not only multi-purpose but also amenable to the smallholder agricultural context. Napier is of great utility to smallholder farmers because it is able to produce high biomass on small parcels of land (Mutimura et al. 2018).The demand of germplasm in recent times has been spurred by the search for disease-resistance traits to mitigate damage caused by devastating diseases such as Napier Grass Stunt Disease (NGSD). NGSD, caused by phytoplasma, has adversely affected Napier yields in western Kenya and in the wider East Africa, resulting in untold suffering among smallholder farmers. Researchers have endeavoured to search for accessions, within and beyond the ILRI collection, that are resistant to phytoplasma in a bid to mitigate the devastating consequences of NGSD. In this regard, Accession Number 16789 has been identified as a promising accession in the mitigation of NGSD (Wamalwa et al. 2017). Finally, the demand for Napier accessions has also been fuelled by the incorporation of the grass in technologies seeking to alleviate pest and weed infestation in cereals (Kebede et al. 2018).

The prominence of *Desmodium* is attributed to its incorporation in push-pull technology developed by the International Centre for Insect Physiology (ICIPE) to combat stemborer and striga infestation in cereal crops.Striga weed infestation is one of the major socio-economic constraints facing cereal production in East Africa with an estimated annual grain yield loss of 40 million dollars, a matter of grave concern given that cereal availability (especially maize) is synonymous with food security (Alene et al. 2008). Forage legumes such as *Desmodium* have been found to abort Striga infestation and have thus been intercropped with maize as a striga mitigation strategy. Nonetheless, there has been a need to identify drought tolerant *Desmodium* species that can be integrated in the mitigation of the parasitic weed in drought prone areas. In this regard, the ILRI collection has been of great utility to researchers not only in the undertaking of evaluation trials but also because researchers have been able to identify drought tolerant accessions within the ILRI collection such as *D. ramosissimum (Accession Number 13615)* in the mitigation of striga in dry conditions (Midega et al. 2017).

5.3 Benefits to farmers

Sesbania sesban is recommended as a supplement based on its high nitrogen content, estimated at 4%, which exceeds that of many legumes and other fodder trees (Manaye, Tolera, and Zewdu 2009). Ruminant diets in many areas of the tropics consist of tropical pastures and crop residues which are of poor nutritional value given their low content of nitrogen and digestible fiber. This challenge is further exacerbated during the dry season (Ondiek et al. 1999). It is within this context that fodder trees such as *Sesbania sesban* have been heavily adopted as a valuable protein supplement by farmers who cannot afford to purchase concentrates (Kabi and Bareeba 2008). Supplementation with *Sesbania* has been shown to have a positive effect on voluntary dry matter intake, organic matter intake, crude protein levels, nitrogen retention, and live weight gain of sheep (Osuji and Odenyo 1997). Supplemented ewes have also been observed to register higher post-partum birth weights and milk yields compared to those ewes supplemented with concentrate (Mekoya et al. 2009). Moreover, it was also observed that pre-weaning average daily gain and lamb birth weight was significantly higher in lambs associated with *Sesbania* supplemented ewes compared to their concentrate supplemented counterparts (Mekoya et al. 2009).

The appreciation of soil fertility improvement by many farmers as a major additional benefit brings to fore the multi-purpose nature of fodder trees and the cost-effective benefits associated with agroforestry interventions (Mbow et al. 2014). Soil fertility improvement is attributed to its rich nitrogen foliage that serves as a source of quality green manure, its ability to biologically fix nitrogen and its contribution to the build-up of soil organic matter (Angima et al. 2002). Finally, the deep-rooted structure of this tree plays an important role in not only reducing soil erosion but also in the cycling of nutrients from below the rooting zone of crops to its foliage which is then transferred to the soil in the form of green manure (Angima et al. 2002).

Medicago sativa is appreciated for its ability to fix nitrogen through symbiotic activity with *Rhizobia* in its root nodules, thereby improving soil fertility; a fact echoed by farmers in the forage user survey (Zhang et al. 2016). The species has been widely in the rehabilitation of many degraded areas in China under the “Grain for green” initiative, the largest land restoration project in the developing worldaimed at combatting soil erosion and degradation (Yuan et al. 2016). In addition to its nitrogen fixation abilities, revegetation with *Medicago sativa* has been shown to increase soil organic carbon concentration through its large fine litter input and root biomass. Enhancement of soil organic carbon stocks is important for improving soil fertility,reducing soil erosion, and mitigating soil carbon dioxide emissions (Yuan et al. 2016). These benefits concur with farmer observations on the important role of the species in mitigating soil erosion.

Kakamega 1 and Kakamega 2 are two cultivars that were specifically developed with a view to combat Napier head smut disease, a devastating disease that had adverse consequences on Napier grass yields (Mwendia et al. 2007). The choice to focus on these cultivars for impacts and benefits was informed by their obvious attribution to the genebank. These cultivars are genebank accessions with Kakamega 1 and Kakamega 2, formally known as ILRI accession No. 16971 and ILRI accession No. 16978, respectively. The greatest benefit that farmers attributed to the use of these cultivars was soil erosion control. The benefits of soil erosion control is attributed to Napier’s massive near lateral root system, an attribute that has seen its integration into contour hedgerows with species such as *Calliandra calothyrsus* making for a formidable combination in the management of soil erosion (Angima et al. 2002). An additional benefit of these cultivars, though not prominent, is push-pull technology. Napier grass has been integrated into the push-pull technology in an effort to combat and mitigate the disastrous effects of stemborer infestation on maize (Cheruiyot et al. 2018). Stem borer infestation is a major constraint to maize productivity in Sub-Saharan Africa (Midega et al. 2015). Push-pull technology has been identified as a cost-effective environmental strategy in the management of stem borer infestation. The technology, as earlier espoused, involves the intercropping of a cereal crop such as maize with *Desmodium*, alongside a grass such as Napier or *Brachiaria*. The *Desmodium* repels the stem borer from the maize crop while the grass functions as a trap plant attracting the stem borer (Chepchirchir et al. 2018).

Though a fairly nascent technology, preliminary impact assessment at farm level as well as aggregate welfare impacts show promising results of adoption. Impacts at farm level reveal that the technology had an incremental effect on yields and net income among adopters in western Kenya; maize yields increasing by 61.9% whilst net income increased by 38.6%. Moreover, economic surplus estimations, at varying adoption rates (25-40%) and open and closed economy assumptions, range between 139-250 million dollars for western Kenya (Kassie et al. 2018). The highlight on push-pull technology demonstrates the value of forage genetic diversity in resolving non-livestock agricultural challenges. This is particularly appreciated in the cereals sub-sector, given the economic importance of cereals such as maize. Diversity has made it possible for researchers to identify forage legumes and grasses amenable to the implementation of this technology. Moreover, the diversity within species' accessions has allowed for the identification of valuable genotypes that exhibit tolerance to a wide range of challenges, namely, pests, weeds and climate change (Hooper et al. 2015). The appeal of these sorts of ingenious solutions in Africa will undoubtedly increase given the precarious context that entangles agriculture.

6. Conclusion

The conservation of forage diversity is a matter of great priority not only for its economic importance to millions of smallholder livestock keepers but also for its important role in the management of agricultural productivity challenges. Nonetheless, land degradation, climate change and anthropogenic activity linked to agricultural expansion are some of the major threats to forage diversity necessitating the need for aggressive conservation. In this regard, the ILRI genebank merits special mention given that it is wholly dedicated to the conservation of forage genetic diversity. That said, conservation of diversity in genebanks demands significant resources to maintain essential operations, hence the imperative of guaranteed resource allocation streams. Hopefully, the evidence documenting the ameliorative benefits of forage diversity germplasm sourced from genebanks provides justification for the continued support of these facilities.

This study endeavoured to investigate the demand for and benefits from utilization by East African farmers of three species conserved and distributed by the ILRI genebank: *Medicago sativa, Sesbania sesban* and *Pennisetum purpureum*. These are the dominant species requested by users in Ethiopia and Kenya from 1984 through 2017. Concerning adoption, we find that *Sesbania sesban* was the most adopted fodder, followed by *Medicago sativa* and finally the two Napier cultivars, Kakamega 1 and 2. Concerning farmer-perceived benefits, soil fertility improvement, soil erosion control and crop protection were identified as the main secondary benefits linked to the adoption of *Sesbania sesban* and *Medicago sativa* in Ethiopia. In Kenya, the main benefit attributed to the two Napier cultivars, Kakamega 1 and 2 was soil erosion control. We also find considerable documentation of impacts in the literature on the utilization of accessions in evaluation trials as well as in the mitigation of serious agricultural challenges beyond fodder production such as Striga, infestation, stem borer infestation and Napier Grass Stunt disease. The study provides useful findings regarding genebank impacts. First, the study reaffirms the substantial contribution of ILRI germplasm to the enhancement of smallholder livestock systems through the provision of a diverse forage portfolio conserved to the highest possible standard. Secondly, the findings point to an even greater future role of forage diversity in the management of serious infestations within the agricultural domain. While it is beyond the mandate of this paper to assess the range of economic losses attributed to these infestations, it is evident that huge agricultural losses may accrue due to a limited genetic base of forage germplasm.

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8. Tables

Table 1. Most requested accessions in Ethiopia for the period 1984-2017

Species	Accession Number	Number of times requested
Medicago sativa	6984	149
Desmodium intortum	104	145
Desmodium uncinatum	6765	143
Chloris gayana	6633	131
Sesbania sesban	10865	118
Stylosanthes scabra	140	105
Leucaena leucocephala	70	101
Stylosanthes guianensis	4	101
Macroptilium atropurpureum	69	100
Leucaena pallida	14203	97
Grand Total		**1190**

Source of data: ILRI genebank

Table 2. Most requested species in Kenya for the period 1984-2017

Species	Number of times requested
Sesbania sesban	326
Lablab purpureus	141
Pennisetum purpureum	79
Cajanus cajan	67
Cenchrus ciliaris	52
Stylosanthes guianensis	51
Cytisus proliferus	49
Medicago sativa	41
Sesbania bispinosa	40
Leucaena leucocephala	34
Grand Total	**880**

Source of data: ILRI genebank

Table 3. Most requested species in Ethiopia for the period 1984-2017

Species	Plant Type	Number of times requested
Vigna unguiculata	Legume	764
Lablab purpureus	Legume	671
Medicago sativa	Legume	630
Cajanus cajan	Browse	610
Sesbania sesban	Browse	575
Stylosanthes guianensis	Legume	391
Chloris gayana	Grass	334
Cytisusproliferus	Browse	304
Leucaena leucocephala	Browse	297
Avena sativa	Browse	296
Grand Total		**4872**

Source of data: ILRI genebank

Table 4. Most requested species in Ethiopia by decade

1984-1993	
Species	**Number of times requested**
Medicago sativa	278
Cajanus cajan	237
Sesbania sesban	231
Stylosanthes guianensis	175
Leucaena leucocephala	161
1994-2003	
Species	**Number of times requested**
Sesbania sesban	224
Lablab purpureus	213
Cajanus cajan	207
Cytisus proliferus	185
Pennisetum purpureum	160
2004-2013	
Species	**Number of times requested**
Medicago sativa	170
Vigna unguiculata	167
Trifolium steudneri	115
Avena sativa	106
Cajanus cajan	100
2013-2017	
Species	**Number of times requested**
Vigna unguiculata	414
Lablab purpureus	285
Avena sativa	129
Medicago sativa	89
Stylosanthes guianensis	87

Source of data: ILRI genebank

Table 5. Most requested accessions in Kenya for the period 1984-2017

Species	Accession number	Number of times requested
Sesbania sesban	10865	15
Desmodium uncinatum	6765	14
Sesbania sesban	15019	14
Desmodium intortum	104	13
Desmodium discolor	6988	13
Leucaena pallida	14203	12
Sesbania sesban	15036	12
Macrotyloma axillare	6756	12
Stylosanthes guianensis	4	12
Desmanthus virgatus	312	11
Cajanus cajan	11575	11
Grand Total		**139**

Source of data: ILRI genebank

Table 6. Most requested species in Kenya by decade

1984-1993	
Species	**Number of times requested**
Sesbania sesban	265
Cajanus cajan	56
Medicago sativa	40
Stylosanthes guianensis	27
Sesbania goetzei	27
1994-2003	
Species	**Number of times requested**
Sesbania sesban	61
Sesbaniabispinosa	17
Tephrosia pumila	15
Trifolium quartinianum	10
Lablab purpureus	9
2004-2013	
Species	**Number of times requested**
Pennisetum purpureum	77
Lablab purpureus	26
Stylosanthes guianensis	23
Stylosanthe shamata	12
Pennisetum purpureum x *glaucum*	11
2013-2017	
Species	**Number of times requested**
Lablab purpureus	81
Cytisus proliferus	37
Cenchru sciliaris	27
Brachiaria brizantha	16
Aeschynomene histrix	10
Clitoria ternatea	10

Source of data: ILRI genebank

Table 7. Fodder adoption in Kenya and Ethiopia by count of sampled villages

Fodder	Country	Village count
Kakamega 1	Kenya	22
Kakamega 2	Kenya	11
Sesbania sesban	Ethiopia	52
Medicago sativa	Ethiopia	152

Source of data: ILRI forage survey

Table 8. Farmer perceived benefits of *Sesbania sesban* in Ethiopia

Benefits	Occurrence by count of villages	Occurrence (%)
Acidity	1	0.267
Coffee shade	2	0.534
Construction	2	0.534
Crop protection	83	22.192
Desalinization	21	5.614
Erosion control	118	31.55
Fence	5	1.337
Push pull technology	18	4.812
Soil fertility	117	31.283
Source of income	1	0.267
Weed break	1	0.267
Wood	5	1.337
Grand Total	**374**	**100**

Source of data: ILRI forage survey

Table 9. Farmers perceived benefits *Medicago sativa* in Ethiopia

Benefits	Occurrence by count of villages	Occurrence (%)
Crop protection	30	24.59
Desalinization	7	5.738
Erosion control	37	30.328
Push pull	6	4.918
Soil fertility	41	33.607
Weed break	1	0.82
Grand Total	**122**	**100**

Source of data: ILRI forage survey

Table 10. Farmer perceived benefits of Kakamega 1 in Kenya

Benefits	Occurrence by count of villages	Occurrence (%)
Crop protection	3	9.375
Erosion control	22	68.75
Mulching	1	3.125
Push pull technology	2	6.25
Soil fertility improvement	3	9.375
Source of income	1	3.125
Grand Total	**32**	**100**

Source of data: ILRI forage survey

Table 11. Farmer perceived benefits of Kakamega 2 in Kenya

Benefits	Occurrence by count of villages	Occurrence (%)
Erosion control	13	72.22
Mulching	1	5.56
Push pull technology	1	5.56
Soil fertility improvement	2	11.11
Source of income	1	5.56
Grand Total	**18**	**100**

Source of data: ILRI forage survey