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Review

Sustainable intensifications of African agriculture through legume-based cropping and *Brachiaria* forage systems

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Legume-based cropping system and *Brachiaria* forage system could play a significant role in enhancing food and nutrition security and sustainable intensifications of African agriculture. To reveal this potential, a comprehensive review of literatures and assessment was performed using key indicators in relation to food and nutrition quality, agro-ecological services and socioeconomic benefits. The key indicators for legumes intercropping systems include: Grain yield, soil organic matter, food availability, nutritive values of legumes, maize and millets- based foods, proportion of income from crop sale and percentage of farmers aware and/or adopting intercropping. In the case of *Brachiaria* system, the forage biomass, milk yield, availability of milk, milk nutrition contents, income from *Brachiaria* grass and milk sale and people practising the *Brachiaria* technology were considered key indicators. Both systems showed positive impacts and contribute to a range of the United Nation's sustainable development goals including 1, 2, 3, 12, 13 and 15 and other associated targets. Integrating legume-based cropping systems and *Brachiaria* forage system will enhance contributions of smallholder farmers to food and nutrition security. The necessary changes needed in technology, institutions and policies to upscale legume-based cropping systems and *Brachiaria* forage system were suggested. These changes include improved varieties, quality seeds, improved cultivation practices, market provision, effective extension and advisory services and support to the seed productions and distribution systems, among others. Yet, to fully tap the potentials of legume-based and *Brachiaria* forage systems sustainably and raise the profile of these climate smart systems, context specific research measures are necessary.

Key words: *Brachiaria* forage, climate change, food and nutrition security, legumes-based cropping systems, sustainable intensifications.

INTRODUCTION

Food and nutrition security (FNS) remain a major challenge in Africa, though some progress has been made in the last two decades, particularly in reducing the proportions of undernourished people (FAO, IFAD and WFP, 2015). The contribution of agriculture to FNS remains minimal in sub-Saharan Africa (SSA) despite the development and release of improved agricultural technologies by research institutions and others (FAO, 2015). Among the factors contributing to this situation is that the current agricultural landscape is dominated by monoculture system and there is limited use of planted forage for livestock feeding. A few crops constitute the staple diets of majority of the population in SSA, for examples, maize in eastern and southern Africa and cassava in the western African (OECD/FAO, 2016). These staple food crops are rich in carbohydrates but do not meet the recommended dietary allowance for proteins, vitamins, and minerals levels necessary for healthy life. Monoculture lessens the soil fertility and increase incidence of pests and diseases. In addition, monoculture of staple crops in large acreage causes negative impacts on the environment and ecosystem services (IPES-Food, 2016). Added to these, poor agricultural extension and advisory services, inappropriate policies, and weak institutional arrangements have aggravated the problem of FNS. Several cases have been reported on major failures of monoculture practices in different crops across the globe that includes the damage of rice crop by brown plant hopper in Indonesia in 1970s and the destruction of citrus industry by citrus greening disease in USA in 1980s (World Conservation Monitoring Centre, 1992).

A shift from monoculture to diverse agro-ecological farming can be an alternative pathway as the latter promotes sustainable agriculture intensification (SAI) and provides multiple benefits and ecosystem services from the use of the same piece of land. These benefits and services entail provision of diverse food sources to human nutrition and animal feeding, agro- biodiversity conservation, greater climate resilience, improved soil fertility, and increased income of smallholder farmers with concomitant decrease in risks of crop failure. Crop diversification with legumes and forages (e.g. *Brachiaria* grass) supply the above-mentioned benefits and services on a sustainable basis (Tables 2 and 3). *Brachiaria* grass is a tropical forage native to East Africa, which is highly palatable, nutritious to livestock, well adapted to drought and low fertility soils, and increase livestock productivity (Mutai et al., 2017; Ghimire et al., 2015).

There is a growing interest to explore the potential of the legumes-based cropping systems and *Brachiaria* forage systems for sustainable FNS and ecosystem services. To explore this potential, a project called Innovations in Technology, Institutional and Extension Approaches towards Sustainable Agriculture and Enhanced Food and Nutrition Security in Africa (InnovAfrica) funded by EU-Horizon 2020 program has been implemented in Ethiopia, Kenya, Malawi, Rwanda, Tanzania and South Africa. This consortium involves eleven institutions from Africa and five institutions from Europe (www.innovafrica.eu). Validation and upscaling of innovative sustainable agriculture intensification systems (SAIs) integrating along with novel extension and advisory services (EASs) and innovative institutional approaches (IIAs) is one of the major objectives of the InnovAfrica project. Crop diversification of maize/millets with legumes and *Brachiaria* forage interventions are two major SAIs being evaluated and promoted in the selected sites of InnovAfrica case countries. These interventions are being implemented integrating various EASs (e.g. farmer to farmer extension) and IIAs (e.g. multi-actor platforms). The multi actor platforms (MAPs) members constituted of public sectors, non-governmental organizations (NGOs), farmers organizations and small and medium enterprises (SMEs).

In this paper, we attempt to review and synthesize recent research findings on two SAIs, that is, legume-based maize/millets system and *Brachiaria* forage system for livestock production. Moreover, the paper assesses the performance of these systems in delivering food and nutrition quality, agro-ecological services and socioeconomic benefits under the smallholder farming system. Finally, the paper concludes with some possible measures to improve the legume-based cropping and *Brachiaria* forage systems thereby revealing their potentials.

Legume based cropping systems

There are several forms of crop diversification practices adopted by smallholder farmers in Africa. These include from mono-cropping to multi-storey intercropping systems (Table 1). Of the above listed cropping systems, there is enormous knowledge and rich experience on the intercropping systems. Some of the benefits and impacts of legume-based intercropping systems are listed in Table 2.

Crop diversification planting legumes with maize/millets could contribute to achieve the various SDGs including SDG 1 (Alemayehu et al., 2017), SDG 2 (Habiyaremye et al., 2017), SDG 3 (Tesfai et al., 2018), SDG 13 (FAO, 2016), and SDG 15 (Chaer et al., 2011). However, their potential to contribute to the SDGs is poorly understood and has not been fully assessed.

Brachiaria forage system

Brachiaria (*Brachiaria* spp.) is a tropical forage with productive lifespan of about 20 years. This native

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Table 1. Brief definitions and concepts of the various types of crop diversification systems.

Cropping system	Definitions/concepts	Reference
Monocropping	Growing a single crop year after year on the same land also called as mono-culturing	Gebru (2015)
Intercropping	Growing two or more crops during the same growing season on the same piece of land	Ghosh et al. (2006)
Crop rotation	Planting by changing the type of crops grown in the field each season or each year	Nyambati et al. (2006)
Sequential cropping	Growing two crops in the same field, one after the other in the same year	Massawe et al.(2016b)
Strip cropping	Planting alternating strips of crops (e.g. cereals and legumes) in broad strips in the field	Szumigalski and Van Acker (2008)
Relay cropping	Growing one crop and then planting another crop in the same field before harvesting the first crop	Massawe et al. (2016a)
Multi-storey intercropping	Growing two or more crops with different heights and cultivating simultaneously on the same field.	Nimbolkar (2016)

Table 2. Benefits and impacts of legume-based intercropping.

Benefit	Impact	Reference
Increases agricultural productivity	Contribute to increased farmers income	Alemayehu et al.(2017)
Grow on residual soil moisture	Contribute to more efficient utilization of water	Mugendi et al.(2011)
Save fossil energy required to manufacture synthetic N fertilizers	Contribute to reduce emissions of nitrous oxides	FAO (2016)
Minimise risks of crop failure and market fluctuations	Increases coping strategies to climate change	Gliessman (1985)
Supply nitrogen through biological N- fixation	Contribute to increase soil organic matter and soil fertility improvement	Dwivedi et al. (2015)
Enhance pollination and provide feed to pollinators and beneficial insects	Promote agro-biodiversity	Tesfai et al. (2018)
Reduced pest and diseases incidence	Reduce cost of pesticides and chemicals	Lithourgidis et al. (2011)
Meets food preferences and/or cultural demands	Increased consumption of plant-based diets	Brooker et al. (2015)
Major source of protein and are rich in iron and zinc, excellent supplier of fibre and vitamins	Contribute to improved nutrition and alleviate malnutrition	Habiyaremye et al. (2017)
Helpful in the fight against non- communicable diseases (e.g. heart disease)	Contribute to improved human health	Tesfai et al. (2018)

African grass is well adapted to drought, marginal soils and drought stress. *Brachiaria* is the most extensively grown tropical forage in Latin America, Asia, South Pacific, and Australia (Mutai et al., 2017). The cultivation of *Brachiaria* grass for pasture production has been spurred in Africa following the pioneering collaborative work among Biosciences eastern and central Africa - International Livestock Research Institute (BecA-ILRI) Hub, Kenya Agricultural and Livestock Research Organization (KALRO) and Rwanda Agricultural Board (RAB), International Centre for Tropical Agriculture (CIAT) and Grasslanz Technology Limited (Ghimire et al., 2015). *Brachiaria* grass is used for hay production and for sale by non-livestock farmers. Some of the benefits and impacts of *Brachiaria* forage systems are listed in Table 3.

Brachiaria forage cultivation could contribute to achieve the various SDGs including SDG 1 (Kermah et

Table 3. Benefits and impacts of *Brachiaria* forage production system.

Benefit	Impact	Reference
Increases forage availability and milk productions	Contribute to increased farmers income	Kermah et al. (2017)
Ability to sequester large amounts of organic carbon	Contribute to reductions of greenhouse gas emissions	Njarui et al. (2016)
High biomass production with nutritious herbage	Hosts diverse groups of bacteria beneficial to plant growth	Mutai et al. (2017)
Improve soil fertility	Significant roles in erosion control	Ghimire et al. (2015)
Adapted to drought conditions and enhance nitrogen use efficiency	Greater climate resilience and efficient resources utilization	Arango et al. (2014)
Minimizes eutrophication and ground water pollution	Contribute to reduce nitrogen and phosphorus losses	Moreta et al. (2014)

Table 4. Challenges faced by African smallholder famers to implement legume-based intercropping and *Brachiaria* forage cultivations.

Challenges faced by African smallholder famers	Reference
Legume based intercropping	
Lack of access to improved seeds	Hauggaard-Nielsen et al. (2003)
Difficulties in farm mechanization or inputs application	Feike et al. (2012)
High cost of maintenance (e.g. labour for weeding)	Kebebew (2014)
Supply chains and markets are inadequately developed	Stagnari et al. (2017)
Inadequate policy support to legume-based intercropping	Mapfumo (2011)
Lack of awareness on long term benefits of legumes	Mapfumo (2011)
Brachiaria forage	
Lack of access to *Brachiaria* seeds	Ondabu et al. (2017)
Lack of information and awareness on *Brachiaria* grass	Njarui et al. (2016)
Inadequate policy support to *Brachiaria* forage cultivation	Njarui et al. (2016)
Upscaling repatriated commercial varieties requires caution	Ondabu et al. (2017)

al., 2017); SDGs 2 and 3 (Vendramini et al., 2014); SDG 12 (Arango et al., 2014); SDG 13 (Moreta et al., 2014); and SDG 15 (Mutai et al., 2017). However, their potentials to contribute to the SDGs is poorly understood and yet to be documented.

Despite the immense benefits and positive impacts of the *Brachiaria* grass; its potential to address the challenge of livestock feed scarcity in Africa, remain unexploited. Some of the challenges faced by African smallholder famers to implement legume-based intercropping and *Brachiaria* grass systems are presented in Table 4.

In the following sections, the multiple services delivered by legume-based cropping and *Brachiaria* forage systems are assessed and discussed using a set of key ecological, food and nutrition and socioeconomic indicators.

APPROACH

It is assumed that with integrated interventions in technology (e.g. legume-based intercropping with maize/millets plus Brachiaria forage); innovative institutional approaches (e.g. MAPs) and EASs (e.g. F2F), the combined effects of ecological and food/nutritional impacts will contribute positively to socio-economic impacts (Figure 1).

The criteria used to select these indicators include: (i) methodological soundness and base line data availability, (ii) easy to measure and sensitivity to changes in short term, (iii) relevance to objectives of the study and utility for users, (iv) capacity to monitor the indicators, and (v) usefulness of indicators for project monitoring and evaluation.

Indicators for legume-based cropping systems

Six key indicators were selected to assess the performance of maize/millets-legumes intercropping systems against sole crops. These indicators assess the ecological, food and nutrition and socioeconomic aspects of the cropping systems.

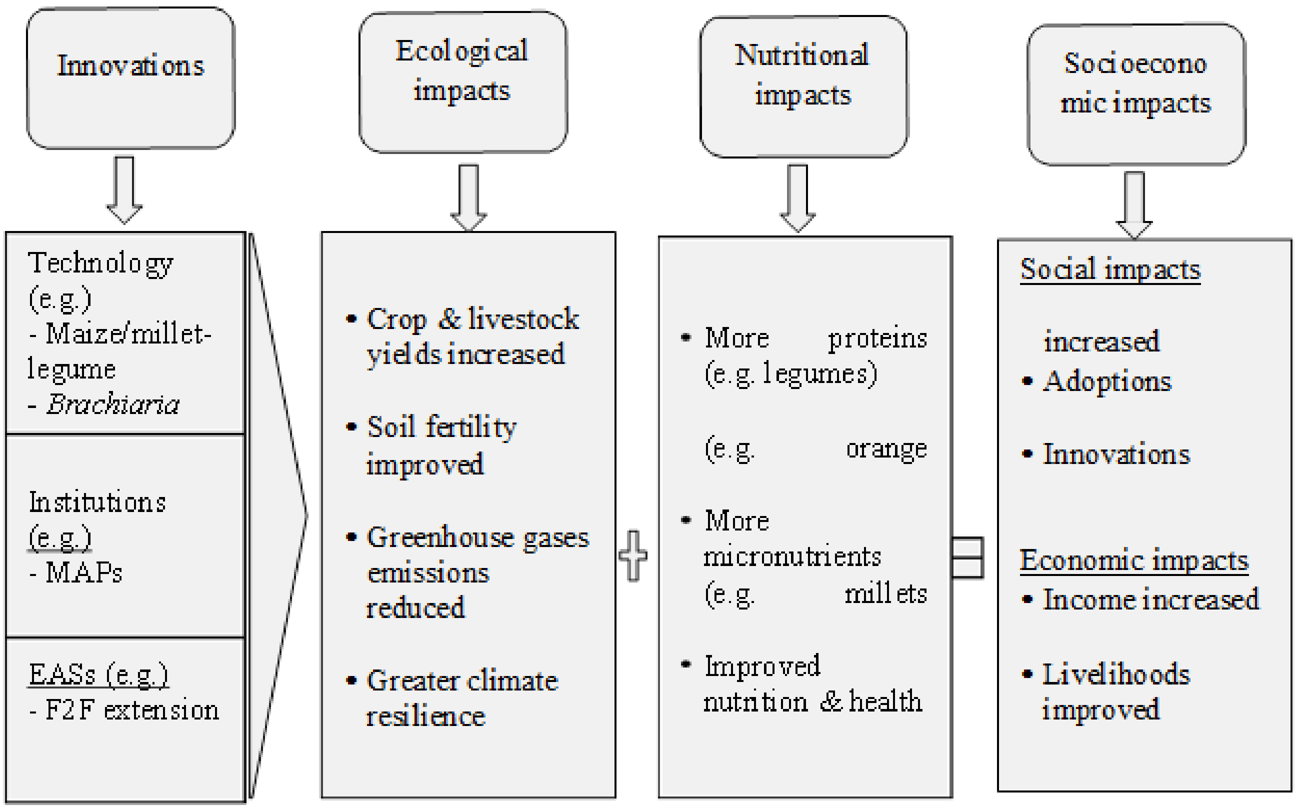

Figure 1. Innovations in technology, extension and advisory services (EASs) and institutional approach on ecological, nutritional and socio-economic conditions of a smallholder in Africa.

Crop yield

The grain yield in maize-legume intercropping was higher than sole cropping in Ethiopia (Alemayehu et al., 2017), in South Africa (Tsubo et al., 2004) and in Malawi (Mhango, 2011), and in Tanzania (Massawe et al., 2016b). The higher yield for intercrop compared with sole crop maize was due to the additional bean (dry) yield obtained from intercropping. However, the yield is lower than sole crop when computing the yield separately for intercropping. The yield penalty of intercropping maize was compensated for by yield of the companion bean crop leading to land equivalent ratio greater than one. This additional yield of bean (dry) is of great benefit to farmers for improved nutrition, as a source of cash, and also for sustainability of the cropping system.

Soil organic matter

Legumes have potential to increase soil organic matter (McCallum et al., 2004) because the nitrogen supplied by legumes through biological nitrogen fixation facilitates the decomposition of crop residues in the soil and their conversion to increase soil organic matter. Switching from monoculture to a rotation with legume crops is reported to stimulate the accumulation of 0.5 to 1.0 t/ha of soil organic carbon annually, with the legume component in the cropping sequence contributing up to 20% of the carbon gain (Wu et al., 2003). Legume intercropped with millet, the glume/chaff residues left after threshing of millet represents a potential source of reusable organic material when applied with N and P fertilizers (Issoufa, 2015).

Food availability

The level of food availability is expressed in terms of how long the food stock lasts (number of months in a year) and the household dietary diversity score (HDDS) that ranges from 0 to 12. The food stock lasts between 8 and 11 months in all the case countries. In other words, none of the countries are food secure throughout the year. The HDDS varies from 5.8 to 10 which indicate that household diets offer some diversity in both macro- and micronutrients (Table 5).

This food diversity could include cereals and pulses. Except for Malawi, diet diversity scores are mostly lower (< 4) for female-headed households than male headed

Table 5. Number of months food stock lasts and dietary diversity scores in case of study countries (average values).

Case study	Food stock lasts (No. of months)	Household dietary diversity score * ((0 – 2)
Malawi	10	8
Ethiopia	8	6
South Africa	11	10
Tanzania	9	6
Kenya	8.6	5.8

*Source: Household survey

households.

Nutrient contents of food from legumes, maize and millets

Legumes are important food crops that can play a major role in addressing future global FNS while providing multiple ecosystem services (FAO, 2016). They have important role in human nutrition, especially in the dietary pattern of low-income households in developing countries and vegetarians. Pulses are often called 'the poor man's meat' for their protein source and their rich content of minerals especially iron and zinc, fibre and vitamins (Tharanathan and Mahadevamma, 2003). Except for carbohydrate, the nutrient composition of pulses in general is higher than rice and wheat (Tesfai et al., 2018). On the other hand, millets, in general are rich proteins, fiber, mineral, iron and calcium compared to rice and wheat. For example, finger millet has 7.6 times more calcium than rice while some of the other millets group contains even more calcium compared to rice and wheat (Tesfai et al., 2018).

Maize seeds are rich in various nutrients including carbohydrates and vitamins. Intercropping of unfertilized maize with grain legumes increased protein yields compared to sole maize stands (Snapp et al., 2010; Waddington et al., 2007a). Similar increments in protein are possible through some maize-grain legume rotations (Waddington et al., 2007b). This shows possible to enhance the production of protein without large investments in subsidized mineral fertilizer (Droppelmann et al., 2017). Therefore, consuming legumes with millets/maize -based diets can alleviate malnutrition that affects millions of people in Africa.

Proportion of income from crop sale

In Ethiopia, economics of the intercropping versus sole cropping system was analysed following a partial budget procedure based on the existing cost of production. Legume-based intercropping increased financial returns by 16% relative to sole crop maize (Alemayehu et al., 2017). According to this finding, the highest financial advantage was obtained from the single row intercropping plant arrangement (with 128 kg N and 20 kg P kg per ha) due to the high productivity of the component crops. Similar results were also found by Workayehu and Wortmann (2011) who reported the profitability of maize–common bean intercropping as compared with sole crop production.

Percentage of farmers aware and/or practising intercropping

The practice of intercropping (e.g. cereals with legumes) has existed over a long period of time and is embedded in the indigenous knowledge systems. Almost all the sampled farmers in the case countries were aware of intercropping principles and practices, and most of them cultivate legumes intercropped with cereals or other suitable crops to the area. There are several success stories on legume based intercropping practices in the case countries. One good example is the Malawi Farmer to Farmer Agroecology project that aimed to implement intercropping of cereal crops with legumes using a Farmer to Farmer (F2F) extension approach. Intercropping of legumes and cereals was encouraged for soil health improvement through biomass incorporation and nitrogen fixation. The incorporation of legume residues into the soil redressed the soil nutrients in areas used to apply bush burning. Moreover, the project encouraged farmers to apply compost and/or organic manure, and organic pest control methods. The maize-legumes intercropping rendered a 6% increase in yield when compared to sole cropping (Nyantakyi-Frimpong et al., 2016). However, constraints such as lack of access to improved seeds and low market prices deter farmers from fully integrating the intercropping system in their farm. In this case, the MAPs members (in each case country) are actively engaged in linking the value chain actors (from producers to consumers continuum). The MAPs members also participate in other activities of the project (www.innovafrica.eu).

Indicators for *Brachiaria* forage systems

The multiple services delivered by *Brachiaria* forage grass

Table 6. DM yield of *Brachiaria* spp. at different field management in Kenya and Tanzania.

Country	AEZs and field management	DM yield (t/ha)	Source
Kenya	With fertilizer applications	5 - 36	Bogdan (1977)
	Coastal lowlands	≥ 8.0	Ondiko et al. (2016)
	Central highlands	> 10.0	Nyambati et al. (2016)
	Semi-arid eastern region	4.0	Njarui et al. (2016)
Tanzania	With no fertilizer application	3.0	Frederiksen and Kategile (1980)
	With N fertilizer application	6.0 - 26.5	Urio et al. (1988)

are assessed using six key indicators in contrast to other forage grasses. These indicators assess the ecological, food and nutrition and socioeconomic aspects of the *Brachiaria* forage systems.

Forage biomass

There is limited information on the productivity of *Brachiaria* spp. in different agro-ecological zones (AEZ) in Africa. The dry matter (DM) yields of *Brachiaria* vary among countries and are influenced by a range of factors including variety, moisture, soil fertility, and fertilizer applications (Table 6).

Furthermore, the cultivated forages are relegated to the less fertile part of the land and degraded soils and, as a result, growth is poor, they suffer mineral deficiencies, and are low in crude protein and energy. This is primarily because forages are not the final product.

Milk yield

In Kenya, *Brachiaria* grass has shown remarkable response when fed to livestock. It is superior to Rhodes grass which is the commonly cultivated grass for livestock feed. Studies carried out with smallholder farmers showed increased milk production from 4 to 4.6 L per cow per day for low yielding animals, a 15% increase and 9 to 12.6 L per cow per day for the relatively higher yielding dairy cattle representing a 40% increase (Muinga et al., 2016).

In Rwanda, dairy cattle feed *Brachiaria* grass and supplemented with legumes reported higher daily milk yield than those based on Napier grass. Cows fed with sole *Brachiaria brizantha* cv. Piata produced 33% more milk than cows fed with sole Napier grass diets. Cows fed with *Brachiaria brizantha* cv. Piata-legume diets produced approximately 21% more milk than cows fed with Napier-legume diet (Mutimura et al., 2018).

Availability of milk

Feeding *Brachiaria* has significant positive impacts on annual milk production. Data from recent trials indicates that adoption of *Brachiaria brizantha* cultivars increased baseline milk production by up to 4 L per cow per day on participating farmers thus improving the availability of milk at both household level and for sale.

Milk nutrition contents

Milk contains numerous nutrients and it makes a significant contribution to meeting the body's needs for calcium, magnesium, selenium, riboflavin, vitamin B12 and pantothenic acid (vitamin B5) (Muehlhoff, 2013). As a concentrated source of macro- and micronutrients, milk and dairy products can play a particularly important role in human nutrition in smallholder farm that frequently lack diversity and consumption of animal-source foods. Water is the maincomponent and make up approximately 90% of milk followed by fat (or lipid) which constitute from 3.5 to 6.0% of milk. Milk is also a major source of dietary energy, protein and fat (FAOSTAT, 2012). The concentration of protein in milk varies from 3.0 to 4.0 percent or 30 to 40 g L^{-1} (Wattiaux, 1995). Milk is recommended as part of a healthy diet since it contains naturally many essential nutrients.

Income from Brachiaria grass and milk sale

Livestock are important source of income for smallholder farmers in Africa. Adoption of *Brachiaria* technology has positive implications for income generation of smallholder livestock farmers. The most important contribution of *Brachiaria* forage is their direct effect on increasing milk production which generates cash. Although no economic analysis has been conducted from the milk yield increment as a result of adoption of *Brachiaria,* it is quite clear that the extra milk produced would give high profit margin as there is no additional cost in establishment of *Brachiaria* compared with the other traditional forages. The use of *Brachiaria* for hay production also offers not only as feed resource for livestock but also an opportunity to raise income by selling the baled hay to other livestock farmers.

People practising the Brachiaria technology

The current dissemination and expansion of *Brachiaria* acreage in Africa depends on seeds imported from South America and East Asia. The seeds are not easily accessible and expensive for smallholder farmers. Despite numerous efforts to promote cultivation of forages in Africa, adoption of *Brachiaria* grass have remained slow and its expansion of acreage is low in Africa. The contributing factors could be: (i) lack of information and awareness on *Brachiaria* grass*; (ii)* small land holding size (1-2 ha) and (iii) shortage of labour. The source of labour is mainly from the family and forage production yet to be mechanised (Njarui et al., 2011). Hence, small scale farmers give preference to grow food crops than forages in general. On average, less than 10% of the households' land holdings are allocated for forage production. For example, in Kenya, the *Brachiaria* technology is practised mainly by smallholder crop-livestock farmers in the coastal lowlands, eastern region, central highlands and north western highlands. The farmers are more commercially oriented, and the main animals reared are exotic and crossed with local zebu for milk production (Njarui et al., 2011).

CONCLUSIONS AND RECOMMENDATIONS

In this paper, the benefits of growing legume-based cropping systems and *Brachiaria* forage grass and associated constraints of both systems was reviewed. Legume-based cropping systems and *Brachiaria* forage system contribute to a range of SDGs including 1, 2, 3, 12, 13 and 15 and other associated targets. Adoption of legume-based cropping systems with *Brachiaria* forage system will enhance contributions to SDGs and associated targets. Moreover, legume-based inter cropping systems and *Brachiaria* forage system showed positive impacts on the key indicators chosen for ecological, food and nutrition, and socioeconomic conditions of smallholder farmers. Despite these, adoption and expansion of legume-based cropping systems and *Brachiaria* forage system is limited and slow in SSA. Possible measures that could improve the adoption of legume-based cropping and *Brachiaria* forage systems are suggested below.

Measures to improve legume-based cropping system

Measures that could improve the adoption of legume-based cropping include the following:

1. Improved varieties and quality seeds by:

a. Increasing investments to research and development on improved varieties that are climate resilient and tolerant to abiotic and biotic stress through participatory plant breeding programs; and
b. Providing better access to quality seeds of improved varieties of legumes, maize/millets that are rich in the essential micronutrients, minerals and vitamins for human nutrition and livestock feeding.

2. Improved cultivation practices (including farm mechanization or inputs application) by:

a. Intensifying crop diversification in smallholders farming systems through crop rotations or intercropping of legumes with maize/millets or other suitable cereals; and
b. Integrating conservation agriculture practices in legume-based cropping system.

3. Making legumes-maize/millets marketing accessible and attractive to consumers by:
a. Investing in value added product innovations (for e.g. developing legume/maize/millet-based food recipes) gives the opportunity to diversify their use and reuse; and
b. Promoting access to markets by establishing effective legume/maize /millet networks that connect the different value chain actors and enhances public-private partnerships

4. Improved extension and advisory services by*:*

a. Raising awareness and promotional campaign on benefits of legumes particularly targeting women, children and youth on the health and nutrition benefits of legumes with maize and millets;
b. Providing customized trainings on seed production, multiplication, storage, and consumption of legumes with maize and millets; and
c. Stimulating the development of agribusiness services to support smallholders' access to inputs and services for e.g. by supporting legumes maize/millets seed systems (like community seed banks)

5. Creating enabling policy environment by:

a. Reforming policies that are barriers to the development of legumes and maize/millets cultivation (for e.g. insecure land ownerships laws); and
b. Developing upscaling strategies/incentives that promote legume-based cropping system in SSA.

Measures to improve *Brachiaria* forage cultivation

Measures that could improve the adoption of Brachiaria forage cultivation includes the following:

1. Improvement of Brachiaria for specific trait by:

a. Initiating breeding for drought tolerance as well as pest

and diseases resistance; and
b. Capitalizing on acquisition and screening of existing germplasm that are stored in gene banks in different part of the world. For e.g. ILRI Ethiopia and CIAT-Colombia gene banks hosting about 700 accessions of *Brachiaria*.

2. Improved Brachiaria forage management by:

a. Implementing improved agronomic practices and management technologies to maximize herbage yield and improve plant persistence; and
b. Developing guidelines on forage cultivation practices (including planting, harvesting, fertilizer application) for optimum production and nutritive quality.

3. Increased Brachiaria seed production by:

a. Developing a sustainable seed production system to address seed availability at affordable costs. Research should focus on identifying optimum conditions for maximizing seed production for smallholder farmers; and
b. Developing simple and affordable seed harvesting, threshing technologies and storage structures at smallholder level.

3. Improved extension and advisory services for Brachiaria by:

a. Raising awareness program on the potential of different *Brachiaria* forage spp. for income generation of livestock farmers and identify best extension methods to increase adoption and upscaling.

4. Conducive policy and institutional environment of Brachiaria by:

a. Supporting local institutions to promote *Brachiaria* forage cultivation; and
b. Developing upscaling strategies to promote *Brachiaria* forage production and to repatriate commercial varieties as problem of pests and diseases are foreseen.

CONFLICT OF INTEREST

The authors confirm that there is no conflict of interest.

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