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Potential of legume diversification in soil fertility management and food security for resource poor farmers in Sub-Saharan Africa

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Abstract

Declines in soil fertility and its effect on crop production is a major problem in sub Saharan Africa. It is a major factor limiting crop production and consequently food security in agrarian communities. The causes of soil fertility decline on smallholder farms in Southern and East Africa include continuous cropping without sufficient soil replenishment, degradation through erosion and leaching, and limited biological nitrogen-fixation. Using inorganic fertilizers to address this problem doesn't add organic matter and is not accessible for small scale farming communities who cannot access fertilizer or afford the high costs of purchase. In this review, we explore the literature on legume diversification as part of a sustainable approach to fertility management. Legumes in the farming systems can improve soil fertility through the rhizobium-legume symbiotic relationship (referred to as biological nitrogen fixation (BNF), and have the potential to enhance soil organic matter and conserve other soil resources as well. In addition legumes can provide multipurpose roles by contributing food, fodder and fuel to households. The information that is compiled in this review is vital to guide research efforts and farmers to integrate more relevant legume crops into their farming systems, particularly those types of legumes which produce large amounts of vegetative biomass that can be used to ameliorate soil fertility for enhanced food production and security.

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Introduction

Soil fertility refers to the ability of soil to provide plant with essential plant nutrients in adequate amounts and proportions for plant growth and reproduction, to sustain high quality and consistent crop yields (Watson *et al.,* 2002). Low soil fertility and degraded, soil structure can results in poor crop production. Degraded and infertile soils are turn often linked to food insecurity, particularly among smallholder farmers who depend largely on their own agriculture production for food and income (Tully *et al.,* 2015). It is clear that Food security is defined by the FAO to be "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2006). To achieve this, fertile soils are crucial for rising sufficient crops; yet, soil fertility status may be on the decline and causing major problems for sustainable production in Africa (Chukwuka, 2009).

Soils in Africa are typically highly variable in fertility, and in the way they respond to inputs (Omotayo and Chukwuka, 2009). Most soil resources in Africa have low nutrient levels with a high propensity towards nutrient loss due to their fragile nature (Silva and Uchida, 2000); although not all, as some are volcanic in nature and thus less nutrient depleted. Highly cultivated soils in the tropics have been observed to suffer from multiple nutrient deficiencies and nutrient imbalances (Kinsey, 2012). Nearly 40% of soils in SSA are low in nutrients reserves (<10% weather able minerals), 25% suffer from aluminum toxicity, and 18% have a high leaching potential (low buffering capacity) (Tully *et al*., 2015). One study suggested that, in the 2002─2004 cropping season, about 85% of African farmland (185 million hectares) had nutrient removal rates of more than 30kg/ha of nutrients yearly, and 40% had rates greater than 60kg/ha yearly (Henao *et al*., 2006).

Inorganic fertilizer applications across Africa are highly variable and nil in many instances, and very low in some east Africa countries, close to zero across much of Uganda for example, and higher in parts of Central Africa, in the range of 30 to 40 kilograms (kg) of nitrogen, phosphorus, and potassium (NPK)/ha yearly (Malingreau *et al*., 2012; (Shiningayamwe, 2012).) Government subsidies have promoted the use of fertilizer in some instances, such as in Malawi and some regions of Tanzania – yet inorganic fertilizers alone do not address soil degradation, which is becoming of increased concern due to such factors as limited soil cover and poor nitrogen-fixation as well as physical soil degradation, soil erosion and leaching (Jonas *et al.,* 2011). In addition, use of inorganic fertilizers by resource poor farmers is constrained by profound lack of knowledge of application, high fertilizer cost, unavailability, access (Cagley and Gugerty, 2009; Njira *et al.,* 2012; IFDC, 2012; Williams *et al.,* 2014; Cedric and Nelson, 2014). Use of inorganic fertilizers also has been reported to have negative effects on water quality, soil fauna and soil health (Jonas *et al.,* 2011; Schröder, 2014).

Farmers apply different methods to addressing soil fertility, such as application of animal manure, recycling of crop residues and shifting cultivation (Henao *et al,* 2006; Omondi *et al*., 2014). Shifting cultivation, which relies on extension of agriculture to new land, is no longer considered sustainable in many regions due to increasing pressure on land resources (Druilhe and Barreiro-hurlé, 2012; Baijukya, 2004; Shuaibu *et al.,* 2015). To address the challenges of improving soil fertility for small scale farmers, several approaches such as integrating legumes in the farming systems and legume diversification are now being advocated for soil fertility management (Snapp *et al.* 2010; 2002). Legumes harbor rhizobia bacteria which can fix atmospheric nitrogen (N) and convert it to a form that can be used by plants (Lindström, 1999). Fixed N can reduce or eliminate the need for inorganic N fertilizer either as intercrop or in rotation, making it an attractive and affordable source of N for resource-poor farmers (Toomsan *et al.,* 2004; Snapp *et al.* 2002). Legume diversification is a practice of growing more than one legume crop within one unit area to increase financial and biological stability of the farm (Johnston *et al*., 2001). Much that these strategies are used in sustainable soil fertility management, limited literature is available on their application in Africa.

Therefore this review article aims at highlighting the potentiality of legume diversification in soil fertility management and food security for resource poor farmers in Sub Saharan Africa.

Legumes diversification in SSA

Legumes are important components of most farming systems in SSA, making positive contributions of legumes in improving soil fertility and food security (Amede, 2003). Farmers grow legumes either as a sole crop, by crop rotation, mixed farming or intercropping with cereals (Massawe *et al.*, 2016). It is estimated that there are about 30 species of economically important legumes grown in the SSA (Baldev *et al.*, 1988; Raemaekers, 2001; Gowda *et al.*, 2007). Among the major ones are common bean (*Phaseolus vulgaris*), cowpea (*Vigna unguiculata*), chickpea (*Cicer arietinum*), groundnut (*Arachis hypogaea*), pigeonpea (*Cajanus cajan*), and soybean (*Glycine max*). of these, cowpea (*Vigna unguiculata* L.) and common bean (*Phaseolus vulgaris* L.) are the most widely grown in SSA (Ronner *et al.*, 2013). Others that are important in one or other regions of SSA include faba bean (*Vicia faba*), lentil (*Lens culinaris*), field pea (*Pisum sativum*), Bambara groundnut (*Vigna subterranea*), hyacinth bean (*Lablab purpurea* also known as Dolichos lablab), Kerting's groundnut (*Macrotyloma geocarpum*), lima bean (*Phaseolus lunatus*), yam bean (*Sphenostylis stenocarpa*), mung bean or green gram (*Vignaradiata*), black gram or black bean (*Vigna mungo*), moth bean (*Vigna aconitifolia*), rice bean (*Vigna umbellata*), and horse gram (*Macrotylomau niflorum*) (Tsedeke Abate *et al.*, 2011).

Integrating legumes in farming systems

Integrating legumes in farming systems is among the strategies used by smallholder farmers for crop diversification and effective utilization of the land in SSA (Matusso *et al.*, 2012). Intercropping is extensively practiced by smallholder farmers in SSA and commonly practiced in tropical parts of the world compared with other cropping systems (Amede, 2003; Massawe *et al.*, 2016). It is estimated that 80% of the legumes grown in SSA are intercropped with cereals (Tsedeke Abate *et al.*, 2011; Nyasasi & Kisetu, 2014).

Variations exist in cereal-legumes plant species used in intercropping across regions in SSA and the system commonly involves cereal being considered as the main crop (Massawe *et al.*, 2016). Cereals are, in most cases, the main food source hence more efforts are made to increase their yield than that of the legumes (Ronner *et al.*, 2013). Cowpea occupies the largest proportion (43%) of all grown legumes in SSA, followed by groundnut (34%), common bean (19%), soybean (<5%), pigeon pea (<2%), and chickpea (<2%) (Tsedeke Abate *et al.*, 2011). Legumes are also grown in association with what is known as doubled-up legume technology (legume-legume intercrop) whereby longer-duration legumes such as pigeonpea are intercropped with other short duration legumes such as cowpea, groundnuts or soybean, a cropping system that has been developed in Malawi (Smith *et al.*, 2016). Although intercropping has been used by smallholder farmers in SSA for thousands of years and is widespread in many parts of the world, it is still poorly understood from an agronomic perspective (Njoku and Muoneke, 2008). More research is needed to better understand how intercrops (legumes-cereal or legume-legume) function and to develop intercropping systems that are compatible with current traditional farming system.

Nitrogen fixation in legumes improves soil fertility

Legumes improve soil fertility through a symbiotic relationship between legumes and rhizobia bacteria called Biological Nitrogen Fixation (BNF) (Zahran, 1999). The terms Rhizobium or rhizobia are used collectively for the genera *Rhizobium*, *Bradyrhizobium*, *Sinorhizobium*, *Mesorhizobium*, *Allorhizobium*, and *Azorhizobium*, unless specified otherwise (Haque and Lupwayi, 2017). BNF is the process whereby a number of species of bacteria use the enzyme nitrogenase to convert atmospheric N_2 into ammonia (NH_3), a form of nitrogen (N) that can then be incorporated into organic components, e.g. protein and nucleic acids, of the bacteria and associated plants (Jessica *et al.*, 2014). Interactions between rhizobia and legume roots result in formation of root nodules, in which rhizobia use energy from the host plant to transform atmospheric N_2 into plant available forms of nitrogen (Massawe *et al.*, 2017).

The amount of N_2 fixed by a legume crop varies widely because it depends on the legume genotype, rhizobium strain and the soil environment (Lupwayi *et al.*, 2011). Legumes can supply up to 90% of their own N hence they do not usually require addition N (Bohlool *et al.*, 1992; Stagnari *et al.*, 2017).

Through BNF, legumes provide a relatively low-cost method of replacing nitrogen in the soil, enhancing soil fertility and boosting subsequent crop yields (Baddeley *et al.,* 2014; Saikia and Jain, 2007.).

There exist different rhizobia strains which are specific to some legumes (Andrews and Andrews, 2017; Oono *et al.*, 2009), due to this legumes have different N fixation rates capacities (Danso and Eskew, 1998; Nglade and Illen, 2015). Table 1 below indicates some common legumes and their N fixation rates capabilities. Having two or more legumes intercrop will doubles soil fertility benefits as both crops contribute fertility to the soil through N fixation (Mungai *et al.*, 2016).

Table 1. N fixation rates (kg ha^{-1} $crop^{-1}$) by some common legumes grown in SSA.

Legume	N. fixation rate (Kg/ha)	References
	35	(One Acre Fund, 2014)
	61 - 155	(Baijukya *et al.*, 2013)
	30 - 125	(Ennin *et al.*, 2004)
	30	(Martins *et al.*, 2015)
	42.68	(Yabuku *et al.*, 2010)
	120	(Woomer, 2010)
	28	(Chikowo *et al.*, 2004)
	47	(Rowe and Giller, 2003)
Vigna unguiculata (Cowpea)	73–354	(Silva and Uchida, 2000)
	16 - 27	(Argaw and Tsigie, 2017)
	35	(Devi *et al.*, 2013)
	25-45	(Miyamoto *et al.*, 2008)
	35	(Woomer, 2010)
	125	(Woomer, 2010)
Phaseolus vulgaris (Common bean)	40–70	(Silva and Uchida, 2000)
	200	(One Acre Fund, 2014)
	138 - 156	(Baijukya *et al.*, 2013)
	45-130	(Miyamoto *et al.*, 2008)
	60 - 240	(Ennin *et al.*, 2004)
	70	(Chianu *et al.*, 2011)
	60–168	(Silva and Uchida, 2000)
Glycine max (Soybean)	165	(Gibson *et al.*, 1982)
	76	(Egbutah and Obasi, 2016)
	150	(One Acre Fund, 2014)
	47 - 52	(Baijukya *et al.*, 2013)
	27.19	(Yabuku *et al.*, 2010)
	160	(Bationo *et al.*, 2007)
	50 - 150	(Ennin *et al.*, 2004)
	25-56	(Gibson *et al.*, 1982)
Arachis hypogaea (Groundnut)	26	(Montanez, 2000)
	30 -100	(Mhango *et al.*, 2016)
	40	(Bationo *et al.*, 2007)
	97	(Chikowo *et al.*, 2004)
	39	(Rowe and Giller, 2003)
	8 - 82	(Mapfumo *et al.*, 2000)
	168–280	(Silva and Uchida, 2000)
Cajanus cajan (Pigeonpea)	44	(Mendonça *et al.*, 2017)
	130-220	(Miyamoto *et al.*, 2008)
	140	(Haque and Lupwayi, 2017)
	89	(Sanginga, 2003)
	15 - 210	(Zahran, 2001)
Lablab purpurea (Hyacinth bean)	270	(Rochester *et al.*, 2000)
	55	(Egbutah and Obasi, 2016)
	28	(Egbe *et al.*, 2013)
	32 - 81	(Mukhtar *et al.*, 2016)
	32.53	(Yabuku *et al.*, 2010)
	10 - 62	(Ncube *et al.*, 2009)
Vigna subterranea (Bambara nut)	52	(Rowe and Giller, 2003)

The ability of legumes to fix N_2 allows farmers to grow them with minimal to no inputs of N fertilizer (Jessica *et al.*, 2014). Non-legume crops grown in association or in rotation with them usually have reduced fertilizer N requirement ("Nitrogen Cycling"), which has both economic and environmental benefits (Lupwayi *et al.*, 2011). There is a need for more definitive studies on the nutritional factors limiting N fixation in legumes in general, and in those legumes that have a potential in farming systems in SSA (Haque and Jutzi, 1984: Snapp *et al.*, 1998).

Incorporation of legumes crop residues in the soil (Organic materials)

Legumes improve soil fertility through their decomposed residues (Singh *et al.*, 2011). Application of organic materials is one of the strategy used by farmers in SSA for soil fertility management (Omotayo and Chukwuka, 2009). Organic matter includes any plant or animal material that returns to the soil and goes through the decomposition process (FAO, 2005). Organic materials contribute directly to the deposition of soil organic matter (SOM) and is important in improving the physical, chemical and biological composition of the soil (Moyin-jesu, 2015; Silva and Uchida, 2000). Most soils in SSA contain 2-10 percent organic matter (Omotayo and Chukwuka, 2009) and they are plant tissue such as crop residues, leguminous, cover crops, green manures, mulches and household wastes (Vanlauwe *et al.*, 2015). Plant residues contain 60–90 percent moisture, the remaining dry matter consists of carbon (C), oxygen, hydrogen (H) and small amounts of sulphur (S), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) (FAO, 2005). At maturity 30–40% of the N in legume crops is in the seeds, which are typically 25–30% protein (Chukwuka, 2009). When this grain is harvested, much of the N that has been fixed will be exported off of the property and the rest in the stem and other part which when incorporated in the soil it release nutrients (Lindemann *et al.*, 2007; Tully *et al.*, 2015). Although present in small amounts, these nutrients are very important from the viewpoint of soil fertility management.

The effects of applied materials vary with cropping systems, soil types, organic material management and environmental factors, the information on their interaction is scarce (Mugwe *et al.*, 2009). Legumes crop residues contains different amount of nutrients, hence legumes diversification allow double or multiple soil fertility contribution in the soil (Njira *et al.*, 2012). Organic matter contributed by legumes residues in the soil provide essential nutrients to plant as a result crop yield is increasing hence food security is assured to resource poor farmers (Tittonell, 2015). There is limited knowledge on the multiple benefits from legume residues on soil fertility improvement to SSA's smallholder farmers. More research should be done on the farming systems which will have high or better contribution of legumes crop residues on soil fertility improvement in different soil types in order to suggest the best legumes crop residue incorporation system which gives high returns to farmers.

Grain legumes – root systems and soil health

Most legumes have well-developed taproots reaching 6 to 8 feet deep and half inch in diameter which go deeper into the soil which helps them to recycle crop nutrients that are deeper into the soil. This result into effective use of applied fertilizers and reduces leaching of nutrients especially nitrate-nitrogen for the shallower-rooted crops (Sharifai, 1985). Moreover, nitrogen rich legume residues encourage earthworms and the burrows they create with the root channels and earthworm burrows increase soil porosity, promoting air movement and water percolation deep into the soil (Truscott *et al.*, 2009).

Through their effects on soil biology, legume crops also improve soil structure by enhancing the formation and maintenance of soil aggregates (Schröder, 2014). Soil structure improvements are attributed to increases in more stable soil aggregates (Stein-bachinger *et al.*, 2015). The protein, glomalin, symbiotically along the roots of legumes and other plants, serves as "glue" that binds soil together into stable aggregates.

This aggregate stability increases pore space and tilth, reducing both soil erodibility and crusting i.e. reduces soil erosion, protects soil organic C from microbial breakdown, and increases water infiltration and air circulation (Tanner and Ababa, 2002). Lupwayi *et al.*, (2011) has reported order of crops in maintaining soil structure: lupin (*Lupinus angustifolius* L.) > lentil > canola > pea > linseed (*Linum usitatissimum* L.) > barley. Probably these results will be the same in SSA, but researches are needed on this area. In Nigeria, Obi (1999) observed the following order of legume and grass cover crops in cumulative water infiltration in a degraded soil: legumes (*Stylosanthes gracilis* L. and *Pueraria phaseoloides* L.) > grasses (*Panicum maximum* L., *Pennisetum polystachion* L., *Cynodon plectostachion* L., and *Axonopus compressus* L.) > bare soil. The order of soil organic C contents was similar, and the differences were related to soil structure. Therefore, the forage legumes had greater restorative effects of the soil than grasses and bare soil. These are some of the benefits of legumes, but unfortunately, they are often omitted because of difficulty in quantifying them. More research should be focused on influence of grain legumes on nutrients recycling and soil structure improvement.

Legumes diversification reduce risk of crop failure to smallholder farmers

Legume diversification is a practice of growing more than one legume crop in any year to increase biological stability of the farm, food security and financial status (Johnston *et al*, 2001). There are highly diverse species of grain legumes which are indigenous to various parts of the world (Katunga *et al.*, 2014). Soil fertility status and food security of smallholder communities are hindered by the reduction in legume species utilized in agricultural ecosystems (Small and Raizada, 2017). The potential for crop failure is worsened by the reliance on a few crop species (Koenen *et al.*, 2013). Plant species vary in their vulnerabilities and resistances to harsh condition such as environmental stress including heat, cold, drought, floods, pests, and disease. Due to this reliance on a few legumes crop species is a risk to farmers (Sundström *et al.*, 2014).

Farming system relies on monoculture increases exposure of crops to pests, diseases, and environmental stress (Kim, 2005). Total crop yields are stabilized by the capacity for each individual crop species to adapt and be productive in different conditions, and hence, legumes diversification is an asset to farmers in adapting environmental changes (Rosegrant *et al.*, 2008). The consequence of reduced legumes crop species can be immense for smallholder farmers whose livelihood depends on their crop yield. For example, due to unpredictable rainfall in sub-Saharan Africa it has been experienced rainfall delayed by up to a month, thus reducing the growing season (Lobell and Gourdji, 2012). The unpredictable onset of the rain challenges farmers to utilize crops that will be productive in growing seasons of varying durations. When the growing season is delayed, the utilization of short maturing, drought-tolerant crops like cowpea and common bean, and short-duration varieties, is an important adaptive strategy for small holder farming system (Ebert, 2014).

Legume diversification in food security and nutrition

Legumes can survive under hot, dry and area with little N, the area where other crop such as cereals cannot perform better (Koenen *et al.*, 2013). They have aggressive taproots reaching 6 to 8 feet deep and a half inch in diameter that open water pathways deep into the soil (Sharifai, 1985). This increase the surface area for biodiversity-plant root zone interaction, for instance earthworms can burrow the soil and provide access of roots to nutrients and air for root respiration. Also facilitates activities of soil flora and fauna lending to a greater stability of the soil's total life (Truscott *et al.*, 2009; FAO, 2009; Michael, 2010; Cong *et al.*, 2014; UNEP, 2008; M. Williams *et al.*, 2014). These help legumes to survive on the environment where other crops cannot survive and give out a reasonable yield which helps smallholder farmers to get enough food in each year (Chibarabada *et al.*, 2017). Legumes provide an excellent break in a crop rotation that reduces the build-up of grassy weed problems, insects, and diseases as a result reduces the loss which can be caused by pest and increase crop yield (Khan *et al.*, 2007; Truscott *et al.*, 2009; Lupwayi *et al.*, 2011; Tanner and Ababa, 2002).

Due to these unique features, integrating legumes in the existing system can reduce the risk of crop failure and insuring food security to SHF in SSA (Kerr *et al.*, 2007). The ability to survive under different harsh environment differ from one legume to another and within species one variety to another (Staniak and Księżak, 2014). Having a diverse of legumes will widen or multiply a chance for utilizing the benefits brought by legumes due to their different capability to survive in different environment (Abate and Orr, 1981). Diverse foods outputs are obtained through multiple cropping, thus providing a chance of choice for using food commodities in smallholders farmers (Stagnari *et al.*, 2017).

Grain legumes are an essential source of protein, Carbohydrates, vitamins and micronutrients thus, a valuable component to attain nutritional security (Ebert, 2014). Legumes are consumed mainly in association with cereals with legumes constituting the main component of traditional dishes (Gepts, 2004). Some legumes provide food during its all stage of growth, they are consumed in many forms: seedling and young leaves are eaten in salads, fresh immature pods and seeds provide a green vegetable, and dry seeds are cooked in various dishes (Burstin *et al.,* 2011.).

Grain legumes contain a wide range of nutrients, including low glycaemic index (GI), high content of fibers, antioxidants, vitamins especially the B-group and minerals such as iron, calcium, phosphorus, zinc and magnesium (Messina, 1999; Mugendi and Njagi, 2010; Oboh, Osagie *et al.*, 2010). Low GI in legumes mean that they can release glucose into the bloodstream less rapidly making them preferred by people with diabetes and those who wish to reduce their body weights as well as for the community in general (Duranti, 2006; Williams *et al.,* 2008; Rovner *et al.,* 2009). Except soybeans, legumes contain low fat and large amount of fibers which may help control appetite by keeping one feeling fuller for longer. Legumes contain different nutritional value depending on the species (Table 2) hence having a diverse of legumes will provide an opportunity for smallholder farmers to benefit from different nutritional requirement from these legumes (Rivas-Vega *et al.,* 2006). Current trends suggest that there is an increasing gap between human population and protein supply (Chibarabada *et al.*, 2017). Legumes which are cheapest source of proteins still not widely used in the diet because of few diversity (Chibarabada *et al.*, 2017). Legumes diversifications are potential strategies for making legumes available and increase protein supply to communities in SSA.

Table 2. Nutritional value for some common grown grain legumes in 100 gram.

Legume crop	Carbohydrates	Proteins	Dietary fibre	Fat	Calcium	Iron
Cowpea	7	16	28	0	2	13
Pigeon pea	21	44	60	2	13	28
Common beans	21	42	64	1	15	28
Soybean	10	72	36	30	27	87
Groundnuts	5	52	36	75	10	25
Lablab	7	16	-	0	4	25
Bambaranuts	66	20	6	6	2	12
Chick pea	20	38	68	9	10	34
Green gram	21	48	64	1	13	37

Source: modified from United States Department of Agriculture (USDA).

Other benefits of Legumes to smallholder farmers in SSA

Resource poor farmers in developing countries both consume and sell legumes thus getting profit in terms of nutrition and income (Chibarabada *et al.*, 2017). Legumes diversification allows smallholder farmers to get multiple crops from same cropped land, while act as risk management system in case of failure for one of the companion crops (Smith *et al.*, 2016; Smýkal *et al.*, 2017). Due to this surplus legumes produced by farmers are sold as a raw materials and become a direct source of income to farmers and create employment to the processing industries (Bezner Kerr *et al.,* 2007) Legumes produces high value grains with 2-3 times higher price than cereals and oil crops, example fresh pods, peas and leaves attract highest prices in urban and export markets (Ebert, 2014). Legume diversification provide a wide ranges of food products which are processed locally from row materials creating remunerative employment, especially for rural women (CGIAR, 2016). Legume is processing into products such as soymilk, soy cheese and cowpea cake which are sold and become common income generating activities (ITC, 2016). This food processing activity plays a vital role in the survival and sustenance of their household and in meeting domestic financial obligations (Chibarabada *et al.*, 2017). However, these products are usually prepared under poor sanitary conditions, processors need to be trained on improved processing methods and food safety practices (Subuola *et al.*, 2012). Income obtained is used to buy other important food crops such as cereals (Banjarnahor *et al*, 2015). Legumes diversification is also important from marketing point of view, as getting more than one crop simultaneously, even if the selling price of one crop is less in the market, the other will be there to compensate (Preissel *et al.*, 2015). This information is well known to farmers especially in SSA, but its utilization is still minimal (ITC, 2016). Lack or little information, research, resource and skills are some of the reasons for low adoption of legume diversification. Keeping in view the economic benefits of legumes diversification, there is a need to promote it among the farming community.

Conclusion and recommendation

Legume diversification is a solution for soil infertility and food security among resource poor farmers in SSA due to unaffordability of inorganic fertilizers and limited access to fertile land. This review suggests that legumes contribute to soil fertility improvement and food security through nitrogen fixation and crop residues which contribute the organic matter into the soil. Legumes are a cost-effective option for improving the diets of low-income consumers who cannot easily afford other protein sources like meat, dairy products and fish. It is a source of income and employment to poor people.

Legumes also will help poor resource farmers to solve some of the agronomic problems such as lowering soil pH, increase soil porosity, reduces the incidence of pest and disease resulting into yield increase and reduce food insecurity. Future research should focus on legumes diversification to different agro ecologies and especially in the resource poor farming systems. This would help to understand legumes which fit to a specific environment and farming system hence increases farmer's adoption to grow more legumes.

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Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

Reference

Abate T, Orr A. 1981. Research and development for tropical legumes: towards a knowledge-based strategy. Journal of SAT Agricultural Research **10,** 1-12.

Abate T, Alene AD, Bergvinson D, Shiferaw B, Silim S, Orr A, Asfaw S. 2012. Tropical grain legumes in Africa and south Asia: Knowledge and opportunities. International Crops Research Institute for the Semi-Arid Tropics.

Amede T. 2004. Pathways for fitting legumes into the farming systems of East African highlands: A dual approach. Soil Fert Net and CIMMYT.

Andrews M, Andrews ME. 2017. Specificity in Legume-Rhizobia Symbioses. International Journal of Molecular Sciences **18,** 705.

Argaw A, Tsigie A. 2017. The inorganic N requirement, nodulation and yield of common bean (*Phaseolus vulgaris* L.) as influenced by inherent soil fertility of eastern Ethiopia. Journal of Plant Nutrition **40(13),** 1842-1855.

Baddeley JA, Jones S, Topp CFE, Watson CA, Helming J, Stoddard FL. 2014. Legume Futures Report 1-5.

Baijukya F, Mukalama J, Waswa W, Boahen S, Jibrin J, Sanginga J, Chataika B. 2013. Identified soyabean, common bean, cowpea and groundnut varieties with high Biological Nitrogen Fixation potential identified in N2Africa impact zones.

Banjarnahor D, Scholberg J, Almekinders C. 2015. Legume-based diversification; lessons learned from the small-scale farmers in the semi-arid Tanzania. In Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia (Vol. 1, No. 3, pp. 667-672).

Bationo A, Waswa B, Kihara J, Kimetu J. 2007. Advances in integrated soil fertility management in sub-Saharan Africa: Challenges and opportunities (p. 1091). Dordrecht Springer.

Bohlool BB, Ladha JK, Garrity DP, George T. 1992. Biological nitrogen fixation for sustainable agriculture: A perspective. In Biological nitrogen fixation for sustainable agriculture (pp. 1-11). Springer Netherlands.

Burstin J, Gallardo K, Mir RR, Varshney RK, Duc G. 2011. 20 Improving Protein Content and Nutrition Quality. Biology and breeding of food legumes 314.

CGIAR Research Program on Grain Legumes. 2016. People. Planet. Pulses. Palangana India.

Chianu JN, Nkonya EM, Mairura FS, Chianu, Justina N, Akinnifesi FK. 2011. Biological nitrogen fixation and socioeconomic factors for legume production in sub-Saharan Africa. In Sustainable Agriculture Volume 2 (pp. 309-329). Springer Netherlands.

Chibarabada TP, Modi AT, Mabhaudhi T. 2017. Expounding the Value of Grain Legumes in the Semi- and Arid Tropics. Sustainability **9(1),** 60.

Chikowo R, Mapfumo P, Nyamugafata P, Giller KE. 2004. Woody legume fallow productivity, biological N 2-fixation and residual benefits to two successive maize crops in Zimbabwe. Plant and Soil **262(1),** 303-315.

Chikowo R, Snapp S. 2016. Doubled-up legume technology: Boosting land productivity by intercropping two grain legumes with different growth habits.

Chukwuka KS. 2009. Soil fertility restoration techniques in sub-Saharan Africa using organic resources. African Journal of Agricultural Research **4(3),** 144-150.

Danso SKA, Eskew DL. 1998. Enhancing biological nitrogen fixation. Plant and Soil **141,** 29-34.

Devi MJ, Sinclair TR, Beebe SE, Rao IM. 2013. Comparison of common bean (*Phaseolus vulgaris* L.) genotypes for nitrogen fixation tolerance to soil drying. Plant and Soil **364(1-2),** 29-37.

Duranti M. 2006. Grain legume proteins and nutraceutical properties. Fitoterapia **77(2),** 67-82.

Ebert AW. 2014. Potential of underutilized traditional vegetables and legume crops to contribute to food and nutritional security, income and more sustainable production systems. Sustainability **6(1),** 319-335.

Egbe MO, Alhassan GA, Ijoyah M, Onyilo M. 2013. Nodulation, nitrogen yield and fixation by bambara groundnut (*Vigna subterranea* (L.) Verdc.) landraces intercropped with cowpea and maize in Southern Guinea Savanna of Nigeria. Agricultural Science **1(4),** 15-28.

Egbutah EU, Obasi MO. 2016. Productivity, Nitrogen Fixation and Grain Yield of Legumes Intercropped with Roselle in Southern and Northern Guinea Savannah of Nigeria. Continental J. Agricultural Science 10 (2): 1 - 14, 10, 105-118.

Ennin SA, Dapaah HK, Abaidoo RC. 2004. Nitrogen credits from Cowpea, Soybean, Groundnut and Mucuna to Maize in rotation. West African Journal of Applied Ecology **6(1).**

Eriksen J, Søegaard K, Askegaard M, Hansen EM. 2010. Forage legume impact on soil fertility and N balance. NJF report **6 (3),** 61-65.

FAO. 2005.The importance of soil organic matter. FAO SOILS BULLETIN. Retrieved from http://www.fao.org/3/a-a0100e.pdf

FAO. 2006. Food Security **(2),** 1-4. Retrieved from http://www.fao.org/forestry/13128-0e6f36f27e0091055bec28ebe830f46b3.pdf

Gepts P. 2004. Crop domestication as a long-term selection experiment. Plant breeding reviews **24(Part 2),** 1-44.

Gibson AH, Dreyfus BL, Dommergues YR. 1982. Nitrogen fixation by legumes in the tropics. In Microbiology of tropical soils and plant productivity (pp. 37-73). Springer Netherlands.

Haque I, Jutzi S. 1984. Nitrogen fixation by forage legumes in sub-Saharan Africa Potential and limitations 23-27.

Haque I, Lupwayi NZ. 2017. Nitrogen fixation by annual forage legumes and its contribution to succeeding wheat in the Ethiopian highlands. Journal of plant nutrition **23(7),** 963-977.

Henao J, Baanante C, Henao J, Baanante C. 2006. Agricultural production and soil nutrient mining in Africa: Implications for resource conservation and policy development.

International Trade Centre (ITC) . 2016. United Republic of TanzaniaValue Chain Roadmap for Pulses.Geneva Switzerland.

Jessica M, Gary V, Ramsay J. 2014. Biological Nitrogen Fixation in Agricultural Systems **501**.

Johnston GW, Vaupel S, Kegel FR. 2001. Crop and farm diversification provide social benefits. California Agriculture **49(1),** 10-16.

Katunga MMD, Muhigwa BJB, Kashala KJC, Kambuyi M, Nyongombe N, Maass BL, Peters M. 2014. Agro-Ecological Adaptation and Participatory Evaluation of Multipurpose Tree and Shrub Legumes in Mid Altitudes of Sud-Kivu, DR Congo. American Journal of Plant Sciences **5(13),** 2031.

Kerr Bezner R, Snapp S, Chirwa M, Shumba L, Msachi R. 2007. Participatory research on legume diversification with Malawian smallholder farmers for improved human nutrition and soil fertility. Experimental Agriculture **43(4),** 437-453.

Kim JB. 2005. Pathogen, insect and weed control effects of secondary metabolites from plants. Han'guk Eungyong Sangmyong Hwahakhoeji **48(1),** 1-15.

Kinsey N. 2012. Managing Soil Fertility and Organic Matter. Retrieved from https://mosesorganic.org/wp-content/uploads/Publications/Fact_Sheets/08ImportanceOrganicMatterToFertility.pdf

Koenen E JM, Vos JM, Atchison GW, Simon MF, Schrire BD, Souza ERDe, Hughes CE. 2013. South African Journal of Botany Exploring the tempo of species diversi fi cation in legumes **89,** 19-30.

Kumwenda JD, Waddington SR, Snapp SS, Jones RB, Blackie MJ. (1996). Soil fertility management research for the maize cropping systems of smallholders in southern Africa: A review.

Lindemann W, Glover R. 2007. Nitrogen Fixation by Legumes. Cooperative Extension Service, New Mexico State University, Las Cruces 1-4.

Lobell DB, Gourdji SM. 2012. The influence of climate change on global crop productivity. Plant Physiology **160(4),** 1686-1697.

Lupwayi NZ, Kennedy AC, Chirwa RM. 2011. Grain legume impacts on soil biological processes in sub-Saharan Africa. African Journal of Plant Science **5(1),** 1-7.

Malingreau J, Eva H, Maggio A. 2012. NPK: Will there be enough plant nutrients to feed a world of 9 billion in 2050. Foresight and Horizon Scanning Series. JRC70936, Joint Research Centre of the European Commission.

Mapfumo AE, Chanasyk DS, Baron VS, Naeth MA. 2000. Society for Range Management Grazing Impacts on Selected Soil Parameters under Shortterm Forage Sequences on Grazing impacts term forage sequences selected soil parameters under **53(5),** 466-470.

Martins JCR, De Freitas ADS, Menezes RSC, Sampaio EV, De SB. 2015. Nitrogen symbiotically fixed by cowpea and gliricidia in traditional and agroforestry systems under semiarid conditions. Pesquisa Agropecuaria Brasileira **50(2),** 178-184.

Massawe PI, Mtei KM, Munishi LK, Ndakidemi PA. 2016. Existing practices for soil fertility management through cereals-legume intercropping systems **3(2),** 80-91.

Massawe PI, Mtei K, Munishi KL, Ndakidemi AP. 2017. Effects of Rhizobiuminoculation and cropping systems on macronutrients uptake and partitioning in two legumes (Common bean and Lablab). Indian Journal of Agricultural Research **51(3),** 206-213.

Matusso JMM, Mungwe JN, Mucheru-Muna M. 2012. Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of Sub-Saharan Africa. Research Journal of Agriculture and Environmental Management **3(3),** 162-174.

Mendonça ED S, Lima PC, Guimarães, GP. 2017. Biological Nitrogen Fixation by Legumes and N Uptake by Coffee Plants. Revista Brasileira de Ciência do Solo, 41.

Messina MJ. 1999. Legumes and soybeans: overview of their nutritional profiles and health effects. The American journal of clinical nutrition **70(3),** 439s-450s.

Miyamoto C, Ketterings Q, Cherney J, Kilcer T. 2008. Nitrogen fixation. Agronomy sheet series. Fact Sheet 39. Management Spear Program Cornell University.

Montanez A. 2000. Overview and case studies on biological nitrogen fixation: Perspectives and limitations. FAO, Case Study B **2,** 1-11.

Moyin-jesu EI. 2015. Use of different organic fertilizers on soil fertility improvement, growth and head yield parameters of cabbage (*Brassica oleraceae* L). International Journal of Recycling of Organic Waste in Agriculture **4(4),** 291-298.

Mungai LM, Snapp S, Messina JP, Chikowo R, Smith A, Anders E. 2016. Smallholder farms and the potential for sustainable intensification. Frontiers in plant science 7.

Mugendi JB, Njagi EM. 2010. Effects of processing techniques on the nutritional composition and anti-nutrient content of mucuna bean (*Mucuna pruriens* L.). African Journal of Food Science **4(4**), 156-166.

Mugwe J, Mugendi D, Odee D, Mairura F. 2009. Effect of selected organic materials and inorganic fertilizer on the soil fertility of a Humic Nitisol in the central highlands of Kenya. Soil Use and Management **25(4),** 434-440.

Ncube B, Dimes JP, Van-Wijk MT, Twomlow SJ, Giller KE. 2009. Productivity and residual benefits of grain legumes to sorghum under semi-arid conditions in south-western Zimbabwe: Unravelling the effects of water and nitrogen using a simulation model. Field Crops Research **110(2),** 173-184.

Nglade JUA, Illen GIB. 2015. Relationships for estimating N 2 fixation in legumes incidence for N balance of legume-based cropping systems in Europe, 6(March) 1-24.

Njira K, Nalivata PC, Kanyama-phiri GY, Lowole MW. 2012. Biological nitrogen fixation in sole and doubled-up legume cropping systems on the sandy soils of Kasungu, Central Malawi. Journal of Soil Science and Environmental Management **3(9),** 224-230.

Njoku DN, Muoneke CO. 2008. Effect of Cowpea Planting Density on Growth, Yield and Productivity of Component Crops in Cowpea/Cassava Intercropping System **7(2),** 106-113.

Nyasasi BT, Kisetu E. 2014. Determination of land productivity under maize-cowpea intercropping system in agro-ecological zone of mount Uluguru in Morogoro, Tanzania. Global Journal of Agricultural Science **2,** 147-157.

Oboh H, Osagie A, Omotosho A. 2010. Glycemic response of some boiled legumes commonly eaten in Nigeria. Diabetologia Croatica **39(4),** 125-131.

Oliver K, Njira W, Nalivata PC, Kanyama GY, Lowole MW. 2013. Effects of sole cropped, doubled-up legume residues and inorganic nitrogen fertilizer on maize yields in Kasungu, Central Malawi. Agricultural Science Research Journals **3(3),** 97-106.

Omondi JO, Mungai NW, Ouma JP, Patrick F. 2014. Effect of tillage on biological nitrogen fixation and yield of soybean (*Glycine max* L. Merril) varieties **8(8),** 1140-1146.

Omotayo OE, Chukwuka KS. 2009. Soil fertility restoration techniques in sub-Saharan Africa using organic resources. African Journal of Agricultural Research **4(3),** 144-150.

One Acre Fund. 2014. Maize- Legume Intercropping. www.oneacrefund.org

Oono R, Denison FR, Kiers T. 2009. Controlling the reproductive fate of rhizobia: How universal are legume sanctions?. New Phytologist **183(4),** 967-979.

Preissel S, Reckling M, Schläfke N, Zander P. 2015. Field Crops Research Magnitude and farm-economic value of grain legume pre-crop benefits in Europe a review. Field Crops Research **175,** 64-79.

Rivas-Vega ME, Goytortúa-Bores E, Ezquerra-Brauer JM, Salazar-García MG,Cruz-Suárez LE, Nolasco H, Civera-Cerecedo R. 2006. Nutritional value of cowpea (*Vigna unguiculata* L. Walp) meals as ingredients in diets for Pacific white shrimp (*Litopenaeus vannamei* Boone). Food Chemistry **97(1),** 41-49.

Rochester IJ, Peoples MB, Constable GA, Gault RR. 2000. Faba beans and other legumes add nitrogen to irrigated cotton cropping systems. Australian Journal of Experimental Agriculture **40(2),** 681-696.

Ronner E, Giller KE, Ronner E. 2013. N2Africa: Putting nitrogen fixation to work for smallholder farmers in Africa (No. 18). N2 Africa project.

Rosegrant MW, Ewing M, Yohe G, Burton I, Huq S, Valmonte-santos R. 2008 Climate change and agriculture: Threats and opportunities. Verlag nicht ermittelbar.Giz, 36.

Rovner AJ, Nansel TR, Gellar L. 2009. Research and Professional Briefs Diet on Blood Glucose Levels and Macronutrient Intake in Children with Type 1 Diabetes. YJADA **109(2),** 303–307.

Rowe E, Giller KE. 2003. Legumes for soil fertility in southern Africa: Needs, potential and realities. Grain Legumes and Green Manures for Soil Fertility in Southern Africa: Taking Stock of Progress. Soil Fert Net-CIMMYT, Harare, Zimbabwe 15-19.

Saikia SP, Jain V. 2007. Biological nitrogen fixation with non-legumes: An achievable target or a dogma?. Current science 317-322.

Sanginga N. 2003. Role of biological nitrogen fixation in legume based cropping systems; a case study of West Africa farming systems. Plant and soil **252(1),** 25-39.

Schröder JJ. 2014. The position of mineral nitrogen fertilizer in efficient use of nitrogen and land: a review. Natural resources **5(15),** 936-948.

Sharifai AI. 1985. Improving Sustainability and Productivity of Drylands through Legumes 121-127.

Shiningayamwe EN. 2012. Crop Rotation as a Soil Fertility Improvement Strategy Using Different Legumes on a Pearl Millet Yield. Agricola, 40.

Shuaibu YM, Garba AA. 2015. Influence of legume residue and nitrogen fertilizer on the growth and yield of sorghum (*Sorghum bicolor* (L.) Moench) in Bauchi state, Nigeria. African journal of food, agriculture, nutrition and development **15(3),** 10060-10076.

Silva A, Uchida R. 2000. Essential nutrients for plant growth: nutrient functions and deficiency symptoms. Plant nutrient management in Hawaii's soils 31-55.

Silva J, Uchida R. 2000. Biological nitrogen fixation: Nature's partnership for sustainable agricultural production. Plant nutrient management in Hawaii's soils, approaches for tropical and subtropical agriculture. College of Tropical Ag. and Human Resources, Univ. of Hawaii, Manoa 121-126.

Singh BB, Musa A, Ajeigbe HA, Tarawali SA. 2011. Effect of feeding crop residues of different cereals and legumes on weight gain of Yankassa rams **2(2),** 17-23.

Small FAA, Raizada MN. 2017. Mitigating dry season food insecurity in the subtropics by prospecting drought-tolerant, nitrogen-fixing weeds. Agriculture & Food Security **6(1),** 23.

Smith A, Snapp S, Dimes J, Gwenambira C, Chikowo R. 2016. Doubled-up legume rotations improve soil fertility and maintain productivity under variable conditions in maize-based cropping systems in Malawi. Agricultural Systems **145,** 139-149.

Smýkal P, Coyne CJ, Ambrose MJ, Maxted N, Blair MW, Berger J, Besharat N. 2017. Legume crops phylogeny and genetic diversity for science and breeding. Critical Reviews in Plant Sciences **34(1-3),** 43-104.

Snapp S, Aggarwal VD, Chirwa R. 1998. Note on phosphorus and cultivar enhancement of biological nitrogen fixation and productivity of maize/bean intercrops in Malawi. Field crops research **58(3),** 205-212.

Snapp S, Rohrbach D, Simtowe F, Thombozi J, Freeman H. A. 2002. Sustainable soil management options for Malawi: Can smallholder farmers grow more legumes?. Agriculture, ecosystems & environment **91(1),** 159-174.

Snapp SS, Blackie MJ, Gilbert RA, Bezner Kerr R, Kanyama-Phiri GY. 2010. Biodiversity can support a greener revolution in Africa. PNAS **107(48),** 20840-20845.

Stagnari F, Maggio A, Galieni A, Pisante M. 2017. Multiple benefits of legumes for agriculture sustainability: an overview. Chemical and Biological Technologies in Agriculture **4(1),** 2.

Staniak M, Księżak J, Bojarszczuk J. 2014. Mixtures of legumes with cereals as a source of feed for animals. In Organic Agriculture Towards Sustainability InTech.

Stein-bachinger K, Reckling M, Bachinger J, Hufnagel J, Koker W, Granstedt A. 2015. Ecological recycling agriculture to enhance agro-ecosystem services in the baltic sea region: guidelines for implementation Land **4(3),** 737-753.

Subuola F, Widodo Y, Kehinde T. 2012. Processing and Utilization of Legumes in the Tropics. In Trends in Vital Food and Control Engineering InTech.

Sujatha G, Jayabalan N, Kumari BR. 2007. Rapid in vitro micropropagation of Cicer arietinum L. Hort. Sci **34(1),** 1-5.

Sundström JF, Albihn A, Boqvist S, Ljungvall K, Marstorp H. 2014. Future threats to agricultural food production posed by environmental degradation, climate change, and animal and plant diseases-a risk analysis in three economic and climate settings. Food Security **6(2),** 201-215.

Taa A, Tanner DG, Bennie ATP. 2002. Effect of stubble management, tillage and cropping sequence on the severity of take-all and eyespot diseases of wheat.

Tittonell P. 2015. Soil fertility and the role of soils for food security in developing countries. In EGU General Assembly Conference Abstracts (Vol. **17).**

Toomsan B, Limpinuntana V, Jogloy S, Patanothai A. 2004. Role of Legumes in Improving Soil Fertility and Increasing Crop Productivity in Northeast Thailand Rice-based System 67-91.

Truscott BL, Aranda D, Nagarajan P, Travaglini AL. 2009. A Closer Look at Crop Diversification in Organic Cotton Farming.

Tully K, Sullivan C, Weil R, Sanchez P. 2015. The state of soil degradation in sub-Saharan Africa: Baselines, trajectories, and solutions. Sustainability **7(6),** 6523-6552.

Vanlauwe B, Descheemaeker K, Giller KE, Huising J, Merckx R, Nziguheba G, Wendt J. 2015. Integrated soil fertility management in sub-Saharan Africa: unravelling local adaptation 491-508.

Waddington SR. 2002. Grain Legumes and Green Manures for Soil Fertility in Southern Africa : Taking Stock of Progress. (W. Stephen, Ed.). Harare Zimbabwe.

Watson CA., Atkinson D, Gosling P, Jackson LR, Rayns FW. 2002. Managing soil fertility in organic farming systems. Soil Use and Management **18(s1),** 239-247.

Woomer PL. 2010. Biological nitrogen fixation and grain legume enterprise: Guidelines for N2Africa Master Farmers. CIAT-TSBF.

Yabuku H, Kwari JD, Ngala AL. 2010. N 2 Fixation by Grain Legume Varieties as Affected By Rhizobia Inoculation in The Sandy Loam Soil Of Sudano-Sahelian Zone of North Eastern Nigeria. Nigerian Journal of Basic and Applied Science (2010), **18(2)**, 229-236 ISSN, 18, 229-236.

Zahran HH. 1999. Rhizobium -Legume Symbiosis and Nitrogen Fixation under Severe Conditions and in an Arid Climate **63(4),** 968-989.

Zahran HH. 2001. Rhizobia from wild legumes: Diversity, taxonomy, ecology, nitrogen fixation and biotechnology. Journal of Biotechnology **91(2-3),** 143-153.