Research Application Summary

Potential role of cereal-legume intercropping systems in integrated soil fertility management in smallholder farming systems of sub-Saharan Africa

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Abstract

The sub-Saharan Africa's population is growing exponentially and it has to fulfill its food and nutrition requirement. An attractive strategy for increasing productivity and labour utilization per unit area of available land is to intensify land use. Intercropping is advanced as one of the integrated soil fertility management practices consisting of cultivating two or more crops in the same space at the same time, which have been practiced in past decades and achieved the goals of agriculture. Also, intercropping systems are beneficial to the smallholder farmers in the low-input and/or high-risk environment of the tropics, where intercropping of cereals and legumes is widespread among smallholder farmers due to the ability of the legume to contribute to addressing the problem of declining levels of soil fertility. The principal reasons for smallholder farmers to intercrop are flexibility, profit maximization, risk minimization, soil conservation and improvement of soil fertility, weed, pests and diseases control and balanced nutrition. This is a review paper that explores the role of cereal legume intercropping systems in integrated soil fertility management in smallholder farms of Sub-Saharan Africa. The intercropping systems are useful in terms of increasing productivity and profitability, water and radiation use efficiency, control of weeds, pests and diseases. The critical role of biological nitrogen fixation and the amounts of N transferred to associated non-leguminous crops determines the extent of benefits. In intercropping, land equivalent ratio (LER), benefit cost ratio (BCR) and monetary advantage index (MAI) are used to assess the productivity and its economic benefits. In this study, the work carried out by various researchers about different intercropping system is discussed, and it would be beneficial to the researchers who are involved in this field.

Key words: Cereal-legume, intercropping, ISFM, smallholder farmers, sub-Saharan Africa

Résumé

La population de l'Afrique sub-saharienne est en croissance exponentielle et elle doit satisfaire son besoin alimentaire et nutritionnel. Une stratégie intéressante pour accroître la productivité et l'utilisation de la main-d'œuvre par unité de surface de terre disponible est d'intensifier l'utilisation des terres. La culture intercalaire est reconnue comme l'une des pratiques de gestion intégrée de la fertilité du sol consistant à cultiver deux ou plusieurs cultures dans un même espace au même moment, qui ont été pratiquées au cours des décennies passées et ont atteint les objectifs de l'agriculture. De même, les systèmes de cultures intercalaires sont bénéfiques pour les petits agriculteurs dans l'environnement à faibles intrants et / ou à haut risque des tropiques, où la culture intercalaire des céréales et des légumineuses est très répandue parmi les petits agriculteurs en raison de la capacité de la légumineuse à contribuer à la résolution du problème de baisse des niveaux de fertilité des sols. Les raisons principales pour lesquelles les petits exploitants agricoles effectuent des cultures intercalaires sont la flexibilité, la maximisation du profit, la minimisation des risques, la conservation des sols et l'amélioration de la fertilité du sol, le contrôle de mauvaises herbes, des ravageurs et des maladies et la nutrition équilibrée. Ceci est un article de synthèse qui explore le rôle des systèmes de cultures intercalaires des légumineuses avec les céréales dans la gestion intégrée de la fertilité des sols au sein de petites exploitations agricoles en Afrique sub-saharienne. Les systèmes de cultures intercalaires sont utiles en termes d'accroitre la productivité et la rentabilité, l'efficacité d'utilisation de l'eau et du rayonnement, le contrôle de mauvaises herbes, des ravageurs et des maladies. Le rôle essentiel de la fixation biologique de l'azote et des quantités de N transférées aux cultures des non-légumineuses associées détermine l'ampleur des bénéfices. En culture intercalaire, le rapport d'équivalence de terre (LER), le ratio coût-bénéfice (BCR) et l'indice de l'avantage monétaire (AMI) sont utilisés pour évaluer la productivité et ses avantages économiques. Dans cette étude, le travail réalisé par divers chercheurs sur les systèmes différents de cultures intercalaires est abordé, et il serait bénéfique pour les chercheurs qui sont impliqués dans ce domaine.

Mots clés: Céréales-légumineuses, intercalaires, ISFM, petits agriculteurs, Afrique sub-saharienne

Background

In Sub-Saharan Africa (SSA), agriculture accounts for 35 percent of Gross Domestic Product (GDP), employs about 62 percent of the population, represents 60 percent of export earnings, contributes to food security and supplies raw materials to domestic industries (FAO, 2004). Since last 45 years this sector had an average growth rate of 1.7 percent to 1.9 percent per annum. And, population growth rate has increased from 2.7 percent per annum during the last 15 years, to about 3.1 percent per annum since then, making it one of the world's fastest growing populations (Taylor *et al.*, 1996; AfDB, 2010).

However, only 8 percent of the total land of the SSA is inherently fertile and permanent cropland (WRI, 2005). This situation has resulted in the loss of the fertile top soil due to overgrazing, overcultivation, and soil erosion (World Bank, 1989). Consequently, poor soil fertility has emerged as one of the greatest biophysical constraint to increasing agricultural productivity hence threatening food security in this region (Mugwe *et al*., 2009; Mugendi, 1997). Furthermore, the majority of the farmers of this region lack financial resources to purchase sufficient amount of mineral fertilizers to replace soil nutrients removed through harvested crop products (Jama *et al*., 2000), crop residues, and through loss by runoff, leaching and as gases (Bekunda *et al*., 1997).

Therefore, it is necessary to adopt improved and sustainable technologies in order to guarantee improvements in food productivity and thereby food security (Gruhn, Goletti, and Yudelman, 2000; Landers, 2007). Such technologies include the use of integrated soil fertility management practices (ISFM) which have intercropping cereals with legumes as one of its main components (Sanginga and Woomer, 2009; Mucheru-Muna *et al.*, 2010).This practice is an attractive strategy to smallholder farmers for increasing productivity and land labour utilization per unit of area of available land though intensification of land use (Seran and Brintha, 2010). Furthermore, intercropping cereals with legumes have huge capacity to replenish soil mineral nitrogen through its ability to biologically fix atmospheric nitrogen (Fujita *et al.*, 1992; Giller, 2001)

Intercropping systems. The cropping system is defined as the combination of crops grown on a given area and time (Reddy, Floyd and Willey, 1980). Intercropping system is a type of mixed cropping and defined as the agricultural practice of cultivating two or more crops in the same space at the same time (Andrews and Kassam, 1976; Sanchez, 1976). This a common practice in SSA, and it is mostly practiced by smallholder famers. The common crop combinations in intercropping systems of this region are cereal-legume, particularly maize-cowpea, maize-soybean, maize-pigeonpea, maize-groundnuts, maize-beans, sorghum-cowpea, millet-groundnuts, and rice-pulses (Beets, 1982; Rees, 1986a, 1986b). The features of an intercropping system differ with soil, local climate, economic situation and preferences of the local community (Steiner, 1982).

Several scientists have been working with cereal-legume intercropping systems in SSA (Nzabi *et al.*, 1998; Waddington and Karigwindi, 2001; Kambabe and Mkandawire, 2003; Abera *et al*., 2005; Ndung'u *et al.*, 2005; Adeniyan *et al*., 2007; Waddington *et al*., 2007; Egbe, 2010; Mucheru-Muna *et al.*, 2010; Obadoni*et al*., 2010; Addo-Quaye *et al*., 2011; Okoth and Siameto, 2011; Osman *et al*., 2011) and proved its success compared to the monocrops. In this region, one of the most important reasons for smallholder farmers to intercrop is to minimize measures against total crop failures and to get different produces to take for his family's food and income (Steiner, 1982; Ofori and Stern, 1987; Sullivan, 2003). Furthermore, intercropping systems use more efficient the growth factors because they capture more radiation and make better use of the available water and nutrients, reduce pests, diseases and suppress weeds and favour soil-physical conditions, particularly intercropping cereal and legume crops which helps maintain and improve soil fertility (Willey *et al.*, 1983; Horwith, 1985; Ofori and Stern, 1987; Jarenyama *et al.*, 2000; Sanginga and Woomer, 2009).

Main aspect to be considered in cereal-legume intercropping system. For the success of intercropping system several aspects need to be taken into consideration before and during the cultivation process (Seran and Brintha, 2010). For example, the potential of cereal-legume intercropping system to provide nitrogen depends in density of crop, light interception, crop species and nutrients (Francis, 1989). Despite that, the choice of compactable crops depends on the plant growth habit, land, light, and water and fertilizer utilization (Brintha and Seran, 2009).

Maturity of the crops. The biggest complementary effects and biggest yield advantages occur when the component crops have different growing periods so make their major demands on resources at different times (Ofori and Stern, 1987). Therefore, crops which mature at different times thus separating their periods of maximum demand to nutrients and moisture aerial space and light could be suitably intercropped (Enyi, 1977). For instance, Reddy and Reddi (2007) reported that, in maize-greengram intercropping system, peak light demand for maize was around 60 days after planting, while greengram was ready to harvest.

Compactable crops. Choosing of the right crop combination is very important in intercropping systems due to the fact that plant competition could be minimized not only by spatial arrangement, but also by combining those crops best able to exploit soil nutrients (Fisher, 1977). Intercropping of cereals and legumes would be valuable because the component crops can utilize different sources of N (Benites *et al.*, 1993; Jensen, 1996; Chu *et al*., 2004;), which is scarce in most soils small-scale farms of SSA (Mugwe *at al.*, 2011; Palm *et al.*, 1997). The cereal may be more competitive than the legume for soil mineral N, but the legume can fix N symbiotically if effective strains of *Rhizobium* are present in the soil.

However, some combinations have negative effects on the yield of the components under intercropping system. For example, Mucuna (*Mucuna utilis*) when intercropped with maize was found lowering maize yields, while cowpeas (*Vigna sinensis*) and greengram (*Phaseolus aureus*) had much less effect on maize and where themselves tolerant to maize shade (Agboola and Fayemi, 1971). Odendo *et al*. (2011) reported that maize-bean intercrop is predominant in eastern Africa, and whilst in southern Africa maize is intercropped with cowpeas, groundnuts and bamabara nuts.

Plant density. The seedling rate of each crop in intercrop is adjusted below its full rate to optimize plant density. If full rate of each crop were planted, neither would yield well because of intense overcrowding (Seran and Brintha, 2010). Morgado and Willey (2003) reported that dry matter yield accumulation of individual maize plant decreased with increase in bean plant population. Muoneke *et al.* (2007) found that increasing maize planting density reduced soybean seed yield by 21 and 23 percent at maize planting density of 44,440 and 53,330 plants/ha, respectively, compared with intercropping at 38,000 maize plants/ha. Bulson *et al.* (1997) reported that the nitrogen content of the wheat grain and whole plant biomass was significantly increased when the density of beans in the intercrops was increased; which was reflected in a significant increase in grain protein at harvest. And, the total amount of N accumulated by the wheat, however, decreased with increasing bean density due to a reduction in the biomass of wheat. Egbe (2010) found that the competitive ratio of soybean increased (0.76 - 1.15) with increasing density of the soybean in the intercrop combinations, indicating higher competitiveness at higher densities than the sorghum component, while the competitive ratio of sorghum had the opposite response (1.23 - 0.76). Prasad and Brook (2005) reported that with increasing maize density, rates of accumulation of dry matter and leaf area index also increased the latter, resulting in decreasing transmission of light to the intercropped soybean. The studies above are clear indication of the challenge that comes in knowing how much to reduce the seedling rates.

Plant density has also been reported to influence N_2-fixation, but total N_2-fixation activity on an area basis appeared less variable. For example, van Kessel and Roskoski (1988) reported that the percentage of total N derived from N_2 fixation in cowpea was largely independent of spacing and, overall, cowpea derived from 30 to 50 percent of its N from BNF. The reports indicate that plant density has little effect on quantity of N derived from dinitrogen fixation. More importantly, the BNF of the legume is not always reduced, but is dependent on the legume's ability to intercept light (Fujita and Ofosu-Budu, 1996).

Time of planting. Several studies have proven the effects of the planting time on the performance of the components under intercrop. For instance, Mongi *et al.* (1976) reported that planting cowpea simultaneously with maize gave batter yield. Barbosa *et al*. (2008) reported that intercropping corn with cowpea, especially when done early, provides intermediate results, indicating that cowpea controls weeds to a certain extent. Addo-Quaye *et al*. (2011) found that maize planted simultaneously with soybean or before soybean recorded significantly higher values of leaf area index (LAI), crop growth rate (CGR) and net assimilation rate (NAR), compared to when it was later.

Benefits of intercropping systems. Most researchers believe that the intercropping system is especially beneficial to the smallholder farmers in the low-input/high-risk environment of the tropics (Gunasena *et al*., 1978; Willey *et al.*, 1983; Fujita and Ofosu-Budu, 1996; Rana *et al*., 2001). The intercropping of cereal and legumes is widespread among smallholder farmers due to the ability of the legume to cope with soil erosion and with declining levels of soil fertility. The principal reasons for smallholder farmers to intercrop are flexibility, profit maximization, risk minimization against total crop failure, soil conservation and improvement of soil fertility, weed control and balanced nutrition (Shetty *et al.,* 1995).

Other advantages of intercropping include potential for increased profitability and low fixed costs for land as a result of a second crop in the same field (Thobatsi, 2009). Furthermore, intercrop can give higher yield than sole crop yields, greater yield stability, more efficient use of nutrients, better weed control, provision of insurance against total crop failure, improved quality by variety, also cereal as a sole crop requires a larger area to produce the same yield as cereal in an intercropping system (Viljoen and Allemann, 1996). However, the efficient use of basic resources in the cropping system depends partly on the inherent efficiency of the individual crops that make up the system and partly on complementary effect between the crops (Willey and Reddy, 1981).

Water use efficiency (WUE). The availability of water is one of the most important factors determining productivity in cereal-legume intercropping systems. Improvement of water use efficiency in these systems lead to increases the uses of other resources (Hook and Gascho, 1988), and it have been identified to conserve water largely because of early high leaf area index and higher leaf area (Ogindo and Walker, 2005). Garba and Renard (1991) reported that the continuous pearl millet/forage legume system was the most efficient in terms of production and water use efficiency. Hulugalle and Lal (1986) found that WUE in a maize-cowpea intercrop was higher than in the sole crops, when soil water was not limiting. However, under water limiting conditions, WUE in the intercrop compared to sole cereal can be higher resulting in returned growth and reduced yield (Ofori and Stern, 1987).

Nutrient use efficiency (NUE). Increased nutrient uptake in intercropping systems can occur spatially and temporally. Spatial nutrient uptake can be increased through the increasing root mass, while temporal advantages in nutrient uptake occur when crops in an intercropping system have peak nutrient demands at different times (Anders *et al*., 1996). Also, if the species have different rooting and uptake patterns, such as cereal/legume intercropping system, more efficient use of available nutrients may occur and higher N-uptake in the intercrop have been reported, compared monocrops (Fujita and Ofosu-Budu, 1996). Whereas when only one species is grown, all roots tend to compete with each other since they are all similar in their orientation and below surface depth (Seran and Brintha, 2010).

Some studies developed outside the SSA region have proven the comparative efficiency of intercrops to monocrops. For instance, Vesterager, Neilsen, and Hogh-Jensen (2008) found that maize and cowpea intercropping is beneficial on nitrogen poor soils. Dahmardeh, Ghanbari, Syahsan and Ramrodi (2010) reported that maize-cowpea intercropping increases the amount of nitrogen, phosphorus and potassium contents compared to monocrops of maize.

Despite the beneficial effects of the intercropping to the cereal crops, it may also accelerate soil nutrient depletion, particularly for phosphorous, due to more efficient use of soil nutrients and higher removal through the harvested crops (Mucheru-Muna *et al.*, 2010). However, Chalka and Nepalia (2006) found that maize intercropped with soybean produced significantly lower NPK depletion and higher N uptake. And, recent efforts on replenishment of soil fertility in Africa have been through the introduction of legumes as intercrop and/or in rotation to minimize external inputs (Sanginga and Woomer, 2009).

Radiation use efficiency (RUE). Total system light interception is determined by crop geometry and foliage architecture (Trenbath, 1983). In intercropping between high and low canopy crops is to improve light interception and hence yields of the shorter crops requires that they be planted between sufficiently wider rows of the taller once (Seran and Brintha, 2010). Two factors that affect yield in relation to incident radiation in an intercropping system are the total amount of light intercepted and the efficiency with which intercepted light is converted to dry matter (Keating and Carberry 1993). For instance, Tsubo, Walker, and Mukhala (2001) reported that the radiation intercepted was higher in maize-bean intercropping than of the sole crop. Tsubo and Walker (2003) found that intercropped bean with maize had 77 percent higher RUE than sole-cropped beans. Mucheru-Muna *et al.* (2010) reported that the MBILI system increases maize and legume yields through higher light penetration. Keating and Carberry (1993) found that maize – soybean intercropping has better use of solar radiation over the monocrops. Other studies from outside SSA region had proven the same results (Reddy *et al.*, 1980; Ennin *et al.*, 2002).

Weed control. It is often believed that traditional intercropping systems are better in weeds, pests and diseases control compared to the monocrops, but it must be known that intercropping is an almost infinitely variable, and often complex, system in which adverse effects can also occur. Weed growth basically depends on the competitive ability of the whole crop community, which in intercropping largely depends on the competitive abilities of the component crops and their respective plant populations (Willey *et al.*, 1983).

For instance, intercropping of cereals and cowpea has been observed to reduce striga infestation significantly (Khan *et al.*, 2002). This was attributed to the soil cover of cowpea that created unfavorable conditions for striga germination (Mbwaga *et al.*, 2001; Mbwaga *et al.*, 2001; Musambasi *et al.*, 2002). Mashingaidze (2004) found that maize-bean intercropping reduced weed biomass by 50-66 percent when established at a density of 222,000 plants ha^{-1} for beans equivalent to 33 percent of the maize density (37,000 plants ha^{-1}). Weed suppression in maize-groundnut intercropping was reported by Steiner (1984). Other studies where intercropping systems were used as an integrated weed management tool reported the same results (Caporali *et al.*, 1998; Itulya and Aguyoh, 1998; Rana and Pal, 1999).

Pest and diseases. For pests and diseases, the most commonly quoted effect is that one crop can provide a barrier to the spread of a pest or disease of the other crop (Willey *et al.*, 1983). Brown (1935) cited by Seran and Brintha (2010) noted that bud worm infestation in sole maize was greater than in maize intercropped with soybean. The number of corn borer in maize was reduced when it was intercropped with soybean (Sastrawinata, 1976). Sekamatte *et al.* (2003) reported that soybean and groundnut are more effective in suppressing termite attack than common beans. The average percentage of maize stalk borer infestation was significantly greater in monocropped (70 percent) than in intercropped maize-soybean (Martin, 1990).

Erosion control. Intercropping systems control soil erosion by preventing rain drops from hitting the bare soil where they tend to seal surface pores, prevent water from entering the soil and increase surface runoff (Seran and Brintha, 2010). Kariaga

(2004) found that in maize-cowpea intercropping system, cowpea act as best cover crop and reduced soil erosion than maize-bean system. Reddy and Reddi (2007) found that taller crops act as wind barrier for short crops, in intercrops of taller cereals with short legume crops. Similarly, sorghum-cowpea intercropping reduced runoff by 20-30 percent compared with sorghum sole crop and by 45-55 percent compared with cowpea monoculture. Moreover, soil loss was reduced with intercropping by more than 50 percent compared with sorghum and cowpea monocultures (Zougmore *et al.,* 2000).

Biological Nitrogen Fixation (BNF) in cereal-legume intercropping system. Biological Nitrogen Fixation, which enables legumes to depend on atmospheric nitrogen (N), is important in legume-based cropping systems when fertilizer-N is limited (Fujita and Ofosu-Budu, 1996), particularly in SSA where nitrogen annual depletion was recorded at all levels at rates of 22 kg ha^{-1} (Smaling *et al.,* 1997) and mineral-N fertilization is neither available nor affordable to smallholder farmers (Jama *et al.,* 2000; Mugwe *et al.,* 2011). BNF contributes N for legume growth and grain production under different environmental and soil conditions. In addition, the soil may be replenished with N through decomposition of legume residues (Fujita and Ofosu-Budu, 1996). Legumes species commonly used for provision of grain and green manure have potential to fix between 100 and 300 kg N ha^{-1} from the atmosphere (Table 1).

Within the SSA region there are limited studies quantifying N_2-fixation by different legumes. However, the relatively few studies available have generated critical lessons and technical knowledge on the potential contributions of legumes to the farming systems of region (Mapfumo, 2011). For instance Reijntjes, Haverkort, and Waters-Bayer (1992) reported that

Table 1. A summary of N_2 fixation potential from different categories of tropical legumes.

Legume system	%N derived from fixation	Amount fixed (kg N ha^{-1})	Time (days)
Grain	60-100	105-206	60-120
Green manure	50-90	110-280	45-200
Trees	56-89	162-1.063	180-820

Source: Giller (2001).

30-60 kg N ha^{-1} $year^{-1}$ is added to the soil by legumes. Osunde, Tsado, Bala, and Sanginga, (2004) found that without the addition of fertilizer the proportion of N derived from N_2-fixation was about 40 percent in the intercropped soybean and 30 percent in the sole crop. Sanginga *et al.* (1996) reported that Mucuna accumulated in 12 weeks about 160 kg N ha^{-1} when intercropped with maize. Eaglesham *et al.* (1981) reported that the fixed-N by component cowpea was about 41 kg N ha^{-1}, in maize-cowpea intercropping system.

According to Ofori and Stern (1987) the amount of N fixed by the legume component in cereal- legume intercropping systems depends on several factors, such as species, plant morphology, density of component crops, type of management, and competitive abilities of the component crops. Nambiar *et al.* (1983) reported that with zero application of N-fertilizer, shading did not affect N_2-fixation by the component groundnut crop although incoming light reaching the legume was reduced 33 percent. While, when 50 kg N ha^{-1} was applied, BNF was reduced 55 percent, although light reaching the groundnut was 54 percent of incoming radiation. This suggests that heavy application of combined N significantly reduces BNF, which was confirmed by Ofori and Stern (1987) who evaluated the N economy of a maize-cowpea intercrop system and found that N-fertilizer applications reduced N fixation.

On the other hand, Fujita *et al.* (1992) reported that the soil with a relatively high N content (high organic matter) the mixed cropping yield increased by 25 percent due to enhanced soil N uptake by the sorghum component, while the soybean component depended mostly on BNF. Still according Fujita *et al.* (1992) the plant density has little effect on quantity of N derived from dinitrogen fixation and the BNF of the legume is not always reduced, but is dependent on the legume's ability to intercept light. Mandimba (1995) revealed that the nitrogen contribution of groundnut to the growth of *Zea mays* in intercropping systems is equivalent to the application of 96 kg of N-fertilizer ha^{-1} at a ratio of plant population densities of one maize plant to four groundnut plants.

Despite the potential for annual fixation rates of 300 kg N ha^{-1}, the amount measured on farmer's fields are still very low (6 kg N ha^{-1} to 80 kg N ha^{-1}), except soybean which fixed between 100 and 260 kg N ha^{-1} within periods of no more than three months (Mapfumo, 2011). Additionally, it has been reported that seeds harvested from the component crops are the major source of N loss from the intercropping system and can range from 50 to 150 kg N ha^{-1}. Nitrogen in the system can be lost through harvested material, principally the seed, and through denitrification, leaching and volatilization (Stern, 1993).

Nitrogen transfer in cereal-legume intercropping systems. Evidence suggests that associated non-legumes may benefit through N-transfer from legumes (Fujita *et al*., 1990). This N-transfer is considered to occur through root excretion, N leached from leaves, leaf fall, and animal excreta if present in the system (Fujita *et al*., 1992). The limited studies carried out within SSA suggested that N_2-fixed by a leguminous component may be available to the associated cereal in the current growing season (Eaglesham *et al.*, 1981), known as direct N transfer (Stern, 1993). Eaglesham *et al.* (1981) showed that 24.9 percent of N fixed by cowpea was transferred to maize.

However, Ofori and Stern (1987) and Danso *et al.* (1993) reported that there is little or no current N transfer in cereal-legume intercropping system. In addition, Fujita *et al.* (1992) reported that benefits to associated non-leguminous crop in intercropping systems is influenced by component crop densities, which determine the closeness of legume and non-legume crops, and legume growth stages.

Despite claims for substantial N-transfer from grain legumes to the associated cereal crops, the evidence indicate that benefits are limited (Giller *et al.*, 1991). Benefits are more likely to occur to subsequent crops as the main transfer path-way is due to root and nodule senescence and fallen leaves (Ledgard and Giller, 1995).

Residual effects of cereal-legume cropping system. The intercrop legume may accrue N to the soil and this may not become available until after the growing season, improving soil fertility to benefit a subsequent crop (Ofori and Stern 1987; Ledgard and Giller, 1995). For instance, Yusuf, Iwuafor, Olufajo, Abaidoo, and Sanginga (2009) found that maize grain yield was 46 percent significantly higher when grown after soybean than after maize and natural fallow. Kumwenda *et al.* (1998) reported that sunnhemp (*Crotalaria juncea*), Tephrosia (*Tephrosia vogelii*) and velvet bean (*Mucuna pruriens*) green manure often resulted in maize yields of 3-6 t ha^{-1} even with no addition of mineral N fertilizer.

Moreover, Chibudu (1998) found that maize yields were increased about 25 percent and 88 percent after maize-mucuna and maize-cowpea intercropping systems, respectively. Phiri *et al.* (1999) found that maize yields were increased about 244 percent after maize-*Sesbania sesban* intercropping system. Kureh and Kamara (2005) found that maize grain yield was 28 percent higher after one year of soybean and 21 percent higher after one year of cowpea than in the continuously cropped maize. Maize grain yield was 85 percent higher after two years of soybean, and 66 percent higher after two years of cowpea than in the continuously cropped maize.

Furthermore, Akinnifesi *et al*. (2007) found that over 4 consecutive cropping seasons, grain yields of maize increased by 340 percent in gliricidia-maize intercropping, when compared to unfertilized sole maize. Bationo *et al.* (1995) reported that intercropping of cowpea with millet may enhance millet grain yields by 30 percent above the control. According to People and Herridge (1990) to maximize the contribution of legume N to a following crop, it is necessary to maximize total amount of N in legume crop, the proportion of N derived from N_2 fixation, the proportion legume N mineralized and the efficiency of utilization of this mineral N. Unfortunately, it is not always possible to optimize these factors.

Intercropping productivity. One of the most important reasons for intercropping is to ensure that an increased and diverse productivity per unit area is obtained compared to sole cropping (Sullivan, 2003). For instance, using LER in a maize-soybean intercropping system, Kipkemoi *et al.* (2001) reported that it was greater than one under intercrop. Muoneke *et al.* (2007) found that the productivity of the intercropping system indicated yield advantage of 2-63 percent as depicted by the LER 0f 1.02-1.63 showing efficient utilization of land resource by growing the crops together. Raji (2007) had also reported of higher production efficiency in maize-soybean intercropping systems. Addo-Quaye *et al.* (2011) found that LER was greater than unity, implying that it will be more productive to intercrop maize-soybean than grow them in monoculture. Allen and Obura (1983) observed LER of 1.22 and 1.10 for maize-soybean intercrop in two consecutive years. Samba *et al.* (2007) found that the pearl millet-cowpea intercropping was more productive than their monocrops, what was proved through the LER of 1.2. Osman *et al*. (2011) reported that LERs were always larger than unity indicating benefits of intercropping over sole cropping of millet and millet. Abera *et al*. (2005) observed that the LER values ranged from 1.15 to 1.42 indicting more productivity and land use efficiency of maize (*Zea mays*)- climbing bean (*Phaseolus vulgaris*) intercropping in terms of food production per unit area than separate planting.

Economic benefits of cereal-legume intercropping systems. According to Seran and Brintha (2010) the intercropping system provides higher cash return to smallholder farmers than growing the monocrops. Gunasena *et al.* (1978) studying maize-soybean intercropping system, found that the gross economic returns were increased by the intercropping. Mucheru-Muna *et al.* (2010), using benefit cost ratio, found that the MBILI system with beans as the intercrop resulted in 40 percent higher net benefits relative to the conventional system with beans, and 50–70 percent higher benefits, relative to the MBILI system with cowpea or groundnut. Using the same BCR, Segun-Olasanmi and Bamire (2010) reported that maize-cowpea intercropping was found to be profitable than their sole crops. On the other hand, using monetary advantage index (MAI), Osman *at al.* (2011) reported that intercropping with two rows of cowpea and one row of millet gave significantly higher economic benefit than mixture with one row of each of the crops. Using the same MAI, Oseni (2010) found that intercropping with two rows of sorghum and one row of cowpea gave higher economic return compared to the other planting arrangements and the sole crops. These results suggest that intercropping could improve the system's productivity, increase the income for smallholder farmers, and compensate losses (Osman *et al.,* 2011).

Constraints of cereal-legume intercropping system contribution to soil fertility management in smallholder farms. Despite the benefits of cereal-legumes intercropping systems in ISFM, there are some constraints that need to be curbed so as to attain progress (Bationo *et al.,* 2011; Mugendi *at al.,* 2011; Mapfumo, 2011; Odendo *et al.,* 2011). For instance, in some of countries within the region the soils are acidic with limited phosphorus availability (Sanchez *et al.,* 1997; Mapfumo, 2011), which is harmful for BNF process and therefore lessen the N contribution of the legume component to system (Fujita and Ofosu-Budu, 1996; Giller, 2001). This is worsened by the current use of mineral fertilizers is still low among smallholder farmers (Palm *et al.,* 1997; Maphumo, 2011), which is associated to accessibility and affordability of appropriate fertilizer (Maphumo, 2011) due to financial and infrastructure problems (Jama *et al*. 2000). Lack of access to improved seed on time to these farmers, which is associated to poor market and policy are also contributing negatively to the successful contribution of these systems (Bationo *et al.,* 2011; Mugendi *et al.,* 2011; Maphumo, 2011).

Moreover, legume trees and legume cover crops have been repeatedly demonstrated to improve and maintain soil fertility under different environmental conditions, compared to grain legumes intercropping systems (Mugendi, 1997; Mugendi *et al.,* 1999; Kumwenda *et al.,* 1998; Mugwe *et al.,* 2011; Maphumo, 2011; Bationo *et al.,* 2011). However, they have increasingly emerged as the least prioritized by smallholder farmers under their prevailing circumstances, which can be largely attributed to their lack of short-term benefits of both food and income (Maphumo, 2011; Mugendi *et al.,* 2011; Bationo *et al.,* 2011).

Furthermore, there is lack of information and knowledge about fertility management technologies because most of the research that has been done related to cereal-legumes intercropping system in the past decades had less involvement of farmers, particularly the resource-constrained farmers (Mugendi *et al.,* 2011; Maphumo, 2011), which is worsened by low know how of extension services on legume-based ISFM technologies (Maphumo, 2011). Consequently, there are misconceptions among smallholder farmers about the role of legumes in the soil fertility management (Mtambanegwe and Maphumo, 2009).

Conclusions

Research on cereal-legume intercropping systems in SSA has shown improvements in both soil fertility and crop yields, particularly for cereal crop which is the staple food crop for smallholder farmers. However, lack of participatory approaches and under farmer's conditions, mainly the inclusion of resource-less farmers, could not allow easy adoption by these smallholders. Furthermore, most of the studies that have been done on cereal-grain legume intercropping systems were focused on cereal yields, and were not able to show clearly the amount of nitrogen was fixed by the legume component within the season, probably due to difficult on the measurements procedures. Therefore, it is necessary more participatory research that involves smallholder farmers, extension services and other stakeholders on the contribution of the grain legume component to BNF in cereal-grain legume intercropping systems, under farmer's conditions. Also, there is need for proper handle of issues of accessibility and affordability of improved seed and appropriate fertilizers, if the gains of cereal-legume intercropping systems in ISFM under smallholder farmers have to be adopted.

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