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Research Article

Existing practices for soil fertility management through cereals-legume intercropping systems

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Low crop production has been attributed to inherently low availability of plant nutrients, nutrient imbalances and inadequate soil moisture for plant growth. Past and current soil management practices have enhanced the degradation of the soils. These have been caused by increased withdrawal of plant nutrients from the soil and consequently to reduced plant growth. To meet future food requirements, it is inevitable that the use of inorganic fertilizers will continue to increase. However, such fertilizers are expensive to farmers and they are potential environmental pollutants. The intensification and diversification of the cropping systems and traditional practices in Africa have compounded the decline in soil fertility. To raise and sustain soil fertility and productivity in Africa, appropriate traditional soil fertility management practices have to be developed and adopted by farmers. Cereal-legumes cropping systems accompanying management technologies indicated the advantage of these technologies and their function of socio-economic and bio-physical conditions. This review explored the mechanisms and processes associated with soil fertility management, effect of intensive agriculture on soil degradation, role of traditional and scientific knowledge, benefits, challenges and additional cereal-legumes cropping systems. These contributed to understanding the effects soil fertility management decisions and human-use impacts on long-term ecological composition and function.

Key words: Intercropping, Cereal-legumes, Nutrient management, Soil degradation, Sustainable farming, Traditional knowledge

INTRODUCTION

In Africa, soil nutrients studies show evidence of widespread nutrients mining (Bekunda et al., 2010; Mugendi et al., 2012). Amount of nutrients annually taken away in the form of harvested crops, crop residues transferred out of fields or lost through leaching, erosion and volatilization are higher than the amount of nutrients added into the soil through fertilizers, plant residues decomposition, atmospheric deposition and biological nitrogen fixation (Deanna and Jihoo, 2008; Shisanya et al., 2009; Felix et al., 2012). Soil nutrients mining have been estimated to average 660kg of nitrogen (N), 75 kg of phosphorus (P) and 450 kg of potassium (K) per hectare per year during the last 30 years from about 200 million hectares of cultivated land in 37 countries in Africa (Mugendi et al., 2012; Felix et al., 2012).

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Fertilizer use worldwide in 2009 was on average about 122 kg ha^{-1}, but only between 8 and 11 kg ha^{-1} were in Sub-Saharan Africa which have resulted as the fundamental biophysical root cause for declining per capita food production in Sub-Saharan Africa smallholder farms (Bationo et al., 2015). Further studies by Mugwe et al. (2009) and Sanchez (2002) indicated that failure by smallholder farmers to intensify agricultural production and lack of plant nutrients due to land degradation caused by continuous crop nutrients uptake, nutrients leaching and soil erosion (Sanginga and Woomer, 2009), are the principal causes of low agricultural productivity and food insecurity in Africa where rain fed farming is dominant. The continuous nutrients depletion and low soil fertility have led to the development of integrated soil fertility management technologies that offer potential for improving soil fertility in Africa and triggered extensive studies on nutrients balance in various African farming and cropping systems (Mugendi et al., 2012).

Cereal/ legumes cropping system is advanced as one of the integrated soil fertility management practices consisting of growing two or more crops in the same space at the same time, which have been practiced over the years and achieved the soil fertility restorations and crops yield in agriculture (Matusso et al., 2014). The most common cropping system in developing countries consists of growing several crops in association or in mixtures mainly being cereal and legumes (Ouma and Jeruto, 2010). A study by Mekuria et al. (2004) noted the decline in soil fertility being the major limitation to crops yield in cereal based cropping systems in Eastern and Southern Africa. As the case with most other Sub Saharan African countries, Tanzania faces the same challenge of declining soil fertility with nitrogen being considered the main limiting factor to crops yield (Njira et al., 2012). Soil fertility assessments in Tanzania showed that 77% of agricultural soils have very low (0.01 %) to low (0.15 %) nitrogen content (MAFC, 2006) possessing serious threats to successful production of food crops and therefore requires the use of nitrogen fertilizers (Wei-Dong et al*,* 2008).

In Tanzania, 80% of the farmers are classified as small-scale farmers (TASDS, 2001) who lack financial resources to purchase sufficient amount of mineral fertilizers to replace soil nutrients removed through various processes that include harvested crop products (Jama et al., 2000) crop residues for livestock feeds, and through loss by runoff, leaching and as gases (Bekunda et al., 1997). Technologies that involved integrated soil fertility management practices (ISFM) with cereals-legumes intercropping have proved to improve soil fertility (Mucheru-Muna et al., 2010; Sanginga et al., 2009). Such technologies have led to changes in trend in global agriculture by searching for highly productive, sustainable and environmentally friendly cropping systems with renewed interest in cereal-legumes cropping systems research (Crews et al., 2004). Studies conducted in Australia showed that, legume produced an average of 225 kg N ha^{-1}, and replaced over 60% of the nitrogen fertilizer requirement for optimum cereals production (Zablotowicz et al., 2011). Further, the contribution of legume crops on cereal crop yields indicated an increase in yields of crops planted after harvesting of legumes are often equivalent to those expected from application of 30 - 80 kg of fertilizer-N ha^{-1} (Peoples et al., 2009).

Intercropping is a kind of common cropping system in Africa, Asia and Latin America of which more than 80% of smallholder farmers grow the bulk of the food crops and some of the cash crops (Mekuria et al., 2004). In Eastern Africa, cereal is often intercropped with legumes such as beans (*Phaseolus vulgaris L.),* cowpeas *(Vigna unguiculata L. Walp).* and pigeon peas *(Cajanus cajan L.)* (Mekuria et al., 2004). In Tanzania, smallholder farmers intercrop cereal and legumes such as beans, cowpeas, pigeon peas, green peas and bambara nuts (Mekuria et al., 2004). The main objective of intercropping has been to maximise use of resources such as space, light and nutrients (Li et al., 2003) as well as to improve crop quality and quantity (Mpairwe et al., 2002). Other benefits include water quality control through minimal use of inorganic nitrogen fertilizers that at high doses pollute the environment (Crews and Peoples, 2004).

Studies have further indicated that intercropping cereals with legumes have huge capacity to replenish soil mineral nitrogen through its ability to biologically fix atmospheric nitrogen (Giller, 2001; Ndakidemi, 2006). Estimate indicates that, when cereal and legumes are intercropped, the legumes can fix up to 200 kg N /ha/ year under optimal field conditions (Giller, 2001). However, very limited information highlights the effects of these legumes when inoculated with rhizobia and grown in diversified cereal-legumes cropping systems. Besides the benefit of yield and soil fertility improvement, cereal-legumes intercropping can be seen to produce social benefits to both the land-holder and the surrounding community such as productivity of various plant constituents and economic returns (Geno and Geno, 2001). Therefore, updating traditional cereal-legumes intercropping practices (as opposed to promoting monocultures) offers the potential of scale specific technologies for soil fertility improvement that favour the smallholder farmer. The goal of this paper is to review existing literature in order to identify and assemble the available information that can be used to suggest the best cereal-legume cropping systems that would improve N_2 fixation, uptake by plants and subsequently crops yield.

MECHANISMS AND PROCESSES ASSOCIATED WITH SOIL FERTILITY MANAGEMENT IN CEREAL/ LEGUME INTERCROPPING SYSTEMS

Soil fertility refers to the soil capacity to supply nutrients to the plant in sufficient amount at the right time and involves a combination of soil chemical, physical and biological factors that affect the land capacity to supply nutrients to the plants (Juma, 2011). Nutrient acquisition and management in cropping systems is entering a critical phase (Dahmardeh et al., 2010). Biological nitrogen fixation (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 (Davidson et al., 2007). Legumes assimilate some soil mineral N by their roots, they indirectly acquire this element from atmospheric N_2, through endosymbiosis with N_2-fixing bacteria that involves the formation of a specific symbiotic organ (nodules) on roots (Lodwig et al., 2003). Intercropping legumes with cereal crops can result in competition for water and nutrients (Peoples et al., 2009). This competition can affect N_2 fixation negatively. However, it has been shown that when mineral N is depleted in the root zone of the legume component by the cereal intercrops, N_2 fixation of legumes will be promoted (Ashish et al., 2015). Interestingly, cereals plants such as rice (Chi et al., 2005), wheat (Iniguez et al., 2004) or maize (Perin et al., 2006) are also able to interact with N_2 fixing bacteria for N acquisition (Rosenblueth and Martinez-Romero, 2006).

Some modifications in nutrient management and equilibrium of traditional cropping systems need a particular attention to soil and crop health. Studies in the semi-arid tropics of India revealed that the addition of pigeon pea, as a sole crop or as an intercrop in a cropping system, not only helps soil N fertility, but also makes more phosphorus reserves available for subsequent crops by solubilizing insoluble P in soil, improving the soil physical environment, increasing soil microbial activity and restoring organic matter (Ghosh et al., 2015; Elodie, 2010). Sanginga et al. (2009) noted that soybean is often cultivated in rotation with maize or other cereal crops, because of its N-fixing capability. However, soybean seems to reduce the nitrate concentration in the soil profile much more than cereal does (Sanginga et al., 2009).

Sileshi and Mafongoya (2003) indicated that the productivity of current cropping systems, and the protection of environmental quality, cannot be sustained for long if we continue such practices as the application of too many or too few nutrients, and inefficient utilization of crop residues and wastes. Research must be intensified, so that we can quantify measurable sustainability indicators such as levels of organic carbon, soil micro-flora and fauna, nutrients lost through runoff and leaching, and the rates of change in those variables as affected by specific nutrient management practices in cereal-legumes cropping systems (Sakané, 2011). Many of the existing knowledge in cereal/legumes intercropping are not used especially in developing countries that are essential to devote major efforts towards adoption of soil sustainability. Therefore, more studies are needed to identify the mechanisms and processes that influence soil organic matter decomposition, nutrient availability and uptake in different cereal/legumes cropping systems.

INTERCROPPING IN SMALLHOLDER FARMING SYSTEMS

In many areas of the world, traditional smallholder farmers have developed and/or inherited complex farming systems, adapted to the local conditions that have helped them to sustainably manage harsh environments and meet their subsistence needs (Alteria et al., 2011). However, intercropping still dominates the cropping systems, it is reported more extensively practiced by smallholder farmers and is commonly evident in tropical parts of the world compared with other types of cropping systems (Papanastasis et al., 2004). Smallholder farmers have limited resources with limited capacity to tolerate production failures and, therefore, are compelled to practice intercropping as a means of crop diversification (Henriet et al., 1997; Langer et al., 2007). Moreover, this resource -poor farmers mostly practice intercropping due to scarcity of land, agricultural inputs (fertilizers, seeds and pesticides) and limited labour (Nkonya, 1998).

The cereal-legumes plant species used in intercropping are specific and vary across regions (Alireza et al., 2014). Nedumaran et al. (2015) estimated that 80% of the cultivated area of sub Saharan Africa is intercropped. In Latin America, Akibonde and Maredia (2011) estimated that 60% of the cereal and 80'% of the field beans are intercropped while in India, the majority of pigeon pea farms are intercropped In tropical Asia and the Pacific, multi-storey intercropping is common with tree species that dominate the upper canopy (Sullivan, 2003). Further, Sullivan (2003) reported that the types and choices of crops grown are normally governed by physical, economic, and social factors. Traditional agriculture, as practiced through the centuries all around the world, has always included different forms of intercropping (Lithourgidis et al., 2011). In fact, many crops have been grown in association with one another for hundred years and crop mixtures probably represent some of the first farming systems practiced. Traditional multiple cropping systems are estimated to still provide as much as 15-20% of the world’s food supply (Alteria et al., 2011). In Latin America, farmers grow 70-90% of their beans with maize, potatoes, and other crops, whereas maize is intercropped on 60% of the maize-growing areas of the region (Akibonde and Maredia, 2011). Other quantitative evaluations suggest that 89% of cowpeas in Africa are intercropped, 90% of beans in Colombia are intercropped, and the total percentage of cropped land actually devoted to intercropping varies from a low 17% for India to a high of 94% in Malawi (Lithourgidis et al., 2011).

In Tanzania, as in many other sub-Saharan Africa countries, intercropping is the dominant peasant traditional cropping practice characterized by little or no mechanization and minimal utilization of inputs such as fertilizers and insecticides (Friesen and Mbaga, 2003). The main regions in Tanzania where the cereal/legume intercrops are common are Rukwa, Ruvuma, Arusha, Kagera, Shinyanga, Iringa, Mbeya, Kigoma, Tabora, Tanga, Morogoro, Kahama and Biharamulo (Baltazari, 2014). The system commonly involves a cereal and legume crops, with the cereal being considered as the main crop. This is due to the fact that cereals are, in most cases, the main food source and efforts are made to increase their yield than that of the legumes. Although many intercrops particularly in Tanzania contain legumes, such as groundnuts, common beans, cowpeas, or green grams, the increase in yield is not attributed solely to the presence of the legume but the presence of other soil nutrients and water (Friesen and Mbaga, 2003). Frequency of intercropping practices is decreasing due to changes in temperature and rainfall in many areas (Gordon et al., 2010). This trend is the result of fewer plant species being adapted to harsh growing conditions and farmers' favouring species that have a better probability of producing something in a bad year.

As our environment and production concerns increase it is likely that intercropping will offer very genuine benefits to poorer or smallholder farmers compared to monoculture (Carlson, 2008). Although intercropping has been used traditionally for thousands of years and is widespread in many parts of the world, it is still poorly understood from an agronomic perspective (Hailu, 2015). This is partly due to the wide use of pure crop cultures in the developed world, and partly to the relative lack of resources in the developing world, but not least to the complexity of the problems involved in the mixed culture systems (Malézieux et al., 2009). In this regards, there is a sufficient justification for conducting research on cereal-legumes intercropping systems. Thus, more research is needed to better understand how intercrops function and to develop cereal-legumes intercropping systems that are compatible with current farming system. An evidence of soil fertility improvement coupled with quantitative measures/data by different cropping systems against areas where this practice is absent is important. This would be useful to create a baseline from which to show the impacts of the intercropping systems on management of soil fertility and crop yield.

EFFECT OF INTENSIVE AGRICULTURE ON BIOLOGICAL AND PHYSICO-CHEMICAL SOIL DEGRADATION

Soil degradation, mainly the decline both in quality and quantity of soil organic matter, is one of the major reasons linked to stagnation and decline in yields in the most intensive agriculture (Dawe et al., 2000; Ladha et al., 2003; Yadav and Yadav, 2001). The decline in soil organic matter is related to the improper use of synthetic fertilizers and lack of organic fertilization, practices that are now widespread in the most intensive agriculture areas in Tanzania and Africa at large (Masto et al., 2008; Singh et al., 2005). Repeated-application of nitrogen fertilizers (usually only urea), common in Tanzania farms and influenced by the government’s subsidy system on nitrogen, is not only causing nutrient imbalances, but also negatively affecting the physical and biological properties of the soils (Bouajila and Sanaa, 2011; Crawford et al., 2006). For example, indicators of good soil fertility like microbial biomass, enzymatic activity and water-holding capacity are all drastically reduced under common nitrogen fertilizer applications (Masto et al., 2008). Another common detrimental effect of the excessive use of nitrogen fertilizer on soil health is acidification, and the impact it has on soil living organisms, crucial also for natural nutrient cycling and water-holding capacity and nitrate accumulation in water bodies (Darilek et al., 2009; Kibblewhite et al., 2008). By considering the environmental problems associated with current cropping systems, it seems reasonable to continue research on the possibilities of growing cereal-legumes intercropping which will rival the current monoculture systems.

THE USE OF TRADITIONAL KNOWLEDGE COUPLED WITH SCIENTIFIC KNOWLEDGE ON SOIL FERTILITY MANAGEMENT

The increasing attention paid to local soil knowledge in recent years is the result of greater recognition that the knowledge of people who have been interacting with their soils for a long time can offer many insights into the sustainable management of tropical soils (Edmundo et al., 2002). In various places in the world, scientists and indigenous people are collaborating to build bridges between modern science and indigenous knowledge, among others, to improve ecological management of a particular region (Reijntjes, 2004). In order to design more appropriate research and development programmes geared to improving integrated nutrient management practices, researchers need to understand farmers’ knowledge and perceptions of soil fertility (Corbeels et al., 2000). Mathiu and Kariuki (2007) indicated that many indigenous people have extensive knowledge in management of natural resources in their traditional landscapes. Traditional subsistence farmers' throughout the tropics exhibit a deep understanding of their local ecosystems (Talawar and Rhoades, 1998). Small farmers in such farming systems are often confronted with complex and heterogeneous environments, including different soil qualities of which they develop a systematic knowledge (Kolawole, 2001).

The low input nature of intercropping system is often linked to the traditional soil fertility management practices (TSFMP) of smallholder farming systems in developing countries (Dixon, 2002). It promotes environmentally, socially and economically sound production of food crops and takes soil fertility as key to successful production (Dahmardeh et al., 2009). Thus, farmers have traditional followed integrated soil fertility management practices and these practices are built into the indigenous methods of farm management (Tagseth, 2008). For example, terracing, slicing the walls of terrace riser, bringing flood water into the field, leaf and in situ terrace manuring, application of organic manure (Farm Yard Manure, compost, oil cakes, bone-meal etc.), shifting herds for in situ terrace manuring and inclusion of various legumes in crop rotations are all in built agronomical practices that supply plant nutrients to the field (Kolawole, 2001).

Traditional intercropping interventions on organic inputs contribute to enhancing fertilizer uptake of crops as well as its retention in soils due to processes that balance nutrient immobilization and release (Chivenge et al., 2009). The system enhances fertilizer use efficiency by promoting adoption of: i) incorporation of urea into the soil that reduces volatilization losses (Paynel et al., 2008) ii) banding of fertilizers on soils that strongly absorb P that enhances the nutrient availability to plants (Bronick and Lal, 2005) and iii) point placement of inorganic inputs in cereal crops that increases fertilizer recovery and reduces fertilizer requirements (Aune and Batiano, 2008). Input of stover residues in a millet cropping system as part of ISFM intervention on organic resource management has demonstrated increase of total biomass yield by more than seven times, while neutralizing acidity and reducing export of K, Ca and Mg (Bationo and Buerkert, 2001). However, land shortage and land fragmentation have increasingly forced farmers to abandon soil fertility management practices such as fallowing, manuring, terracing, and using crop residues (Deugd et al., 1998). Further, the role of indigenous knowledge system in current soil management practices and its contribution in reducing land degradation and ecosystem management has been undermined (Corbeels et al., 2006). An analysis of the present situation reveals that future food security will not be passing without crisis if measures to cope with the declining soil fertility are not taken seriously (Abera and Belachew, 2011; Tagseth, 2008).

A study by Dixon (2002) indicated that, recognizing, empowering and incorporating indigenous knowledge has been considered a means of ensuring socially, environmentally and economically sustainable natural resources management. Rufino et al. (2011){Rufino, 2011 #98} reported that organic inputs contain nutrients that are released at a rate determined in part by their chemical characteristics or organic resource quality. These organic inputs when applied at realistic levels seldom release sufficient nutrients for optimum crop yield (Rufino et al., 2011). Combining organic and mineral inputs has been advocated as a sound management principle for smallholder farming in the tropics because neither of the two inputs is usually available/ accessible in sufficient quantities and because both inputs are needed in the long-term to sustain soil fertility and crop production (Lambrecht et al., 2016). The combinations of all possible sources of nutrients are needed to arrive at integrated plant nutrients system that is appropriate for sustainable agricultural development. These can reach the smallholder farmers through field trials demonstration and farms visit with combined scientific and indigenous knowledges because farmers learn more by seeing. Therefore, there is a need to consider indigenous knowledge coupled with recent scientific technologies on cereal-legumes intercropping system as a means to develop situation-specific and sustainable soil management measures.

POSSIBLE BENEFITS OF VARIOUS TYPES OF CROPPING SYSTEMS

Cropping system is an old practice, self-sustaining, low-input, and energy-efficient agricultural system used by subsistence farmers, especially under rain-fed conditions (Lithourgidis, 2011). It provides a balanced diet to human being, reduces labour peaks, and minimizes crop-failure risks (Geren et al., 2008). It has been suggested that intercropping, crop rotations, strip cropping and relay cropping can reduce the adverse effects of pests (diseases, insects, and weeds), provide higher returns, and protect soil against erosion (Carlson, 2008; Deveikyte et al., 2009; Innis, 1997; Mekuria and Waddington, 2004). According to Carlson (2008) the advantages of cropping system include: reduced soil erosion and protection of topsoil, especially in contour strip cropping; attraction of beneficial insects, especially when flowering crops are included to the intercropping system; increased or maximization of land productivity, particularly in the high rainfall areas increased total production and farm profitability, ensuring contribution to better farm labour use and even harvesting period and reduction of storage problems. Where legumes and cereals are intercropped, the cereal crop may benefit from the nitrogen fixed by the companion leguminous crop (Agegnehu et al., 2008).

A study on fertilizer responses in cereal-legume rotations systems demonstrated that N benefits from green gram, pigeon pea or cowpea were equal to a fertilizer N input of

16, 19 and 25 kg N per hectare (Marandu et al., 2014). When two or more crops with different rooting systems (Innis, 1997), different patterns of water and nutrients demand (Ncube, 2007), and a different aboveground growth habit were planted together (Crookston and Hill, 1979), water, nutrients and sunlight were used more efficiently, thus higher yields in intercrop than in pure stands. Cropping system provides insurance against crop failure or against unstable market prices for a given commodity, especially in areas subject to extreme weather conditions such as frost, drought, and flood (Onduru and Preez, 2007). Many reports indicate the superiority of cereal-legumes intercropping over monocropping of each crop (Esmaeil, 2011; Hailu, 2015; Mahapatra, 2011). Besides, cropping system allowing lower inputs through reduced fertilizer and pesticide requirements, thus minimizing environmental impacts of agriculture (Mugwe et al., 2009), general experience with intercropping in Africa has shown that the yield of one or all of the crops in the intercrop is lower than the yield of their respective pure stands, but the combined yield from the intercrop is higher than the yield of any of the crops as a pure stand (Bronick and Lal, 2005; Ndakidemi and Dakora, 2007). Therefore it is important to establish and provide useful information on how the cereal/legume mixtures practices may influence the overall yields of the component crops in the intercropping systems.

CHALLENGES FACING SMALLHOLDER FARMERS IN TRADITIONAL CROPPING SYSTEMS

Land-use change and environmental pollution are expected to jeopardize continued increases in agricultural production (Thayamini and Brintha, 2010). Farming operations such as ploughing, organic residuals addition, fertilizers and pesticides application can contribute to nutrient pollution when not properly managed (Vance, 2001). Urzua (2005) revealed that only 50 % to 60 % of the inorganic nitrogen fertilizer applied is used by the crop and the rest is lost by volatilization, denitrification or leaching of nitrate into the ground water. It is therefore evident that fertilizers and animal manure, which are both rich in nitrogen and phosphorus, could be one of the primary sources of nutrient pollution from agricultural practices (Moss, 2008). However, nutrient management by applying fertilizers in the proper amount, at the right time of year and with the right method can significantly reduce the potential for pollution (Haygarth, 2005).

Soil erosion is another major cause of nutrient loss, particularly where agronomic inputs are low, vegetation cover is poor, soils are not resilient and where intense rainfall sometimes occur (Powlson et al., 2011). According to Stolte et al. (2009) soil erosion has direct negative effects on the productivity of land by loss of soil, water and nutrients. Continue cropping without sufficient inputs of nutrients and organic matter leads to localised but extensive soil degradation and renders many soils in a non-responsive state and constitutes a chronic poverty trap for many smallholder farmers in Africa (Pablo and Giller, 2013). It has been suggested that cereal/legumes intercropping address mutual relationships among soil, nutrient and water concurrently (Baligar and Fageria, 2007; Fageria et al., 2005). Further, Palm et al. (1997) noted that solutions to smallholder farmers' soil fertility problems may be found in the strategic combination of organic resources, particularly from nitrogen-fixing legumes. Better understanding of intercropping systems with numerous cereal-legumes intercrop combinations will enhance soil nutrients for plant growth.

ADDITIONAL CROPPING SYSTEMS TO SMALLHOLDER FARMERS

Intercropping is a common practice in most small scale farming systems of Africa and Tanzania, in particular (Friesen and Mmbaga, 2003). Cereals being the most important food crops in Africa are in most cases intercropped with a minor/ companion crop for various reasons including as a complement in most local dishes (Friesen and Mmbaga, 2003; Rowhani et al., 2011). According to Sanginga and Woomer (2009) four cropping systems were suggested to be integrated to the existing cropping systems of small holder farmers. (i) Crop rotation, planting cereal one year and legumes the next. This means changing the type of crops grown in the field each season or each year (or changing from crops to fallow). Crop rotation is a key principle of conservation agriculture because it improves the soil structure and fertility, and because it helps control weeds, pests and diseases (Nyambati et al., 2006). (ii) Sequential cropping, planting cereal in the long rains, then legumes during the short rains. This involves growing two crops in the same field, one after the other in the same year. In some places, the rainy season is long enough to grow two crops: either two main crops or one main crop followed by a cover crop. Growing two crops may also be possible if there are two rainy seasons, or if there is enough moisture left in the soil to grow a second crop (Maass et al., 2010). (iii) Strip cropping, planting alternating strips of cereals and legumes. This involves planting broad strips of several crops in the field. On slopes, the strips can be laid out along the contour to prevent erosion (Szumigalski and Van Acker, 2008). The next year, the farmer can rotate crops by planting each strip with a different crop. Strip cropping has many of the advantages of intercropping: it produces a variety of crops, the legume improves soil fertility, and rotation helps reduce pest and weed problems (Ojiem et al., 2007). The residues from one strip can be used as soil cover for neighbouring strips. At the same time, strip cropping avoids some of the disadvantages of intercropping: managing the single crop within the strip is easy, and competition between the crops is reduced (Ojiem et al., 2007). (iv) Relay cropping involves planting cereals such as maize, wheat and millet and then sowing legumes between the cereals rows four weeks later (Matata, 2001; Yirzagla et al., 2013). This is growing one crop, and then planting another crop (usually a cover crop) in the same field before harvesting the first. This helps to avoid competition between the main crop and the intercrop. It also uses the field for a longer time, since the cover crop usually continues to grow after the main crop is harvested (Matata, 2001).

The crop rotations, intercropping, sequential, strip, relay cropping systems, reduced tillage, legume cover crops, adding manure and compost and fallow techniques are all proven and available practices to farmers (Bationo et al., 2007; Maass et al., 2010; Matata, 2001; Ojiem et al., 2007; Szumigalski and Van Acker, 2008). These practices make soils richer in organic matter, more able to hold soil moisture and reduce erosion, out of which biodiversity is increased in the system and all help in making farm production and income more resilient and stable (Onduru and Preez, 2007). Besides increasing stability and resilience to more droughts and/or floods in the near future, also contribute to climate change mitigation through sequestration of soil carbon (Rosenzweig and Tubiello, 2007).

The choice of the system could be a function of such factors as rainfall (amount, duration, and pattern) available land, available technology and types of crops needed for the system (Mbuya et al., 1988). In countries where crops are grown on ridges, the potential combination of planting patterns of two or more crops is relatively small (Matusso et al., 2014). However, where crops are planted on flat fields, the number of combinations can be quite large (Thayamini and Brintha, 2010), and the competition among crops can be complex, so too is the potential benefit from the associated crops. It has been observed in Tanzania and elsewhere that farmers may grow cereal and legumes, in the same row but different hills, both crops on the same row and at the same time one or more legume rows between two cereal rows (Mbuya et al., 1988). The smallholder farmers generally plant their intercrop crops randomly without any defined row arrangements, use variable relative planting times and also use low yielding varieties (especially cereals). This has resulted in lower component crop populations, difficulty in management, low crop yields and overall productivity of the systems. The traditional cropping systems are not stagnant, but innovation and change are normal features to accelerate its wide growth while maintaining the benefits inherent in stable systems. It is therefore, important to determine the effect of legume rows distance from cereal rows on the soil fertility improvement and yields of both crops.

CONCLUSION

Cereal/ legume cropping system have become one of the solutions for food security among smallholder cereal producers due to unaffordability of chemical nitrogenous fertilizers and limited access to arable land. On-farm nitrogen contributions as achieved largely through biological nitrogen fixation in cereal/ legume cropping systems have proved to increase nitrogen content in the soils. This review suggests that traditional practices such as the use of legumes as green manure, cover cropping, crop residues and the application of manure are keys to the benefits of increasing soil rich in organic matter, enhancing water infiltration, reduces soil erosion, reduces environmental pollution and make nutrients more accessible to the plant. These build a healthy soil and are a crucial element in helping farmers to cope with climate variability and enhance farm productivity and income more resilient and stable. Cropping systems have great potential to be more beneficial to agriculture in the future and thus receive more attention because of its more efficient use of environmental resources. Future research should focus on the amount of nitrogen and other soil nutrients added to the soils through cereal/ legume cropping systems. This would help better understanding of cropping systems that could lead to the increased adoption rates of these systems in the agricultural sector.

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