Potential Role of Maize-Legume Intercropping Systems to Improve Soil Fertility Status under Smallholder Farming Systems for Sustainable Agriculture in India

Ashish Dwivedi[1], Ista Dev[1], Vineet Kumar[1], Rajveer Singh Yadav[2], Mohit Yadav[3], Dileep Gupta[4], Adesh Singh[1], and S. S. Tomar[1]
[1] Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.), India
[2] Department of Agronomy, Mahatma Gandhi Chitrakoot Gramodaya Vishwa Vidyaliya, Chitrakoot, Santa (M.P.), India
[3] Department of Biochemical Engineering and Food Chemical, Harcourt Butler Technological Institute, Kanpur, (U.P.), India
[4] Department of Agriculture extension, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.), India
Email: ashishdwivedi842@gmail.com

Abstract—**The Indian population is growing rapidly (1.25 billion) and it has to fulfill its food and nutrition requirement. A collaborative strategy should be adopted for increasing productivity by intensifying available land use system. Intercropping is advanced management practices of soil fertility status, 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. The most common advantage of intercropping is the production of greater yield on a given piece of land by making more efficient use of the available resources using a mixture of crops of different rooting ability, canopy structure, height, and nutrient requirements based on the complementary utilization of growth resources by the component crops. Moreover, intercropping improves soil fertility through atmosphere nitrogen fixation from atmosphere (150 tons/year) with the use of legumes, increases soil conservation through greater ground cover than sole cropping. Also, intercropping systems are beneficial to the smallholder farmers in the low-input and/or high-risk environment of the sub-tropic, where intercropping of maize 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, improvement of soil fertility, weed, pests and diseases minimizing and balanced nutrition. However, intercropping has some disadvantages such as the selection of the appropriate crop species, including extra work in preparing and planting the seed mixture and also extra work during crop management practices, including harvest. This is a review paper covering the role of maize legume intercropping systems to improved soil fertility status under smallholder farms of semi-arid area of India. 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 atmosphere 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 (B:C) and monetary advantage index (MAI) are used to assess the system productivity and its economic benefits. In this study, the work carried out by researchers about different intercropping system is discussed, and it would be beneficial to the researchers who are involved in this field.**

Index Terms—**maize-legume, intercropping, improving soil fertility status, smallholder farmers, sustainable agriculture, LER, efficient utilization of resources**

I. Introduction

Maize (*Zea mays* L.) remains at third position among the cereals after rice and wheat across the globe. Maize is widely grown as cereal crop in many developing countries including India. Maize is considered as a staple food besides its other uses such as energy, etc. Even as, maize has a high yield potential and is suited to various climatic zones of India. Moreover, India is the fourth largest producer of maize which produces about 22.5 million tons from an area of 8.7 million hectares with an average productivity of 2586 kg/ha in 2012-13. Karnataka, Andhra Pradesh, Maharashtra, Tamil Nadu, Rajasthan and Uttar Pradesh together contribute about 60 per cent of area and 70 per cent of maize production in India [1].

Intercropping 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 [2]. The important reasons to grow two or more crops together are

Manuscript received April 23, 2015; revised June 26, 2015.

the increase in productivity per unit of land. In intercropping system, all the environmental resources utilized to maximize crop production per unit area per unit time. Risk may be minimized in intercropping [3]. Biological efficiency of intercropping gets improved due to exploration of large soil mass compared to monocropping [4]. This advanced agriculture techniques has been practiced in past decades and achieved the goal of agriculture. There are some socio economic, biological and ecological advantages [5], [6] in intercropping over monocropping. Intercropping can also referred to as mixed cropping or polyculture is the agricultural practice of cultivating two or more crops in the same space at the same time [2], [7], [8]. The component crops of an intercropping system neither necessarily have to be sown at the same time nor they have to be harvested at the same time, but they should be grown simultaneously for a great part of their growth periods. In intercropping, there is normally one main crop and one or more added crops, with the main crop being of primary importance for economic or food production reasons.

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 [9]. Furthermore, intercropping cereals with legumes have huge capacity to replenish soil mineral nitrogen through its ability to biologically fix atmospheric nitrogen [10].

II. Intercropping: Global Prospective

Various types of intercropping were known and presumably employed in ancient Greece about 300 B.C. Theophrastus, among the greatest early Greek philosophers and natural scientists, notes that wheat, barley, millets and certain pulses could be planted at various times during the growing season often integrated with vines and olives, indicating knowledge of the use of intercropping [11]. Traditional agriculture, as practiced through the centuries all around the world, has always included different forms of intercropping. 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 [12]. Now a day, intercropping is commonly used in many temperate, tropical and subtropical parts of the world particularly by small-scale traditional farmers [13]. Traditional multiple cropping systems are estimated to still provide as much as 16-22% of the world's food supply [14]. 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 [15].

III. Meaning and Scope of Intercropping Systems

The cropping system is defined as the combination of crops grown on a given area and time [16]. Intercropping system is a type of mixed cropping and defined as the agricultural practice of cultivating two or more than two crops in the same space at the same time [2], [17]. 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 [18], [19]. This is a common practice in India, and it is mostly practiced by smallholder famers. The features of an intercropping system differ with soil, climatic condition, economic situation and preferences of the local community [20].

Several scientists have been working with cereal-legume intercropping systems [21]-[29] and proved its success compared to the monocrops. One of the most important reasons for smallholder farmers to intercrop is to minimizing the risk against total crop failures and to get different produces to take for his family's food and income [7], [20], [30]. Moreover, intercropping systems more efficiently used the growth factors because they capture more radiation and make better use of the available water and nutrients, reduce pests, diseases incidence and suppress weeds and favour soil-physical conditions, particularly intercropping cereal and legume crops which also maintain and improve soil fertility [7] [31]-[34].

IV. Basic Principles and Practice of Maize-Legume Intercropping

The success of intercropping system have achieved by various aspects which are need to be taken into consideration before and during the cultivation process [9]. Singh *et al*. [35] Reported that intercropping of legume, particularly black gram with maize has been efficiently utilized the growth resources besides maintaining the soil health. 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 [7]. 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 [36]. For instance, Reddy and Reddi [37] reported that, in maize-green gram intercropping system, peak light demand for maize was around 60 days after planting, while greengram was ready to harvest.

A. Suitable Crops

Selection of the right crop combination is more important in intercropping systems due to the reason that competition of plant could be minimized not only by spatial arrangement, but also by combining those crops which have best able to exploit soil nutrients [38]. Intercropping of cereals and legumes would be valuable because the component crops can utilize different sources of N [39]-[41]. 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 down the maize yields, while cowpeas *(Vigna sinensis)and* greengram *(Phaseolus aureus)* had much less effect on maize and where themselves tolerant to maize shade [42]. maize-bean intercrop is predominant in eastern Africa, and whilst in southern Africa maize is intercropped with cowpeas, groundnuts and bamabara nuts.

B. Time of Sowing

Several findings have proved the effects of the planting time on the performance of the components under intercrop. For instance, Mongi, Uriyo, and Singh [43] reported that planting cowpea simultaneously with maize gave batter yield. Barbosa, Lima, Oliveira and Sousa [44] reported that intercropping corn with cowpea, especially when done early, provides intermediate results, indicating that cowpea controls weeds to a certain extent. Addo-Quaye, Darkwa and Ocloo [45] 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.

V. Advantages of Intercropping

A. Efficient Utilization of Resource and Yield Advantage

The principal advantage of intercropping is the more efficient utilization of the all available resources and the increased productivity compared with each sole crop of the mixture [46]-[56]. An alternative to yield for assessing the advantages of intercropping is to use units such as monetary units or nutritional values which may be equally applied to component crops [57]. Yield advantage occurs because growth resources such as light, water, and nutrients are more efficiently absorbed and converted into crop biomass by the intercrop over time and space as a result of differences in competitive ability for growth resources between the component crops, which exploit the variation of the mixed crops in characteristics such as rates of canopy development, final canopy size (width and height), photosynthetic adaptation of canopies to irradiance conditions, and rooting depth [58, 59, 60]. Regularly intercropped pigeonpea or cowpea can help to maintain maize yield to some extent when maize is grown without mineral fertilizer on sandy soils in sub-humid zones of Zimbabwe [24]. Intercropping maize with cowpea has been reported to increase light interception in the intercrops, reduce water evaporation, and improve conservation of the soil moisture compared with maize grown alone [61]. In ecological terms, resource complementarity minimizes the niche overlap and the competition between crop species, and allow to crops to capture a greater range of resources than the sole crops. Improved resource use gives in most cases a significant yield advantage, increases the uptake of other nutrients such as N, P, K, and micronutrients, and provides better rooting ability and better cover-up ground as well as higher water use efficiency [58], [59]. Shivay and Singh [62] assumed that grain yield significantly increased due to intercropping and the highest grain yield (32.48 q/ha) was recorded in maize+urdbean intercropping system. Pandey *et al.* [63] studied the effect of rainfed maize (*Zea mays* L.) based intercropping systems on maize yield and observed that intercropping systems reduced the values of grain yield of maize than sole cropping of maize, but significant reduction in grain yield was recorded only with sesame, turmeric, and forage intercropping systems. However all intercropping systems resulted into significantly higher productivity. However, Pathak and Singh [64] observed that the grain yield of maize was not significantly influenced by the different intercropping treatments at Pantnagar. Thus, selection of crops that differ in competitive ability in time or space is essential for an efficient intercropping system as well as decisions on when to plant and at what density. Several researches have shown that intercrops are most productive when component crops differ greatly in growth duration [65]-[67]. For example, when a long-duration pigeonpea cultivar was grown in mixture with three cereal crops of different growth durations, i.e. setaria, pearl millet, and sorghum, the Land Equivalent Ratio was highest with the quick-maturing setaria and lowest with the slow-maturing sorghum (Rao and Willey, 1980) [68]. It must be noted here that Land Equivalent Ratio shows the efficiency of intercropping for using the environmental resources compared with monocropping with the value of unity to be the critical value. When the Land Equivalent Ratio is greater than one (unity) the intercropping favours the growth and yield of the species, whereas when the Land Equivalent Ratio is lower than one the intercropping negatively affects the growth and yield of the plants grown in mixtures [46]. Asynchrony in resource demand ensures that the late- maturing crop can recover from possible damage caused by a quick-maturing crop component and the available resources, e.g. radiation capture over time, are used thoroughly until the end of the growing season [67]. Moreover, when the component crops have similar growth durations their peak requirements for growth factor normally occur about the same time and the competition for environments where water stress occurs. Combinations involving crops with slightly differing growth duration, e.g. millet and sorghum or mixtures of early and late maturing variety of the same species are used in areas with growing seasons of variable-length to exploit the occasional favorable season yet insure against total failure in unfavorable seasons [69]. Differing growing seasons may thus lead to reversals of success in such intercrops, giving more stable yield in intercropping when measured over a run of seasons. If the growing season is long, the late-maturing benefit by abundant resources, whereas if the growing season is short, the early-maturing type can provide a reasonable yield.

B. Insurance Against Crop Failure

One important reason for which intercropping is popular in the developing world is that it is more stable than monocropping [33]. From this point of view, intercropping provides high insurance against crop failure, especially in areas subject to extreme weather conditions such as frost, drought, flood, and overall provides greater financial stability for farmers, making the system particularly suitable for labor-intensive small farms. Thus, if a single crop may often fail because of adverse conditions such as frost, drought, flood, or even pest attack, farmers reduce their risk for total crop failure by growing more than one crop in their small farm [70]. Consequently, intercropping is much less risky than monocropping considering that if one crop of a mixture fails, the component crops may still be harvested. Data from 94 experiments on mixed cropping sorghum/pigeonpea showed that for a particular 'disaster' level quoted, sole pigeonpea crop would fail 1 year in 5, sole sorghum crop would fail 1 year in 8, but intercropping would fail only 1year in 36 [68]. The stability under intercropping can be attributed to the partial restoration of diversity that is lost under monocropping. Moreover, small farmers may be better able to cope with seasonal price variability of commodities which often can destabilize their income. For example, if the market price may be low favorable for one crop than for others, farmers may be able to benefit from good prices and may suffer less due to poor prices for particular crops, if they grow more crops. Intercropping maize with beans reduced nutrient decline and raised household incomes compared with monocropping of either of the two crops [71]. In semi-arid environments, yield increases from intercropping have been reported in several studies during the past 20 year. On the basis of these studies, intercropping has been found to increase crop yield and improve yield stability in environments where water stress are more common. Combinations involving crops with slightly differing growth duration, e.g. millet and sorghum or mixtures of early- and late-maturing cultivars of the same species are used in areas with growing seasons of variable-length to exploit the occasional favourable season yet insure against total failure in unfavourable seasons [69] . On an average, late-maturing variety of groundnut and sorghum gave higher dry pod and grain yield, respectively, when intercropped with early-maturing cultivars of the associated crops [72].

C. *Conservation of Soil*

Intercropping of cereal with legumes is an excellent practice for reducing soil erosion and sustaining crop production. Where rainfall is excessive, cropping management systems that leave the soil bare for great part of the season may permit excessive soil erosion and runoff, resulting in infertile soils with poor characteristics for crop production. Moreover, deep roots penetrate more breaking up hardpans into the soil and utilize moisture and nutrients from deeper down in the soil. Shallow roots bind the soil particle at the surface and thereby help to reduce erosion. Also, shallow roots help to aerate the soil which increase water holding. Reduced runoff and soil loss were observed in intercrops of legumes with cassava [73]. 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 [9]. Kariaga [74] mention that in maize + cowpea intercropping system, cowpea act as best cover crop and reduced soil erosion than maize-bean system. Reddy and Reddi [37] found that tall crops act as wind barrier for short crops, in intercrops of tall cereals with short legume crops. Similarly, sorghum-cowpea intercropping reduced runoff by 20-30% compared with sorghum sole crop and by 45-55% compared with cowpea monoculture. Moreover, soil loss was reduced with intercropping by more than 50% compared with sorghum and cowpea monocropping.

TABLE I. TOTAL LOSSES OF THE SOIL AS TRANSPORTATION, DEPOSITION AND LOST INTO THE SEA

Parameter	Erosion (MT)	Per cent
Total soil loss	5334	100
Transported from one place	3282	61
Deposited in the reservoirs	480	10
Lost into the sea	1572	29

Source: Lemlem [75]

D. *Improvement of Soil Fertility*

Legumes enrich soil by fixing the atmospheric nitrogen converting it from an inorganic form to forms that are available for plants uptake. Biological fixation of atmospheric nitrogen can replace nitrogen fertilization wholly or in part. Biological nitrogen fixation is the major source of nitrogen in legume-cereal mixed cropping systems when nitrogen fertilizer is limited [76]. Moreover, because inorganic fertilizers have much environmental damage such as nitrate pollution, legumes grown in intercropping are regarded as a sustainable and alternative way of introducing N into lower input agro ecosystems [77]. In addition, roots of the legume component can decompose and release nitrogen into the soil where it made available to subsequent crops. [78]. Intercropping corn with legumes was far more effective than corn sole to produce higher dry matter yield and roughage for silage with better quality [79]. Also, intercropping common bean with corn in 2 row-replacements improved silage yield and protein content of forage compared with sole crops [80]. The dry matter yield, crude protein yield, and ash content of maize forage increased by intercropping with legumes compared with maize monoculture [81]. Furthermore, intercropping legumes with maize significantly reduced neutral detergent fiber and acid detergent fiber content, increasing digestibility of the forage. It is evident from the above that intercrops of maize with legumes can substantially increase forage quantity and quality and decrease the requirements for protein supplements compared with maize sole crops [81]. Maize and cowpea intercrops gave higher total forage dry matter digestibility than maize or cowpea sole crops and led to increased forage quality (crude protein and dry matter digestibility concentration) than maize monoculture and higher water-soluble carbohydrate concentrations than sole cowpea [82].

E. Atmospheric Nitrogen Fixation (ANF) and Transfer of Nitrogen to Main Crop

ANF, which enables legumes to depend on atmospheric nitrogen, is important in legume-based cropping systems when fertilizer-Nitrogen is limited [83], where nitrogen annual depletion was recorded at all levels at rates of 22 kg/ha [84] and mineral-Nitrogen fertilization is neither available nor affordable to smallholder farmers [85], [86]. ANF contributes Nitrogen for legume growth and grain production under different environmental and soil conditions. In addition, the soil may be replenished with Nitrogen by decomposition of legume residues [83]. Legumes species commonly used for provision of grain and green manure have potential to fix between 100 and 300 kg Nitrogen/ha from the atmosphere. Osunde, Tsado, Bala, and Sanginga, [87] observed that the proportion of Nitrogen derived from atmosphere fixation was about 40 percent in the intercropped soybean and 30 percent in the sole crop without the addition of fertilizer. Sanginga *et al.* [88] Reported that Mucuna accumulated in 12 weeks about 160 kg Nitrogen ha when intercropped with maize. Eaglesham, Ayanaba, Ranga Rao, and Eskew [89] reported that the fixed-N by component cowpea was about 41 kg Nitrogen ha, in maize- cowpea intercropping system.

According to Ofori and Stern [7] the amount of Nitrogen fixed by the legume component in cereal-legume intercropping systems depends on several factors, such as species, plant morphology, density of component crops, rooting ability, type of management, and competitive abilities of the component crops. Nambiar *et al.* [90] found that shading did not affect Nitrogen fixation by the component groundnut crop although incoming light reaching the legume was reduced 33.3 percent. While, when 50.0 kg Nitrogen ha was applied, ANF was reduced 55.2 percent, although light reaching the groundnut was 54.5 percent of incoming radiation. This suggests that heavy application of combined N significantly reduces BNF, which was confirmed by Ofori and Stern [7] who evaluated the Nitrogen economy of a maize+cowpea intercropping system and considered that Nitrogen fertilizer applications reduced Nitrogen fixation. Fujita *et al.* [76] On the other hand, reported that the soil with a relatively high Nitrogen content (high organic carbon) the mixed cropping yield increased by 25.0 percent due to enhanced soil Nitrogen uptake by the sorghum component, while the soybean component depended mostly on ANF. Still according Fujita *et al.* [76] the plant density has little effect on quantity of Nitrogen derived from the nitrogen fixation and the ANF of the legume is not always reduced, but is dependent on the legume's ability to intercept light. Mandimba [91] revealed that groundnut nitrogen contribution to the growth of *Zea mays* in intercropping systems is equivalent to the application of 96.0 kg of Nitrogen fertilizer/ha at a ratio of plant population densities of four groundnut plants to one maize plant. Despite the fact that annual fixation rates of 300 kg Nitrogen/ha, the amount measured on farmer’s fields are still very low (6 kg Nitrogen/ha to 80 kg Nitrogen/ha), except soybean which fixed between 100 and 260 kg Nitrogen/ha within periods of three months [92]. Beside this, it has been reported that seeds of component crops are the major source of Nitrogen loss from the intercropping system and can range from 50 to 150 kg Nitrogen/ha.. This Nitrogen transfer is considered to occur through root excretion, Nitrogen leached from leaves, leaf fall, and animal excreta if present in the system [76]. The benefits of a legume intercrop with respect to nitrogen are direct transfer of nitrogen from (Pisum sativum ssp. arvense) resulted in values of Land Equivalent Ratio ranging from 1.05 to 1.24 on a biomass basis and from 1.05 to 1.26 on a protein basis indicating a production advantage of intercropping [93], known as direct Nitrogen transfer Eaglesham *et al.* [89]. He also showed that 24.9 percent of Nitrogen fixed by cowpea was transferred to maize. Despite claims for substantial Nitrogen transfer from grain legumes to the associated cereal crops, the evidence indicate that benefits are limited [94]. 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 [95]. However, Ofori and Stern [7] and Danso, Hardarson, and Zapata [96] reported that there is little or no current Nitrogen transfer in cereal-legume intercropping system. In addition, Fujita *et al.* [76] 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.

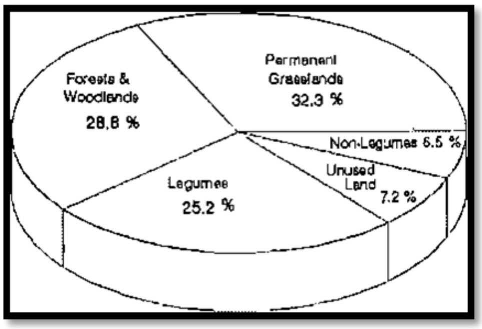

Figure 1. Distribution of 139 million tonnes of N2 estimated to be biologically fixed in various terrestrial systems.

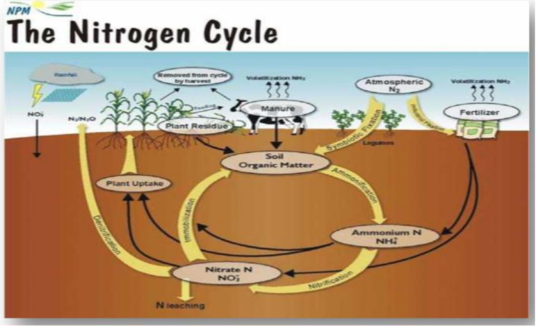

Figure 2. Nitrogen cycle under the atmospheric nitrogen fixation

Figure 3. Observation recording in the Maize + legume trial carryout in S.V.P.U.A & T Meerut Uttar Pradesh

Figure 4. Nodulation study in the Maize + legume trial carryout in S.V.P.U.A & T Meerut Uttar Pradesh

Figure 5. Weed and Pest problem in the Maize + legume trial carryout in S.V.P.U.A & T Meerut Uttar Pradesh

TABLE II. EXAMPLES OF ESTIMATES RANGE OF NITROGEN FIXATION BY SOME LEGUMES

Crop	Nitrogen fixation kg/ha
Alfalfa	100-300
Black gram	119-140
Clover '	100-150
Chickpea	23-97
Cluster bean	37-196
Common bean	Nill
Cowpea	*9*-125
Groundnut	27-206
Lentle	35-100
Greengram	50-56
Pigeonpea	4-200
Rice bean	32-97
Soybean	49-450
Peas	46
Fenugreek	44

Sources: Mugwe *et al*. [85]

F. *Promotion of Biodiversity*

Intercropping of compatible plants promotes biodiversity by providing a habitat for a variety of insects and soil organisms that would not be present in a single crop environment. Stable natural systems are typically diverse, containing numerous different kinds of plant species, arthropods, mammals, birds, and microorganisms. As a result, in stable systems, serious pest outbreaks are rare because natural pest control can automatically bring populations back into balance [97]. Therefore, on-farm biodiversity can lead to agroecosystems capable of maintaining their own soil fertility, regulating natural protection against pests, and sustaining productivity [98, 99], from this point of view, crop mixtures which increase farmscape biodiversity can make crop ecosystems more stable and thereby reduce pest incidence problems. Increasing the complexity of the crop environment through intercropping also limits the places where pests can find optimal foraging or reproductive conditions. Intercropping is one way of introducing more biodiversity into agro ecosystems and results from intercropping studies indicate that increased crop diversity may increase the number of ecosystem services provided. Higher species richness may be associated with nutrient cycling characteristics that often can regulate soil fertility [100], limit nutrient leaching losses [101], and significantly reduce the negative impacts of pests (Bannon and Cooke, [102]; Boudreau and Mundt, [103] also including that of weeds [104], [105].

G. *Weed Control*

It is often believed that traditional intercropping systems are better in weeds control compared to the modern monocrops, but it must be known that intercropping is an almost often infinitely complex, and variable system in which adverse effects can also occur. Weed growth basically depends on the competitive ability of the entire crop community, which in intercropping largely depends on the competitive abilities of the component crops and their respective plant populations [34]. Weed control is an important view in intercropping because chemical control is difficult when the crops have emerged. This is also because normally in intercropping a dicotyledonous crop species is combined with a monocotyledonous crop species and therefore the use of herbicides is harmful. In general, intercrops may show weed control advantages over sole crops in two ways. First, suppressing the growth of weeds through allelopathy or greater crop yield and less weed growth may be achieved if intercrops are more effective than sole crops in usurping resources from weeds [106]. Moreover, intercrops may provide yield advantages without suppressing the growth of weeds below levels observed in sole crops if intercrops use resources that are not exploitable by weeds or convert resources into harvestable materials more efficiently than sole crops. Intercropping may often result in reduced weed density and growth compared with sole crops [105]. Intercrops that are effective at suppressing weeds capture a greater share of available resources than sole crops and can be more effective in pre-empting resources by weeds and suppressing weed growth. Intercrops of sorghum with fodder cowpea intercepted more light, captured greater quantities of macronutrients N, P, and K, produced higher crop yields, and contained lower weed densities and less weed dry matter compared with sole-cropped sorghum [107]. Intercropping leek and celery in a row replacement design considerably lowering the critical period for weed control in the intercrop compared with the leek pure stand. Also, the relative soil cover of weeds that emerged at the end of the critical period in the intercrop was reduced by 41% [108]. Pea intercrops with barley had greater competitive ability towards weeds as compare to sole crop in cropping systems under high weed pressures [104]. Similarly, intercropping such as wheat-canola-pea tended to provide maximum weed suppression compared to crops grown alone, indicating some type of synergism among crops within intercrops with respect to weed suppression [109].

Mixed cropping of peas with false flax in additive series had a great suppressive effect on weed coverage, i.e. 63% in 2003 and 52% in 2004, compared with pea grown alone [110]. Intercropping single, double and strip (3:3) rows of sorghum, soybean, and sesame with cotton was advantageous in chacking purple nut sedge density (75-90 %) and dry matter production (76-92 %) [111]. Farmers reported that intercropping maize with improved varieties of horsegram (Macrotyloma uniflorum) reduced labour since less weeding was required and, in most cases, did not have a yield-reducing impact on their maize crop or on the availability of fodder [112]. Recently, it was reported that intercropping maize with legumes considerably reduced weed density in the intercrop compared with maize pure stand due to decrease in the available light for weeds in the maize-legume intercrops, which led to a reduction of weed density and weed dry matter compared them with sole crops [113].

Mashingaidze [114] found that maize- bean intercropping reduced weed biomass by 55-66 percent when established at a density of 222,000 plants/ha for beans equivalent to 33 percent of the maize density (37,000 plants/ha). Weed suppression in maize-groundnut intercropping was reported by Steiner [20], for instance, intercropping of cereals and cowpea has been observed to reduce striga infestation significantly [115]. Similarly, finger millet (Eleusine coracana) intercropped with greenleaf desmodium (Desmodium intortum) reduced Striga hermonthica counts in the intercrops than in the monocrops [116]. This was attributed to the soil cover of cowpea that created unfavorable conditions for striga germination [117], [118]. Other studies where intercropping systems were used as an integrated weed management tool reported the same results [119], [120].

H. Role in Minimize Pest and Disease Incidence

A review of 150 published field studies in which 198 herbivore species were studied showed that 53% of the pest species were less abundant in the intercrop, 18% were more abundant in the intercrop, 9% showed no significant difference, and 20% showed a variable response [121]. An important role of intercropping systems is their ability to reduce the incidence of pests and diseases. However, this is a very complex aspect and both beneficial and detrimental impact has been observed. Infect, sole crops are often more damaged by various pest and disease organisms than when grown as, components of intercrops but the effectiveness of this escape from attack often varies unpredictably [66].

Crops grown as intercropping enhance the abundance of predators and parasites, which in turn prevent the build-up of pests and disease, thus minimizing the need of using expensive and dangerous chemical insecticides and fungicide. Mixed crop species can also delay the introduction of diseases by reducing the spread of disease carrying spores and by modifying environmental conditions so that they are less favorable to the spread of certain pathogens. The worsening of most insect problems has been associated with the expansion of monocropping at the expense of the natural vegetation, thereby decreasing local habitat diversity. Results from 209 studies involving 287 pest species were analyzed [122]. Compared with monocultures, the population of pest insects was lower in 52% of the studies, i.e. 149 species and higher in 15% of the studies, i.e. 44 species. Of the 149 pest species with lower populations in intercrops, 60% were zoophagous and 28% polyphagous. The population of natural enemies of pests and disease were higher in the intercrop in 53.6 % and lower in 9.0 %. Thus, the simplification of intercropping systems can affect the abundance and efficiency of the natural enemies or predators, which depend on habitat complexity for resources. Compared with a monoculture, adding more plant species to a cropping system can affect herbivores in two ways. Firstly, the environment of the host plants, e.g. neighboring plants and microclimatic conditions, is changed and secondly, the host plant quality, e.g. morphology and chemical content, is altered [123]. Changes in environment and host plant quality lead to direct effects on the host plant searching behavior of herbivorous insects as well as indirect effects on their developmental rates and on interactions with natural enemies. Mixed cropping of cowpeas with maize reduced significantly the population density and activity of legume flower bud thrips (Megalurothrips sjostedti) compared with sole cowpea crop [124]. Similar results were also reported with intercrops of beans, cowpea, and maize, where the reduced pest incidence was attributed to the increased populations of natural enemies favoured by intercropping [125]. However, the simultaneous effect on both the environment and the quality may complicate comparisons between systems as several mechanisms can affect herbivorous insects [126]. Black aphid (Aphis fabae) infestation of beans was greatly reduced when beans intercropped with older and taller maize plants [127]. There was significantly lower population of insects on the cowpea crop when grown in mixture with maize at specific ratios than in monoculture [128]. Intercropping maize with groundnut, soybean, and common beans reduced significantly termite attack consequent loss in grain yield of maize compared with maize as sole crop, whereas it increased the predatory ants in maize fields. Also, groundnut and soybean were more effective in suppressing termite attack than common beans, suggesting the necessity to identify suitable legumes for each intercropping situation [129]. Intercropping upland rice with groundnut at low and medium populations of groundnut resulted in lower stem borer (Chilo zacconius) and green stink bug (Nezara viridula) infestations in rice compared with rice monoculture [130]. Also, intercropping cowpea with cotton proved the best in suppressing the population of whiteflies and thrips, produced high yield, and *on par* with the intercrops of cotton with marigold and cotton with sorghum [131]. Intercropping sugar bean between the sugarcane rows reduced nematode infestation when compared with a standard aldicarb (nematicide) monocrop treatment and an untreated control [132]. Turnip root fly (Delia floralis) oviposition was found to be lower in a clover-cabbage intercrop compared with the monocultures and the reduction in the number of D. floralis pupae in intercropping could be explained by a disruption in the oviposition behaviour caused by the presence of clover because predation or parasitization rates did not differ between cultivation systems [133]. Intercropping has been shown to be an effective disease management tool. Also, variety mixtures provides functional diversity that limits pathogen and pest expansion due to differential adaptation, i.e. adaptation within races to specific host genotypic backgrounds, which may prevent the rapid evolution of complex pathotypes in mixtures [134]. Trenbath [66] proposed three principles to explain yield of intercrops. The productivity of an attacked crop component may be increased several-fold through intercropping. The influence of attack on the LER is positive where escape occurs, especially if two or more components each escape from their own specific attacker. Use of symptomless carriers of disease can lead to low LER values. Several examples have shown that intercropping can reduce considerably the incidence of various diseases by limiting the spread of carrying spores through certain modification of environmental conditions so that they become less favorable for the spread of certain pathogens. For example, intercropping potato with maize or haricot beans has been reported to reduce the incidence and the rate of bacterial Pseudomonas solanacearum development in potato crop [135]. A mixture of wheat and black medic (Medicago lupulina) reduced the incidence of take-all disease (Gaeumannomyces graminis) of wheat, a soilborne pathogen [136]. Common bacterial blight incidence levels were reduced in mixed cropping by an average of 23.5 % and 5.0 % than with sole cropping and row intercropping, respectively, whereas intercropping reduced rust incidence levels by an average of 51.0 % and 25.0 % relative to sole cropping and row intercropping, respectively. It was also found that when pea was intercropped with barley, the level of ascochyta blight (Ascochyta pisi) was reduced and also net blotch (Pyrenophora teres), brown rust (Puccinia recondita), and powdery mildew (Blumeria graminis), in order of incidence, on barley during the period between flag leaf emergence and heading were reduced in every intercrop combination than with barley monocrop [137]. Dual mixtures of grain legumes such as pea, faba bean, and lupin with barley reduced the disease incidence compared with the corresponding sole crops, with a general disease reduction in the range of 20-40% [138]. Ascochyta blight (Mycosphaerella pinodes) severity on pea was substantially reduced in pea- cereal intercrop compared to the pea monocrop when the epidemic was moderate to severe and the disease reduction was partially explained by a modification of the microclimate within the canopy of the intercrop, in particular, a reduction in leaf wetness duration during and after flowering [139]. Climbing genotypes of common beans most susceptible to angular leaf spot (Phaeoisariopsis griseola) had less diseased pods in the bean intercrop with maize than in the monocrop and also anthracnose (Colletotrichum lindemuthianum) on pods of a susceptible bean cultivar was less intense in the intercrop with maize than in the sole crop [140].

VI. Intercropping Productivity

Intercropping treatments gave higher pigeonpea equivalent yield than the sole crop. The pigeonpea+sesame gave the highest pigeon pea equivalent yield (1.97 t/ha) and the land equivalent ratio (1.89). 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 [141]. For instance, using LER in a maize-soybean intercropping system, Kipkemoi *et al.*, [142] reported that it was greater than one under intercrop. Productivity of the intercropping system indicated yield advantage of 263 percent as depicted by the LER 0f 1.02-1.63 showing efficient utilization of land resource by growing the crops together. Raji [143] had also reported of higher production efficiency in maize-soybean intercropping systems. Addo-Quaye, Darkwa, and Ocloo [21] 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 [144] observed LER of 1.22 and 1.10 for maize-soybean intercrop in two consecutive years. Samba, Coulibay, Kone, Bagayoko and Kouyate [145] found that the pearl millet-cowpea intercropping was more productive than their monocrops, what was proved through the LER of 1.2. Osman, R^bild, LERs were always larger than unity indicating benefits of intercropping over sole cropping of millet and millet. Abera, Feyissa and Yusuf [26] 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 Pathak and Singh [64] reported that the intercropping of urdbean recorded significantly higher land equivalent ratio (LER) Pant U 19 and NU 1 recorded the highest LER (1.37) in 1:1 ratio, whereas UPU 97-10 in 2:1 ratio recorded the lowest value (1.18).

TABLE III. LER FOR SOLE MAIZE, MAIZE+LABLAB AND MAIZE+COWPEA INTERCROPPING

Levels	LER
Maize-cowpea (MC)	1.71
Maize- lablab (ML)	1.65
Maize sole	1
SE	0.009
CV%	2.7
LSD (P<0.01)	0.0.29

Source: Lemlem [75]

VII. ECONOMIC BENEFITS OF CEREAL-LEGUME INTERCROPPING SYSTEMS

According to Seran and Brintha [9] the intercropping system gave higher cash return to smallholder farmers than growing as the monocrops. Gunasena *et al.* [146] studying maize-soybean intercropping system, found that the gross economic returns were increased by the intercropping. Mucheru-Muna *et al.* [23], using benefit cost ratio, found that the MBILI system with beans as the intercrop resulted in 40.0 percent higher net benefits relative to the traditional 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 [147] mentioned that maize-cowpea intercropping was found to be profitable than their sole crops. On the other hand, using monetary advantage index (MAI), Osman *et al.* [148] reported that intercropping with 2 rows of cowpea and 1 row of millet gave significantly higher economic return than mixture with one row of each of the crops. Using the same MAI, increase the income for smallholder farmers, and compensate losses due to uneven condition. Oseni [149] found that intercropping with 2 rows of sorghum and 1 row of cowpea gave higher economic benefits compared to the other planting arrangements and the sole crops. These results suggest that intercropping could improve the system's productivity, [148]. Intercropping could enhance total productivity of the system with low input investment by changing planting population and configuration [150]. Ullah *et al.* [151] found that soybean+maize in 90 cm spaced double row strips gave maximum maize grain equivalent yield and maximum land equivalent ratio). Similarly all intercropping systems gave substantially higher net income over mono-cropping with highest net income (Rs. 56043.50/ha) in case of maize+soybean followed by sole crop of maize (Rs. 52654 /ha). Dhima *et al*. [50] found bean+oat (65:35) and bean+wheat (55:45) as the most profitable intercropping system with higher intercropping advantages.

Despite the benefits of cereal-legumes intercropping systems in SFS, there are some limitation that need to be solved so as to attain progress [22], [152], [153]. For instance, in some of countries within the region the soils are acidic with limited phosphorus availability [154], which is harmful for ANF process and therefore lessen the N contribution of the legume component to system [10]. This is worsened by the current use of mineral fertilizers is still far-low among smallholder farmers [155], which is associated to accessibility and affordability of appropriate fertilizer. Lack of access to improved seed on time of sowing to these farmers, which is associated to poor market and policy are also contributing negatively to the successful contribution of these systems [152]. Moreover, legume cover crops and legume trees have been repeatedly demonstrated to improve and maintain soil fertility status under different environmental conditions, compared to grain legumes intercropping systems [152]. However, they have increasingly emerged as the least prioritized by smallholder farmers under their prevailing condition, which can be largely attributed to their lack of short-term benefits of both food and income [152], [160]. 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 [152], [160], which is worsened by low know how of extension services on legume-based ISFS technologies. Consequently, there are misconceptions among smallholder farmers about the role of legumes in the soil fertility management [161].

VIII. CONCLUSIONS

Research on maize-legume intercropping systems in India has shown advantage in both soil fertility and crop yields, particularly for cereal crop which is the staple food crop for smallholder farmers, beside its other advantage for soil conservation, minimizing incidence of pest and disease and insurance against crop failure,. However, lack of participatory approaches and fragmentation of land under farmer's conditions, mainly the inclusion of resource-less farmers, could not allow easy adoption by these smallholders. Moreover, most of the studies that have been done on maize-legume intercropping systems were focused on maize yields, which 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 research that involves smallholder farmers for sustainable. Also, there is need for proper handle of several issues of accessibility and affordability of improving economic status of smallholder farmer.

REFERENCES

[1] Agricultural Statistics at a Glance. (2013). Ministry of Agriculture. [Online]. pp. 46-53. Available: http://*www.cimmet.nic.in*.

[2] D. J. Andrew and A. H. Kassam, "The importance of multiple cropping in increasing world food supplies," in *Multiple Cropping*, R. I. Papendick, A. Sanchez, and G. B. Triplett, Eds., Madison, Wi., USA: American Society Agronomy, 1976, pp. 1-10.

[3] J. Woolley and J. H. C. Davis, "The agronomy of intercropping with beans," in *Common Beans: Research for Crop Improvement*, A. Van Schoonhoven and O. Voyese, Eds., Wallingford, 1991, pp. 707-735.

[4] C. A. Francis, "Biological efficiency in multiple cropping systems," *Adv. Agro.*, vol. 42, pp. 1-42, 1989.

[5] P. K. Aggarwal, S. P. Garrity, D. P. Liboon, and R. A. Morris, "Resource use and plant interactions in a rice mungbean intercrop," *Agron. J.*, vol. 84, pp. 71-78, 1992.

[6] C. Fininsa, "Effect of intercropping bean with maize on bean common bacterial blight and rust diseases," *Int J Pest Manag*, vol. 42, pp. 51-54, 1996.

[7] F. Ofori and W. R. Stern, "Cereal-legume intercropping systems," *Adv Agron*, vol. 41, pp. 41-90, 1987.

[8] L. Anil, J. Park, R. H. Phipps, and F. A. Miller, "Temperate intercropping of cereals for forage: A review of the potential for growth and utilization with particular reference to the UK," *Grass Forage Sci*., vol. 53, pp. 301-317, 1998.

[9] T. H. Seran and I. Brintha. "Review on maize based intercropping," *Journal of Agronomy*, vol. 9, no. 3, pp. 135-145, 2010.

[10] K. E. Giller, *Nitrogen Fixation in Tropical Cropping Systems*, 2nd Ed., CABI, Wallingford, p. 423, 2001.

[11] V. P. Papanastasis, M. Arianoutsou, and G. Lyrintzis, "Management of biotic resources in ancient Greece," in *Proc. 10th Mediterranean Ecosystems (MEDECOS) Conference*, Rhodes, Greece, vol. 25, April-01 May 2004, pp. 1-11.

[12] D. L. Plucknett and N. J. H. Smith, "Historical perspectives on multiple cropping," in *Multiple Cropping Systems*, C. A. Francis, Ed., New York, USA: MacMillan Publishing Company, 1986.

[13] M. A. Altieri, "Traditional farming in Latin America," *The Ecologist*, vol. 21, pp. 93-96, 1991.

[14] M. A. Altieri, "The ecological role of biodiversity in agroecosystems," *Agr Ecosyst Environ*, vol. 74, pp. 19-31, 1999.

[15] C. A. Francis, "Distribution and importance of multiple cropping," in *Multiple Cropping Systems*, C. A. Francis, ed., New York, USA: MacMillan Publishing Company, 1986.

[16] M. S. Reddy, C. N. Floyd, and R. W. Willey, "Groundnut in intercropping systems," in *Proc International Workshop on Groundnuts*, India, October 13-17, 1980.

[17] P. A. Sanchez, *Properties and Management of Soils in the Tropics*, New York: Wiley, 1976, pp. 478-532.

[18] W. C. Beets, *Multiple Cropping and Tropical Farming Systems*, Boulder: Westview Press, 1982, p. 156.

[19] D. J. Rees, "Crop growth, development and yield in semi-arid conditions in Botswana. II. The effects of intercropping sorghum bicolor with vigna unguiculata," *Experimental Agriculture*, vol. 22, pp. 169-177, 1986.

[20] K. G. Steiner, "Intercropping in tropical smallholder agriculture with special reference to West Africa," *Schriftenreihe der GT2, N. 137*, Eischbon, Germany, 1982.

[21] A. A. Addo-Quaye, A. A. Darkwa, and G. K. Ocloo, "Yield and productivity of component crops in a maize-soybean intercropping system as affected by time of planting and spatial arrangement," *J. Agric. Biol. Sci.*, vol. 6, no. 9, pp. 50-57, 2011.

[22] M. Odendo, A. Bationo, and S. Kimani, "Socio-economic contribution of legumes to livelihoods in sub-Saharan Africa," in, *Fighting Poverty in Sub-Saharan Africa: The Multiple Roles of Legumes in Integrated Soil Fertility Management*, Springer Science+Business Media B. V., 2011, pp 27-46.

[23] M. Mucheru-Muna, P. Pypers, D. Mugendi, J. Kung'u, J. Mugwe, *et al*., "A staggered maize- legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of Central Kenya," *Field Crops Res*, vol. 115, pp. 132-139, 2010.

[24] S. R. Waddington, M. Mekuria, S. Siziba, and J. Karigwindi, "Long-term yield sustainability and financial returns from grain legume-maize intercrops on a sandy soil in sub-humid north central Zimbabwe, *Exp. Agric.* vol. 43, pp. 489-503, 2007.

[25] O. N. Adeniyan, S. R. Akande, M. O. Balogun, and J. O. Saka, "Evaluation of crop yield of african yam bean, maize and kenaf under intercropping systems," *Am-Eur J. Agric. Environ. Sci.*, vol. 2, no. 1, pp. 99-102, 2007.

[26] T. Abera, D. Feyissa, and H. Yusuf, "Effects of inorganic and organic fertilizers on grain yield of maize-climbing bean intercropping and soil fertility in Western Oromiya, Ethiopia," in *Proc. Conference on International Agricultural Research for Development*, October 11-13, 2005.

[27] K. W. Ndung'u, T. Kwambai, J. Barkutwo, E. Wanjekeche, J. Mulati, *et al.*, "Effect of different spatial arrangements on yield of maize and different bean varieties in North Rift Kenya," *Kenyan Agriculture Research Institute*, Unpublished Paper, 2005.

[28] V. H. Kambabe and R. Mkandawire, "The effect of pigeonpea intercropping and inorganic fertilizer management on drought and low nitrogen tolerant maize varieties in Malawi," in *Maize Agronomy Research Report*, W. D. Sakala and V. H. Kabambe, Ed., 2003, pp. 7-13.

[29] A. W. Nzabi, F. Makini, M. Onyango, N. Kidula, C. Muyonga, *et al.*, "Effect of organic and inorganic fertilisers on maize yield and soil fertility improvement in kisii and Gucha Districts, South West Kenya," *Kenyan Agriculture Research Institute*, Unpublished Paper, 1998.

[30] P. Sullivan. (2003). Intercropping Principles and Production Practices. Appropriate Technology Transfer for Rural Areas Publication. [Online]. Available: http://www.attra.ncat.org

[31] N. Sanginga and P. L. Woomer, "Integrated soil fertility management in Africa: principles, practices and development process," Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture, Nairobi, 2009.

[32] P. Jarenyama, O. B. Hesterman, S. R. Waddington, and R. R. Harwood, "Relay-Intercropping of sunnhemp and cowpea into a smallholder maize system in Zimbabwe," *Agron. J.*, vol. 92, pp. 239-244, 2000.

[33] B. Horwith, "A Role for Intercropping in Modern Agriculture," *Biol. Sci.* vol. 35, no. 5, pp. 286-291, 1985.

[34] R. W. Willey, M. Natarajan, M. S. Reddy, M. R. Rao, P. T. C. M. Nambiar, J. Kannaiyan, and V. S. Bhatnagar, "Intercropping studies with annual crops," *Better Crop for Food*, Pitman Co., London, 1983.

[35] M. K. Singh, R. Thakur, U. N. Verma, S. K. Pal, and S. Pasupalak, "Productivity and nutrient management of maize+blackgram intercropping as affected by fertilizer and plant density management of blackgram," *Ind. J. Agron.*, vol. 43, no. 3, pp. 495-500, 1998.

[36] V. A. C. Enyi, "Grain yield in groundnut," *Exp. Agric.*, vol. 13, pp. 101-110, 1977.

[37] T. Y. Reddy and G. H. S. Reddi, *Principles of Agronomy*, India: Kalyani Publishers, 2007, pp. 468-489.

[38] N. M. Fisher, "Studies in mixed cropping," *Exp. Agric*., vol. 13, pp. 169-177, 1977.

[39] J. R. Benites, R. E. McCollum, and G. C. Naderman, "Production efficiency of intercrops relative to sequentially planted sole crops in a humid tropical environment," *Field Crops Research*, vol. 31, pp. 1-18, 1993.

[40] G. X. Chu, Q. R. Shen, and J. L. Cao, "Nitrogen fixation and N transfer from peanut to rice cultivated in aerobic soil in intercropping system and its effect on soil N-fertility," *Plant Soil*, vol. 263, pp. 17-27, 2004.

[41] E. S. Jensen, "Grain yield, symbiotic N_2 fixation and interspecific competition for inorganic N in pea-barley intercrops," *Plant Soil*, vol. 182, pp. 25-38, 1996.

[42] A. A. Agboola and A. A. Fayemi, "Preliminary trials on the intercropping of maize with different tropical legumes in Western Nigeria," *J. Agric. Sci. Camb.*, vol. 77, pp. 219-225, 1971.

[43] H. O. Mongi, A. P. Uriyo, Y. A. Sudi, and B. R. Singh, "An appraisal of some intercropping methods in terms of yield, response to applied phosphorus and monetary return from maize and cowpea," *East Afr. Agric. For. J.*, vol. 42, pp. 66-70, 1976.

[44] P. I. B. Silva, P. S. L. Silva, O. F. de Oliveira, and R. P. de Sousa, "Planting times of cowpea intercropped with corn in the weed control," *Revista Caatinga (Mossoro, Brasil)*, vol. 21, no. 1, pp. 113-119, 2008.

[45] A. A. Addo-Quaye, A. A. Darkwa, and G. K. Ocloo, "Yield and productivity of component crops in a maize-soybean intercropping system as affected by time of planting and spatial arrangement," *J. Agric. Biol. Sci.*, vol. 6, no. 9, pp. 50-57, 2011.

[46] R. W. Willey, "Intercropping its importance and research needs. I. Competition and yield advantages," *Field Crop Abstr*, vol. 32, pp. 1-10, 1979.

[47] R. W. Jannasch and R. C. Martin, "The potential for capturing the forage yield of white lupin by intercropping with cereals," *Biol Agr Hort*., vol. 17, pp. 113-130, 1999.

[48] L. Li, S. Yang, X. Li, F. Zhang, and P. Christie, "Interspecific complementary and competitive interactions between intercropped maize and faba bean," *Plant Soil*, vol. 212, pp. 105-114, 1999.

[49] F. Zhang and L. Li, "Using competitive and facilitative interactions in intercropping systems enhances crop productivity

and nutrient-use efficiency," *Plant Soil*, vol. 248, pp. 305-312, 2003.

[50] K. V. Dhima, A. S. Lithourgidis, I. B. Vasilakoglou, and C. A. Dordas, "Competition indices of common vetch and cereal intercrops in two seeding ratio," *Field Crops Res*, vol. 100, pp. 249-256, 2007

[51] J. Ofosu-Anim and N. V. Limbani, "Effect of intercropping on the growth and yield of cucumber (cucumis sativus L.) and okra (abelmoschus esculentus L. moench)," *Int J. Agr Biol*, vol. 9, pp. 594-597, 2007.

[52] C. O. Muoneke, M. A. O. Ogwuche, and B. A. Kalu, "Effect of maize planting density on the performance of maize/soybean intercropping system in a guinea savannah agro-ecosystem," *African J. Agric. Res.*, vol. 2, no. 12, pp. 667-677, 2007.

[53] G. Agegnehu, A. Ghizaw, and W. Sinebo, "Yield potential and land-use efficiency of wheat and faba bean mixed intercropping," *Agron Sustain Dev*., vol. 28, pp. 257-263, 2008.

[54] A. Carrubba, R. La Torre, F. Saiano, and P. Aiello, "Sustainable production of fennel and dill by intercropping," *Agron Sustain Dev*, vol. 28, pp. 247-256, 2008.

[55] M. Launay, N. Brisson, S. Satger, H. Hauggaard-Nielsen, G. Corre-Hellou, *et al*., "Exploring options for managing strategies for pea-barley intercropping using a modeling approach," *Eur J. Agron*, vol. 31, pp. 85-98, 2009.

[56] M. Mucheru-Muna, P. Pypers, D. Mugendi, J. Kung'u, J. Mugwe, *et al*., "Staggered maize-legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of Central Kenya," *Field Crops Research*, vol. 115, pp. 132-139. 2009.

[57] R. W. Willey, "Evaluation and presentation of intercropping advantages," *Exp Agr*, vol. 21, pp. 119-133, 1985.

[58] D. J. Midmore, "Agronomic modification of resource use and intercrop productivity," *Field Crops Res.*, vol. 34, pp. 357-380, 1993.

[59] R. A. Morris and D. P. Garrity, "Resource capture and utilization in intercropping-water," *Field Crops Res*., vol. 34, pp. 303-317, 1993.

[60] M. Tsubo, S. Walker, and E. Mukhala, "Comparisons of radiation use efficiency of mono-/inter-cropping systems with different row orientations," *Field Crops Res*., vol. 71, no. 1, pp. 17-29, 2001.

[61] A. Ghanbari, M. Dahmardeh, B. A. Siahsar, and M. Ramroudi, "Effect of maize *(*zea mays L.) - cowpea *(*vigna unguiculata L.) intercropping on light distribution, soil temperature and soil moisture in and environment," *J. Food Agr Environ*, vol. 8, pp. 102-108, 2010.

[62] Y. S. Shivay and R. P. Singh, "Effect of nitrogen levels on productivity of grain legumes intercropped with maize (Zea mays)," *Legume Res*, vol. 26, no. 4, pp. 303-306, 2003.

[63] I. B. Pandey, V. Bharati, and S. S. Mishra, "Effect of maize (Zea mays)-based intercropping systems on maize yield and associated weeds under ainfed condition," *Ind. J. Agron*., vol. 48, no. 1, pp. 30-33, 1999.

[64] K. Pathak and N. P. Singh, "Genotypic compatibility and planting pattern in urdbean and maize intercropping system," *Ind. J. Pulses Res*., vol. 19, no. 1, pp. 116-118, 2006.

[65] M. E. Smith and C. A. Francis, "Breeding for multiple cropping systems," in *Multiple Cropping Systems*, C. A. Francis, Ed. New York, USA: MacMillan Publishing Company, 1986.

[66] S. Fukai and B. R. Trenbath, "Processes determining intercrop productivity and yields of component crops," *Field Crops Res*, vol. 34, pp. 247-271, 1993.

[67] B. A. Keating and P. S. Carberry, "Resource capture and use in intercropping: Solar radiation," *Field Crops Res*., vol. 34, pp. 273-301, 1993.

[68] M. R. Rao and R. W. Willey, "Evaluation of yield stability in intercropping: Studies on sorghum/pigeonpea," *Exp Agr*, vol. 16, pp. 105-116, 1980.

[69] M. R. Rao, "Cereals in multiple cropping systems," in *Multiple Cropping Systems*, C. A. Francis, Ed. New York, USA: MacMillan Publishing Company, 1986.

[70] D. L. Clawson, "Harvest security and intraspecific diversity in traditional tropical agriculture," *Econ Bot*, vol. 39, pp. 56-67, 1985.

[71] D. D. Onduru and C. C. Du Preez, "Ecological and agro-economic study of small farms in sub-Saharan Africa," *Agron Sustain Dev*, vol. 27, pp. 197-208, 2007.

[72] T. Tefera and T. Tana, "Agronomic performance of sorghum and groundnut cultivars in sole and intercrop cultivation under semiarid conditions," *J. Agron Crop Sci*., vol. 188, pp. 212-218, 2002

[73] S. A. El-Swaify, L. Akf, R. Joy, L. Shinshiro, and R. S. Yost, "Achieving conservation effectiveness in the tropics using legume-intercrops," *Soil Technol*, vol. 1, pp. 1-12, 1988.

[74] B. M. Kariaga, "Intercropping maize with cowpeas and beans for soil and water management in Western Kenya," in *Proc. 13th International Soil Conservation Organization Conference*, *Conserving Soil and Water for Society*, Brisbane, July 2004, pp. 1-5.

[75] A. Lemlem, *Herald Journal of Agriculture and Food Science Research*, vol. 2, no. 5, pp. 156–170, 2013.

[76] K. Fujita, K. G. Ofosu-Budu, and S. Ogata, "Biological nitrogen fixation in mixed legume-cereal cropping systems," *Plant Soil*, vol. 141, pp. 155-176, 1992.

[77] J. Fustec, F. Lesuffleur, S. Mahieu, and J. B. Cliquet, "Nitrogen rhizodeposition of legumes," *A Review. Agron Sustain Dev*, vol. 30, pp. 57-66, 2010.

[78] T. Lunnan, "Barley-pea mixtures for whole crop forage. Effect of different cultural practices on yield and quality," *Nor J. Agr Sci*, vol. 3, pp. 57-71, 1989.

[79] H. Geren, R. Avcioglu, H. Soya, and B. Kir, "Intercropping of corn with cowpea and bean: Biomass yield and silage quality," *Afr J. Biotechnol*, vol. 7, pp. 4100-4104, 2008.

[80] A. S. Lithourgidis, K. V. Dhima, I. B. Vasilakoglou, C. A. Dordas, and M. D. Yiakoulaki, "Sustainable production of barley and wheat by intercropping common vetch," *Agron Sustain Dev*, vol. 27, pp. 95-99, 2007.

[81] A. Javanmard, A. D. M. Nasab, A. Javanshir, M. Moghaddam, and H. Janmohammadi, "Forage yield and quality in intercropping of maize with different legumes as doublecropped," *J. Food Agr Environ*, vol. 7, pp. 163-166, 2009.

[82] M. Dahmardeh, A. Ghanbari, B. Syasar, and M. Ramrodi, "Intercropping maize (zea mays L.) and cow pea (vigna unguiculata L.) as a whole-crop forage: Effects of planting ratio and harvest time on forage yield and quality," *J. Food Agr Environ*, vol. 7, pp. 505-509, 2009.

[83] K. Fujita and K. G. Ofosu-Budu, "Significance of intercropping in cropping systems," in *Dynamics of Roots and Nitrogen in Cropping Systems of the Semi- Arid Tropics. Japan International Research Center for* Agricultural *Sciences*, O. Ito, C. Johansen, J. J. Adu-Gyamfi, K. Katayama, J. V. D. K. Kumar Rao, and T. J. Rego, Eds. 1996, pp. 19-40.

[84] E. M. A. Smaling, S. M. Nandwa, and B. H. Janssen, "Soil fertility in Africa is at stake," in *Replenishing Soil Fertility in Africa*, Soil Science Society of America, R. J. Buresh, P. A. Sanchez, and F. G. Calhoun, Eds. vol. 51, Wisconsin, USA, 1997, pp. 47-61.

[85] J. Mugwe, D. N. Mugendi, M. Mucheru-Muna, and J. Kung'u, "Soil inorganic N and N uptake by maize following application of legume biomass, tithonia, manure and mineral fertilizer in Central Kenya," in *Innovations as Key to the Green Revolution in Africa*, A. Bationo, *et al.*, Eds. Springer Science+Business Media B.V. 2011, pp. 605-612.

[86] B. Jama, C. A. Palm, R. J. Buresh, A. Niang, C. Gachengo, *et al*., "Tithonia diversifolia as a green manure for soil fertility improvement in Western Kenya: A review," *Agrofor. Syst.*, vol. 49, pp. 201-221, 2000.

[87] A. O. Osunde, P. A. Tsado, A. Bala, and N. Sanginga, "Productivity of a maize-promiscuous soybean intercrops as affected by fertilizer in the Southern Guinea Savanna Zone of Nigeria," *West Afr. J. Appl. Ecol.,* vol. 5, 2004.

[88] N. Sanginga and P. L. Woomer, *Integrated Soil Fertility Management in Africa: Principles, Practices and Development Process*, Tropical Soil Biology and Fertility Institute of the International Centre for Tropical Agriculture, Nairobi, 2009.

[89] A. R. J. Eaglesham, A. Ayanaba, V. R. Rao, and D. L. Eskew, "Improving the nitrogen nutrition of maize by intercropping with cowpea," *Soil Biol. Biochem.*, vol. 13, pp. 169-171, 1981.

[90] P. T. C. Nambiar, M. R. Rao, M. S. Reddy, C. N. Floyd, P. J. Dart, and R. W. Willey, "Effect of inter-cropping on nodulation and N_2-fixation by groundnut," *Exp. Agric.*, vol. 19, pp. 1979-1986, 1983.
[91] G. R. Mandimba, "Contribution of nodulated legumes on the growth of zea mays l. under various cropping systems," *Symbiosis*, vol. 19, pp. 213-222, 1995.
[92] P. Maphumo, "Comparative analysis of the current and potential role of legumes in integrated soil fertility management in Southern Africa," in *Fighting Poverty in Sub-Saharan Africa: The Multiple Roles of Legumes in Integrated Soil Fertility Management*, A. Bationo, *et al*., Eds. Springer Science+Business Media B. V., 2011, pp. 175-200.
[93] C. Chen, M. Westcott, K. Neill, D. Wichman, and M. Knox, "Row configuration and nitrogen application for barley-pea intercropping in Montana," *Agronomy J*., vol. 96, pp. 1730-1738, 2004.
[94] K. E. Giller, J. Ormesher, and F. M. Awah, "Nitrogen transfer from phaseolus bean to intercropped maize measured using 15N-enrichment and 15N-isotope dilution methods," *Soil Biol. Biochem.*, vol. 23, pp. 339-346, 1991.
[95] S. J. M. Ledgard and K. E. Giller, "Atmospheric N_2- fixation as alternative nitrogen source," in *Nitrogen Fertilization and the Environment*, P. Bacon, Ed. New York: Marcel Dekker, 1995, pp. 443-486.
[96] S. K. A. Danso, G. Hardarson, and F. Zapata, "Misconceptions and practical problems in the use of the 15N soil enrichment techniques for estimating N fixation," *Plant Soil*, vol. 152, pp. 25-52, 1993.
[97] M. A. Altieri, *Biodiversity and Pest Management in* Agroecosystems, New York, USA: Food Products Press, 1994.
[98] L. A. Thrupp, "Linking agricultural biodiversity and food security: The valuable role of agrobiodiversity for sustainable agriculture," *Int. Aff.*, vol. 76, pp. 283-297, 2002.
[99] S. J. Scherr and J. A. McNeely, "Biodiversity conservation and agricultural sustainability: Towards a new paradigm of 'ecoagriculture' landscapes," *Philos Trans Royal Soc. B*, vol. 363, pp. 477-494, 2008.
[100] A. E. Russell, "Relationship between crop-species diversity and soil characteristics in southwest Indian agroecosystems," *Agr Ecosyst Environ*, vol. 92, pp. 235-249, 2002.
[101] H. Hauggaard-Nielsen, P. Ambus, and E. S. Jensen, "The comparison of nitrogen use and leaching in sole cropped versus intercropped pea and barley," *Nutr Cycl Agroecosys*, vol. 65, pp. 289-300, 2003.
[102] F. J. Bannon and B. M. Cooke, "Studies on dispersal of septoria tritici pycnidiospores in wheat-clover intercrops," *Plant Pathol*, vol. 47, pp. 49-56, 1998.
[103] M. A. Boudreau and C. C. Mundt, "Mechanisms of alterations in bean rust epidemiology due to intercropping with maize," Phytopathology, vol. 82, pp. 1051-1060, 1992.
[104] H. Hauggaard-Nielsen, P. Ambus, and E. S. Jensen, "Interspecific competition, N use and interference with weeds in pea-barley intercropping," *Field Crops Res*, vol. 70, pp. 101-109, 2001.
[105] M. Liebman and E. Dyck, "Crop rotation and intercropping strategies for weed management," *Ecol Appl*, vol. 3, pp. 92-122, 1993.
[106] P. M. Olorunmaiye, "Weed control potential of five legume cover crops in maize/cassava intercrop in a Southern Guinea savanna ecosystem of Nigeria," *Aust J. Crop Sci*, vol. 4, pp. 324-329, 2010.
[107] C. T. Abraham and S. P. Singh, "Weed management in sorghum-legume intercropping systems," *J. Agr Sci*, vol. 103, pp. 103-115, 1983.
[108] D. T. Baumann, M. J. Kropff, and L. Bastiaans, "Intercropping leeks to suppress weeds," *Weed Res*, vol. 40, pp. 359-374, 2000.
[109] A. Szumigalski and R. Van Acker, "Weed suppression and crop production in annual intercrops," *Weed Sci*., vol. 53, pp. 813-825, 2005.
[110] H. Saucke and K. Ackermann, "Weed suppression in mixed cropped grain peas and false flax (camelina sativa)," *Weed Res*, vol. 46, pp. 453-461, 2006.
[111] J. Iqbal, Z. A. Cheema, and M. An, "Intercropping of field crops in cotton for the management of purple nutsedge (cyperus rotundus L.)," *Plant Soil*, vol. 300, pp. 163-171, 2007.
[112] J. R. Witcombe, M. Billore, H. C. Singhal, N. B. Patel, S. B. S. Tikka, *et al*., "Improving the food security of low-resource farmers: Introducing horsegram into maize-based cropping systems," *Exp Agr*, vol. 43, pp. 339-348, 2008.
[113] D. Bilalis, P. Papastylianou, A. Konstantas, S. Patsiali, A. Karkanis, and A. Efthimiadou, "Weed-suppressive effects of maize-legume intercropping in organic farming," *Int J. Pest Manag*, vol. 56, pp. 173-181, 2010.
[114] A. B. Mashingaidze, *Improving Weed Management and Crop Productivity in Maize*, 2004.
[115] Z. R. Khan, A. Hassanali, W. Overholt, T. M. Khamis, *et al.*, "Control of witchweed striga hermonthica by intercropping with desmodium spp., and the mechanism defined as allelopathic," *Journal of Chemical Ecology*, vol. 28, no. 9, pp. 1871-1885, 2002.
[116] C. A. O. Midega, Z. R. Khan, D. M. Amudavi, J. Pittchar, and J. A. Pickett, "Integrated management of striga hermonthica and cereal stemborers in finger millet [eleusine coracana (L.) gaertn.] through intercropping with desmodium intortum," *Int J. Pest Manag*, vol. 56, pp. 145-151, 2010.
[117] A. M. Mbwaga, C. R. Massawe, A. M. Kaswende, and J. P. Hella, "On-farm verification of maize/cowpea intercropping on the control of striga under subsistence farming," *Seventh Eastern Africa Regional Maize Conference*, pp. 165-167, 2001.
[118] D. Musambasi, O. A. Chivinge, and I. K. Mariga, "Intercropping maize with grain legumes for striga control in Zimbabwe," *Afr. Crop Sci. J*., vol. 10, no. 2, pp. 163-171, 2002.
[119] F. Caporali, E. Campiglia, R. Paoline, and R. Mancinelli, "The effect of crop species, nitrogen fertilization and weed on winter cereal/pea intercropping," *Ita. J. Agron.*, vol. 2, pp. 1-9, 1997.
[120] F. M. Itulya and J. N. Aguyoh, "The effect of intercropping kale with beans on yield and suppression of redroot pigweed under high altitude conditions in Kenya," *Exp. Agric.*, vol. 34, pp. 171-176, 1998.
[121] S. J. Risch, "Intercropping as cultural pest control: Prospects and limitations," *Environ Manage*, vol. 7, pp. 9-14, 1983.
[122] D. A. Andow, "Vegetational diversity and arthropod population response," *Annu Rev Entomol*, vol. 36, pp. 561-586, 1991.
[123] V. Langer, J. Kinane, and M. Lyngkjsr, "Intercropping for pest management: The ecological concept," in *Ecologically Based Integrated Pest Management*, O. Koul and G. W. Cupreus, Eds. Wallingford, UK: CABI Publishing, 2007.
[124] S. Kyamanywa and J. K. O. Ampofo, "Effect of cowpea/maize mixed cropping on the incident light at the cowpea canopy and flower thrips (Thysanoptera: Thripidae) population density," *Crop Prot*, vol. 7, pp. 186-189, 1988.
[125] S. Kyamanywa and E. M. Tukahirwa, "The effect of mixed cropping beans, cowpeas and maize on population densities of bean flower thrips, megalurothrips sjostedti (trybom) (thripidae)," *Insect Sci Appl*, vol. 9, pp. 255-259, 1988.
[126] T. Bukovinszky, H. Trefas, J. C. van Lenteren, L. E. M. Vet, and J. Fremont, "Plant competition in pest-suppressive intercropping systems complicates evaluation of herbivore responses," *Agr Ecosyst Environ*, vol. 102, pp. 185-196, 2004.
[127] M. W. Ogenga-Latigo, C. W. Baliddawa, and J. K. O. Ampofo, "Factors influencing the incidence of the black bean aphid, aphis fabae scop. On common beans intercropped with maize," *Afr Crop Sci J*., vol. 1, pp. 49-58, 1993.
[128] O. Olufemi, R. Pitan, and J. A. Odebiyi, "The effect of intercropping with maize on the level of infestation and damage by pod-sucking bugs in cowpea," *Crop Prot*, vol. 20, pp. 367-372, 2001.
[129] B. M. Sekamatte, M. Ogenga-Latigo, and A. Russell-Smith, "Effects of maize-legume intercrops on termite damage to maize, activity of predatory ants and maize yields in Uganda," *Crop Prot*, vol. 22, pp. 87-93, 2003.
[130] T. T. Epidi, A. E. Bassey, and K. Zuofa, "Influence of intercrops on pests' populations in upland rice *(*oryza sativa L.)," *Afr J. Environ Sci Technol*, vol. 2, pp. 438-441, 2008.
[131] P. Chikte, S. M. Thakare, and S. K. Bhalkare, "Influence of various cotton-based intercropping systems on population dynamics of thrips, scircothrips dorsalis hood and whitefly, bemisia tabaci genn," *Res Crop*, vol. 9, pp. 683-687, 2008.
[132] S. D. Berry, P. Dana, V. W. Spaull, and P. Cadet, "Effect of intercropping on nematodes in two small-scale sugarcane farming systems in South Africa," *Nematropica*, vol. 39, pp. 11-33, 2009.
[133] M. Bjorkman, P. A. Hamback, R. J. Hopkins, and B. Ramert, "Evaluating the enemies hypothesis in a clover-cabbage intercrop: Effects of generalist and specialist natural enemies on the turnip

root fly (delia floralis)," *Agr Forest Entomol*, vol. 12, pp. 123-132, 2010.

[134] M. R. Finckh, E. S. Gacek, H. Goyeau, C. Lannou, U. Merz, C. C. Mundt, *et al*., "Cereal variety and species mixtures in practice, with emphasis on disease resistance," *Agronomie*, vol. 20, pp. 813-837, 2000.

[135] A. Autrique and M. J. Potts, "The influence of mixed cropping on the control of potato bacterial wilt (pseudomonas solanacearum)," *Ann Appl Biol*., vol. 111, pp. 125-133, 1987.

[136] M. Lennartsson, "Take-all disease of wheat," in *Proc. 6th International Scientific Conference of the International Federation of Organic Agriculture Movements (IFOAM): Global Perspectives on Agroecology and Sustainable Agricultural Systems*, P. Allen and D. Van Dusen, Ed. Santa Cruz, USA, August 18-21, 1986, pp. 575-580.

[137] J. Kinane and M. Lyngkjsr, "Effect of barley-legume intercrop on disease frequency in an organic farming system," *Plant Prot Sci*, vol. 38, pp. 227-231, 2002.

[138] H. Hauggaard-Nielsen, B. Jernsgaard, J. Kinane, and E. S. Jensen, "Grain legume-cereal intercropping: The practical application of diversity, competition and facilitation in arable and organic cropping systems," *Renew Agr Food Syst*, vol. 23, pp. 3-12, 2008.

[139] A. Schoeny, S. Jumel, F. Rouault, E. Lemarchand, and B. Tivoli, "Effect and underlying mechanisms of pea-cereal intercropping on the epidemic development of ascochyta blight," *Eur J. Plant Pathol*, vol. 126, pp. 317-331, 2010.

[140] R. F. Vieira, T. J. De Paula Junior, H. Teixeira, and C. Vieira, "Intensity of angular leaf spot and anthracnose on pods of common beans cultivated in three cropping systems," *Cienc Agrotec*, vol. 33, pp. 1931-1934, 2009.

[141] P. Sullivan. (2003). Intercropping Principles and Production Practices. Appropriate Technology Transfer for Rural Areas Publication. [Online]. Available: http://www.attra.ncat.org

[142] P. L. Kipkemoi, V. W. Wasike, P. A. Ooro, T. C. Riungu, P. K. Bor, and L. M. Rogocho, "Effects of intercropping pattern on soybean and maize yield in central rift valley of Kenya," Kenyan Agricultural Research Institute, Unpublished paper, 2001.

[143] J. A. Raji, "Intercropping soybean and maize in a derived savanna ecology," *Afr. J. Biotechnol.*, vol. 6, no. 16, pp. 1885-1887, 2007.

[144] J. R. Allen and R. K. Obura, "Yield of corn and soybean in intercropping soybeans," *Agron. J.*, vol. 75, pp. 1005-1009, 1983.

[145] T. Samba, B. S. Coulibay, A. Kone, M. Bagayoko, and Z. Kouyate, "Increasing the productivity and sustainability of millet based cropping systems in the Sahelian zones of West Africa," in *Advances in Integrated Soil Fertility Management in Sub-Saharan Africa: Challenges and Opportunities*, A. Bationo, Ed. 2007, pp. 567-574.

[146] H. P. M. Gunasena, R. Sangakkara, and P. Wickramasinghe, "Studies on the Maize-Soybean Intercrop System," Faculty of Agriculture. University of Peradenia. Peradenia-Hawai. Unpublished paper, 1978.

[147] A. O. Segun-Olasanmi and A. S. Bamire, "Analysis of costs and returns to maize-cowpea intercrop production in Oyo State, Nigeria," Poster presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 481th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010.

[148] A. N. Osman, A. Rbild, J. L. Christiansen, and J. Bayala, "Performance of cowpea *(*vigna unguiculata*)* and pearl millet (pennisetum glaucum) intercropped under parkia biglobosain an agroforestry system in burkina faso," *Afr. J. Agric. Res.*, vol. 6, no. 4, pp. 882-891, 2010.

[149] T. O. Oseni, "Evaluation of sorghum-cowpea intercrop productivity in savanna agro-ecology using competition indices," *J. Agric. Sci.*, vol. 2, no. 3, pp. 229-23, 2010.

[150] P. Banik, A. Midya, B. K. Sarkar, and S. S. Ghose, "Wheat and chickpea intercropping systems in an additive series experiment: Advantages and weed smothering," *Eur. J. Agron,* vol. 24, pp. 325-332, 2006.

[151] A. M. A. Ullah, Z. A. Bhatti, S. Guramani, and M. Imran, "Studies on planting patterns of maize (Zea mays L.) facilitating legumes intercropping," *J. Agric.*, vol. 45, no. 2, pp. 114-118, 2007.

[152] A. Bationo, J. Kimetu, B. Vanlauwe, M. Bagayoko, S. Koala, and A. U. Mokwunye, "Comparative analysis of the current and potential role of legumes in integrated soil fertility management in west and Central Africa," in *Fighting Poverty in Sub-Saharan Africa: The Multiple Roles of Legumes In Integrated Soil Fertility Management*, A. Bationo *et al.*, Eds. Springer Science+Business Media B.V., 2011, pp. 117-150.

[153] D. N. Mugendi, B. S. Waswa, M. W. Mucheru-Muna, and J. M. Kimetu, "Strategies to adapt, disseminate and scale out legume based technologies," in *Fighting Poverty in Sub-Saharan Africa: The Multiple Roles of Legumes in Integrated Soil Fertility Management*, A. Bationo, *et al*., Eds., Springer Science+Business Media B.V., 2011, pp. 85-116.

[154] P. A. Sanchez, K. D. Shepherd, M. J. Soule, *etc*., "Soil fertility replenishment in Africa: An investment in natural resource capital," in *Replenishing Soil Fertility in Africa*, Soil Science Society of America, R. J. Buresh, P. A. Sanchez, and F. Calhoun, Eds. no. 51, 1997. pp. 1-46.

[155] C. A. Palm, R. J. K. Myers, and S. M. Nandwa, "Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment," in *Replenishing Soil Fertility in Africa*, Soil Science Society of America, R. J. Buresh, P. A. Sanchez, and F. Calhoun, Ed. no. 51, 1997, pp. 193-217.

[156] D. N. Mugendi, "Tree biomass decomposition, nitrogen dynamics and maize growth under agroforestry conditions in the sub-humid highlands of Kenya," PhD thesis, University of Florida, Gainesville, Florida, USA, 1997.

[157] D. N. Mugendi, P. K. R. Nair, J. N. Mugwe, M. K. O'Neill, and P. Woomer, "Alley cropping of maize with calliandra and leucaena in the sub-humid highlands of Kenya. Part 1. Soil fertility changes and maize yield," *Agroforest Syst.*, vol. 46, pp. 39-50, 1999.

[158] J. D. T. Kumwenda, A. R. Saka, S. S. Snapp, R. P. Ganunga, and T. Benson, "1998: Effects of organic legume residues and inorganic fertilizer nitrogen on maize yield in Malawi," in *Proc. the* Soil *Fertility Network Results and Planning Workshop on the Soil Fertility Network for Maize-Based Cropping Systems in Malawi and Zimbabwe*, Africa University Mutare, Zimbabwe, July 7-11, 1997, pp. 165-171.

[159] J. Mugwe, D. Mugendi, M. Mucheru-Muna, R. Merckx, J. Chianu, and B. Vanlauwe, "Determinants of the decision to adopt integrated soil fertility management practices by smallholder farmers in the Central Highlands of Kenya," *Expl Agric*, vol. 45, pp. 61-75, 2009.

[160] D. N. Mugendi, B. S. Waswa, M. W. Mucheru-Muna, J. M. Kimetu, and C. Palm, "Comparative analysis of the current and potential role of legumes in integrated soil fertility management in East Africa," in *Fighting Poverty in Sub-Saharan Africa: The Multiple Roles of Legumes in Integrated Soil Fertility Management*, A Bationo, *et al*., Eds., Springer Science+Business Media B.V., 2011, pp. 151-173.

[161] F. Mtambanegwe and P. Maphumo, "Combating food insecurity on sandy sails in Zambabwe: The legume challenge," *Symbiosis*, vol. 48, pp. 25-36, 2009.

