Agronomic and Economic Feasibility of Maize Soybean Intercropping System

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Abstract: Intercropping is a widespread practice, which is generally accepted, has some advantages over sole cropping in the tropics. The main advantage of intercropping is the more efficient utilization of the available resources and the increased productivity compared with each sole crop of the mixture. Intercropping can conserve soil water by providing shade, reducing wind speed and increasing infiltration with mulch layers and improved soil structure. This review summarizes the most important aspects of maize soybean intercropping system comparative to mono-cropping system.

Key words: Intercropping • Maize • Resource • Soybean • Yield advantage

INTRODUCTION

Cropping system refers to the crops and crop sequences and the management practices used on a particular field over a period of years. One of these systems is intercropping [1]. It is referred as the growing of two or more crops at the same time on the same field with crop diversification in both time and space. Intercropping is important for the development of sustainable food production [2] particularly in a limited external input agriculture [3]. Intercropping has been honed by small-holder farmers in the tropics specifically legume and cereal intercropping [4, 5]. Ordinarily, C4 cereal crops, for example, maize, pearl millet and sorghum are the dominant crop, while C3 legume crops, for example, soybean, beans, cowpea, groundnut and pigeon pea are the accompanying or secondary crops [5]. Intercropping system varies from one area to another with difference in soil and climate while social and cultural conditions may overlay on the ecological and economic zones. Regions and ethnic groups differ in their food preferences, so also do they differ in their cropping system.

Crop productivity is often limited by the amount of the limiting resources and is mostly determined by how efficiently the crop can utilize it. In sole cropping, understanding of the relevant processes is enhanced by examining how crops capture the resources which are limiting crop growth and how the resources are used in assimilate production. Partitioning of the assimilates among various plant parts and particularly allocation to the harvested part, are important processes determining final yield. We can use a similar approach in intercropping to determine how yields of component crops and total intercrop productivity are related to resource capture and utilization. The main objective of intercropping is to deliver an optimum yield on a given area by utilizing resources that would not be used by a sole crop [6]. The efficient use of resources (i.e. light, water, land and nutrients) is attributed to the spatial arrangement of crops in intercropping. This is carried out by selecting appropriate crops that have different morpho-physiological nature and planting arrangement [7]. Maize-soybean intercropping is an alternative system for small-scale farmers to improve income and food production per unit area [8] and lessen the risk of total crop failure due to environmental stress [9]. In respect of the economic and nutritional importance of soybean as grain legume and maize as an important cereal crop, cultivation of maize and soybean in the mixture is more profitable compared to monocropping [4, 10]. The aim of this paper is to provide reviews of agronomic and economic aspects of maize soybean intercropping.

Advantages of Intercropping: The advantage of intercropping depends upon the extent and nature of competition between component crops. Intercropping may be more beneficial if the components have different growth habits, maturity time, growth requirements and root system. Growing of two or more crops utilize better resources than monocropping [11]. Mahapatra [12] stated
that complementary effect between the component crops increases production due to the reduction of the competition between them. The most important factor for the selection of crops for intercropping includes their compatibility, low competition and ability to produce higher yield [13]. Cereal-legume intercropping can be possible for both organic and conventional farmers.

According to Eskandari et al. [14] intercropping can improve total production by increasing growth rate of crops, controlling weeds, pests and diseases and increasing efficiency of resources utilization due to differences in resource consumption. Intercropping can also maximize profits, minimize the risk of crop failure, improve soil conservation and maintain fertility status of soil and enhance the quality of forage through [15].

**Resource Use Efficiency:** Several studies on intercropping have concentrated on resource utilization such as light, water and nutrients, bringing about a higher yield advantage than monocropping [16] since the major benefit of intercropping is an effective use of resources and improved efficiency over monocropping [17]. Increased crop production (Over-yielding) often observed in intercrops compared to sole crops has been attributed to enhanced resource use. The use of resources can be improved by either utilization of more resources (Greater resource capture) or by effective use of a given unit of resource (Greater resource conversion efficiency) [18]. The efficient use of resources in the intercropping system influenced by the inherent competence of the component crops and the corresponding effect on the crop [19]. Fujita and Budu [20] reported that intercropping is more beneficial when the intercrops varied greatly in growth period so that their greatest requirements for limited resources happen at different times. Ghanbari et al. [21] explained that intercropping can improve light interception compared to monocropping. Furthermore, the high efficiency of intercrops relative to that of monocultures may be a result of the higher captured light intensity per unit of cultivated land [22]. Adamu Molla and Sharaiha [23] also reported that mixed cropping system gave more options for combining important characters in a cropping system so as to enhance productivity through complementary resource use.

Another important feature is a difference in time of maturity and hence in nutrient demand among different species in intercropping which will create the time dimension of the system. In intercropping systems, increase in nutrient uptake can occur both spatially and temporally [24]. Spatial nutrient uptake can be improved by the increasing root mass, whereas temporal nutrient uptake occurs when component crops have different peak time of nutrient [25]. Likewise, the component crops have different rooting and uptake patterns, for example cereals and legumes utilize resources more efficiently than monocrops [15]. On the other hand, when the same species are grown together, the roots tend to compete with each other due to similar root orientation and below surface depth [1]. Several researchers reported that the nutrient uptake in the mixed crops is higher than in monocrop [26, 27]. Flores-Sanchez et al. [28] also reported that the N uptake in intercropping was higher than in monocropping. Thus the cumulative nutrient use efficiency of an intercropping system is higher than either of the sole crops. However, nutrient use efficiency of the individual crops in an intercrop is mostly lower than their respective sole crops [29]. This is because of solar radiation, water and some nutrients would be wasted during early growth stages of long-term crops, but they can be utilized by an associated crop growing between the rows [30]. They reported that in maize/mung bean intercropping the nutrient absorption by both maize and mung bean was reduced due to intercropping, mung bean being more affected than maize.

**Productivity and Yield Stability:** Increased crop productivity is among the most important and frequently cited benefits of intercropping. Overyielding occurs when the productivity of an intercrop is increased relative to the average of each component species grown in monoculture. This is the most common way that crop productivity is increased with intercropping and is often driven by resource partitioning. Intercropping can increase yield stability, allowing yields to be more reliable [31]. The primary concept of intercropping is to boost total productivity per unit area and time in addition to efficient and judicious utilization of limited resources and inputs such as labor [32]. Cereal-legume intercropping produces higher combined yields and give greater yield stability than when growing legumes and cereals as a monoculture [33, 34]. Ibeawuchi [26] stated in his reviewed paper, intercropping provides insurance against crop failure besides improve the diversity of farm products. Due to diversified crops, intercropping can stabilize yield through the principle of compensation, if one component crop suffers from pests, diseases, drought, etc., the loss of this crop can be compensated at least partially by the other component crop(s). However, in monoculture, there is no compensation since the crop is only one [35]. Snapp et al. [36] reported that
the legume-maize intercropping has brought a steadying effect on the food security of the small holder farmers in Africa. Similarly, Rose and Adiku [37] revealed that the intercropping systems can be the best alternative for the semi-arid areas by providing a more stable production that is less variable under the variable climate.

**Soil Fertility Improvement:** Intercropping is one of sustainable soil management in many developed and developing countries [21]. According to Matusso et al. [19] cereal-legume intercropping has a capacity to maintain soil fertility on smallholder farmers in the developing country. Legumes in the intercropping system can fix N and contribute to a cereal component to get a higher yield [38]. Nitrogen fixation by grain legume crops is gaining attention [39, 40] as it contributes substantial amounts of nitrogen in agricultural ecosystems [41]. Nitrogen fixing legumes generally do not need nitrogen fertilizer, whereas, the non-legumes require additional mineral nitrogen for optimum growth. Besides its own nitrogen requirement, legumes may contribute additional nitrogen for the subsequent crops. According to Sanginga and Woomer [42] the current programme on maintenance of soil fertility in Africa have included legumes as an intercrop and/or in rotation to reduce the cost of chemical fertilizer.

In the intercropping system the legume component helps to improve and maintain soil fertility since crops such as soybean, cowpea, mungbean and groundnuts accumulate nitrogen from 80 to 350 kg ha⁻¹ [42]. Dahmardeh et al. [43] discovered that maize/cowpea intercropping increased the amount of soil N, P and K compared to monocrop maize. Similarly, Chalka and Nepalia [44] reported higher N uptake and NPK availability in the soil in maize/soybean intercropping than sole maize. Legume-based cropping systems improve soil organic matter, thus increasing soil quality [45].

**Disadvantages of Intercropping:** There are, however, some disadvantages in intercropping systems. These include yield reduction of the main crop, loss of productivity during drought periods and high labor inputs in regions where labor is scarce and expensive [46]. Because of competition between intercropped plants for light, soil nutrients and water, in most cases the main crop in an intercropping system will not reach as high a yield as in a monoculture [31]. This yield reduction may be economically significant if the main crop has a high market price than the other intercropped plants.

According to Zhang and Li [47] competition might be possible in intercropping systems where two or more crops use similar growth factors, each far below their combined demands the competition will occur. The major factor affecting yield among mixtures is competition. Thole [48] reported the high probability of a reduction in yield of component crop occurs in intense competition. If the intercrops have the same root systems and the uptakes of nutrients are from the same soil zone, competition will occur. Brainard and Bellinder [49] also stated that if the crop selections or timing differences in crop life cycles are not managed properly, the component crops can compete with each other for resources, thus reducing the yield.

In intercropping system shading from tall cereal crops can affect the growth and yield of shorter legume. Legumes are often shaded by taller cereals and under low soil fertility conditions, poor emergence and growth of the intercropped legume is common [50]. Similarly, Fukai and Trenbath [51] reviewed that shading of one component by another in intercropping leads to a retarded development of the shoot and the root system of the shaded crop. Moreover, in legume/cereal intercropping, high nitrogen availability usually increases the plant height and canopy spread of the cereal component, thus reducing the light intensity reaching the legume component and hence decelerating the legume growth [52]. In general, in an intercropping a taller vigorous component becomes dominant over a shorter and slow-growing crop [53].

Furthermore, Leihner [54] explained that intercropping can diminish soil moisture and nutrient levels as a result of higher water and nutrient use caused by the rapid development of leaf and root density. Mucheru-Muna et al. [55] also reported that intercropping can hasten decline of nutrients in the soil, mainly for phosphorous, due to increased efficiency of nutrient uptake by the crops.

**Evaluation of the Productivity of Intercropping System:**
Land Equivalent Ratio (LER) is one of the important tool for evaluation of an intercropping system. LER is an index that measures the yield advantage found by growing of two or more crops as an intercrop compared to growing of the same crops as a monoculture [56]. It is defined as the relative land area under sole crop conditions required to provide the yield reached in intercropping. LER particularly indicates the biological efficiency of intercropping for using the resources of the environment, as compared to sole crop [57, 58].
According to Agrawal [59] and Mazaheri and Oveysi [60] if the LER is equal to 1, indicating no difference in yield between growing the crop in the intercrop or monocrop. If the LER is greater than 1, indicating yield advantage when both crops were grown as an intercrop as compared to monoculture. If the LER is less than 1, indicating yield disadvantage or it will be better to grow both crops separately. LER gives an indication of the percentage of the land required by the monocrops to produce equal yield as intercropped. For instance, a LER of 1.2 indicated that 20% more area would be required by the sole cropping system to produce the same yield as that of combined yield under the intercropping system [61]. The LER measures the extent of component crop interference in the cropping system. Theoretically, if the crop in intercropping has exactly the same agro-ecological characteristics, the total LER would be 1.0 and the partial LERs would be 0.5 for each [59]. A total LER of greater than 1.0 indicates positive interferences between the component crops in the intercropping system and any negative interspecific interference that occurs in the system is not as serious as that occurs in the sole crop.

The mutual complementary effects of the component crops in intercropping such as efficient use of resources attributed to yield advantage of intercropping over sole cropping. In general, the yield of legumes in monocropping is higher than in intercropping with cereal. Nevertheless, the productivity of land measured by LER mostly shows the advantage of cereals/legumes intercropping system [62]. The partial LER refers to the relative competitive abilities of the component crops in intercropping system. Therefore, the component crop with higher partial LER means more competitive for the limiting resource compared to the crop with lower partial LER [63].

Since the time factor (Duration of the crops) is not considered in the LER, the advantage of intercropping might be overestimated mainly when the intercrops have different maturity. It is very common for the duration of land occupancy by the component crops being longer than duration for monocrop. Hiebsch and McCollum [64] have modified LER index by including the time of the crop present on the land from planting to harvest. This index is known as the area time equivalent ratio (ATER). ATER is appropriate in crop mixture where component crops have different maturity dates [65]. These indices may underestimate the intercropping advantage mainly when the intercrops have different maturity. For instance, Allen and Obura [66] showed that the yield advantages of maize + cowpea/soybean intercropping system was 22 to 32% and 19 to 25% based on LER and ATER, respectively.

Muoneke et al. [4] reported yield advantage of 2-63 percent of intercropping as shown by the LER of 1.02-1.63, indicating the efficient utilization of land resource by growing the crops together. Similarly, Allen and Obura [66] obtained LER of 1.22 and 1.10 for maize-soybean intercropping in two consecutive years. The higher production efficiency in maize-soybean intercropping systems has been also reported by Raji [67].

All the competition indices provide no information about the economic advantage of the intercropping system over monocropping. The yield and economics of the intercropping were determined to decide whether maize and soybean yield are sufficient to justify recommending farmers to use this intercropping system. The economic advantage can be determined by monetary advantage index (MAI). The positive the MAI value indicates the profitability of the system [35].

Maize and Soybean Intercropping System: Among the several crops used in intercropping, maize is one of the major cereal crops widely used in cereal/legume intercropping [68]. Maize-legume intercropping systems can minimize a large amount of nitrogen taken from the soil compared to sole maize [9]. In addition, maize-legume intercropping system is productive and low-risk system compared to monocropping [69]. Tsubo et al. [70] reported that maize-bean intercropping systems had higher crop productivity and resource use efficiency than respective sole cropping.

Among the several grain legumes intercropped with maize, soybean is becoming popular and thrives under a wide range of conditions [71]. This is because of the nutritive and economic importance of the crop [8]. When maize was intercropped with soybean, the maize could capture and convert more sunlight into more grain yield since maize is a C4 plant with a high photosynthetic efficiency than C3 soybean crop [72]. Ariel et al. [73] reported that the growth and yield of maize were increased by intercropping systems, while soybean growth and yield were reduced, particularly at 1:1 corn-soybean ratio.

A field experiment was carried out by Rezvani et al. [74] on corn and soybean intercropping in a replacement series experiment in Iran. The result showed a significant difference in yield of corn and soybean in intercropping and monocropping. The yield of corn in intercropping was higher, but the yield of soybean was reduced due to strong competition by the corn crop. However, the land use efficiency and total productivity of the system were higher compared to monocropping. Based on their finding corn and soybean intercropping increased total productivity per unit area and improved land use.
efficiency. Similarly, Muyayabantu et al. [68] confirmed the intrinsic advantage of maize-soybean intercropping over sole crops as a result of greater than 1 area-time equivalent ratio (ATER) for all the treatments. However, Hasibuan and Lumbanraja [75] reported that there was no significant effect of intercropping system in soybean/corn intercropping combination on soybean growth (Plant height) and yield (Number seed per pod and thousand seed weight) except on the number of soybean pods per plant.

[6] have evaluated yield and system productivity of maize-soybean intercropping. The results showed that yield of soybean were reduced by 43.8% and 55.6% in 2011 and 2012, respectively when intercropped with maize. In contrast, the yield of maize was not significantly affected by intercropping. The combined yield was higher than the monocrop yields. In addition, the LER value (1.40 and 1.29) showed the higher productivity of intercropping per unit area compared to monocropping. Likewise, Muoneke et al. [4] reported that the number of soybean pods and seed yield per plant was reduced by 42 and 46% in intercropping. However, plant height and leaf production of maize were not significantly affected by intercropping. The LER value of 1.02-1.63 showed yield advantage of 2-63% of intercropping due to efficient utilization of limited resource by intercrops.

Economic Benefits of Intercropping Systems: Cereal-legume intercropping system is more productive and profitable cropping system than the corresponding monocropping [5, 34, 77]. The intercropping system delivers a higher profit to smallholder farmers compared to monocropping [1]. Segun-Olasanmi and Bamire [78] indicated that maize-cowpea intercropping was more profitable than their monocrops. In addition, Osman et al. [79] recommended that intercropping would increase the productivity of the system and improve the income of smallholder farmers.

Kumar and Thakur [80] observed a significantly higher system productivity and profitability (25.2 kg ha⁻¹-day⁻¹ and Rs 141.3 ha⁻¹-day⁻¹) and B:C ratio (2.7) in maize/soybean intercropping system than maize/cowpea intercropping system (22.9 kg ha⁻¹-day⁻¹ and Rs 126.1 ha⁻¹-day⁻¹). Muoneke et al. [4] also indicated that the total monetary return was higher in maize/soybean intercrops than the monocropping system. Within the cropping systems, soybean as previous crop produced the highest grain yield of wheat and was similar to that of soybean/sorghum intercropping system.

Saleem et al. [81] evaluated the feasibility and economic benefits of the intercropping system. The result from the partial budget analysis revealed that the highest gross and net benefits of Rs.96, 544 ha⁻¹ and Rs.93, 547 ha⁻¹ were observed in maize + mash beans with half poultry manure + half PK+ inoculation with PGPR treatment while maize + mungbean intercropping system gave gross and net benefits of Rs. 68, 721 ha⁻¹ and Rs. 64, 741 ha⁻¹. Sole maize cropping system without fertilizer gave the minimum benefit of Rs. 32, 362 ha⁻¹. The study conducted by Waktola et al. [83] to evaluate the productivity of maize-soybean intercropping system revealed that LER was greater than, showing a yield advantage of (14 - 32%) and (6 - 28%) over sole cropping as described by LER 1.14-1.32 and 1.06 -1.28 due to varieties and planting densities, respectively. Furthermore, the Gross Monetary Value (GMV) of intercrops (ETB 12, 176 ha⁻¹) was greater by 41.05% over sole cropped maize, but lower than that of soybean sole cropped GMV by ETB 3, 773 ha⁻¹ or 23.66%.

CONCLUSION

In general, intercropping, growing of two or more crops in the same space at the same time, is an old and commonly used cropping practice which aims to match efficiently crop demands to the available growth resources and labor. The most common advantage of cereal legume intercropping is the production of greater yield on a given piece of land by making more efficient use of the available growth resources. Cereal legume intercropping improves soil fertility through biological nitrogen fixation with the use of legumes, increases soil conservation through greater ground cover than sole cropping. Moreover, cereal such as maize and legume such as soybean intercropping increase incomes obtained by smallholder farmers through better utilization of land.

REFERENCES


