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Intercropping Practice as an Alternative Pathway for Sustainable Agriculture: A review

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World population is growing exponentially and it has to fulfill their food requirements. An attractive strategy for increasing productivity and labour utilization per unit area of available land is to intensify land use. Intercropping is advanced agro technique of cultivating two or more crops in the same space at the same time and has been practiced in past decades and achieved the goal of agriculture. It increases productivity per unit area of land via better utilization of resources, minimizes the risks, reduces weed competition and stabilizes the yield. Moreover, intercropping improves soil fertility through biological nitrogen fixation with the use of legumes, increases soil conservation through greater ground cover than sole cropping, and provides better lodging resistance for crops susceptible to lodging than when grown in monoculture. It also provides insurance against crop failure or against unstable market prices for a given commodity, especially in areas subject to extreme weather conditions such as frost, drought, and flood. Thus, it offers greater financial stability than sole cropping, which makes the system particularly suitable for labor-intensive small farms. Besides, intercropping allows lower inputs through reduced fertilizer and pesticide requirements, thus minimizing environmental impacts of agriculture.

Key words: Alternative, intercropping, significance, sustainable agriculture

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INTRODUCTION

Self-sustaining, low-input and energy-efficient agricultural systems in the context of sustainable agriculture have always been in the centre of attention of many farmers, researchers, and policy makers' worldwide (Altieri *et al*., 1983; Altieri, 1999). However, most practices of modern agriculture, e.g. mechanization, monocultures, improved crop varieties, and heavy use of agrochemicals for fertilization and pest management, led to a simplification of the components of agricultural systems and to a loss of biodiversity. Restoring on-farm biodiversity through diversified farming systems that mimic nature is considered to be a key strategy for sustainable agriculture (Jackson *et al*., 2007; Scherr and McNeely, 2008). On-farm biodiversity, if correctly assembled in time and space, can lead to agro ecosystems capable of maintaining their own soil fertility, regulating natural protection against pests, and sustaining productivity (Thrupp, 2002; Scherr and McNeely, 2008). Biodiversity in agro ecosystems can be enhanced in time through crop rotations and sequences in space through cover crops, intercropping, and agroforestry (Altieri, 1999; Malézieux *et al*., 2009).

While modern agriculture has brought vast increases in productivity to the world's farming systems, it is widely recognized that much of this may have come at the price of sustainability (Tilman *et al.*, 2002; Lichtfouse *et al.*, 2009). This is because modern farming systems imply the simplification of the structure of the environment over vast areas, replacing natural plant diversity with only a limited number of cultivated plants in extensive areas of arable monocultures (Vandermeer *et al.,* 1998). By contrast, on farm biodiversity is familiar to traditional farmers mainly in developing countries, where traditional farming systems are characterized by their great degree of genetic diversity in the form of mixed cropping and agroforestry patterns, based on numerous varieties of domesticated crop species as well as their wild relatives (Altieri, 1999). These farming systems offer a means of promoting diversity of diet and income, stability of production, reduced insect and disease incidence, efficient use of labor, intensification of production with limited resources, and also maximization of returns under low levels of technology (Anil *et al.*, 1998; Malézieux *et al.*, 2009).

Intercropping 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 (Andrews and Kassam, 1976; Ofori and Stern, 1987; Anil *et al.*, 1998). The two or more crops in an intercrop normally are from different species and different plant families, or less commonly they may be simply different varieties or cultivars of the same crop, such as mixing two or more kinds of wheat seed in the same field. The most common advantage of intercropping is to produce a greater yield on a given piece of land by achieving more efficient use of the available growth resources that would otherwise not be utilized by each single crop grown alone. Therefore there is need of reviewing the scope of research made in an intercropping to achieve sustainable agriculture. Thus, this review work has been made with the following objectives:

- To evaluate (review) the scope of research made in an intercropping practice as an alternative pathway for sustainable agriculture
- To summarize significance of intercropping practice in the context of sustainable agriculture.

OVERALL REVIEW

Intercropping worldwide

Traditional agriculture, as practiced through the centuries all around the world, has always included different forms of intercropping. Today, intercropping is commonly used in many tropical parts of the world particularly by small-scale traditional farmers (Waddington *et al.*, 2007). Traditional multiple cropping systems are estimated to still provide as much as 15-20% of the world's food supply (Altieri, 1999). 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 (Lithourgidis *et al.*, 2011). Other quantitative evaluations suggest that 89% of cowpeas in Africa are intercropped, 90% of beans in Colombia are intercropped, and the total percentage of cropped land actually devoted to intercropping varies from a low 17% for India to a high of 94% in Malawi (Vandermeer, 1989).

In the tropical regions, intercropping is mostly associated with food grain production, whereas in the temperate regions it is receiving much attention as a means of efficient forage production (Waddington *et al.*, 2007; Lithourgidis *et al.*, 2011). Although intensive monocropping is much easier for large-scale farmers, who plant and harvest one crop on the same piece of land using machinery and inorganic fertilizers, small-scale farmers, who often do not have readily access to markets and grow enough food only to sustain themselves and their families, recognize that intercropping is one good way of ensuring their livelihood.

Intercropping is a common practice in many areas of Africa as a part of traditional farming systems commonly implemented in the area due to declining land sizes and food security needs (Waddington *et al.*, 2007). It is mostly practiced on small farms with limited production capacity due to lack of capital to acquire inputs. Features of an intercropping system can differ largely with soil conditions, local climate, economic situation, and preferences of the local community. However, in the mechanized agricultural sector of Europe, North America, and some parts of Asia, intercropping is far less widespread. This is because modern agriculture has shifted the emphasis to a more market-related economy and this has tended to favour intensive monocropping systems (Horwith, 1985; Lauk and Lauk, 2009). Although agricultural research originally focused on sole cropping and ignored the potential of intercropping, there has been a gradual recognition of the value of this kind of cropping system. In fact, despite its advantages, the agricultural intensification in terms of plant breeding, mechanization, fertilizer and pesticide use experienced during the last 50 years has led to elimination of intercropping from many farming systems. However, intercropping has been shown to produce higher and more stable yields in a wide range of crop combinations, while the system is characterized by minimal use of inputs such as fertilizers and pesticides, emphasizing the production of healthy, safe, and high quality food in the context of environmentally sound production. For organic sector, intercropping is considered an effective means of self regulation and resilience of the organic agro ecosystems to meet environmental perturbations in the organic culture practice (Lammerts van Bueren *et al.*, 2002). Nowadays, organic farmers still depend mainly on modern varieties developed from conventional breeding programs (Murphy *et al*., 2007; Vlachostergios and Roupakias, 2008; Vlachostergios *et al*., 2010), but the majority of these varieties cannot face up efficiently problems as pest and fungus pathogens, weed competitiveness, or resource exploitation under organic farming systems (Wolfe *et al*., 2008; Lammerts van Bueren *et al*., 2003). On the contrary, intercropping offers effective weed suppression, pest and disease control, and use of soil resources under organic farming systems (Bulson *et al*., 1997; Theunissen, 1997; Jensen *et al*., 2005). The last decades, several organic farmers are experimenting and gradually adapt intercropping systems in order to benefit from the advantages of intercropping (Entz *et al*., 2001).

Main aspects to be considered in an intercropping systems

Successful intercropping needs several considerations before and during cultivation. Careful planning is required when selecting the component crops of a mixture, taking into account the environmental conditions of an area and the available crops or varieties. It is particularly important not to have crops competing with each other for physical space, nutrients, water, or sunlight. Silwana and Lucas (2002) found intercropping affects vegetative growth of component crops, therefore have to consider the spatial (Willey and Rao, 1981a), temporal and physical resources. Economically viable intercropping largely depends on adaptation of planting pattern and selection of compatible crops (Seran and Brintha, 2009a). Examples of intercropping strategies are planting a deep rooted crop with a shallow-rooted crop, early maturing crops with long maturing crops or planting a tall crop with a short crop that requires only partial shade (Fan *et al*., 2006). The combination of cereals with legumes in mixed cropping offers particular scope for developing energy-efficient and sustainable agriculture due to the nitrogen fixation capability of the legume and the provision of protein in the form of either grain or forage (Figure 1). There are many different types of species that can be used for intercropping: annuals, e.g. cereals and legumes, perennials including trees (agroforestry), or a mixture of the two (Malezieux *et al*., 2009; Lithourgidis and Dordas, 2010).

Significance of Intercropping

Efficient resource utilization and increase productivity and yield stability

Yield is taken as the primary consideration in the assessment of the potential of intercropping practice (Anil *et al*., 1998). Intercropping gives a greater stability of yield over monoculture (Willey and Reddy, 1981b) and productivity than sole crop grown on the same area of land (Lithourgidis *et al.,* 2007; Dahmardeh *et al.,* 2009). The main reasons for higher yields in intercropping is that component crops make better overall use of natural resources differently than grown separately (Willey,1979; Andersen *et al*., 2007; Agegnehu *et al*., 2008) (Figure 2).

Yield advantage occurs because growth resources such as light, water, and nutrients are more completely absorbed and converted to 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 (Agegnehu *et al*.,2008;Tsubo *et al*.,2001; Walelign, 2004).

Different root and leaf systems are able to harmless more light and make use of more water and nutrients than when the roots and leaves of only one species are present. Intercropping between high and low canopy crops is a common practice in tropical agriculture and to improve light interception and hence yields of the shorter crops requires that they be planted between sufficiently wider rows of the taller once(Hugar and Palled,2008a; Dusa,2013). Agegnehu *et al.* (2008) and Yayeh (2014) reported greater total yields and land equivalent ratios for all intercrops than for sole crops (Figure 2 & and Table1).

Intercrops have been identified to conserve water largely because of early high leaf area index and higher and higher leaf area (Ogindo and Walker, 2005). In areas where water scarcity, intercropping is suitable methods (Lynam *et al*., 1986). Barhom (2001) and Ulah *et al*. (2007) reported that water use efficiency was the highest under soybean-maize intercropping compared with monocropping maize and soybean.

The competitive relationship between the component crops, efficient utilization of land and overall productivity of intercropping system can be accurately assessed with the help of land equivalent ratio (LER) (Willey, 1979; Willey and Rao, 1980). 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 (Willey, 1979; Willey and Rao, 1980) (Table 1). By contrast, when the component crops have similar growth durations their peak requirements for growth resources normally occur about the same time and the competition for the limiting growth resources is intense (Fukai and Trenbath, 1993;

Figure 1: Strip intercropping, where several rows of a plant species are alternated with several rows of another plant species (one broomcorn row with two bush bean rows) (Lithourgidis *et al.*, 2011)

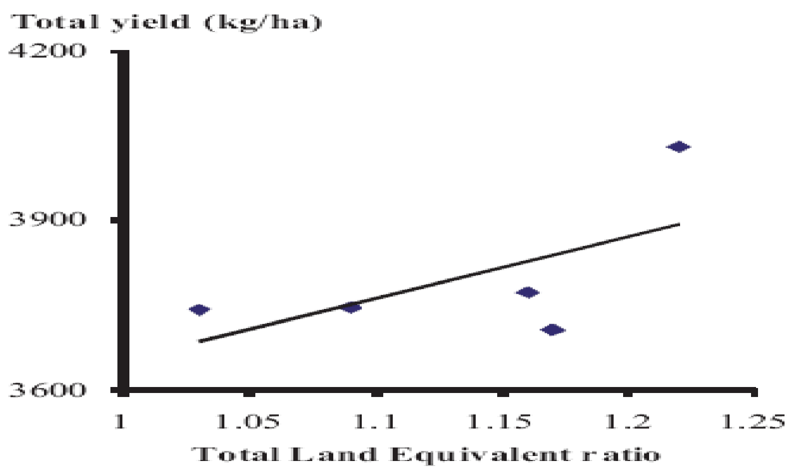


Figure 2: Interrelationships of total land equivalent ratios and total grain yield (kgha^{-1}) of wheat and faba bean grown under mixed intercropping. Y=1092.3 x + 2560.7 (R2=0.38) (Agegnehu, 2008)

Table 1: Land equivalent ratio of different intercropping systems in different countries at different years

Intercropped species	LER	Country	References
Wheat-Faba bean	1.22	Ethiopia	Agegnehu *et al.*(2008)
Maize-tef relay	1.54	Ethiopia	Walelign (2004)
Maize-potato	1.91	Ethiopia	Yayeh,2014
Maize-Bean	1.47	South Africa	Tsubo *et al.*(2004)
Maize-soybean	1.62	India	Ulah *et al.* (2007)
Maize-Coriander	1.42	India	Hugar and Palled(2008a)
Oat-lentil	1.40	Rome	Dusa, (2013)

Ulah *et al.*,2007).

Promotion of biodiversity and stability

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 (Lithourgidis *et al*., 2011). 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 ((Lithourgidis *et al*., 2011; Tsubo *et al*., 2005). As a result, in stable systems, serious pest outbreaks are rare because natural pest control can automatically bring populations back into balance (Altieri, 1994). Therefore, on-farm biodiversity can lead to agro ecosystems capable of maintaining their own soil fertility, regulating natural protection against pests, and sustaining productivity (Thrupp, 2002; Scherr and McNeely, 2008).

Risk spreading and food security

One important reason for which intercropping is popular in the developing world is that it is more stable than monocropping (Lithourgidis *et al*., 2011). When two or more crops are grown on the same field, the risk for the crop failure is spread over the different crops as the different crops have different periods and patterns of growth, and are affected by different diseases (Tefera and Tana, 2002). Thus, If one of the crops fails (due to drought, flood, pests or diseases), there still is a harvest from the other crops (Hauggaard- Nielsen *et al*., 2001a; Lithourgidis *et al*., 2011). Moreover, farmers may be better able to cope with seasonal price variability of commodities which often can destabilize their income (Osman *et al*., 2007). This ultimately increases food security (IPMS, 2005).

Intercropping as alternative means of lodging resistance to prone crops

Intercropping can provide better lodging resistance for some crops highly susceptible to lodging (Assefa and Ledin, 2001) (Figure 3). Lodging, which is commonly observed in some crops, frequently can reduce plant growth severely. Some of the damage is often attributable to subsequent disease infections and mechanical damage, whereas loss of plant height reduces efficiency of light interception. In addition, lodged crops may slow harvest operations or may cause harvest loss. Improved stand ability commonly results in increased harvestable yield, improved crop quality, and increased efficiency of harvest. The introduction of legumes intercropped with non legumes has drawn considerable interest because not only is there the ability to improve cash returns by increasing land use efficiency, but the inclusion of component crops such as canola or mustard as an intercrop will also greatly improve lodging resistance of grain legumes, thereby increasing yield, product quality, and harvest efficiency (Waterer *et al*., 1994). This is because legumes are sensitive to shading, resulting in thinner stems and easier to lodging. Lodging of climbing bean intercropped with corn was prevented to some extent because corn provided support to common bean and also acted as a wind barrier (Rauber *et al*., 2001).

Impact of Intercropping on Pests, diseases and weed control

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. neighbouring plants and microclimatic conditions, is altered and secondly, the host plant quality, e.g. morphology and chemical content, is altered (Langer *et al*., 2007). Insects or other pests can also be mislead by the canopy of an intercrop and not recognize the specific crop they use as a host (Thrupp, 2002; Scherr and McNeely, 2008). Substances that other crops produce may drive insects away from the main crop or natural enemies of insects may be attracted by one of the crops in the intercrops. Intercropping maize/ cassava with cowpea/bean diseases incidence in legumes was reduced than sole cropped (Chemeda and Yuen, 2002; Sikirou and Wydra, 2008). Degri *et al.* (2014) also investigated that pear millet intercropped with groundnut significantly ($p < 0.05$) reduced stem borer (*Chilo zacconius*) incidence compared with the control (Table 2). According to the findings of Degri *et al.* (2014) intercrop pattern of 1:2 ratio and 1:1 ratio yielded less stem borer infestation and abundance in pearl millet, and as well supported high panicle weight and grain yield. Similarly, Intercropping maize-haricot bean reduces the stalk borer infestation on maize (Ashenafi *et al*, 2015) (Table 3). Agegnehu *et al.* (2008) also found intercrops were more suppressive of weeds and diseases than either wheat or faba bean sole crops (Table 3). According to (Tsubo et al., 2005) intercropping is an ecological method to manage insect pest, diseases and weeds via natural competitive principle.

Recently, it was reported that intercropping provides better weed control as compared to monoculture due to a more competitive effect against weeds either in time or space than monocropping. In intercropping legume cover the soil that suppress the growth of weeds and sustain plant health (Baumann *et al*., 2002; Jensen *et al*., 2005;

Figure 3: Lodging resistance for susceptible crops through intercropping: b) corn with climbing bean, c) barely with common vetch **(**Source: Rauber *et al*., 2001)

Hauggaard- Nielsen *et al*., 2001a). Intercropping of 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 with sole crops (Langer *et al*., 2007; Bilalis *et al*., 2010). Similarly, Weed population was reduced in wheat-faba bean intercropping (Agegnehu *et al*., 2008) (Table 4). Bibi and Khan (2014) also reported that weed biomass was significantly affected by the intercropping treatments (Table 4).

Intercropping for erosion control

Davidson (1994) described that well managed strip intercropping system could result into greater soil and water conservation potential than most of the monocropping systems. Chen *et al.* (2010) observed that intercropping of wheat and potato grown in strips up to 5m can reduce wind erosion, soil desertification and degradation effectively. Chen *et al.* (2010) concluded that wheat-potato intercropping resulted into reduction in wind erosion. They also stated that effective width of strip for control of wind erosion should be greater than or equal to 5.5 meters.

Table 2: Effect of pear millet-groundnut intercropping system on stem borers infestation, panicle weight and grain yield of pear millet in Nigeria (Degri *et al.,* 2014)

Intercropping pattern (Pear millet: ground nut)	Stem borer/plant N=20	Mean panicle weight (kg/ha)	Mean grain yield (kg/ha)
1:0	9.17	652.41	596.70
1:1	5.75	1049.22	975.62
2:1	6.08	769.20	681.51
1:2	3.83	1249.33	1209.13
SE±	0.40	32.51	24.61
LSD(0.05)	0.82	66.22	49.32

Table 3: Stalk borer infestation on maize grown in sole maize and intercropped haricot bean and septoria diseases on wheat grown in sole and intercropped faba bean at the respective location of west Badewacho and Holeta, Ethiopia (Ashenafi *et al.* (2015) and Agegnehu *et al.* (2008)

Ashenafi *et al.*(2015)		**Agegnehu *et al.* (2008)**	
Treatments		Treatment	SPT (%)
Cropping systems	Stalk borer infestation	Sole wheat	76
Sole	8.89a	Wheat/faba bean(100:12.5)	75
Intercropped	4.95b	Wheat/faba bean(100:25)	74
LSD(0.05)	1.92	Wheat/faba bean(100:37.5)	73
CV (%)	43.78	Wheat/faba bean(100:50)	74
		Wheat/faba bean(100:62.5)	73
		Level of significance	ns
		LSD(@0.05)	ns
		CV (%)	3.6

SPT (%) - Septoria diseases in percent, LSD=least significant difference, CV (%) = Coefficient of variance

Table 4: Weed biomass as affected by intercropping treatment in Peshawar, Pakistan and Holeta, Ethiopia

Bibi and Khan (2014)			**Agegnehu *et al.* (2008)**	
Treatments	Weed biomass(kgha^{-1})			
	2012	2013	Treatments	WDM(gmm^{-2})
Sole maize(6-rows)	2389a	2906a	Sole wheat	40.4a
Sole mungbean(15 rows)	1837c	2231c	Wheat/faba bean (100:12.5)	34.6ab
Sole cowpea(15 rows)	2159b	2621b	Wheat/faba bean (100:25)	28.5b
Sole sesbania(15 rows)	2056b	2500b	Wheat/faba bean (100:37.5)	32.5b
5- row- sesbania + 6- row- maize	1192g	1455g	Wheat/faba bean (100:50)	31.2b
5- row-Mungbean + 6-row- maize	1373ef	1671ef	Wheat/faba bean (100:62.5)	28.8b
5- row-cowpea+ 6-row- maize	1101g	1345g	Level of significance	**
10- row-sesbania + 6-row- maize	1330f	1619f	Least significance difference(@0.05)	6.3
10- row-cowpea + 6-row- maize	1456de	1770de	CV (%)	19.0
10- row-Mungbean + 6-row- maize	1515d	1835d		
LSD@0.05	113.89	138.09		

WDM-Weed dry matter

Source: Bibi and Khan (2014) and Agegnehu *et al.* (2008)

Table 5: Runoff for various treatments (Kariaga, 2004)

Treatments	Runoff (L)	Percent of bare fallow
Bare fallow	1226.3	100
Sole maize	856.6	67.6
Maize intercropped with beans	434.7	34.6
Maize intercropped with cowpeas	180.7a	14.3
Maize intercropped with beans and cowpeas	222.6a	17.6

LSD Procedure: Values followed by the same letter were not significantly different at P>0.05

Table 6: Soil loss for various treatments (Kariaga, 2004)

Treatments	Soil loss (tha^{-1})	Percent of bare fallow
Bare fallow	83.0	100
Sole maize	28.9	35.0
Maize intercropped with beans	16.3	19.9
Maize intercropped with cowpeas	11.6a	14.0
Maize intercropped with beans and cowpeas	12.5a	15.2

LSD Procedure: Values followed by the same letter were not significantly different at P>0.05

Sharaiha and Ziadat (2007) suggested that multiple cropping systems increase the soil protection by increased vegetative growth during critical erosion periods.

Moreover, deep roots penetrate far into the soil breaking up hardpans and use moisture and nutrients from deeper down in the soil. Shallow roots bind the soil at the surface and thereby help to reduce erosion and help to aerate the soil. Reduced runoff and soil loss were observed in intercrops of legumes with maize (Kariaga, 2004). According to Kariaga (2004) Sole maize produced the highest runoff while maize inter-cropped with cowpeas produced the lowest runoff in the cropped plots (Table 5). The results showed that cowpeas are better at covering the ground surface than beans and when inter-cropped with maize give a better protection of the soil against erosion than when inter-cropped with beans and maize (Table 5 & 6). Similarly, sorghum-cowpea intercropping reduced runoff by 20-30% compared with sorghum sole crop and by 45-55% compared with cowpea monoculture (Zougmore *et al.*, 2000).

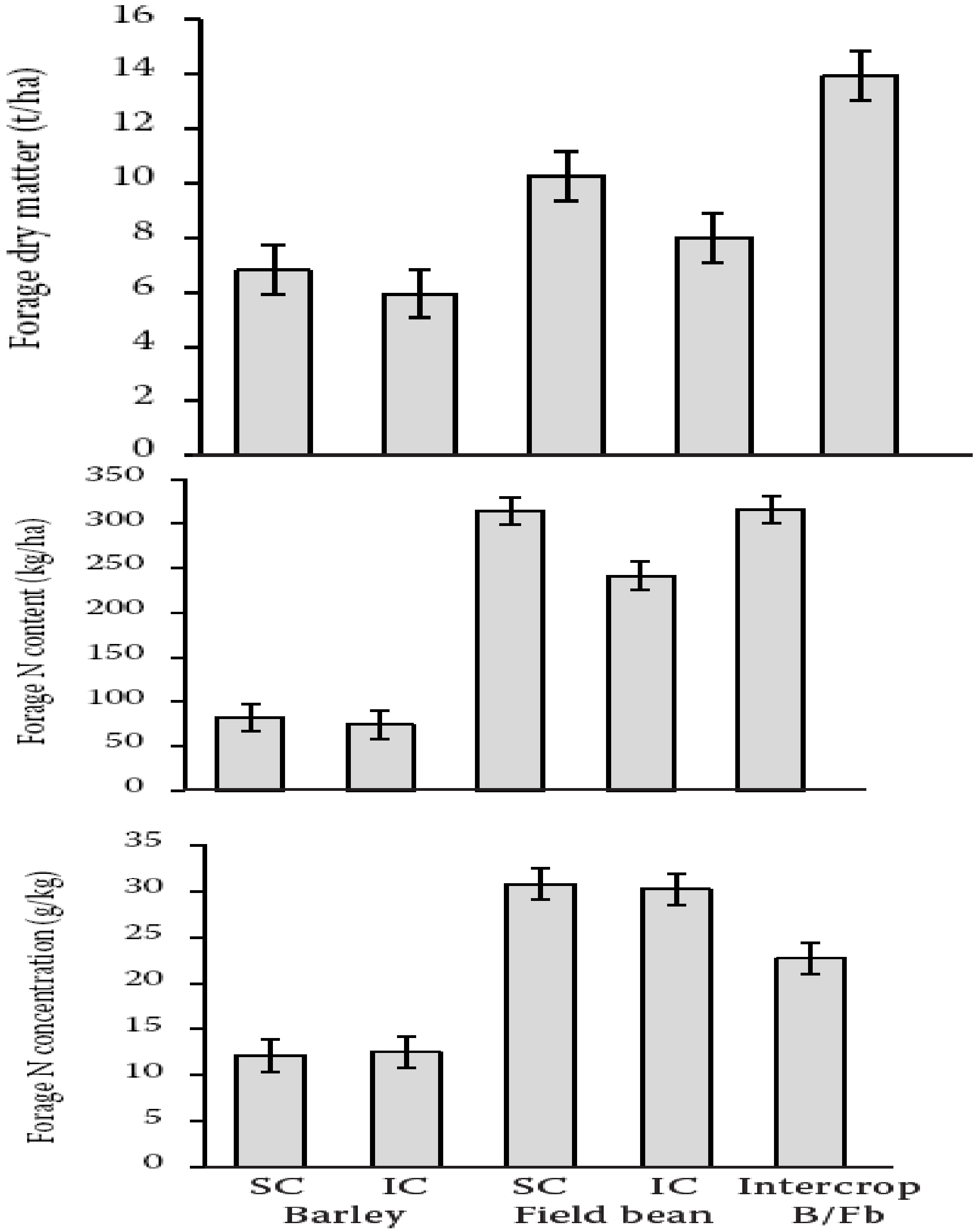
Improvement of soil fertility

Soil fertility problems are not only an agronomic issue, but also strongly related to economical and social issues. Poor farmers are typically risk adverse and cannot afford to make large investments in relation to fertility management. Thus, an important reason for intercropping is the improvement and maintenance of soil fertility (Russell, 2002). This is reached when a cereal crop (such as maize) is grown in association with a pulse (beans, peas and etc). Pulses also called legumes are protein rich sources of food. Legumes enrich soil by fixing the atmospheric nitrogen changing it from an inorganic form to forms that are available for uptake by plants. Biological fixation of atmospheric nitrogen can replace nitrogen fertilization wholly or in part (Fustec *et al.*, 2010). When nitrogen fertilizer is limited, biological nitrogen fixation is the major source of nitrogen in legume-cereal mixed cropping systems (Lithourgidis *et al.*, 2011; Fujita *et al.*, 1992). Moreover, because inorganic fertilizers have contributed to environmental damage such as nitrate pollution, legumes grown in intercropping are regarded as an alternative and sustainable way of introducing N into lower input agro ecosystems (Fustec *et al.*, 2010). Deep rooting Pulse crops, such as pigeon pea also take up nutrients from deeper soil layers; there by recycle nutrients leached from the surface (Adu-Gyamfi *et al.*, 2007; Rahman *et al.*, 2009).

After the intercrop is harvested, decaying roots and fallen leaves provide nitrogen and other nutrients for the next crop (Lunnan, 1989 as cited by Lithourgidis *et al.*, 2011). This residual effect of the pulse crop on the next crop is largest when the remains of the pulse are left on the field and ploughed after harvest (Adu-Gyamfi *et al.*, 2007; Rahman *et al.*, 2009).

Vesterager *et al.* (2008) found maize and cowpea intercropping is beneficial on nitrogen poor soils. Mariotti *et al.* (2015) also found that barely-field bean intercropping increases the nutrients contents compared to mono crop of barely (Figure 4).

From the graph thus, the N yield of IC equaled that of field bean SC and was three times higher than barley SC. The LER showed that N was used 67% more efficiently in IC, while partial LERs (0.90 for barley and 0.77 for field bean) highlighted that field bean had suffered the most also in terms of N uptake.



SC – sole crop; IC – intercropping; B – barley; Fb – field bean

Figure 4: Forage dry matter, N concentration and content of barely and field bean sole crops and intercrops (Source: Mariotti *et al.*, 2015)

Economic benefit of intercropping

Intercropping often provides higher cash return than growing one crop alone (Grimes et al., 1983; Kurata, 1986; Wasaya et al., 2013). Kalara and Gangwar (1980) reported that intercropping helps in increasing farm income on sustained basis. Intercropping commonly gave greater combined yields and monetary returns than obtained from either crop grown alone (Ahmad and Rao, 1982). Intercropping wheat and faba bean gave high net return compared to monocropping (Agegnehu et al., 2008) (Table 7).

Table 7: Economic benefit of intercropping over sole planting (Agegnehu *et al.*, 2008)

Treatments	Gross monetary value (us$ ha^{-1})
Sole wheat	760b
Sole faba bean	418c
Wheat/faba bean(100:12.5)	753b
Wheat/faba bean(100:25)	760b
Wheat/faba bean(100:37.5)	823a
Wheat/faba bean(100:50)	772ab
Wheat/faba bean(100:62.5)	761b
Significance level	***
LSD@0.05	50.7
CV	7.0

1US$= 8.69 Ethiopian birr (ETB), *, **, *** significant at p<0.05, p<0.01, p<0.001: NS=non significant at p<0.05

CONCLUSION

In most multiple cropping systems by smallholders, productivity in terms of harvestable products per unit area is higher than under sole cropping with the same level of management due to reduction of pest incidence, diseases, soil loss and more efficient use of nutrients, water, and solar radiation. These micro ecosystems promote biodiversity, thrive without agrochemicals, and sustain year-round yields. Thus, more research is needed to better understand how intercrops function and to develop intercropping systems that are compatible with current farming systems. It has been emphasized already that for an intercrop combination to be biologically advantageous, the mixture components need to be chosen with care.

If intercropping is soundly practiced, it requires less pesticides and fertilizers, less capital and therefore can be a low-polluting method of farming. Obviously, to have persisted, these systems had to have merit biologically, environmentally, economically, and sociologically. However, to gain acceptance, any agricultural practice must provide advantages over other available options in the eyes of practitioners.

Considering the multiple advantages that can occur from intercropping, particularly in the sake of sustainable agricultural systems, and the environmental problems with current farming systems, it seems reasonable to continue research on the possibilities of growing more than one crop in a field at the same time.

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