Role of Intercropping in Modern Agriculture and Sustainability: A Review

[ab]Kugbe X. Joseph, [b]Richard N. Yaro, [c]Jerry K. Soyel, [d]Ebenzer S. Kofi, [e]Philip Ghaney

[a]Center for Development Research (ZEF), Division of Ecology and Natural Resources Management, University of Bonn, Walter Flex Str. 3, D53113, Bonn, Germany
[b]Faculty of Agriculture, University for Development Studies, Tamale-Ghana

*Corresponding author email address: yaronaabe@yahoo.com, Tel: +233 242043313

Abstract

Sustainable agriculture seeks, at least in principle, to use nature as the model for designing agriculture systems. Since nature consistently integrates her plants and animals into a diverse landscape, a major tenet of sustainable agriculture is to create and maintain diversity. Nature is also efficient. There are no waste products in nature. Outputs from one organism become inputs for another. The death of one organism becomes food for other organisms. Intercropping offers farmers the opportunity to engage nature's principle of diversity on their farms. Plant spatial arrangements, planting rates, and maturity dates must be considered when planning intercrops. Intercrops can be more productive than growing pure stands. Many different intercrop systems are discussed including mixed intercropping, strip cropping, row and relay intercropping arrangements. Pest management benefits can also be realized from intercropping due to increased diversity.

Introduction

Sustainable agriculture is described as farming systems that are capable of maintaining their productivity and usefulness to society indefinitely. Such systems must be resource-conserving, socially supportive, commercially competitive, and environmentally sound (Idowu, 2013). Farming sustainably, means growing crops and livestock in ways that meet three objectives simultaneously: economic profit, Social benefits to the farm family and the community, and environmental conservation (Sullivan, 2003). Sustainable agriculture can be understood as an ecosystem approach to agriculture (Altieri, 1995). In this regard, it is the type of agriculture that is more efficient in the use of resources such as soil and water, for the benefit of human, and is in balance with the environment (Sayed and Hamdollah, 2011). This perceived form of agriculture aims at maximizing on-farm productivity and profit without compromising the integrity of the off-farm environment.

Agriculture in the 21st century faces multiple challenges: it has to produce more food and fibre to feed a growing population whiles the available arable lands are highly competed for other infrastructural development. The approach to increasing food production in recent times has been an increase in crop productivity per unit hectare, which requires the adoption of more efficient and sustainable cropping systems and production methods. According to Emerson (2007), cropping system refers to crops and crop sequences and the management techniques used in a particular field over a period of years. Farmers practice different cropping systems to increase productivity and sustainability (Hauggaard-Nieson, 2001). It has long been hypothesized that the form of cropping can be used to enhance the sustainability of our agricultural production systems. For instance, heavy and large scale application of chemical fertilizers and pesticides that characterizes the monocropping system has received global concerns and is considered a hindrance to achieving environmental sustainability as they cause serious pollution and threatens the earth's existence (Reganold, 1992). Intercropping as a type of sustainable agriculture can be exploited to achieve sustainable farming. This review looks at intercropping and the way it enhances agricultural productivity in an era ever increasing pressure on the static available lands.

Rise and fall of intercropping system

In the early 90`s, growing more than one crop on the same land was not unusual, even in most of the advanced countries of the world (Kass 1978; Andersen, 2005). With the rapid increasing human population especially in most developing countries, came the challenge of meeting the demand for food and fibre within these regions. The dawn of the green revolution was born. The Green Revolution, which according to Hazell (2009) was the period between the 1940s and the late 1960s characterized by series of research development and technology transfer initiatives that increased agricultural production worldwide, particularly in the developing world, beginning most markedly in the late 1960s.

Cereal production more than doubled in developing nations, with yields of rice, maize, and wheat increasing steadily during this period (Conway, 1997). The production increases can be attributed roughly equally to irrigation and mechanization, intensification of synthetic fertilizer use, and seed development (high yielding varieties) (Conway, 1997). Global fertilizer use increased from 27 million tonnes in the late 1950s to 197 million tonnes in 2007–2008, according to Food and Agricultural Organization data. No longer was it necessary to intercrop a legume with a grain to provide nutrients needed by the latter. While agricultural output increased as a result of the Green Revolution, the energy input to produce a crop has increased faster (Church, 2005), so that the ratio of crops produced to energy input has decreased over time. Monocropping, which is growing only one crop in a field at a time, became the economically efficient way to go (Horwith, 1985).

Soon fertilizer shortages and escalating prices developed. The composite fertilizer price increased 113% between 2000 and 2007, led by gains in nitrogen prices (Huang, 2007). As synthetic fertilizer is a petroleum-based product, agriculture was increasingly becoming reliant on crude oil extraction. Additionally, environmental problems associated with heavy use of fertilizers and chemicals were becoming pronounced; surface- and groundwater pollution, soil acidification, and ammonia volatilization are among the most common. Monoculture is characterized by lack of diversity, proliferation of weeds, as well as increased insect pressure. The latter problem is sparingly due to diverse insect community that includes fewer or no pest predators (Horwith, 1985; Horrigan et al., 2002). As these and other problems associated with the monoculture system became more apparent, interest in intercropping grew as possibly, part of the solution to achieving and maintaining sustainability. Intercropping is one of the many systems that hold great potential in solving future food and economic problems in developing countries (Tsubo et al., 2001). A noted reason for the popularity of intercropping in the developing world is that it is more stable than monocropping (Horwith, 1985).Environmental stress which can lead to total crop failure is common in developing countries and intercropping ensures stability due to the partial restoration of species diversity and soil fertility restoration that are lost during monocropping (Li *et al*., 2001b).

Application of intercropping in modern agriculture

Intercropping is the presence of two or more crops in the same field at the same time, planted in an arrangement that results in the crops not competing with one another for resources (Emerson, 2007). Though an ancient practice, intercropping is still widespread in most of the developing world. Cereals such as maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), or millet (*Panicum* and *Pennisetum* spp.) are intercropped with grain legumes such as pumpkin (*Cucurbita* spp.) cowpeas (*Vigna unguiculata* (L.) Walp), pigeon peas (*Cajanus cajan* (L.) Millsp.), or beans (*Phaseolus* spp.) in Africa, whiles maize is grown with beans and squash (*Cucurbita* spp.) in the tropical Americas (Stephen, 2007). In both Africa and Latin America, beans or peas (*Pisum sativum* L.) climb tall cornstalks while pumpkins or squash cover the ground below. Farmers within these countries are notably limited in their efforts to accessing agricultural resources and inputs, which characterizes most of the developed world (Stephen, 2007). Besides, intercropping is much less risky in that if one crop fails another or the others may still be harvested.

Types of intercropping systems

There are four types of intercropping (Ofori and Stern, 1987;Vandermeer, 1992):

a. Mixed intercropping: Broadcasting the seeds of both crops or dibbling the seeds without any row arrangement. It is easy to do but makes weeding, fertilization and harvesting difficult. Individual plants may compete with each other because they are too close together.

b. Row intercropping: Planting both the main crop and the intercrop in rows. The rows make weeding and harvesting easier than with mixed intercropping.

c. Strip Inter-cropping: Growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact ergonomically.

d. Relay inter-cropping: Growing two or more crops simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage but before it is ready for harvest. This helps avoid competition between the main crop and the intercrop. It also uses the field for a longer time, since the second crop (the intercrop) usually continues to grow after the main crop is harvested.

According to Singh (1990) intercropping may be divided into the following four groups;

i) Parallel Cropping: Under this cropping two crops are selected which have different growth habits and have a zero competition between each other and both of them express their full yield potential. Examples are green gram or black gram with maize and green gram or soybean with cotton.

ii) Companion Cropping: In companion cropping the yield of one crop is not affected by the other. In other words, the yield of both the crops is equal to their pure crops in which their standard plant population is maintained. Examples are mustard, wheat, potato, etc. with sugarcane and wheat, radish, cabbage, sugar beat etc., with potato.

iii) Multistoried Cropping or Multi-tire cropping: Growing plants of different height in the same field at the same time. It is mostly practiced in orchards and plantation crops for maximum use of solar energy even under high planting density. Example, eucalyptus +papaya + berseem. Sometimes it is practiced under field crops such as sugarcane + potato + onion.

iv) Multi-tire Cropping: It is mostly prevalent in plantation crops like coconut and areca nut. It involves intercropping different crops of varying heights, rooting pattern and duration. The objective of this system of cropping is to utilize the vertical space more effectively. In this system, the tallest components have foliage tolerant of strong light and high evaporative demand and the shorter component(s) with foliage requiring shade and or relatively high humidity. Example coconut + black pepper + cocoa + pineapple.

Prospects of intercropping

1. **Increasing crop productivity**

One of the main reasons for the use of intercropping around the world is that it produce more than a pure cropping of same land amount (Caballero and Goicoechea, 1995).Corn-soybean intercrop produced DM yields similar to those of monocropped corn due to higher corn yields in border rows adjacent to soybean. However, crude protein (CP) yields per hectare in intercrop treatments were higher (27.5 to 42.8%) than those of monocropped corn, due to greater CP concentrations in intercrops (16 to 21 g kg–1) (Reta Sánchez *et al*., 2010). Hamdollah and Ahmed, (2009) reported a significant effect of Maize (*Zea mays*) and cowpea (*Vignasinensis*) intercropping systems on forage dry weight, where dry matter yield was increased by intercropping as compared with maize and cowpea sole crops. It was related to higher consumption of environmental resources, such as photosynthetic active radiation and soil moisture by intercropping. Maize forage quality in terms of crude protein was improved by intercropping. It was because of more nitrogen availability for maize in intercropping compared with its sole crop. Also Martin and Snaydon, (1982) in their study reported that grain and dry matter yield in bean and barley intercrops was more than their pure cropping.

2. **Better utilization of environmental resources**

Intercropping improves the use of limited resources (Willey, 1979; Dapaah *et al*., 2003). Intercropping of cereals and legumes often gives higher resource use efficiency compared to sole cropping (Ofori and Stern, 1987) because intercropping of species that differ in the time of their maximum demands on the environmental resources extends the duration of resource use (Chandra ., 2011). Due to the differential utilization of environmental resources between the main crop and the intercrop, the resources are used more effectively than a pure cropping with a resultant increasing yield (Jensen, 1996). Furthermore, a cereal-legume intercrop would be valuable because the component crops can utilize different sources of N (Chu *et al*., 2004). The cereal may be more competitive than the legume for soil mineral N, whiles the legume can fix N symbiotically if effective strains of *Rhizobium* are present in the soil. Such complementarity of crops in resource use is particularly important in low input subsistence farming systems such as those in the East African highlands (Getachew *et al*., 2006). Moreover, two crops differing in height, canopy, adaptation and growth habits grow simultaneously with least competition (Bhatti *et al*., 2006), greater yield stability over different seasons and better use of land resources.

3. Reduction of pests, diseases and weeds incidence

The component crops used in intercropping systems differ in morphology, growth and adaptation, growing simultaneously with a resultant possibility of better smothering effect on weeds and control over pests and diseases (Chu *et al*., 2004). Intercropping provides increased diversity, which facilitates better biological control of pests (Stephen, 2009). Legumes intercropped with cereals can provide not only nitrogen, but also other minerals, soil cover, as they also smother weeds, provide habitat for pest predators. Lack of diversity in monoculture fosters weed problems, as well as increased insect pressure. The latter problem is partly because of monocultures less diverse insect community that includes fewer or no pest predators (Horwith 1985; Horrigan et al. 2002).

The interference of weeds with cultivated crops is of two main categories; completion for available space, light, water, nutrients and other environmental resources or allelopathy, where the weeds secrets chemicals that are detrimental to and thus interfere with the normal growth and development of the cultivated crop. Weed growth basically depends on the competitive ability of the whole crop community, which in intercropping largely depends on the competitive abilities of the component crops and their respective plant populations. Broadly, where the total intercrop population is higher than in sole crops (which is very often the case), then greater weed suppression can be achieved (Moody and Shetty 1981), but where the total population is similar to that of the sole crops, weed suppression is likely to be some simple average of the two sole crops, taking into account their respective proportions. In pure culture, sole crops are incapable utilizing to the fullest available space, light, water and nutrient resources within its vicinity, this niche is apparently capitalized by weeds and enhances their competitive abilities. In an intercropping system however, supplementary resources are utilized by the complementary crop, leaving an empty nich, thus weed control is better and effective than the monocropping system.

4. Stability and uniformity Yield

Farming is a very risky venture, its net return is influenced by a lot of factor that are not within the domain of the farmer to control. Erratic rainfall, outbreak of fires, incidence of pest and disease but to mention few are some of the factors that militates against a successful farming venture. Farmers, especially those with limited resources are very skeptical about the stability of their yield when entering into crop cultivation. Two or more crop grown together compensate each other in terms of yield, therefore incidence of complete crop failure which is usually associated with monocropping is less likely to occur in intercropping systems.

5. Improvement and maintenance of soil fertility

Legumes intercropped with cereals can increase microbial diversity, such as vesicular arbuscular mycorrhizae (VAM). VAM is a fungus a pivotal role in nutrient transfer, example is phosphorus transfer to the other crop to which it is intercropped with. The association with VAM becomes very significant where one crop has the ability to mine different sources of nutrients than the other. Some evidence shows more P, K, Ca, and Mg availability in intercrops than in monocultures (Vandermeer 1992; Li *et al*., 2007).Legumes fix atmospheric nitrogen, which may be utilized by the host plant or may be excreted from the nodules into the soil and be used by other plants growing nearby. The fixed nitrogen may also be released by decomposition of the nodules or leguminous residue after the legume plants die or are ploughed under. The crop residues left on the surface or incorporated into the soils have an added advantage of reducing surface run-off and subsequent soil losses. This means less nutrients are lost and more water is available for crop growth. Intercropping of cereal and legume crops helps maintain and improve soil fertility (Andrew, 1979).

Conclusion

Intercropping has many advantages especially for the developing world. When factors such as climatic conditions, timing of the intercrop planting and the crop use for the intercrop are right, then the intercropping will be very successful.

References

Altieri Miguel A. (1995) *Agroecology: The science of sustainable agriculture*. Westview Press, Boulder, CO.

Andersen M.K. 2005.Competition and complementarity in annual intercrops—the role of plant available nutrients. PhD thesis, Department of Soil Science, Royal Veterinary and Agricultural University, Copenhagen, Denmark. SamfundslitterаurGrafik, Frederiksberg, Copenhagen.

Andrews, R.W. 1979. Intercropping. Its importance and research needs I. Competition and yield advantages. Field Crops Abstracts 32: pp1-10, II Agronomy and research approaches .Field Crops Abstracts 32: pp73- 85.

Bhatti I. H., Ahmad R., Jabbar A., Nazir M. S. and Mahmood T. 2006. Competitive behaviour of component crops in different sesame-legume intercropping systems. *Internation Journal of Agriculture and Biology,* 08 (2), 165–167.

Caballero R. and Goicoechea E. L., 1995. Forage yield quality of common vetch and oat sown varing seeding ratios and seeding rates of vetch. Field Crops Research, 41: 135-140.

Chandra A., PardhaSaradhi P., Maikhuri R. K., Saxena K. G. and Rao K.S. 2011. Traditional Agro diversity

Management: A Case Study of Central Himalayan Village Ecosystem. *Journal of Mountain Science*, 08, 62-74.

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

Church Norman (1 April 2005). "Why Our Food is So Dependent on Oil". Power Switch. Archived from the original on 1 April 2005.Retrieved 8 August 2011.

Conway, G. 1997. The Doubly Green Revolution: Food for All in the Twenty-First Century. Ithaca, New York: Comstock Publishing Associates.

Dapaah H. K., Asafu-Agyei J. N., Ennin S. A. and Yamoah C. Y. 2003. Yield stability of cassava, maize, soybean and cowpea intercrops. *Journal of Agricultural Science* Cambridge 140:73–82.

Emerson Nafziger. 2007. Cropping systems; Illinois Agronomy Handbook. *Pp 49-50. ednaf@illinois.edu.*

Getachew Agegnehu, Amare Ghizaw and WoldeyesusSinebocrop productivity and land-use efficiency of a teff/faba bean mixed cropping system in a tropical highland environment. *Agric.*, volume 42, pp. 495–504.

Hamdollah Eskandari and Ahmad Ghanbari. 2009. Intercropping of Maize (Zea mays) and Cowpea (Vignasinensis) as Whole-Crop Forage: Effect of Different Planting Pattern on Total Dry Matter Production and Maize Forage Quality. Not. Bot. Hort. Agrobot. Cluj 37 (2), 152-155.

Hartman G L, West E, Herman T. 2011. Crops that feed the world 2. Soybean-worldwide production, use, and constraints caused by pathogens and pests. Food Security 3:5-17.

Hauggaard-Nieson H., Ambus P. and Jensen E. S., 2001. Temporal and spatial distribution of roots and competition for nitrogen in pea-barley intercrops. A field studies employing 23P techniques. Plant Soil 236:63−74

Hazell, Peter B.R. (2009). *The Asian Green Revolution*. *IFPRI Discussion Paper* (Intl Food Policy Res Inst). GGKEY:HS2UT4LADZD.

Horrigan, L., R.S. Lawrence, and P. Walker. 2002. How ES sustainable agriculture can address the environmental and human health harms of industrial agriculture. Environmental Health Perspectives. 110:445-456.

Horwith, B. 1985.A role for intercropping in modern agriculture. Biological Sciences 35(5):286-291.

Huang, Wen-yuan. 2007. Impact of Rising Natural Gas Prices on U.S. Ammonia Supply. Outlook Report No.(WRS-0702). Washington, DC: USDA Economic Research Service.

Idowu Ezekiel Olorunfemi. 2013. The Role of Climate, Soil and Crop on Sustainable Agriculture in Nigerian Ecological Zones: A Brief Overview. *Sci. Agri.* 4 (1): 26-36.

Jensen E. S. 1996.Grain yield, symbiotic N2 Fixation and interspecific competition for inorganic N in pea-barley intercrops. *Plant and Soil* 182:25–38.

Kass, D.C.L. 1978. Polyculture cropping systems: review and analysis. Cornell International Agricultural Bulletin 32.

Li L, Sun JH, Zhang FS, Li XL, Yang SC, et al. (2001b) Wheat/maize or wheat/soybean strip intercropping: I. Yield advantage and interspecific interactions on nutrients. Field Crops Research 71:123–137.

Li L., Li S. M., Sun J. H., Zhou L. L., Bao X. G., Zhang H. G. and Zhang F. S. 2007.Diverstiy enhances agricultural productivity via rhizosphere phosphorus facilitation on phosphorous-deficient soils. Proceedings of the National Academy of Sciences 104:11192-11196.

Martin M. P. L. D. and Snaydon R.W. 1982. Intercropping barley and beans I. Effects of planting pattern. Experimental Agriculture, 18: 139-148.

Moody K and Shetty S.V.R. 1981. Weed management in intercropping systems. In: Proceedings of the International Workshop on Intercropping, 10-13 January 1979. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India, p 229-237

Ofori, F. and W.R. Stern, 1987.Cereal-legume intercropping system. Advance in Agronomy, 41: 41-90.

Saudy H.S., and I.M. El-Metwally, 2009. Weed management under different patterns of sunflower-soybean intercropping. Journal of Central European Agriculture, 10(1): 41-52.

Sayed RohollaMousavi and HamdollahEskandari. 2011. A General Overview on Intercropping and Its Advantages in Sustainable Agriculture. *J. Appl. Environ. Biol. Sci.*, 1(11)482-486.

Reganold, J.P., 1992. Effects of alternative and conventional farming systems on agricultural sustainability. Department of Crop and Soil Sciences Washington State University Pullman, WA, USA.

Reta Sánchez D. G., Espinosa Silva J. T., Palomo Gil A., Serrato Corona J. S., Cueto Wong J. A. and GaytánMascorro A.. 2010. Forage yield and quality of intercropped corn and soybeanin narrow strips. Spanish Journal of Agricultural Research 2010 8(3), 713-721 ISSN: 1695-971-X eISSN: 2171-9292

Stephen Machado. 2009. Does intercropping have a role in modern agriculture?. Journal of soil and water conservation. vol. 64, no. 2. Pp 55A-57A

Sullivan P. 2003. Applying the Principles of Sustainable Farming. ATTRA, 2003.Agriculture/Natural Resource Extension.

Vandermeer, J.H., 1992. The Ecology of Intercropping. Publisher: Cambridge University Press.

Willey R. S. 1979. Intercropping – its importance and research needs. Part 1.Competition and yield advantages. *Field Crop Abstracts* 32:1–10.

Bio Profile of Authors

I. Dr.Kugbe X. Joseph is a lecturer in the faculty of Agriculture University for Development Studies in Tamale, Ghana.
II. Richard N. Yaro is an MPhil crop science student in the University for Development Studies in Tamale Ghana.yaronaabe@yahoo.com
III. Ebenzer Kofi S. is an MPhil student offering crop science in the University of Development Studies in Tamale, Ghana. britecho85@gmail.com
IV. Philip Ghaney is an MPhil crop science student in the University for Development studies in Tamale, Ghana. odoom24@gmail.com