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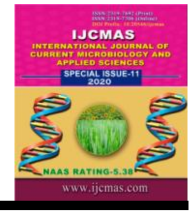


**Review Article**

# Intercropping: Route of Sustainable Intensification

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**A B S T R A C T**

Intercropping is a farming practice involving two or more crop species, or genotypes, growing together and coexisting for a time. On the fringes of modern intensive agriculture, intercropping is important in many subsistence or low-input/resource-limited agricultural systems. By allowing genuine yield gains without increased inputs, or greater stability of yield with decreased inputs, intercropping could be one route to delivering 'sustainable intensification'. The improved understanding can guide approaches for improving intercropping systems, including breeding crops for intercropping. Although such advances can help to improve intercropping systems, we suggest that other topics also need addressing. These include better assessment of the wider benefits of intercropping in terms of multiple ecosystem services, collaboration with agricultural engineering, and more effective interdisciplinary research.

**Keywords**

Intercropping, Intensive agriculture, Sustainable, Breeding, Engineering

## Introduction

Intercropping is a multiple cropping practices involving growing two or more crops in proximity. The most common goal of intercropping is to produce a greater yield on a given piece of land by making use of resources or ecological processes that would otherwise not be utilized by a single crop (Ouma *et al.*, 2010). Intercropping systems involve two or more crop species or genotypes growing together and coexisting for a time. This latter criterion distinguishes intercropping from mixed monocropping and rotation cropping (Vandermeer, 1989; Li *et al.*, 2013). Intercropping is common, particularly in countries with high amounts of subsistence agriculture and low amounts of agricul- tural mechanization. Intercropping is often undertaken by farmers practising low-input (high labour), low-yield farming on small parcels of land (Ngwira *et al.*, 2012). Under these circumstances, intercropping can support increased aggregate yields per unit input, insure against crop failure and market fluctuations, meet food preference and/or cultural demands, protect and improve soil quality, and increase income (Rusinamhodzi *et al.*, 2012). Intercrops can be divided into mixed intercropping (simultaneously growing two or more crops with no, or a limited, distinct arrangement), relay intercropping (planting a second crop before the first crop is mature), and strip intercropping (growing two or more crops simultaneously in strips, allowing crop interactions and independent cultivation

Careful planning is required, taking into account the soil, climate, crops, and varieties. It is particularly important not to have crops competing with each other for physical space, nutrients, water, or sunlight. Examples of intercropping strategies are planting a deep-rooted crop with a shallow-rooted crop, or planting a tall crop with a shorter crop that requires partial shade. Inga alley cropping has been proposed as an alternative to the ecological destruction of slash-and-burn farming. When crops are carefully selected, other agronomic benefits are also achieved.

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Not all intercropping systems provide benefits in terms of all possible metrics. For example, in temperate regions, grain legumes and cereals intercropped as forage yield variable gains depending on the cereal and legume species, the sowing ratio and the specific growing conditions

## Resource-use efficiency in intercropping systems

In 79% of biodiversity experiments, biomass production in species- diverse systems was, on average, 1.7 times higher than in monoculture (Cardinale *et al.,* 2007). Enhanced biodiversity can increase productivity and other ecosystem functions through replacement and complementarity effects. Replacement (or selection) effects result in dominance of mixtures by single, very productive crop species or genotypes: the dominating species increase yields in mixtures relative to expected yields (calculated from monoculture averages of the component species), but not because of beneficial interactions between neighbouring plants (Huston, 1997). Complementarity effects occur when inter-cropped plants with complementary traits interact positively to increase productivity, and genuine yield gains are possible.

## Applying ecological knowledge to intercropping systems

Ecologically, we can define the processes occurring in intercropping systems as the negative interactions of competition, parasitism and amensalism, and positive interactions of mutualism and complementarity (Odum, 1968). To understand species interactions, ecologists have long studied the ecology of agricultural systems (see e.g. Vandermeer, 2010). In return, principles and concepts from ecological research into species interactions undertaken in diverse natural systems, for example their context dependency (Brooker *et al.,* 2008), offer possibilities for improving intercropping systems.

## Mutualism

Planting two crops in close proximity can especially be beneficial when the two plants interact in a way that increases one or both of the plant's fitness (and therefore yield). For example, plants that are prone to tip over in wind or heavy rain (lodging-prone plants), may be given structural support by their companion crop. Climbing plants such as black pepper can also benefit from structural support. Some plants are used to suppress weeds or provide nutrients.. Delicate or light-sensitive plants may be given shade or protection, or otherwise wasted space can be utilized. An example is the tropical multi-tier system where coconut occupies the upper tier, banana the middle tier, and pineapple, ginger, or leguminous fodder, medicinal or aromatic plants occupy the lowest tier.

Intercropping of compatible plants can also encourage biodiversity, by providing a habitat for a variety of insects and soil organisms that would not be present in a single-crop environment. These organisms may provide crops valuable nutrients, such as through nitrogen fixation.

## Advantages of intercropping system

### Greater income, greater yield

Intercropping offers greater financial returns for a farmer. Even if you are growing some produce for your own family or just as part of a hobby, you will have multiple types of produce, which is always a nice outcome. Intercropping will help farmers use the same land as available and yield more as well as diverse produce. This generates more income for the farmer without really taking up any major expenditure. The infrastructure available or the land used remains the same.

### Insurance against crop damage

Intercropping can be the insurance that farmers need, especially when the region is vulnerable to weather extremes. Drought, torrential rain, hurricanes or cyclones and various other weather elements can affect the yield of a given year or season. Having diverse yields allows the farmer to have some income even if the primary crop gets damaged or doesn't yield as much as expected.

### Optimum use of soil

Intercropping makes the most of the available soil. When anything is grown on a farmland, the crop tends to absorb as much water and nutrients as it needs. There could be more nutrients in the soil under the crops and around. This soil and more specifically the nutrients can be used, by the different varieties of crops. Intercropping also averts soil runoff and can prevent the growth of weeds.

### Good for primary crops

Intercropping is good for the primary crops. The secondary crops can provide shelter and even protect the primary crops. Intercropping also allows you to grow cash crops or any crop that will actually supplement the primary crop in some way.

## Future perspectives for intercropping research

Both agronomy and ecology can clearly contribute to the improvement of intercropping systems. They can enhance crop productivity and resource-use efficiency whilst decreasing farm- ing's environmental impact, making intercropping a viable approach for 'sustainable intensification', particularly in regions with impoverished soils and economies where measured benefits have been greatest. But to realize these benefits, major challenges for research remain. Some of them, for example breeding for intercrops, and understanding better the interactions between plants and other organisms in crop systems.

## Designing and breeding for intercropping systems

Plant selection and breeding offer two approaches for improving intercropping systems that, to date, have rarely been considered. The first is selecting crop species and/or cultivar combinations with traits that maximize positive, and minimize negative, interactions. The second is breeding specifically for combinations of desirable traits. Both approaches are promoted through new knowledge concerning the mechanisms underlying intercropping benefits (as detailed earlier), but also by our increasingly detailed understanding of trait variation within crop germplasm collections.

The ideotype required of a particular crop is likely to differ for monocropping and intercropping. In monocropping, traits in the chosen crop exploit the environment exclusively for that crop, and focus on increasing the availability and acquisition of limiting resources (White *et al.,* 2013a,b). By contrast, traits for a compo- nent of an intercrop are those that optimize complementarity or facilitation (Costanzo & Barberi, 2014); traits can be combined from different crops to overcome resource limitations, resource requirements for each crop can be separated temporally, and the cycling of resources can be optimized during the growing season. New approaches to plant breeding are needed for intercropping systems (Hill, 1996). Notably, those crops used currently for assessment of the benefits and management of intercropping have often been bred for and trialled in monoculture systems. Inevitably, their selection has not evaluated interactions between above- and below-ground architectures of multiple species, or tradeoffs provided among nutrient cycling, water redistribution or noncrop biodiversity when several species coexist. Elite monoculture varieties, when assessed using criteria relevant to intercropping systems, might therefore have suboptimal combinations of traits for intercropping.

As a first step to assessing genotypes for intercropping, diverse germplasm of major crops could be trialled in intercropped and monoculture systems to identify traits delivering favourable yield/ quality in one or both systems. Breeding companies are starting to do this (e.g. KWS breeding programme for intercropping bean and maize; Schmidt, 2013). Breeding of plants with traits that benefit a companion crop could also be undertaken, for example by selecting for production of volatiles that deter pests. Finally, the complex interactions that drive resource capture and distribution in intercropped systems could be better understood through resource-based modelling to explore how specific traits can be optimized for complementarity (Trinder *et al.*, 2012).

## Agricultural engineering and management

The greatest changes in intensive agriculture in the past 20 yr have been made possible by developments in engineering. Precision application of nutrients, reduced tillage and the use of genetically modified, herbicide-tolerant crops were all led by industry and promoted by clear farm-gate economic benefits. While generally the targets were increased yield and profit, some innovations such as minimum tillage had perceived benefits for soil sustainability (Powlson *et al.,* 2011). However, the concentration of this technology on monocultures has, in many regions, diminished or negated the original benefits, for example through the rapid evolution of herbicide resistance in weeds caused by a low diversity of cropping practice (Johnson *et al.,* 2009).

Could more diverse systems based on intercropping fare better?

As yet, only a small proportion of larger-scale, intensive farms employ intercropping as a standard practice (Vandermeer, 1989). Mechanization in intercropping is nevertheless possible and is perhaps best demonstrated in legume-based systems. More generally, the development of new machinery that can till, weed and harvest at small spatial scales and in complex configurations is needed to encourage the uptake of intercropping without greater demands for labour. More rapid adoption might also be promoted if benefits are assessed by a wider suite of metrics, and via wider 'systems thinking' through the enactment of schemes, including payment for ecosystem services.

## Intercropping and ecosystem services

More studies are needed to explore the potential of intercrop- ping to deliver ecosystem services beyond crop production, including improving soil and water quality, improving landscape, controlling pests, and mitigating climate change. Ecosystem service approaches should emphasize that intercrops could achieve food security with reduced anthropogenic inputs and lower environmental impact. For example, there is now evidence that increased plant (trait) diversity in grasslands is positively correlated with gross C-allocation below ground, microbial abundance in soil, microbial diversity and soil C sequestration. Therefore, increased plant diversity in cropping systems has the potential to increase soil physical stability and resilience of microbially mediated nutrient cycling processes.

In conclusion, intercropping systems clearly have the potential to increase the long-term sustainability of food production under low inputs in many parts of the world. In the short term, perhaps the most straightforward approach is simply to trial new combinations of crops to exploit beneficial mechanisms that have already been identified, for example, new combinations of cereals and legumes. Rapid improvements are also possible through the development of new agronomic practices, including the mechanization of intercropping systems and improved nutrient management, but again such efforts can be taken forward using existing knowledge and experimental approaches. We will need a better exchange of information among ecologists, environmental scientists, agronomists, crop scientists, soil scientists and ultimately social scientists (e.g. exploring attitudes to uptake, and developing wider cost/ benefit analyses), so that the full potential of intercropping as a sustainable farming system can be realized.

## References

Brooker RW, Maestre FT, Callaway RM, Lortie CJ, Cavieres LA, Kunstler G, Liancourt P, Tielbb€orger K, Travis JMJ, Anthelme F et al. 2008. Facilitation in plant communities: the past, the present, and the future. *Journal of Ecology* 96: 18– 34.

Cardinale BJ, Wright JP, Cadotte MW, Carroll IT, Hector A, Srivastava DS, Loreau M, Weis JJ. 2007. Impacts of plant diversity on biomass production increase through time because of species complementarity. *Proceedings of the National Academy of Sciences*, USA 104: 18123–18128.

Costanzo A, Barberi P. 2014. Functional agrobiodiversity and agroecosystem services in sustainable wheat production. A review. *Agronomy for Sustainable Development* 34: 327–348.

Hill J. 1996. Breeding components for mixture performance. *Euphytica* 92: 135–138.

Huston MA. 1997. Hidden treatments in ecological experiments: re-evaluating the ecosystem function of biodiversity. *Oecologia* 110: 449–460.

Johnson WG, Davis VM, Kruger GR, Weller SC. 2009. Influence of glyphosate-resistant cropping systems on weed species shifts and glyphosate-resistant weed populations. European *Journal of Agronomy* 31: 162–172.

Li L, Zhang L-Z, Zhang F-Z. 2013. Crop mixtures and the mechanisms of over yielding. In: Levin SA, ed. *Encyclopedia of biodiversity*, 2nd edn, vol, 2. Waltham, MA, USA: Academic Press, 382–395.

Ngwira AR, Aune JB, Mkwinda S. (2012). On-farm evaluation of yield and economic benefit of short term maize legume intercropping systems under conservation agriculture in Malawi. *Field Crops Research* 132: 149–157.

Ouma, George; Jeruto, P (2010)."Sustainable horticultural crop production through intercropping: The case of fruits and vegetable crops: A review" (PDF). *Agriculture and Biology Journal of North America*. 1 (5): 1098–1105.

Powlson DS, Gregory PJ, Whalley WR, Quinton JN, Hopkins DW, Whitmore AP, Hirsch PR, Goulding KWT. 2011. Soil management in relation to sustainable agriculture and ecosystem services. *Food Policy* 36: S72–S87.

Rusinamhodzi L, Corbeels M, Nyamangara J, Giller KE. (2012). Maize–grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field Crops Research* 136: 12–22.

Schmidt W. 2013. Experiences from organic maize breeding and prospects of coevolutionary breeding. In: Abstracts of the EUCARPIA Meeting *'Breeding for nutrient efficiency'*, G€ottingen, Germany, 24–26 September 2013. [WWW document] URL http://www.uni-goettingen.de/de/ 415791.html .

Trinder C, Brooker R, Davidson H, Robinson D. 2012. Dynamic trajectories of growth and nitrogen capture by competing plants. *New Phytologist* 193: 948–958.

Vandermeer J. 2010. *The ecology of agroecosystems*. Sudbury, MA, USA: Bartlett and Jones.

Vandermeer JH. 1989. *The ecology of intercropping*. Cambridge, UK: Cambridge University Press.

White PJ, Greenwood DJ. 2013. Properties and management of cationic elements for crop growth. In: Gregory PJ, Nortcliff S, eds. *Soil conditions and plant growth*. Oxford, UK: Blackwell Publishing, Pp. 160–194.