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CONSERVATION IN PRACTICE

Does intercropping have a role in modern agriculture?

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Intercropping—growing two or more crops at the same time on a single field—is an ancient practice still used in much of the developing world. For example, in Africa, corn (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), or millet (*Panicum* and *Pennisetum* spp.) are grown with pumpkin (*Cucurbita* spp.) cowpeas (*Vigna unguiculata* (L.) Walp), pigeon peas (*Cajanus cajan* (L.) Millsp.), or beans (*Phaseolus* spp.). Cocoa (*Theobroma cacao* L.) is grown with yams (*Dioscorea* spp.) or cassava (*Manihot esculenta* Crantz). In the tropical Americas, maize (corn) is grown with beans and squash (*Cucurbita* spp.). In both Africa and Latin America, beans or peas (*Pisum sativum* L.) climb tall cornstalks while pumpkins or squash cover the ground below. In these countries, many farmers have limited access to agricultural chemicals and equipment so prevalent in the developed world. Besides, intercropping is much less risky in that if one crop fails another or the others may still be harvested.

Before the 1940s in the United States and Europe, growing more than one crop in the same field was common practice (Kass 1978; Andersen 2005), again because there was less risk. But with mechanization and the availability of relatively cheap synthetic fertilizers and pesticides, monocropping—i.e., growing only one crop in a field at a time—became the economically efficient way to go (Horwith 1985). No longer was it necessary to grow a legume with a ~~grain~~ to provide nutrients needed by the latter. Under monocropping, synthetic fertilizer-intensive regime, crop yields increased dramatically. US corn yields increased from 1.9 Mg ha^{-1} (30 bu ac^{-1}) in the 1940s to 9.7 Mg ha^{-1} (154 bu ac^{-1}) in 2008. As machines were developed for various single cash crops, intercropping became impractical. These new modern farming methods were also spread to parts of the developing world as high-yielding varieties were developed and fertilized to bring about the Green Revolution that could feed rapidly growing populations. Global fertilizer use increased from 24.5 million Mg (27 million tn) in the late 1950s to 210.5 million Mg (197 million tn) in 2007–2008, according to Food and Agricultural Organization data. Of this composite fertilizer mix, 65% was nitrogen, 19%, phosphorus, and 16% potassium. And worldwide demand for fertilizer is still rising, albeit at a slower rate due to a somewhat increased nutrient use efficiency.

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But now, fertilizer shortages are developing and costs are escalating. The composite fertilizer price increased 113% between 2000 and 2007, led by gains in nitrogen prices (Huang 2007). The US price of ammonia increased from \$250 Mg^{-1} (\$227 tn^{-1}) in 2000 to \$474.4 Mg^{-1} (\$523 tn^{-1}) in 2007, while urea (the main solid US fertilizer form) changed from \$181.4 Mg^{-1} (\$200 tn^{-1}) to \$410.9 Mg^{-1} (\$453 tn^{-1}) (Huang 2007). Meanwhile, environmental problems associated with heavy fertilizer use are becoming well known—e.g., surface- and groundwater pollution, soil acidification, and ammonia volatilization. And as synthetic fertilizer is a petroleum-based product, prices will continue to increase, while their manufacture contributes to greenhouse gas emissions. Also, the lack of diversity in monoculture fosters weed problems, as well as increased insect pressure. The latter problem is partly because of monoculture's less diverse insect community that includes fewer or no pest predators (Horwith 1985; Horrigan et al. 2002). In addition, potent insecticides that kill both pests and their natural enemies are currently being used. US synthetic pesticide use increased 33-fold since 1945, but despite this substantial pesticide cost and use, crop yields continue to be threatened by weeds, insects, and disease. Reasons include built-up pesticide resistance, outbreaks of secondary pests, and susceptibility in the plants (Brenner 1991). As these and other problems with monoculture farming become more apparent, "sustainability" is becoming a household word, and interest in intercropping is growing as, possibly, part of the solution.

Already double cropping is being widely practiced as an alternative to monoculture. In the Midwest, soybeans are being rotated with corn. While soybean itself is a valuable crop, it fixes nitrogen for the next year's corn crop. Similarly, across the nation and beyond, grain crops are rotated with a legume, which may itself be a crop or may be grown as a cover crop. However, in dryland regions of the Pacific Northwest, most grain farmers prefer to stick with grain, not being willing to give up their cash crop for a year of legume without good ways to market that crop.

Intercropping has four general subcategories. There is mixed intercropping, no distinct row arrangement; row intercropping, at least one crop is planted in rows; strip intercropping, growing crops in strips wide enough to separate them, yet narrow enough to allow interaction between them; and relay intercropping, growing two or more crops during differing parts of their life cycles. Whenever two crops are planted together they will interact either or both in competition (for light, water, and nutrients) and facilitation (Vandermeer 1992). That is, they may have negative and positive effects on each other. Of course, intercropping works best when the positive effects are stronger than the negative ones. Intercropping success depends on a good balance between competition and facilitation. Examples of strong facilitation include triticale (*Triticosecale*) that provides a strong stem for the vetch (*Vicia* spp.) vines, while vetch provides the nitrogen for the triticale (Vandermeer 1992). A second crop, whether serving as a cover crop or a windbreaker may increase soil water retention. A windbreaker alters the microclimate of the sheltered crop, which could be very useful in the Pacific Northwest, where gusty wind following rain would ordinarily evaporate the sparse water received. But, on the other hand, the windbreaker crop may also compete with the sheltered crop for the water.

One important reason intercropping is popular in the developing world is that it is more stable than monocropping (Horwith 1985). In Africa and South Asia, where environmental stress is common, intercropping is an insurance against total crop failure (Horwith 1985). The stability under intercropping is attributed to the partial restoration of diversity lost under monocropping. The most well documented advantage of intercropping is reduced damage from insects, nematodes, and disease. One crop may serve as a deterrent (disruptive mechanism) whereby it alters the quality of the other crop, making it a less attractive host for a predator or a parasite. For example, onions (*Allium cepa* L.) are planted with carrots (*Daucus carota* L.) as they mask the carrot smell for carrot flies (Sullivan 2003). The trap hypothesis is that one crop attracts pests that would otherwise have gone to what is being grown as the principal crop. For weeds, a second crop either provides a reduced area for weeds to get a foothold or reduces weed biomass through competition or allelopathy. One study showed that intercropping corn (*Zea mays* L.) and sorghum (*Sorghum bicolor* [L.] Moench) with desmodium (*Desmodium* spp.), effectively controlled witchweed (*Striga hermonthica* Del.) (Khan et al. 2007); another showed that a cover crop of velvetbean (*Mucuna deeringiana* [Bort] Merr.) reduced weed biomass by 68% in corn (Caamal-Maldonado et al. 2001).

If intercropping is, indeed, experiencing a renaissance in response to problems with monoculture, this should not be seen as going back to ancient peasant ways, but, rather, as adopting useful aspects of the practice to modern agriculture. However, the methods described above will likely find their best use in modern *organic* farming. In fact, organic farming is a perfect fit for intercropping as fossil-fuel-based inputs and synthetic pesticides are not allowed.

Intercropping can also fit into conventional cropping systems. Intercropping provides increased diversity, which facilitates better biological control of pests and reduced soil erosion. 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, and increase microbial diversity, such as vesicular arbuscular mycorrhizae (VAM). VAM, a fungus, plays an interesting role in that it is thought to facilitate nutrient transfer—e.g., phosphorus—to the other crop. 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).

Intercropping might also be able to solve the nitrogen dilemma for winter wheat farmers. That is, seeking to maximize yield, these farmers figure the amount of nitrogen to apply to meet the target yield. Generally, as is it certainly more convenient, they apply the precise amount before the crop is planted or at planting. Ideally, they should apply some fertilizer at planting and then apply the remainder as topdress during spring based on the precipitation outlook. However, actual yield depends on the amount of precipitation in that season. If all the fertilizer is applied at planting and if precipitation turns out to be below average or even under drought conditions, the crop has been over fertilized, and it uses up all available water, and dries out. Using intercropping, N-smart cropping systems could be developed. The alternative for these farmers would be to plant a legume and wheat in the same field. The legume can then be killed at appropriate times to avoid too much competition with the primary crop. The goal would be to apply starter N to get the crops going and then rely on the legume to make the "decisions" whether or not to add N to the system; the "decisions" would be based on available soil moisture. The process of N fixation is energy consuming, and the legume will use the easily available N if too much is applied at planting, so the proposed system will not work. Similarly N fixation is sensitive to stress, and when the legume senses drought the plant will stop fixing N (Sinclair et al. 1987), thereby overfertilization is avoided. On the other hand, if environmental conditions permit, the legume can add as much N as possible to the system, presumably leading to high yields of the primary crop. The Columbia Basin Agricultural Research Center's field trials that began in 2003 show that in a 279 mm (11 in) precipitation zone (Moro, Oregon), yields of wheat intercropped with winter pea (seeded at a reduced rate) were 12% to 14% higher than the pure wheat control plot; in the 406 mm (16 in) precipitation zone (Pendleton, Oregon), yield was 4% to 9% higher.

But before intercropping can be widely adopted by organic and conventional farmers, considerably more research is needed. Choosing and managing intercrops requires good planning, that includes selection of appropriate cultivars, proper spacing, etc. For example, in the trials mentioned above, the docile pea variety chosen worked well with the wheat, but when a different pea had to be selected, it turned out to be far too aggressive, out-competing the wheat. Choices of plants for intercrop farming and for research trials are, of necessity, limited to selections that have been bred for monoculture systems. The time when plant breeders have intercropping in mind is far into the future. If and when an effective intercropping breeding program is established, it would require understanding all the competitive and facilitative principles involved in crops working well together. Similarly, most intercropping studies in the past have focused on yields, with little emphasis on the basic inter-specific processes that contribute to those yield results. The success of an intercrop system depends on understanding the physiology of the species to be grown together, their growth habits, canopy and root architecture, and water and nutrient use. Plants compete for light above ground and for water and nutrients below grown, so competition involves a combination of light and soil factors in space and time. What begins as a nutrient competition may end up as a shade issue, as different species compete for various resources at differing times in their growth cycle. This complexity may be discouraging research in these areas (Vandermeer 1992).

The biggest obstacle in adopting intercropping systems is to conceptualize the planting, cultivation, fertilization, spraying, and, particularly, harvesting of more than one crop in the same field. Agronomic recommendations simply do not exist. Furthermore, given the numerous intercrop combinations possible and the myriad of climatic and soil conditions involved, generalization to recommendations may not be possible. Once the potential benefits of intercropping are realized, and the will develops, mechanization could be developed for these potentially beneficial systems, but it will take a long time before mechanized intercropping systems will rival the current monoculture systems. Given the advantages to be enjoyed from intercropping and the environmental and economic 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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