Photo: Jan Valkoun

A dense stand of wild wheats (T. dicoccoides and T. urartu) in southern Syria

In defence of monocultures

David Wood

Crop monocultures are almost universally decried as unnatural, ecologically dysfunctional, and a threat to sustainable agriculture. At least part of this belief is based on the idea that all would be well if agriculture could mimic the structure of natural vegetation, which time has shown to be productive, stable and biodiverse. However, relatively complex natural vegetation - for example, tropical forest– is always suggested as a model for fields rather than simpler vegetation. Consequently, all prescriptions for ecological agriculture recommend between-crop diversity (polyculture), even to the extent of combining trees with crops (agroforestry). This diversity is thought to bring higher levels of productivity, stability, sustainability and equitability. This 'defence of monocultures' will question the *sole* reliance on complex models for *all* agriculture. In contrast, it will suggest that more appropriate models for a key section of farming - annual cereal cropping, now producing most of our food - can be found in vegetation dominated by single species, that is, 'natural monocultures'. Is there something that can be learned from natural monocultures that could be of value to sustainable cereal cropping?

Monocultures in nature

It has now been recognised by ecologists that monocultures exist throughout nature in a wide variety of circumstances, of which two could be of importance for sustainable agriculture.

Marginal conditions*:* Firstly, natural monocultures are found in geographically marginal conditions, very commonly, between water and land. There are many familiar examples like the reed beds of *Phragmites australis* growing on the margins of fresh-water lakes in Europe. Such stands can have an age in excess of 1000 years. Salt marshes on the margin between land and sea in Europe and North America are often dominated by species of the grass genus *Spartina*. Net annual primary productivity of *Spartina alterniflora* marshes has been reported as up to 60 tonnes/ha, a figure close to the highest dry matter yields of intensively managed arable crops.

Disturbed conditions*:* Secondly, natural monocultures are found in disturbed conditions as in the case of *Impatiens glandulifera,* a summer annual that colonises the margins of water courses in Europe. It has been argued that the objective of many forms of arable farming, especially cereal cultivation, is to achieve weed control by creating conditions in which the crop plant attains the dominant status. As in the example, dominance of a cereal crop depends primarily upon the synchronous germination of a high density of large seeds followed by the rapid development of a dense vegetation cover composed of a large number of plants of comparable age and maturity. More generally, the importance of cereals - that is, grasses - in food production may relate to the ability of grasses to resist disturbance, indeed to thrive under seasonally disturbed conditions.

Natural monocultures as models

Rice*:* If there is a natural model for monocrop wet-rice production it should be found in a region of domestication of rice, in southeastern Asia, among wild relatives of domesticated Asian rice. The seasonally flooded rivers and deltas of the great silt-laden rivers draining the Himalayas seem to provide the ecological conditions for wild rice monocultures. The wild rice relative *Oryza coarctata* was the most common and plentiful grass species in the Sundarabans mangrove swamps of Bengal and: 'the first species to establish itself on newly-formed alluvial river banks, which are both marginal and seasonally disturbed by flooding.'

If early farmers chose swamps, first to gather, then to farm rice, they would be working in habitats where 'natural monocultures' are common. Single dominants are able to monopolise a swampy site to the virtual exclusion of any rival and any understorey. In addition, swamp vegetation has relatively high productivity, generally around 15-20 tonnes/ha/year. This is attributed to a plentiful supply of nutrients, due to flushing with nutrient-rich water, and low water stress for most of the year.

Sorghum*:* Savannah grasslands worldwide are often dominated by limited numbers of species, often from the grass tribe *Andropogoneae,* a tribe which includes *Imperata*, but also *Sorghum* and *Saccharum* from which the crops sorghum and sugar cane were domesticated.The *verticilliflorum* race of *Sorghum bicolor* was identified as the progenitor of cultivated sorghums. It was found as the chief dominant, in enormous quantities, of the extensive tall-grass savannah of Sudan and Chad. Sorghum was domesticated somewhere along a belt south of the Sahara from Chad to western Ethiopia. The races *aethiopicum* and *verticilliflorum* of *Sorghum bicolor* are often dominant grasses in the northern savannah of Africa. These 'massive stands' of wild sorghum provide both an evolutionary and ecological pedigree for monoculture sorghum cropping.

Wheat*:* Perhaps the strongest evidence of the importance of natural simple models for cereal agriculture comes from immediate wild relatives of wheat. These are found in the Near Eastern region of domestication, where there has been the most intensive research on crop relatives. Botanists and plant-collectors have repeatedly and emphatically noted the existence of dense stands of wild relatives of wheat. Wild einkorn (*Triticum monococcum* subsp. *boeoticum*) in particular tends to form dense stands, and when harvested its yields per square metre often match those of cultivated wheats under traditional management. Wild emmer (*Triticum turgidum* subsp. *dicoccoides*) grows in massive stands in the northeast of Israel, as an annual component of the steppe-like herbaceous vegetation and in the deciduous oak park forest belt of the Near East. The stand density of these wild cereals is comparable to cultivated fields, suggesting that these southwestern Asian cereals form the basis of modern monocrop agriculture.

Ecological determinants

Although the simple structure of natural monocultures may indicate a model for cereal cropping, a major question remains unanswered. What are the ecological determinants of natural monocultures, and can these be reproduced in sustainable cropping? Answering such questions would allow farmers not just to mimic the structure of natural monocultures, but also to mimic the ecological processes that maintain natural monocultures. Despite considerable recent research by ecologists on the role of species diversity, very little of the newer work takes up the question of why some ecosystems have more species than others. Yet some argue that low species diversity is characteristic of unpredictable and 'environmentally buffeted' environments, and that diversity is not correlated to environmental productivity, as in the case of salt marshes.

Natural flood and fire regimes are examples of environmental buffeting. At the time of transition between food gathering and cropping, early farmers would have been very aware of the impact of ecological determinants such as fire and flood on both productivity and the structure of natural cereal monocultures: human existence depended on this knowledge. A transition to farming that mimicked natural disturbance regimes in early fields would maintain the undoubted robustness of natural monocultures. For rice, the 'artificial swamp' of the field reduces competition from weeds and has allowed rice to persist in pure stands, as with many grasses in natural swamps. For the seasonally-dry grasslands which form a natural model for sorghum, and for wheat and barley fields, seasonal burning or grazing may be the 'fluctuating environment' that gives grasses the competitive advantage in annual seed production.

Diversity within monocultures

The level of within-species diversity in natural monocultures is also of direct importance for agriculture. Monoculture is defined by IBPGR (1991) as: '*the growing of a single plant species in one area, usually the same type of crop grown year after year*'. Nothing is said in this definition of variation within the crop species: complex varietal mixtures, as often found for example in common bean (*Phaseolus vulgaris*) under traditional farming, are monocultures by this definition. However, the term monoculture is now commonly used as a synonym for single-variety fields. Whatever the usage for fields, it will be important to know the genetic structure within natural monocultures and how it compares with the genetic structure of species found in more diverse vegetation. There are indications that some natural monocultures may be genetically uniform – for example, the many examples of aquatic plants, which spread vegetatively – with no intra-specific genetic diversity. It is commonly thought that such a low level of diversity is unsustainable in farmers' fields. How then does it persist in nature? In contrast, if natural monocultures of wild relatives of our cereals are found to be genetically diverse, then varietal mixtures could add sustainability to cereal cropping.

Crop-associated biodiversity

Concern over the ability of crop monocultures to maintain associated biodiversity may be misplaced. There is now substantial evidence that single crops such as rice have self-regulation through great crop-associated biodiversity. At higher trophic levels, including parasites and predators on the herbivores, there is yet more diversity. Management of the crop cycle to increase detritus from the rice crop could encourage detritus feeders and, in turn, natural enemies of rice pests, contributing to substantial biodiversity in a monoculture, and, under most circumstances, minimal pest damage. Indeed, the main problem with monocultures in Green Revolution agriculture could be the loss of associated biodiversity due to the use of agrochemicals, intensive tillage and the large-scale of production, rather than the monoculture itself. More information is needed from wild ecosystems to indicate how the biodiverse properties of natural monocultures can be maintained in agriculture.

Conclusions

Hitherto agroecologists have claimed that sustainability results only from complex polycultures, which mimic complex - and therefore stable - natural ecosystems. While this may be true for more equable tropical regions, it may not always apply to seasonally disturbed or marginal environments. Indeed, cereal cropping – producing most of our food - may be a close mimic of structurally simple but seasonally stressed and disturbed natural grassland ecosystems.

However, before simple natural models can contribute to sustainable farming, we need answers to many questions. There is an urgent need for research on natural monocultures – preferably on the close relatives of our most important cereals such as rice, wheat, and sorghum. We need to know:

- The genetic structure of natural monocultures: are they genetically uniform or diverse? What implications could this have for annual cereal production and could combinations of different varieties be more productive and sustainable than the present monocultures?
- How does the level of genetic diversity relate to persistence under pest and disease pressure and to short-term adaptation? Can this provide lessons for sustainable farming?
- What role does crop-associated biodiversity have in self-regulation of monocultures and what is its contribution to productivity and sustainability? What implications does this have for the technologies used in production of monocultures?
- What are the ecological determinants of natural monocultures? Does their ecology always include natural stress or disturbance such as burning or flooding that could provide models for field management? Are there lessons for zero-tillage systems?
- Finally, were natural monocultures an ecological pathway to domestication, skilfully managed by the first farmers and becoming our first fields? Or, have traditional monocultures always been mixed to some extent with other crops?

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A longer version including references is available from the author and on ILEIA'S web site www.oneworld.org/ileia.

Pasture Cropping

Darryl Cluff and Col Seis have grappled for many years with the development of workable and regenerative solutions to the severe land degradation problems in the Birriwa-Gulgong area in central west New South Wales, Australia. In the 19th century, the perennial grasslands on the flat to undulating country, with an average but highly variable rainfall of about 600 mm, were very productive and ideal for raising livestock. However, the winter-active perennial grasses and palatable native legumes disappeared due to set-stocking and failure to reduce stock numbers during droughts. Since 1882 cropping became a major enterprise for most farmers. Traditional techniques, which involved the complete removal of all vegetation, resulted in vast tracts of bare ground both before and after the crops. Soil erosion and nutrient decline on arable land became extensive.

In 1995, they started to experiment with direct drilling of oat and wheat into native pasture. They direct drilled the grain into the permanent ground-cover at 25-30 cm row spacing, using 80-100 kg seed and 210-330 kg NPS fertiliser per ha. The pasture cropping technique utilises a niche in the growth cycle of what remains of grasslands that have lost cool season perennials almost completely. Yields were similar to those from conventional farmers crops. But as the cool season annual cereal crops face little competition from warm season perennials they require no cultivation and little or no herbicides, and they improve the vigour and biodiversity of the grazed pasture and the condition of the soil.

They are now trying alternative crops such as lupins and are experimenting with resowing of native grasses with the crop seed to improve the pastures. Livestock is an important component of pasture cropping. Seis improved the gross profit on his sheep enterprise by using sheep to heavily graze pastures prior to sowing. Adaptation of machinery to the needs of pasture cropping was important in the creative innovation process.

'Only lack of imagination prevents us from growing productive healthy crops in sustainable biodiverse landscapes'.

Adapted from: Pasture cropping by Christine Jones, published in: In Practice, July/August 1999, pp.12-14. Further information: Christine Jones, PO Box 199a, Armidale NSW 2350, Australia, cjones@dlwc.nsw.gov.au