Functional Biodiversity

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Introduction

Modern non-organic agriculture is characterised by monoculture, which means widespread production of crops formed from a single species, variety or gene combination. The advantages seem clear: the crop can be treated as a single commodity from seed production, through planting, pesticide application, harvesting, processing and marketing. However, such systems are entirely dependent on continuous and large-scale inputs of synthetic chemicals, at each stage, which leads to large direct and indirect costs. As a consequence, biodiversity is minimised not only in terms of cropping but also in relation to non-crop organisms small and large, above and below ground.

At the other extreme, natural plant communities usually comprise a range of species, varieties or gene combinations. The community and its components are never constant: they vary in composition and frequency both within and between seasons. The diversity and dynamism of the community is driven by environmental variation, both physical (climate and weather) and biological (pests, parasites, competition). The nature of the diversity buffers the community against environmental variation and restricts development of pests and pathogens (there are exceptions - but these often prove the rule. For example, Dutch Elm disease became rampant partly because of human intervention and partly because elm populations lack variation in resistance to the pathogen and its carrier. However, elm is still common as a hedgerow bush). Such communities are characterised by a wide range of biodiversity all of which has some function in the dynamics of the community.

A particularly important feature of such natural communities, additional to the fact that they are not dependent on any external inputs except light, air and water (indeed, contamination by external synthetic inputs can lead to destruction of natural communities), is that they are highly productive (Tilman, 1997). Reich et al. (2001) have shown recently that experimental communities of 16 species, at 11.43 t/ha, produced 55% more biomass than the mean of the component species grown in monocultures (7.35 t/ha). The purpose of these particular experiments was to show that with enhanced CO2 and N2 application, as expected from global climate change and human population increase, the monoculture biomass increased by 17% to 8.6 t/ha, but the 16-species mixture increased by 35% to 15.43 t/ha. In other words, not only is the complex mixture more productive, but it is much better able to respond to the major forecast changes in the environment.

Mechanisms

The simplest mechanism by which a complex plant community deals with environmental variation is by the available spread of genetic variation. For example, within the community, there may be components that thrive under wet conditions and others that thrive in dry seasons. More importantly, however, components of the community interact. This happens because the grouping of genetically similar components is usually on a small scale (fine-grained). This can allow for complementation. For example, if our 'wet' and 'dry' plants grow close together, then in a wet year, the thriving 'wet' plants may take up some of the space occupied by the less thrifty 'dry' plants; in a dry year, the reverse would be true. There is also likely to be 'niche differentiation', which means that our 'wet' and 'dry' plants, because of their different kind of adaptation, occupy a somewhat different volume of the available ecological space, reducing their interference with each other.

It is these different mechanisms and interactions that allow a community to survive under varying environmental conditions including protection against overwhelming effects of particular pests and diseases. Understanding of how pests and diseases are restricted has been worked out in detail using agricultural systems which allow for simpler experiments (Finckh et al, 2000, Wolfe 2000, Zhu et al. 2000).

Agricultural biodiversity

At one extreme, then, in agricultural systems we have massive monoculture. At the other, in the tropics, there are systems of highly diversified polyculture, typified by, for example, the forest gardens of Java. Here, a wide range of perennials and annuals are inter-cropped in such a way that synthetic inputs are not needed. Costs, direct or indirect, are minimal: virtually the only form of human intervention is the year-round harvest process. Such systems are highly energy efficient and, by encouraging a wide range of natural biodiversity to carry out processes of crop fertilisation and disease, pest and weed restriction, they are close in character and function to natural plant communities. In addition, a crucial point about the attractiveness of such systems to the farmer is that the numerous outputs, produced at different times of the year, provide a wide range of products both for the family and for the local market ensuring a buffer against variability in the market.

A central question for future development of organic agriculture, therefore, is how far we can move away from monoculture towards polycultural systems with high levels of functional biodiversity so as to attain a practical balance between the positive and negative aspects of these two approaches.

The EFRC programme

Current organic agriculture goes some way towards reversing the monoculture tendency, but by no means far enough. Rotations are seen clearly as a central plank of organic systems, but they represent only a small step from continuous monoculture towards polyculture. In a rotational system, there is relatively little interaction among crops - the interaction is limited to the relationship between the amount and range of living and dead organic matter left by each crop in turn. Much of the EFRC research programme is designed to move further towards higher levels of biodiversity in the cropping system, which has important positive consequences for biodiversity in general, unlike other current systems of agriculture. Examples are:

a) Plant breeding

In wheat and kale, we are trying to develop breeding programmes based on the notion of producing crop populations rather than pure breeding lines. The hypothesis is that a crop population selected under local conditions should have the ability to act as a polyculture at the sub-species level, with the advantages described above.

b) Variety and species mixtures

Particularly for cereals, but also for potatoes and other vegetable crops, mixtures of varieties and species can be highly effective in restricting disease development; this is now well-known and understood, though application is still limited. The cereal trials are part of an EFRC project, whereas the potato trials are part of a large EU project.

c) Companion cropping and bi-cropping

These projects are concerned with inter-cropping legumes (white clover) with a vegetable rotation (Companion cropping project) and with cereals (Bi-crop) so as to bring together the fertility-building and cropping phases of a rotation into the same part of the sequence. For the vegetable rotation, there are numerous potential advantages in terms of preserving the habitat of earthworms, mycorrhizae and other beneficial organisms while restricting development of a range of pests, diseases and weeds. For the cereal system, there is an added advantage of dealing with the current administrative problem with the Arable Area Payments scheme, allowing the potential for continuous qualification for AAP.

Embedded in the projects grouped under b) and c) is the development of a range of machinery designed to handle different aspects of novel systems with minimal power input and soil inversion.

d) Biodiversity project

The joint project with BTO, CEH, RAC and OU is investigating the influence of the farmed and non-farmed aspects of organic and non-organic farms. This will help to identify elements of the overall system that can be made more effective for encouraging biodiversity.

e) N, P and K budgetting

These projects are seen as ways of following the movement of plant nutrients among crop and animal species. Further development in this direction can help in the design first, of improved rotations, and then of inter-crop and polycultural systems to optimise nutrient availability.

f) Semio-chemicals

The joint project with Rothamsted is concerned with reviewing available knowledge on natural signalling processes, particularly those that occur between crops, pests and predators. Such information is already helping in the design of cropping systems to optimise the attraction of beneficial insects into crops and the expulsion of pests from them.

Others? Composts and maximum re-cycling? Weed control and wild life (non-crop plants may be beneficial in various ways at different times - it is only certain plants at certain times that can be fully regarded as weeds)?

Conclusion

Our longer term objective is to use the outcomes from these projects together with others to push forward the development of organic farming systems in the direction of integrating functional biodiversity as widely as possible. In this sense, encouraging biodiversity is seen not as an 'add-on' to the farming system but rather as the driving force behind it. The best illustration of a comprehensive approach to integration of biodiversity lies perhaps in the agroforestry demonstration projects which are intended to show how perennial tree crops can be managed within systems of cropping and livestock production (Wolfe 1998). For example, appropriately placed strips of trees can function as shelter for humans and animals and as habitat for beneficial organisms while providing a long-term cash return, winter labour and increased diversity of production (multifunctionality). Between the tree rows, and influenced by them, the cropping areas include arrays of species and variety mixtures and inter-cropping. They may also include livestock management, one example of which could be production of free range chickens, where the 'range' is defined at least partially in terms of the needs of the chickens. We will start to demonstrate such a system during the next year.

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