Living with Biodiversity and Productivity –
a rationale for much of the EFRC research programme

The place of biodiversity

The human population cannot survive on this planet without massive amounts of biodiversity – in terms of both numbers of species and quantity. Clean air, clean water, recycling of organic matter and the provision of food (the ecosystem services) are all dependent on numerous, intricate and related webs of biodiversity.

The scale of this fundamental dependence and the threats surrounding it has been largely overlooked until recent years. One reason for this oversight has been the development of cheap energy and of technologies, dependent on that cheap energy, which can substitute for some of the ecosystem services. For example, in agriculture, there is synthetic conversion of nitrogen to nitrate, the form of nitrogen available to plants for protein production and thence to us. In addition to the energy cost, this creates massive pollution and global warming problems in its wake (for example, see New Scientist, 21 January 2006).

Such developments have meant that we have been able to support, more or less, the continuing massive increase in the human population and its activities. As one example in UK agriculture, average wheat yields as recently as 60 years ago were 2-3 t/ha harvested by reaper-binder: now, 8+ t/ha comes out of the combine harvester, but at a much increased, and increasing, cost.. The attendant problem is that we have gone too far in removing and substituting biodiversity by methods of increasing productivity based on fossil energy. Conventional agriculture, and indeed, organic production have to change towards methods and systems that are more ecologically sustainable. Organic agriculture, using legume-based systems, does try to use and encourage biodiversity – but it has to go much further to improve both biodiversity and productivity.

It is these kinds of argument that form the background to much of the current EFRC research programme. Even with our small size, we have to develop a set of integrated projects in genetics, ecology and agronomy that aim simultaneously to improve both productivity and biodiversity – ideally, by using the latter to increase the former.

The question of cereals – our main food crop

Current production of our staple cereals has developed through major changes in agronomy (machine power, synthetic fertilisers and pesticides etc.) which, in turn, is dependent on selection of totally new wheat varieties adapted to these conditions (including industrial end-processing). The principal adaptation has been in harvest index – selecting for the effects of dwarfing genes to ensure that a larger proportion of the plant biomass is distributed towards seed rather than straw production, thus exploiting the giant increase in synthetic fertiliser, and fossil energy, use. Little or no attention was paid to ecology during this development, or to biodiversity.

This commodity approach has had many consequences, one of which is that attention has been diverted away from the wider range of crops that are needed for a varied human diet, effective crop rotations, efficient local food systems and the maintenance of biodiversity in the countryside. It has also meant that plant breeding in the UK, as a private sector activity, has had to specialise increasingly in a handful of major crops for ‘conventional’ production. Inevitably, the new crop varieties that are available to farmers, though well adapted to conventional production, are less suited to organic or sustainable systems.

We were able to prove this last point through our participatory research project . Working with a number of organic wheat growers around the country, we confirmed our earlier indications from small plot trials, that, for organic farming systems, the variation in wheat yields was affected much more by site and year than by variety. In other words, wheat yields were not only lower under organic than under conventional conditions (in contrast to oats), but there was no difference among the available varieties bred for conventional production. Interestingly, however, genetic response overall to environment was large. For example, in 2004, the varieties we used were all significantly taller in the trials in the east of the country than in those in the west. Conversely, in 2005, with much higher yields nationally, all varieties were significantly taller in the west than in the east. We don’t know why.

Plant Breeding

So, one objective of a Defra project involving ourselves and the John Innes Centre is to try to replace ‘conventional’ varieties of wheat by new forms that are well-suited to organic production, as quickly and as cheaply as possible. Instead of producing pure line varieties selected under a regime of synthetic inputs, we have produced a series of populations based on all the possible combinations of inter-crosses among nine high yield and 12 high quality varieties that have been successful on a large scale over the last fifty years. Naturally occurring male sterile lines are included in some of the populations to further increase the genetic variation in the populations. These populations, containing large amounts of genetic variation, are being exposed to different management systems (organic and non-organic) in different regions and countries. The outcome should be rapid adaptation to local conditions (“evolutionary plant breeding”). The project is still young, but the early results are encouraging.

Following two years of plot trials, we are now working with a small group of farmers from the participatory project, who are growing and multiplying some of these highly biodiverse populations on farms in different parts of the country. In assuming that this approach will deliver useful results, we have started to extend it to other crops including oats (through the OatLink project, page) and to einkorn, one of the ancient progenitors of wheat, through material provided by Dr Geza Kovacs in Hungary. Ideally, of course, in addition to crops, we should really be developing parallel approaches with our farm animals.

Biodiversity and agronomy

Developing this novel genetic material is only a first step. It needs to go hand-in-hand with research to determine the best ways of growing the material in practice. For this reason we have established a new Defra Link project on wheat agronomy to investigate simultaneous variation in seed rate, method of sowing (narrow rows, wide rows, broadcast, or in strips using the new Claydon system), presence or absence of a clover intercrop and wheat genotype, which will include the populations from next autumn. This multifactorial approach is new to organic production in the UK.

There are, of course, many possibilities based on the idea of inter-cropping. Large scale monocultures, developed over the last 50 years or so, have illustrated repeatedly how they encourage rapid development of diseases and pests, and the evolution of new, adapted races of the organisms involved. Even a change towards the simplest form of inter-cropping, by growing three or four different varieties as a mixture, can lead to a dramatic reduction in the rate of disease or pest development. This has been demonstrated now for different crops on hundreds of thousands of hectares. Our biodiverse populations and legume intercrops should carry this principle a major step further.

Inter-cropping different species, particularly if each species is grown as a mixture or population, mimics the natural world where we know that complex plant and animal populations are often highly productive and well–buffered against environmental change. The challenge is to maintain such complex populations in agriculture at a level which increases productivity while remaining manageable, particularly in terms of harvesting the produce.

Organic Agroforestry

At the extreme, agroforestry systems, in which tree, crop and livestock management are fully integrated, represent the highest level of diversity in agricultural systems. In my view, this is what organic agriculture should aspire to because of the wide range of integrated benefits for productivity and biodiversity.

At its simplest and most common, at least in temperate regions, an agroforestry system comprises narrow strips of tress aligned north-south (‘production hedges’), separated by a cropping strip ideally in the range of 12 to 48 m wide. At Wakelyns Agroforestry, we have established such systems based on hazel, willow, mixed hardwoods or fruit and nut tree combinations. Hazel is an out-crossing plant so that the hedges represent a highly variable population; the willow hedges are grown as a mixture, highly effective in restricting rust development. The mixed hardwood systems are based on seven species (ash, hornbeam, Italian alder, oak, sycamore, small-leaved lime and wild cherry), or the same seven with apple distributed among them, again to try to restrict pest and disease spread. There is also a plum and walnut system. In the silvo-poultry system at Sheepdrove Organic Farm, the trees provide shelter for chickens and an appropriate space to grow an herbaceous under-storey comprising plants that are known to be beneficial for the chickens. The areas occupied by the chickens are part of a crop rotation between the tree lines.

Agroforestry systems are more difficult to manage than monocultures, but they return more, in numerous directions. Apart from shelter for animals, crops and humans, together with nutrient re-cycling, the trees act as ‘beetle banks’ to encourage production of beneficial insects. They can also provide, in addition to the expected crops in the organic rotation, a wide range of wood outputs, valuable both as a raw material for many different kinds of structure and for energy production on the farm or locally. It also seems likely that such combinations of plants should provide a positive contribution to global climate change (carbon sequestration; reduced fossil fuel use) and a buffer against the changes that do occur. The diversity of outputs from such systems also help to buffer against variation in market prices while helping to provide the essential diversity of produce needed for local, energy efficient, food systems.

Conclusion

It is probable that well-designed biodiverse systems using appropriate plant and animal components selected for productivity in such systems can go a long way in reducing fossil energy dependence and greenhouse gas emissions. The larger question is whether, at the same time, their overall productivity could be sufficient to deal with the increasing size and aspirations of the human population, world-wide. The evidence from advanced and intensive forest garden systems is that they can.

Prof Martin Wolfe
Research Director

February 2006