THE ROLE OF NEW TECHNOLOGY IN PROMOTING SUSTAINABLE AGRICULTURAL DEVELOPMENT

J. TAIT, P. PITKIN

Scottish Natural Heritage, Research and Advisory Services Directorate, 2 Anderson Place, Edinburgh EH6 5NP.

ABSTRACT

Scottish Natural Heritage (SNH) has set up a project known as TIBRE (Targeted Inputs for a Better Rural Environment) to investigate how new technology (chemical, biological, IT and engineering) could be introduced into existing agricultural systems (both integrated and intensive) to improve their sustainability. The project is concentrating in the first phase on arable cropping. This paper explains how we have interpreted the concept of sustainable development, and the role of the TIBRE project in achieving greater sustainability.

THE CONCEPT OF SUSTAINABILITY

The concept of sustainability is often treated as self-explanatory and left undefined. While we are aware of the pitfalls in attempting to define it, we feel it is important to clarify our interpretation in the context of the TIBRE project (SNH, 1993).

We see the concept of sustainability as inherently systemic. It can only be applied in practice to the behaviour of a system of interacting variables, referring to the extent to which the system can continue to operate in its present form for the foreseeable future, i.e. its stability and long term viability.

We also see it as a concept that is related to the management of systems and which is irrelevant in the absence of any human interest in the system. For example, some natural ecosystems are relatively stable and, in the absence of external interference, will persist in their present form for the foreseeable future. Others are in transition states which, in the absence of external interference, will develop and change. However, the question of their sustainability only becomes relevant when people have an interest in exploiting the system for some purpose, for example to manage it for conservation purposes or to exploit its natural resources.

Many factors can affect the degree of sustainability of a managed system. At the subsystem level, the sustainability of natural resource use is the most obvious one. The Government's Strategy for Sustainable Development (Anon, 1994) identifies the following ways in which agricultural systems have become less sustainable as they have become more intensive: habitat loss; increased eutrophication of fresh and saline waters; pesticide contamination of land, water and air; loss of organic matter from soils; soil erosion; soil acidification; and contamination by chemicals, although many of these effects are reversible.

All managed systems have economic, political and social components, and these can often trigger a change in the stability and viability of a system before its natural components show signs of strain. In the case of agricultural systems, the pressures to develop integrated and organic cropping systems in the UK have been political rather than agronomic and have arisen from social perceptions and evidence from other countries that intensive agricultural systems are unsustainable. Despite numerous predictions that intensive arable agriculture would inevitably collapse into a degenerative spiral, there is as yet no evidence of this taking place in the UK. This has made it difficult to persuade arable farmers that their intensive cropping systems are agriculturally unsustainable and hence has made it more difficult to persuade them to take up integrated and organic approaches. (The economic sustainability of intensive systems is discussed below.)

In some intensive agricultural systems, the excessive use of pesticides has led to a breakdown of the supporting ecosystem to such an extent that the agricultural system was no longer sustainable. Examples are the growing of cotton in Texas (Curry & Cate, 1984), rice growing in the Philippines (Kenmore *et al.*, 1987) and fruit growing in some parts of the UK (Solomon, 1987). In these cases, where lack of sustainability has been clearly demonstrated to them, farmers have shown a greater willingness to take up integrated cropping systems.

EXTERNAL SUPPORT FOR INTENSIVE ARABLE SYSTEMS

The agricultural revolution that brought about today's intensive farming systems began in the 1950s with the emergence of the modern agrochemical industry producing the inputs that enabled farmers to increase crop yields steadily over a forty year period. For example, cereal crop yields in the UK have increased by approximately half between 1971 and 1992 (MAFF, 1973; MAFF, 1992).

The core feedback loop of Figure 1, with the variables in bold type, illustrates some of the factors that were driving the industrial investment that, until recently, fuelled the growth of intensive systems. Increasing industry investment in research and development for new agrochemical products was fuelled by a combination of increasing crop yields and increasing crop prices. Increased investment in research and development led to more new products on the market which led in turn, through more intensive marketing by industry, to a greater level of uptake of these new products by farmers. The resulting higher crop yields, coupled to stable or increasing crop prices led to steadily increasing farm incomes which closed the feedback loop by encouraging yet higher levels of investment by industry. The main driving force for this positive feedback loop (which was regarded as a virtuous circle from the perspective of the agrochemical industry) was the level of UK Government, and later European Community, support for agricultural production. In addition to guaranteeing farmers a market for their crops at a favourable price, the Government policy set ever increasing standards for freedom from damage by pests and diseases which also encouraged the use of pesticides; a free advisory service was provided to encourage the uptake of new technology, reinforcing the marketing efforts of the industry; and publicly funded near-market research and development supported the development of new products by industry.

Less important, but still significant, drivers of investment are shown at the top of Figure 1. Regulation, which is often claimed to inhibit innovation, in this case acted as a stimulant, by withdrawing from the market out of date products that had outlived their patent protection, making way for a new generation of more expensive, patent-protected products. The emergence of resistance to pesticides among insect pests and diseases had a similar effect. (It was rare for this to occur within the patent protection period for a chemical.)

One output from this feedback loop since the 1960s was a continually increasing level of agricultural surpluses. This was seen as a cause for concern, but was not directly addressed before intensive farming systems had become firmly established.

During the 1980s farm incomes became less secure as the European Community, in order to reduce the cost of disposing of these surpluses and to remedy their distorting effect on world trade, took steps to avoid over-production. The resulting decline in government support for agricultural production has begun to convert this positive feedback loop from a virtuous to a vicious circle from the agrochemical industry perspective leading to a depressed market for new technology. This effect was compounded by the almost complete withdrawal of the free advisory service and a cessation of near market research and development work at public expense.

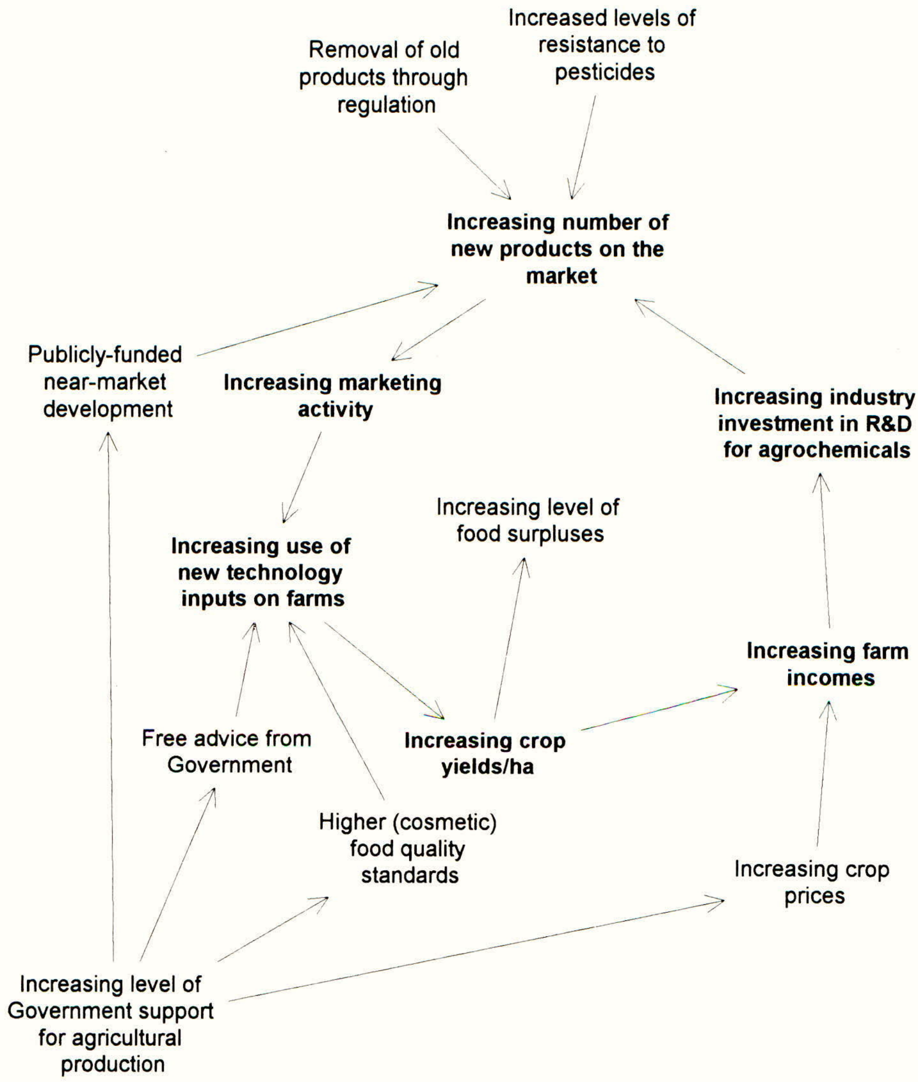

Figure 1. The system sustaining industrial investment in the development of new agrochemicals, in the 1960s and 1970s.

Thus, contrary to many predictions, it was the economic and political unsustainability of the system that finally applied the brakes to this bandwagon, rather than its ecological unsustainability.

ENVIRONMENTAL IMPACT AND SUSTAINABILITY OF FARM CROPPING SYSTEMS

So far, we have focused on the concept of agricultural sustainability and the factors driving agrochemical industry investment which is often seen as a threat to it. From a wider environmental perspective, in most parts of the world and under most agricultural systems, the greatest impact is caused by the basic act of farming the land. Compared to this, the differences in environmental impact between different types of farming system are generally small. However, this impact is not always negative in terms of the natural heritage. Some types of arable farming system, such as appropriately managed organic systems and traditional cropping in the crofting areas of Scotland, create habitats which it is SNH's responsibility to support.

In keeping with its remit "to secure the conservation and enhancement of, and to foster understanding and facilitate the enjoyment of, the natural heritage of Scotland", as stated in its founding legislation, the Natural Heritage (Scotland) Act 1991, SNH must take account of these environmental impacts and benefits. It has done this by attempting to influence the nature of agricultural systems, as outlined below, and also by supporting the creation and maintenance of wildlife habitats on farms.

This section considers the environmental opportunities and problems associated with organic, intensive and integrated farming systems. Table 1 gives our view of the sustainability, acceptability and environmental impact of these three types of system. The first three subsections make a comparison on the basis of the criteria in Table 1.The fourth subsection discusses the impact of policy-related issues on overall sustainability..

Organic cropping systems

Organic systems are widely regarded as the most sustainable form of agricultural system. In the sense that they attempt to operate in a self-contained manner without the aid of extraneous inputs, this is indeed the case (Table 1, criterion 1). Their impact on cropped and non-cropped areas of the farm is usually considerably less than that of more intensive systems and the crop rotations employed on organic farms can increase biodiversity on the farm, both in the soil and among and between the crops (criteria 2 and 3). Their external or wider environmental impact is also generally less than that of the other two types of system, although the amount of nutrient runoff from organic farms can be considerable (criterion 4).

However, organic systems are unlikely to be more than a partial answer to the problem of agricultural sustainability. As explained above, given the extent to which intensive systems have become embedded in the farming community, experience suggests that few farmers will be prepared to take them up unless encouragement is provided in the form of substantially greater public support or unless consumers are prepared to pay a high premium for organic produce (criteria 5 and 6).

Intensive farming systems

At the other end of the spectrum, intensive farming systems generally have the most negative environmental impact, on and off the farm (criteria 2-4), although probably less so in Scotland than in other parts of the UK where pesticide use is greater. Some aspects of intensive farming are not acceptable to many consumers but most are not sufficiently concerned about the source of the produce they buy to pay the present level of the organic premium (criterion 6). Most farmers have a very positive attitude to intensive farming systems (criterion 5) and, while they may be prepared to cut down on inputs to avoid the most obviously wasteful practices, they will not readily give up their allegiance to intensive farming systems (Carr & Tait, 1991).

As noted above, there is little evidence as yet that intensive farming systems are not agriculturally sustainable (criterion 1).

Table 1 Sustainability, environmental impact and acceptability of farming systems

Criterion	Arable Farming Systems* Organic	Integrated	Intensive
1. Agricultural sustainability	++	++	+/++
2. Impact on farmed areas	+/-	-	- -
3. Impact on non-farmed areas of the farm	+/-	-	- -
4. Off-farm environmental impact	o/-	--	- -
5. Acceptability to farmers	--	-	++
6. Acceptability to consumers	+	o/+	o/-

* + = favourable; o = neutral; - = unfavourable

Integrated farming systems

Integrated farming systems attempt to reduce the environmental impact and improve the sustainability of farming systems by more judicious use of inputs, combined with better diagnosis of crop problems, and crop rotations designed to reduce the need for inputs. There is no doubt that, through careful planning and management of an integrated system, the farmer can reduce inputs and maintain or improve yields (Conway & Pretty, 1991), leading to a greater likelihood of improved agricultural sustainability compared to intensive systems (criterion 1). However, generally, this is at the expense of a greater input of managerial skill and time, and often a higher level of risk and these factors reduce the acceptability of such systems to many farmers (criterion 5). As with organic systems, there is little evidence that most consumers are prepared to pay a significant premium for food produced by integrated systems (criterion 6).

The extent to which integrated systems will improve the environmental impact of the farming system will depend on the motivation of the farmer and the degree of skill with which they are implemented, but there is no doubt that they could have a significantly lower environmental impact than intensive systems (criteria 2-4).

Policy issues

The above analysis shows that integrated and organic approaches have considerable potential to reduce the environmental impact of current intensive farming systems, in line with Government policy to modify agricultural systems in order to improve their environmental sustainability. The UK Strategy for Sustainable Development states that environmental pressures from agriculture will be reduced by "... the reduction in levels of price support which will, in turn, reduce the incentives to intensive production ... which, from the point of view of the UK environment is the most important feature of the 1992 CAP reform." (Anon, 1994). The discussion of Figure 1 has already noted that these policy developments are affecting industry strategies.

The impact of these policies on farmer behaviour is more difficult to gauge precisely. As noted already, many farmers do not see the current levels of farming intensity as being unsustainable. This view is held most strongly by the largest and most intensive farmers who are likely to exert a greater impact on the environment. As discussed above, given the entrenched nature of intensive systems, these farmers are unlikely to be willing to change to integrated or organic systems without substantial financial incentives. This will be particularly so since commercial pressures and competitive forces are likely to give rise to price reductions in the currently available technologies from Western European and American companies and a flood of cheap products from Eastern Europe. Farm incomes have also risen rapidly since 1992 as a combined result of the Arable Area Payments Scheme and the ending of the link between the pound Sterling and the European Exchange Rate Mechanism. A strategy which could be adopted by some farmers in response to any future liberalisation of world trade in agricultural commodities may be a move to ever greater intensity of farming systems using the cheapest available technology which is likely to be the most environmentally damaging.

Looking at the agricultural system as a whole, it is reasonable to question whether the current policies attempting to deal with perceived overproduction of many crops are likely to remain in place in the long term. Factors which could lead to a change in this policy include major crop failures due to climate change or some other unforeseen factor, and opportunities to divert agricultural land to the production of non-food crops for industrial feedstock, leading to pressures to maximise production on the remaining land used for food production. In the latter case, both food and non-food crops are likely to receive high levels of inputs. A return to maximum production using existing technology is likely to lead to a significant increase in the environmental impact of agriculture.

A FLEXIBLE AND ROBUST APPROACH TO SUSTAINABLE DEVELOPMENT

It is unfortunate that this faltering in the pace of technological innovation for agriculture is taking place at a time when new opportunities for more environmentally sustainable technology are arising in the areas of biotechnology, chemical technology, information technology and engineering. The SNH TIBRE project is attempting to focus attention on this area with a view to encouraging the evolution of an overall strategy for sustainable agricultural development in the 21st Century which:

- takes account of the wide range of types of agricultural system that exist in the UK;
- is sensitive to the needs and attitudes of individual farmers;
- incorporates a range of approaches to sustainable development; and
- is robust in the face of policy changes.

SNH will continue to support initiatives leading to the creation and management of wildlife habitats and landscape features on agricultural land. However, on many farms, these areas are poorer and less diverse than they might be because of the impacts arising from farming activities on the cropped areas.

Recognising that most intensive farmers are not likely to take up integrated or organic approaches, the TIBRE project aims to encourage the uptake by all non-organic farmers of new, less environmentally damaging technological products and hence to lead to an improvement in the sustainability of intensive and integrated farming systems.

The fastest returns will arise from technology which is already on the market or will soon be available. However, the greatest long term benefits may arise from new technologies and products which are in an early stage of research and development and which may be being held back by companies because they do not see a viable market slot in competition with existing cheaper technology.

SNH have commissioned a series of studies to investigate the range of technological developments (chemical, biochemical, IT and engineering), in both categories, which would enable arable growers to farm in a more environmentally sustainable manner, and we shall report on these elsewhere.

For the short-term options SNH has consulted a group of farmers and others on the feasibility and acceptability of various options. In general there was strong support for the aims of TIBRE and an appreciation of the involvement of the farming community at this early stage in the initiative. There was a perceived need for information on new technology and its potential influence on the environment and considerable sensitivity to the role of public opinion in influencing the adoption of new technology in farming. There was also support for the setting up of farm level projects to demonstrate the managerial and economic feasibility of new technological developments.

Implementation of the longer term options will require the creation of clearly identifiable market opportunities to persuade industry to develop new technology which is more environmentally sustainable. This could be done through a range of policy initiatives operating in this case at the UK and EU levels. In both cases, SNH will be working with partners from Government departments, other agencies and industry, some of whom may eventually take over the lead in implementation of the TIBRE project.

The task of encouraging industry to bring forward new technological products which will enable intensive agricultural systems to become more sustainable seems daunting at first sight. However, the TIBRE project is in keeping with modern thinking on a wider front on constructive approaches to environmental improvement through technological innovation as evidenced by, for example, the UK Government LINK programme, the DoE/DTI Clean Technology Initiative, the European Commission Fourth Framework Programme and the Technology Foresight Initiative of the UK Office of Science and Technology. By adding our weight to this general trend we may be able to achieve a significant shift towards more sustainable development in the strategies of industry, farmers and others involved in land use.

There is no doubt that society has the scientific and technical competence to develop sustainable, intensive agricultural systems. Our social and political competencies are, however, less well developed. The flexibility and robusness of initiatives like TIBRE could have very significant benefits, in terms of both the natural environment and social cohesion. In order to achieve these benefits we will need to use our existing institutions and procedures more effectively and be more creative in developing new ones.

REFERENCES

Anon. (1994) *Sustainable Development: the UK Strategy* London: HMSO.

Carr, S; Tait, J. (1991) Differences in the attitudes of farmers and conservationists and their implications. *Journal of Environmental Management, 32,* 281-294.

Conway, G.R.; Pretty, J.N. (1991) *Unwelcome Harvest: Agriculture and Pollution.* London: Earthscan.

Curry, G.L.; Cate, J.R. (1984) Strategies for cotton - boll weevil management in Texas. In *Pest and Pathogen Control: Strategic, Tactical and Policy Models*, G.R. Conway (Ed), Chichester: Wiley, pp. 169-183.

Kenmore, P.E.; Litsinger, J.A.; Bandong, A.C.; Santiago, A.C.; Salac, M.M. (1987) Philippine rice farmers and insecticides: thirty years of growing dependency and new options for change. In *Management of Pests and Pesticides: Farmers' Perceptions and Practices*, J. Tait and B. Napompeth (Eds), Boulder: Westview, pp 98-108.

MAFF (1973) *Agricultural Statistics, United Kingdom, 1971.* Government Statistical Service, London: HMSO.

MAFF (1992) *The Digest of Agricultural Statistics, United Kingdom, 1991.* Government

Statistical Service, London: HMSO.
Scottish Natural Heritage (1993) *Sustainable Development and the Natural Heritage: the SNH Approach*. Publications Section, Scottish Natural Heritage, Battleby, Redgorton, Perth PH1 3EW, pp 26.
Solomon, M.G. (1987) Fruit and hops. In *Integrated Pest Management*, A.J. Burn, T.H. Coaker and P.C. Jepson (Eds), London: Academic Press, pp 329-360.

Session 7

Workshop Discussions

Chairman	M TALBOT Professor J B DENT C MACKIE
Session Organisers	D YOUNIE J HOOKER

WORKSHOP DISCUSSIONS

Topics

a: Research methodology in Sustainable Farming Systems

b: Approaches towards technical progress in Sustainable Farming Systems

c: Technology transfer in Sustainable Farming Systems