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Systems Methodology and Technological Change in Agriculture

R.M.Morris, C.P. Blackmore, S. Carr, R.L. Ison, A.B. Lane and P.T. Maiteny

Introduction

The changes in technology which have occurred in agriculture during the last half century have been dramatic, and have contributed to a sustained rise in the production of food. Food availability per capita has either remained constant or increased in most areas of the world despite a doubling in world population. The Malthusian spectre has not disappeared, but has certainly been held comfortably at bay. However, the last decades have seen growing disquiet that the undoubted achievements of agricultural technology have been secured at a higher than acceptable cost to "the environment". Given that the majority of the European land surface is farmed in some way (77% of the UK, for example), any such effects of agriculture are likely to be widespread. Effects have included pollution of watercourses (Addiscott *et al*, 1993), possible damage to soils, (Morgan, 1986) changes to the appearance of landscape and to social structures, and reductions in the viability of rural communities (Bowers and Cheshire, 1983, Blunden and Curry 1988). Examples of unpopular change in the European landscape include the loss in area of species-rich grassland and lowland heaths and losses of farmland birds (Bunce *et al*, 1992). Globally, the conversion of tropical forest to agricultural use has been another major cause of concern. Evaluation of the importance of such change is complex, depending on what is being evaluated, by whom and by what means. Research into indicators of ecosystem health is an active area (for example, Bradshaw and Smit, 1997). Nationally or internationally agreed methods for auditing and managing the environmental effects of business activities (ISO14000) have developed rapidly. These have been adopted by the agricultural supply trades, but are as yet relatively untried in farm management. More *ad hoc* methods such as those proposed by LEAF (1996) have gained some acceptance in the UK, and the use of audits is likely to feature increasingly as a requirement for supply to major food retailers (Abel, 1997).

A range of possible technologies has been proposed to reduce or control the impact of agriculture on the biophysical environment. Organic methods of production have been widely advocated, but other technical solutions include Integrated Crop Management, (British Agrochemicals Association, 1994) No-till production and Integrated Pest Management. The importance of organic farming methods has been extensively debated (Lamkin,1997). A fundamental problem with organic farming and to some extent with all environmental audit methods, is that they are seen by a substantial proportion of the farming industry as backward-looking, restrictive or both. This perception is likely to inhibit their uptake. Change in farming practice is a complex response to a wide range of factors, but the farm operator is pivotal. The numbers involved directly in farming have declined considerably, but the industry still includes approximately 9 million individual units across Europe, each with an independent, and often independently-minded operator, managing land of widely varying capability carrying a range of different enterprises. Centralised control of such an industry is impossible. The experience of the centrally planned economies of Eastern Europe has not generally been regarded as a success in terms of production or environmental protection. Neither, it appears from the evidence cited above, can the free-market economies of further west claim to provide an ideal model of sustainable or environmentally acceptable practice. Choosing and implementing technologies which will provide a better balance will require synthesis of technical information and attention to attitudes, markets and power relationships. This paper looks at the role of systems methodology in this. It examines the outcomes of a research contract conducted on behalf of one of the United Kingdom environmental agencies.

Systems Methodology

The importance of systems ideas in dealing with complex, messy problems is widely recognised. Systems methodologies are social and behavioural technologies that aid relationship-building, communication and understanding between sectors, disciplines and their priorities according to a logic that is not linear and 'thing'-orientated but stresses instead the importance of relations and contexts. It is only by understanding the differences and similarities between stakeholders, and moving towards reconciling them, that learning, and hence, agreement becomes possible. Systems methodologies offer a middle-ground between the cost-effectiveness, but relative superficiality, of highly structured survey or rapid participatory type methods and the depth, but costliness, of anthropological methods.

Agriculture and land use is a classic example of a messy problem, with a multiplicity of stakeholders including individual farmers, the ancillary industries, the tourist industry and members of the public for whom farmed land is an important part of their environment. Within agriculture and the related industries, the word "systems", as a noun or an adjective, has been used promiscously and often without rigour, to cover everything from highly specialised computer models to a general way of thinking (Bawden & Ison 1992, Checkland 1992; Ison, Maiteny & Carr 1997, Lauwers *et al*, 1998). There has been wide debate within the "systems community" as to its distinctive methodological features (Checkland & Scholes 1990, Rosenhead 1992, French, 1995, Brocklesby and Cummings 1996, Capra 1997), although at present this does not seem to be moving to any simple resolution. The Open University has attempted to clarify this terminological confusion for its students, working towards an accepted definition of the noun system, and of the methodological frameworks which distinguish systems, or systemic approaches, from other methods of analysis and action (Open University 1987, 1988, 1996; 1997) Practical applications of these ideas have included courses related to agriculture and the environment (Open University 1987, 1997) and to research activities (Carr & Tait 1991, Kersten 1995, McClintock, 1996) and the work on which this paper is based.

New Technology and Agriculture

During 1995-96, a project was set up by the client agency, which has statutory responsibility for the environment and natural heritage, to look at the possibility that new technologies applied to agriculture could offer benefits to the wider environment. Historically, agriculture in Europe has been at the forefront of the adoption of new technologies. A long period (1940 - 1980) of relative producer price stability in Europe, coupled often with capital support and Government sponsored extension facilitated the adoption of these technologies. This encouraged the development of the ancillary industries, which in turn had the assured markets to continue innovation of technologies for agriculture. Agriculture thus became an industry where technology advanced rapidly, and peer pressure within the industry further encouraged this (Gasson, 1973). During the 1980s and 90s, the increasing public perception that some of these technologies were damaging to the wider environment was not shared by the agricultural industry, which perceived farmers as "stewards and guardians of the countryside" (Carr & Tait 1991).

Worries about environmental damage could be highly influential in restricting the development of new agricultural technology. Increased regulation such as the Nitrate directive, (Commission of the European Community, 1988) and stringent requirements for testing of new effect chemicals could restrict innovation, thereby reducing the opportunities for farmers to react to changing circumstances. An underlying premise of much of the concern is that it is changes in technology which have caused undesired environmental effects. The work described here represented an attempt by the client environmental agency to challenge this perception, and to identify ways in which innovation can allow reduced environmental impacts from agriculture. It was promoted as "turning the clock forward faster", as opposed to the perception that much of the rhetoric surrounding sustainable agriculture implied "turning the clock back".

Technologies Offering Environmental Benefit

In the course of this project, a range of new, but well documented, technologies was reviewed, considering cost, timescale of possible implementation and the potential environmental benefit they could offer. Table 1 is a general categorisation of these technologies.

Table 1. Types of new technology considered in the study

Category of technology		Application areas
Chemical		Crop nutrition
Biological		Weed control
Agronomic practices	for	Growth regulation
Machinery		Disease control
Information Technology		Pest control
New crops		
Crop rotation		
Manure management		

New technologies in the first five categories in the left-hand column of Table 1 were identified for each of the different application areas in the right hand-column. In addition, some specific developments such as new crops, crop rotation and manure management were also examined. All such technologies were assumed to provide yield or economic benefits, as they would otherwise be unlikely to be developed. Their environmental benefits were assessed in terms of likely reduction in pollution of water courses, or other non-farmed areas, in their effects on non-target organisms and on human health and in terms of their off-farm impact on rural infrastructure, development and employment. For each aspect, technologies were scored on a scale of 1 to 5. The likely time to availability, cost, economic benefit to the farm, ease of implementation and extent of obstacles to implementation were also assessed using a similar rating. No attempt was made to produce relative weightings of these assessment criteria.

A large number of technologies was identified which could provide environmental benefits, but two criticisms could be levelled at this initial work from a systems perspective. Firstly, it was assumed that in all cases, the technology would be used in such a way that environmental benefits would be realised. Secondly, each technology was assessed in isolation, taking no account of potential synergies.

The first limitation can be illustrated by taking the example of the use of information technology to allow spatially variable application of inputs ("precision farming", Blackmore *et al* 1995). The factors affecting the outcome of using such technologies are illustrated in Figure 1 as a causal loop diagram.

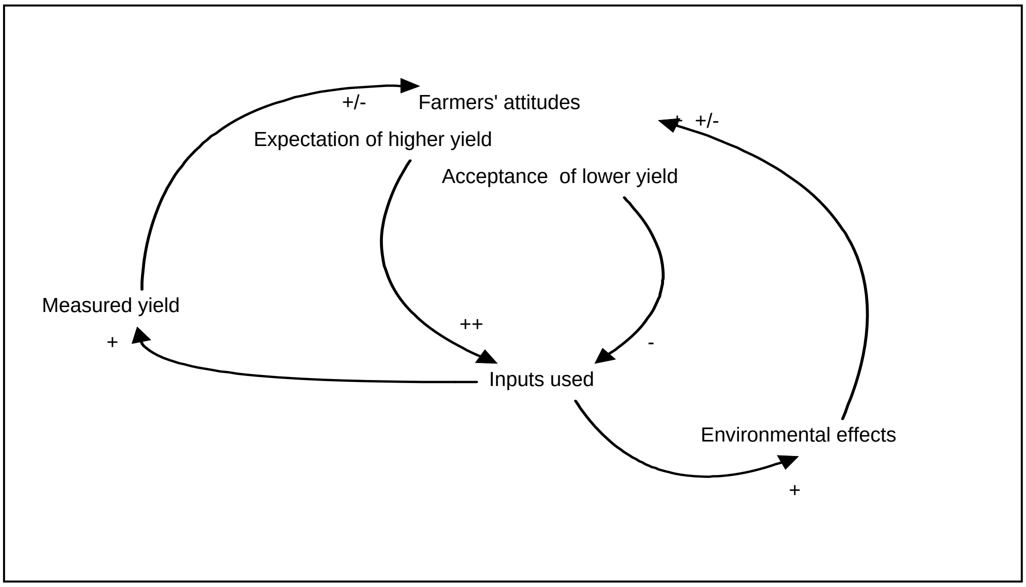

Figure 1. Causal loop diagram of the interactions between measured yield and the use of inputs to an area.

Figure 1 suggests that the interpretation of yield maps by farmers with different attitudes could have very different effects on the environment. A farmer who was prepared to accept low yields on certain areas could reduce inputs to those areas, with reductions in the potential for pollution by inputs in excess of those needed by the crop. However, an operator with high expectations might assume that low yield was a result of low inputs, and attempt to raise yields by increasing inputs. This could well be environmentally damaging. This emphasises that technologies themselves are not necessarily beneficial or damaging, but their effects will depend on the way they are used. This will depend on farmers' attitudes to the environment and to risk and on their economic models of the relevant enterprise.

Systemic Interactions

In light of the preceding comments, the client agency asked us to examine systemic interactions between different technologies. Synergistic interactions were considered to arise at two different systems levels. Within the farm, technologies which release particular binding constraints on farm enterprise choice, could allow changes in enterprise mix which could bring environmental benefits. Alternatively, they could allow the use of time or resource consuming technologies which had unambigous environmental benefits, but would not otherwise be feasible because of binding constraints on time or resource availability. Important constraints are those of timeliness in critical seasons and cash flow. Technologies which reduced constraints of timeliness during the harvest/sowing period or during critical spring periods were identified, and are listed in Table 2. This Table also lists some of the technologies which incur penalties during these same period. From this listing, it was possible to identify several promising combinations of technologies. Weed germination inhibitors, herbicide resistant crops, seed treatments for disease control, disease and lodging resistant varieties and late sowing all appeared to offer benefits in this way and were proposed for more detailed economic evaluation.

Feedback effects within the farm could also amplify the benefits of technologies when used in conjunction with one another. An example, is the use of nitrification inhibitors and on-farm nutrient analyses, to enable better use of the nutrients in manures, giving clear environmental benefits.

In the wider system, we suggested that changes in technology could change peer pressure on farmers, and change their perception of advice and requirements relating to the environment. Thus, endorsement of new technology by institutions whose main remit is environmental protection should increase the credibility of other aspects of the work of those institutions. Farmers might then be more inclined to take note of advice from these institutions which was purely concerned with environmental protection.

At this stage in the work for the client agency, it became apparent that there were other aspects of the situation which required systemic investigation. The future of the programme was perceived as not secure, although no specific threats were in evidence. We therefore proposed that a series of workshops be conducted with stakeholders (Open University 1997) to identify properties of the situation where systemic changes might be required. Two workshops were set up based on adaptations of Soft Systems Methodology (SSM; Checkland and Scholes 1990), the first with stakeholders internal to the client organisation, the second with a wider group. The initial one day workshop was designed around three stages: (i) generation of strengths, weaknesses, opportunities and threats (SWOT) of the project as perceived by individual participants; (ii) grouping, exploring, explaining and ranking of the issues identified and (iii) formulating a number of problem themes and a number of conceptual models derived for systems which might operate on these themes. Table 3 shows some of the problem themes which were identified.

Table 2. Technologies offering benefits (*) in terms of reduced work demands or greater opportunities for working and those imposing higher demands (#) during the three critical periods

	Critical period		
Technology	Sept-Dec	Feb - April	August
Nitrification inhibitor + fertiliser	*	*	
Nitrification inhibitor + manure	*	*	
Targetted herbicide mixtures		*	
Anti-leaching agents with CPPs	*	*	
Delayed breakdown products		*	
Weed germination enhancers	*		
Selective stubble treatment	*		
Seed treatments	*	*	
Herbicide resistant crops		*	
Disease tolerant varieties		*	
Varietal resistance to lodging		*	
Varietal blends		*	
Late sowing	*		
Data source	*	*	*
Liquid fertilisers	#	#	
Integrated weed management	#	#	
Aphid parasites		#	
Organic manure management	#	#	
Ecological nutrient management	#	#	
Erosion management	#	#	
Green manures	#	#	#
Manure spreader upgrades	#	#	
Soil nutrient analysis	#	#	

Table 3. Problem themes derived from stakeholder workshops

Unclear benefits:	
	The programme to encourage new technology did not deliver clear and measurable benefits to the environment
Inter-agency questions	
	To what extent was it acceptable for an agency concerned with the environment to be seen as providing advice on farm management matters, potentially trespassing on the territory of other agencies?
Ownership	
	It was not clear whether the proposed programme was being supported only by a part of the environmental agency, or whether the whole organisation was committed to it
Resources	
	Linked to the previous point; was the programme in competition for resources with other activities of the organisation?
Wrong paradigm?	
	Was the idea of technology transfer appropriate to this area of activity?

The workshop used the SWOT analysis as the means to generate a "rich picture" of the problem/opportunity situation. This had been found to work successfully in earlier research (Ison, Potts & Beale 1989) and is becoming more common under the label of "multimethodology" (e.g. see Mingers and Gill 1997). The output from the initial workshop was, as is expected in SSM, an agenda for debate about problems and opportunities, which was conducted initially within the organisation. From this internal debate and research inputs a number of potential strategies to take the project forward were identified (Table 4).

The second one-day workshop was conducted with a wider group of stakeholders who included board members of the client organisation, and representatives of other interest groups. The items in Table 4 were used as a basis for structuring this second workshop which repeated several of the design features of the first.

The outcome of the debate appears to have been successful, in that the programme came to fruition within its intended timescale, and its effectiveness is now open to scrutiny. Evaluation of the workshops was also positive, however the main realisation by the client organisation was that these processes need more time than is usually allocated or funded to carry them through to their logical conclusion.

Table 4. Possible ways of taking the project forward

1. Establish an information network for farmers based on the project
2. Build an advice and consultancy business for farmers
3. Use the project concept as a scheme which farmers could join
4. Use the concept to establish an enviromental code of practice or quality mark
5. Set up demonstration project(s) based on the project) in one or more countries
6. Use the project as a public relations vehicle with a range of sectors
7. Use the project to stimulate agri-business and industry to develop technologies which deliver, more overtly, environmental benefits
8. Cooperate with other bodies in taking forward related research
9. Attempt to influence policy which may aid any one of these possible initiatives or others which deliver environmental benefits (this might include making registration of new products easier if clear environmental benefits could be shown)

Concluding Remarks

A number of points emerge from this study. Firstly, it was important that the technologies were examined within their own terms, and their benefits and costs at least quantified in ordinal terms. Taking a systems perspective enabled a more complete evaluation of the strengths and weaknesses of new technologies than would have been possible within a purely reductionist framework. To disregard the technical in favour of the sociopolitical aspects would have reduced the credibility of the analysis. The credibility of different sources of advice to farmers varies (MacArthur, 1994), and it is important that conservation advice is seen to come from a source credible to the farmer.

Secondly, it was important that systems ideas were used to inform the development of the project. These ideas kept open the opportunities for consideration of a much wider range of factors, beyond the basic concerns with new technology. As Ison *et al* (1997) observe, many projects involving the interfaces between technology, people and the biophysical environment consistently identify organisational, institutional and other socioeconomic factors as constraints to "natural science" research success. Complex people- and policy-related issues are treated as "external" to the system of interest by those responsible for project development and management. From a systems perspective, they are clearly not external and we argue the need for boundary setting by stakeholders (which may or may not include the project manager) and relevant actors by differentiating a "system" from its "environment" or a "sub-system" from a system (Blackmore and Ison 1998).

The importance of using soft systems methodology was that it provided a framework for discussion which legitimised contribution from the whole range of stakeholders. The acceptance that different actors bring different perspectives to the same situation allows a much wider debate than would be possible if only a technical, economic or managerial perspective was used. Without this wider ranging debate, it is likely that resistance to the programme, both within the organisation and to its introduction to the farming community would have been much greater. However, it is important to recognise that there was political support for the use of SSM within the client organisation. A limitation of SSM in multistakeholder settings such as farming communities is that the institutional space must be created for its use, it cannot be imposed from the outside as may be possible with some traditional technology transfer or extension approaches.

There is increasing evidence that professionals working on discipline-oriented, technological problems find it difficult to hand over responsibility to those they consider to be "non-professionals". The constraints imposed by, for example, power relations between farmers and local officials and between professionals and non-professionals, have to be taken more into account. These are recurring problems in learning process research and practice and needs to be better understood. This suggests two research directions. The first is research into systemic methodologies and techniques which enable professionals to reflect critically on their own practices and to enter into dialogue with other stakeholders. The second is research into the role of metaphors in shaping thinking about technological innovation, and how new metaphors might be used to trigger new ways of thinking and achieving environmental benefits (McClintock, 1996).

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