FARMING ON THE TREADMILL:
AGRICULTURAL CHANGE AND PESTICIDE POLLUTION

By

Neil Ward B.Sc.

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Abstract

The thesis examines the pollution of water by pesticides in Britain, an issue of public and political concern since the late 1980s as the results of extensive water monitoring, required under the EC's Drinking Water Directive have highlighted the spread and levels of contamination. The study explores the co-evolution of post-war agricultural policy and pesticide usage and examines how pesticide pollution of water has been constructed as a 'problem' and how this has been contested by different groups. Survey material from the Bedford Ouse catchment in Bedfordshire and Buckinghamshire is used to explain how farmers use pesticides, for what reasons, and with what understandings of the pollution risks their use brings. The questions to be addressed are: i) why, since the Second World War, have pesticides become such an important element of farming practice in Britain ? ii) how do farmers decide which chemicals to use and how to use them ? iii) how has pesticide pollution of water emerged as a 'problem' ? and iv) what are the implications for farming practices of regulations to tackle pesticide pollution ?

Pollution is conceptualised as the outcome of a 'pollution production process' involving a network of actors, including farmers, advisors, scientists, pesticide manufacturers and regulatory agencies. Through an examination of farmers' actions in this context the thesis shows that, far from being the result of some natural technological progression, the increasing dependence upon pesticide technologies has been shaped and determined by broader social and political factors.

The first part of the thesis explores the historical context for pesticide use in Britain, concentrating on the roles of agricultural policy and science and technology. In the second part, the actions of arable farmers are assessed through locally-based fieldwork conducted in 1991 in the catchment of the Bedford Ouse.

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List of Abbreviations and Acronyms

ADAS	Agricultural Development and Advisory Service
AFRC	Agriculture and Food Research Council
AIC	Action in context
ARC	Agricultural Research Council
AV	Advisory Value (DoE's pesticide standards)
CEC	Commission of the European Communities
CAP	Common Agricultural Policy
COSHH	Control of Substances Hazardous to Health
DDT	Dichlordiphenyl-trichlorethane (insecticide)
DoE	Department of the Environment
DWI	Drinking Water Inspectorate
EC	European Community
ECPA	European Crop Protection Association
ENDS	Environmental Data Services
FoE	Friends of the Earth
GATT	General Agreement on Tariffs and Trade
GIFAP	Groupement International des Associations Nationales de Fabricants de Produits Agrochemiques (International Group of National Associations of Manufacturers of Agrochemical Products)
HSE	Health and Safety Executive
ICI	Imperial Chemical Industries Plc
IPU	Isoproturon (herbicide)
MAC	Maximum Admissible Concentrations
µg/l	Microgramme per litre
MAFF	Ministry of Agriculture, Fisheries and Food
MCPA	2-methyl-4-chlorophynoxy-acetic acid (herbicide)
MSR	Mode of social regulation
NAA	1-napthyl acetic acid (herbicide)
NAAS	National Agricultural Advisory Service
NCC	Nature Conservancy Council
NFU	National Farmers' Union
NRA	National Rivers Authority
Ofwat	Office of Water Services
PATCH	Pollution Agriculture and Technology Change Research Programme
RCEP	Royal Commission on Environmental Pollution
R&D	Research and Development
RASE	Royal Agricultural Society of England
SAFE	Sustainable Agriculture, Food and Environment Alliance
WAA	Water Authorities Association
WHO	World Health Organisation
WRO	Weed Research Organisation

Preface

The contamination of water by pesticides is one of a long line of environmental problems to emerge in Britain associated with contemporary farming practices. It has been of particular concern since the late 1980s as more extensive water monitoring has highlighted the spread and levels of pollution. Today attention is turning to how pesticide pollution might best be tackled, but much still remains to be learned about precisely who should be regulated, how this should be done, and what degree of resistance can be expected from interested parties.

This thesis represents a contribution to these issues. The research was conducted on a part-time basis between 1989 and 1993 while the author was employed on a series of research projects at the Rural Studies Research Centre in the Department of Geography, University College London, and was completed at the Centre for Rural Economy in the Department of Agricultural Economics and Food Marketing at the University of Newcastle upon Tyne. The study has grown out of a set of research interests in the environmental regulation of agriculture which have focused upon the degree to which individual farmers are able to control their own destinies. This 'geography of enablement and constraint' has important implications for whether farmers can deliver the benefits of environmental policies expected of them by policy makers and the public.

The four decades following the Second World War saw a technological revolution in British agriculture stimulated by state intervention in agricultural markets and government support for R&D and advisory services. The application of mechanical and chemical science and technology transformed agricultural production processes, but sometimes with unforseen or disregarded environmental consequences. It is often argued that farmers have been 'forced' to adopt new technologies or go out of business because policies aimed at expanding national food production have left them on a 'technological treadmill' with only tightly constrained choices. If this interpretation is accepted, then environmental problems, such as water pollution from pesticides, implicate national (and European) agricultural policies as much as the husbandry decisions of individual farmers.

The current decade has raised new questions about the future of farming and environmental regulation. A fundamental transition is under way as the post-war 'productivist model'[1] enters a period of structural crisis. Whilst this crisis manifests

[1] The term productivism implies "a commitment to an intensive, industrially-based and expansionist agriculture with state support based primarily on output and increased productivity" (Lowe *et al.*, 1993,

itself as predominantly a budgetary problem, there has been a parallel loss of public and political support for farming - a crisis of legitimacy - an important aspect of which is growing public concern over the state of the rural environment. In consequence, and because it is what individual farmers do in their fields and yards that causes pollution, there is a pressing need to improve our understanding of how individual farmers act in response to the rapidly changing economic, social and political contexts within which they manage their land.

The thesis explores the co-evolution of agricultural policy and pesticide usage in Britain in the post-war period. It examines how pesticide pollution of water has been constructed as a 'problem' and how this process has been contested by different groups. Survey material from the Bedford Ouse catchment is presented to explain how farmers use pesticides, for what reasons, and with what understandings of the pollution risks associated with their behaviour. The questions which guide the thesis are: i) why have pesticides become such an important element of farming practice in Britain since the Second World War ? ii) how has pesticide pollution of water emerged as a 'problem' ? iii) how do farmers decide which chemicals to use and precisely how to use them ? and iv) what are the implications for farming practices of regulations to tackle pesticide pollution ?

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p.221).

INTRODUCTION:

APPROACHING THE RESEARCH QUESTIONS

i) Pesticides, the Environment and the Social World

The 1980s marked a major turning point for agriculture in Britain and Western Europe with the first concerted efforts for several decades to alter the broad direction of agricultural development. Following four decades of 'productivist' agricultural policy, driven primarily by the need to raise productivity, problems of over-production, falling farm incomes and the rising budgetary costs of farm support called into question many of the assumptions which lay behind agriculture's post-war development strategy. At the same time, and partly in response to certain of the consequences of this strategy, pressures for improved environmental regulation have grown, leading to policy statements from the European Commission and the British Government which emphasise the need to improve environmental protection as part of the current reform of agricultural policy (*e.g.* MAFF, 1991; Commission of the European Communities, 1988; 1991; UK Government, 1994).

Environmental problems arising from contemporary farming practices indict the technologies employed, and none have proved more contentious than the usage of pesticides[2]. The potential of pesticides to improve crop yields and reduce production costs on farms has had profound implications for the way that agricultural production is organised. They are an integral feature of productivist agriculture and have come to be of central importance to farmers only in the period since the Second World War. It is only through an improved understanding of the historical evolution of the role of pesticides that the current nature of their use, impacts and regulation can be fully comprehended.

Dominant among the pesticides used in Britain are herbicides. They make up over 48% of UK sales of pesticide active ingredient and are applied to a greater proportion of the cropped area than other types of pesticide (British Agrochemicals Association, 1992, p.26). They differ from fungicides and insecticides in that the latter two are usually only applied after a pest or disease problem has been identified in the crop, whereas, because weeds are invariably found in most crops every year, the application of

[2] The term 'pesticide' is used as an umbrella term to cover three main groups of agrochemicals - insecticides, herbicides and fungicides. All three groups are biocides, specifically designed to kill living organisms, be they insects, weeds or fungi. Together, these three groups account for 88% of the total quantity of active ingredient used in British agriculture (British Agrochemicals Association, 1992). The remainder is made up by plant growth regulators.

herbicides has become routinised (Fryer, 1977). Furthermore, the chemical control of weeds has 'revolutionised' cereal production because it is a key element in eliminating the need for a fallow in the arable rotation. It is only in recent years, however, that the consequences of herbicide use for local water environments have begun to be recognised. Today, herbicides are by far the most commonly detected pesticide pollutants in surface and groundwaters (see Chapter 3). It is for this reason that herbicides will be examined in greatest detail in this thesis. Moreover, one particular cereal herbicide, Isoproturon (IPU), is the most widespread and serious cause of pesticide contamination of water whose use can be solely attributable to agricultural practices. This leaves IPU as a possible target for future regulatory control in Britain, and its use will also be a particular focus for analysis.

When assessing how environmental problems arise from farming practices, it is soon evident that the relations between social and economic processes and their environmental consequences are rarely straightforward. They are especially difficult to predict at the local level and for individual businesses. However, our ability to comprehend these relations at those scales is increasingly demanded by recent shifts in public policy directed towards the greater targeting of environmental protection. As managers of the countryside, farmers are increasingly expected to deliver the goals of public policy. This approach has prompted calls for income support for small producers and the targeting of environmental measures towards vulnerable localities, culminating in demands for farm-based, multi-purpose planning designed to integrate farm and environmental management practice (Lowe *et al.*, 1986; Countryside Policy Review Panel, 1987). While these developments sit uneasily within a wider policy context which is still largely oriented towards voluntarism and minimal controls (Cox *et al.*, 1990), they underline the need in research for farm-based enquiry and analysis.

Equally, it is evident that farm-based analyses cannot be conducted in isolation. Research needs to engage with longer-term processes of technological and policy change and mounting public and political concern about environmental protection. Therefore, it will be argued that pesticide pollution must be conceptualised as a 'pollution production process' (Lowe *et al.*, 1990a) with technological change, farm management and environmental regulation acting as key areas of enquiry.

The story of how agricultural pesticides have come to be used as they are is a complex one. General explanatory models are never more than a simplification and are better viewed as a statement of priorities which highlight some phenomena at the expense of others. The starting point adopted here is that pesticides, like all technologies, must not be seen in purely technological terms (Bijker and Law, 1992). As artifacts, pesticides embody social, political, psychological, economic and professional commitments, skills, prejudices, possibilities and constraints. In acknowledging this, it must be accepted that under different conditions pesticide technologies and their use might have evolved in different ways. According to MacKenzie and Wajcman (1985, p.4), technological determinism, or the notion that technological development is autonomous from society, is "the single most influential theory of the relationship between technology and society". Technological determinism assumes that while technologies shape society, they are not reciprocally influenced, and because social scientific analysis has often concentrated on the effects and impacts of technological change, there has been a tendency to take technological change as a given, independent factor. This thesis takes a markedly different position. The focus here is on the effects of socio-political factors on technological change and, while not denying that technologies have social impacts, the thesis examines the social shaping of technology itself.

Technologies can never provide explanations of their own development and adoption, and if no internal logic drives innovation then technologically determinist explanations are inadequate. Social factors play a crucial role in deciding which technologies are adopted (MacKenzie and Wajcman, 1985). As White (1978, p.28) puts it, a new technology "merely opens a door; it does not compel one to enter". This is an important point in the case of pesticides where the *pretence* of a natural technological trajectory has been promoted by pesticide protagonists while contingencies have been concealed. Pesticides, it is sometimes argued, are symbolic of the scientific domination and control of nature by human ingenuity. They are representative of 'natural' or 'technological progress'.

The particular social contextualisation adopted towards technological change affects not only the study of environmental problems but also the construction of solutions to them. Quite different solutions are proffered by the two scientific 'cultures' - the natural and the social sciences. Newby (1991) has complained that the public perception is one of natural scientists being best equipped to form authoritative judgements, despite the fact that environmental problems arise from human intervention in natural systems. The central role of human agency in environmental change means that environmental issues cannot be reduced to scientific or technological terms. As he argues,

> "advances in the natural sciences will enable us to establish the parameters of environmental change, but they will describe the symptoms and not explain the causes. The causes lie in *human* societies and their systems of economic development" (Newby, 1991, p.2, original author's emphasis).

An over-reliance on natural science approaches to environmental issues has tended to foster what Newby calls "old-style technological determinism" (1991, p.3) with its propensity to promote the adoption of 'technical fixes' to environmental problems. He goes on to suggest that

> "solutions to environmental problems are rarely amenable to technical fixes alone, no more than they can be handled by an equal and opposite 'social fix'. It is the *interplay* between the technical and the human which will hold the key" (1991, p.5, original author's emphasis).

Pesticides, like all other technologies, are contingent. Their development and use is dependent on other sets of influences. They have not always had a momentum of their own and cannot be said to have developed along a 'natural' trajectory. Rather, they have been shaped and reshaped over time by the social world, with their protagonists - such as manufacturers, suppliers, scientists, government departments and so on - seeking to maintain sets of technological arrangements and associated sets of social, scientific, economic and organisational relations in keeping with their interests. Pesticides form part of, and are implicated in, the strategies of their protagonists. Their adoption and increasing use since the 1940s has arisen from the network of social relations in which they are embedded - together with the various strategies that drive and give shape to the network. Understanding the forces that give rise to the use of pesticides is an important precursor to understanding why pollution takes place. But what form does the network surrounding pesticides take, and how might it best be examined in the British context in order to understand pesticide use and resultant water pollution ?

ii) The Pesticide 'Pollution Production Process'

The methodology[3] employed to analyse pesticide pollution must be sensitive to the fact

[3] The thesis and its methodology evolved alongside the conduct of other research work (Ward, 1990; Ward *et al.*, 1990; 1993; 1994 Ward and Munton, 1992; Lowe *et al.*, 1992a;b). Combining part-time research 'study' with full-time contract research 'work' is more common in other European countries, but may increase in Britain given the resource constraints which have restricted the funding of post-graduate studies, especially in the social sciences. (For example, in 1992 the Economic and Social Research Council received applications from 1272 people hoping for funding for their doctoral studies, of which it was only able to fund 315. In 1993 the proportion of applications funded fell to just one in seven).

Both thesis and contract research were carried out within a team of social scientists. This proved a fruitful environment for study, with regular discussions among researchers about methods, concepts and findings. The thesis most closely relates to the PATCH (Pollution, Agriculture and Technology Change) Research Programme, the focus of which was technological change, farm management and water pollution regulation. Responsibilities were divided according to these three themes between three research officers, with the author having responsibility for researching farm management issues. It was intended to develop two case studies - effluent pollution from dairying, and pesticide pollution from cereal farming - but pressures on time and resources and the relocation of some research staff meant that in 1991 it was decided to concentrate on developing the dairy case study where that although it is *farming* practices that cause pesticide pollution, the *outcomes* of interest here, the phenomenon of pesticide pollution and the construction of solutions to it result from much more than just farmers' actions. How then might the *process* of pesticide pollution best be conceptualised ? This is an important question because, as Lowe *et al.* (1990a, p.62) argue, "the development of a coherent policy and institutional framework to deal with agricultural pollution is still a distant prospect" and this is, in part, due to a poor understanding of the pollution production process.

Two levels of analysis can be identified - the field level (Figure I) and the wider system of production and regulatory relations (Figure II). At the field level, pesticides pollute the environment via a range of different pathways, not all of them directly associated with the spraying of crops in fields. Farmers in fields produce goods for the market. Their activities result in pollution, although rainfall, topography and soil type also influence outcomes. It is important, therefore, to note that any one action may result in pesticide pollution in one instance but not in another. However, for contamination to be termed 'pollution', it has to be detected and reported, and this involves other actors, such as a vigilant public (Ward *et al.*, 1994), the scientists who developed the detection methods, and pollution inspectors armed with instruments and knowledge. Thus, while the farmer's role is central and the farm is a compulsory location in the story of pesticide pollution, the processes that foster pesticide use and lead to pollution involve many other actors near and far, in fields, offices, rivers, laboratories, and elsewhere. The methodology needs to be sensitive to the farmer's position among this assemblage of actors.

Until the late 1980s, there was only limited concern about the pollution of water by agricultural pesticides, and this centred around gross pollution incidents usually associated with the careless disposal of surplus pesticides. In recent years, however, it has been increasingly accepted that waters can be contaminated by pesticide run-off and leaching resulting from 'normal' farming practices (Lawrence and Foster, 1987). This realisation has shifted our understanding of the nature of the problem from the question of accidental' pesticide spillages to one of potentially unsound production systems generating unforeseen and endemic environmental externalities. As a result, where pesticide technologies come from, how and why farmers use them, and how their use is regulated become central questions.

Figure II represents this wider pesticide pollution process. Knowledge, products and techniques are produced by scientists in both the public and private R&D sectors in the

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the work was most advanced. This thesis develops and extends the work originally begun under the farm management component of the PATCH Programme's pesticide case study.

Figure I - Pesticides in the Environment: A Schematic Diagram of Pathways

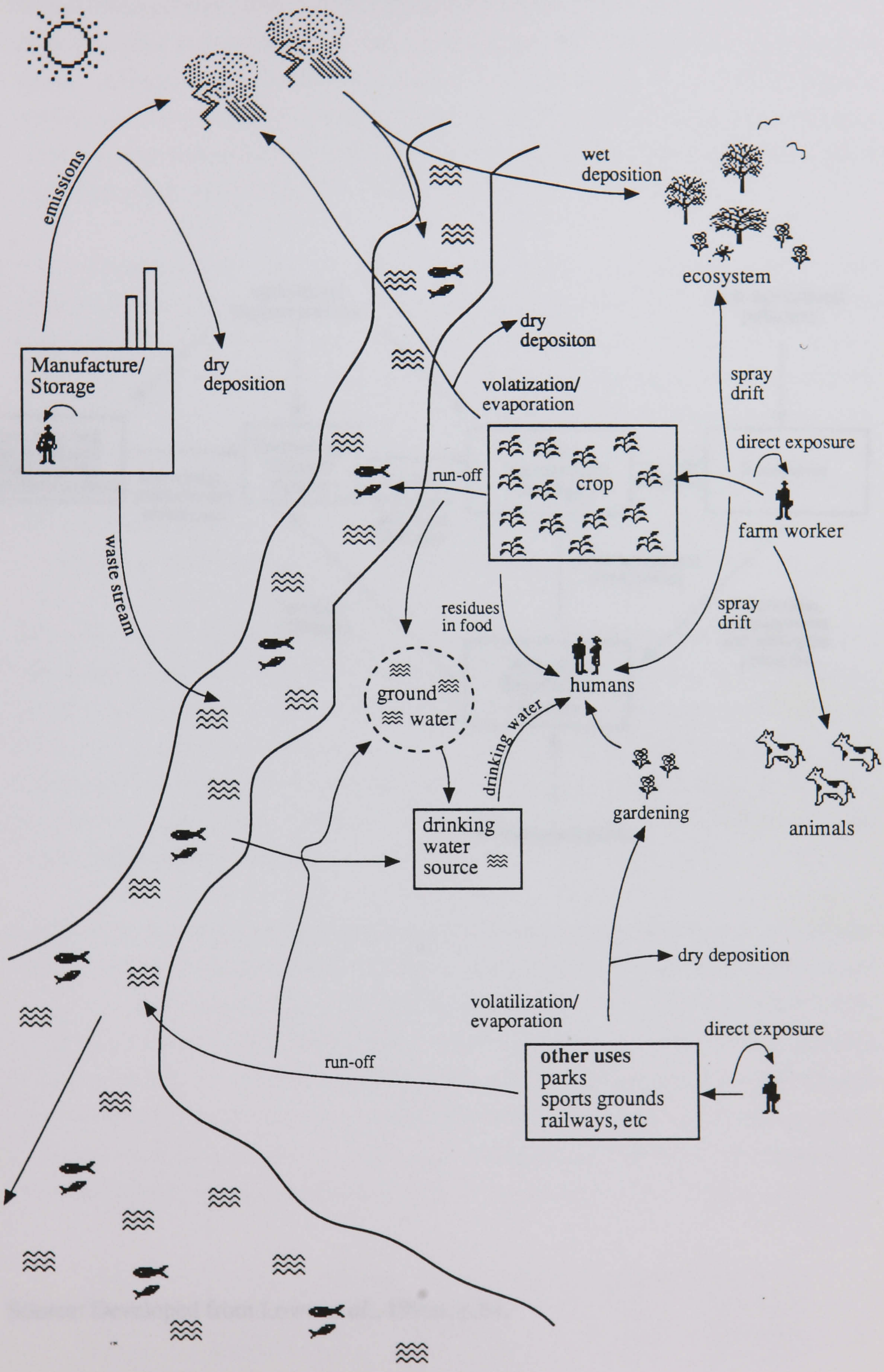
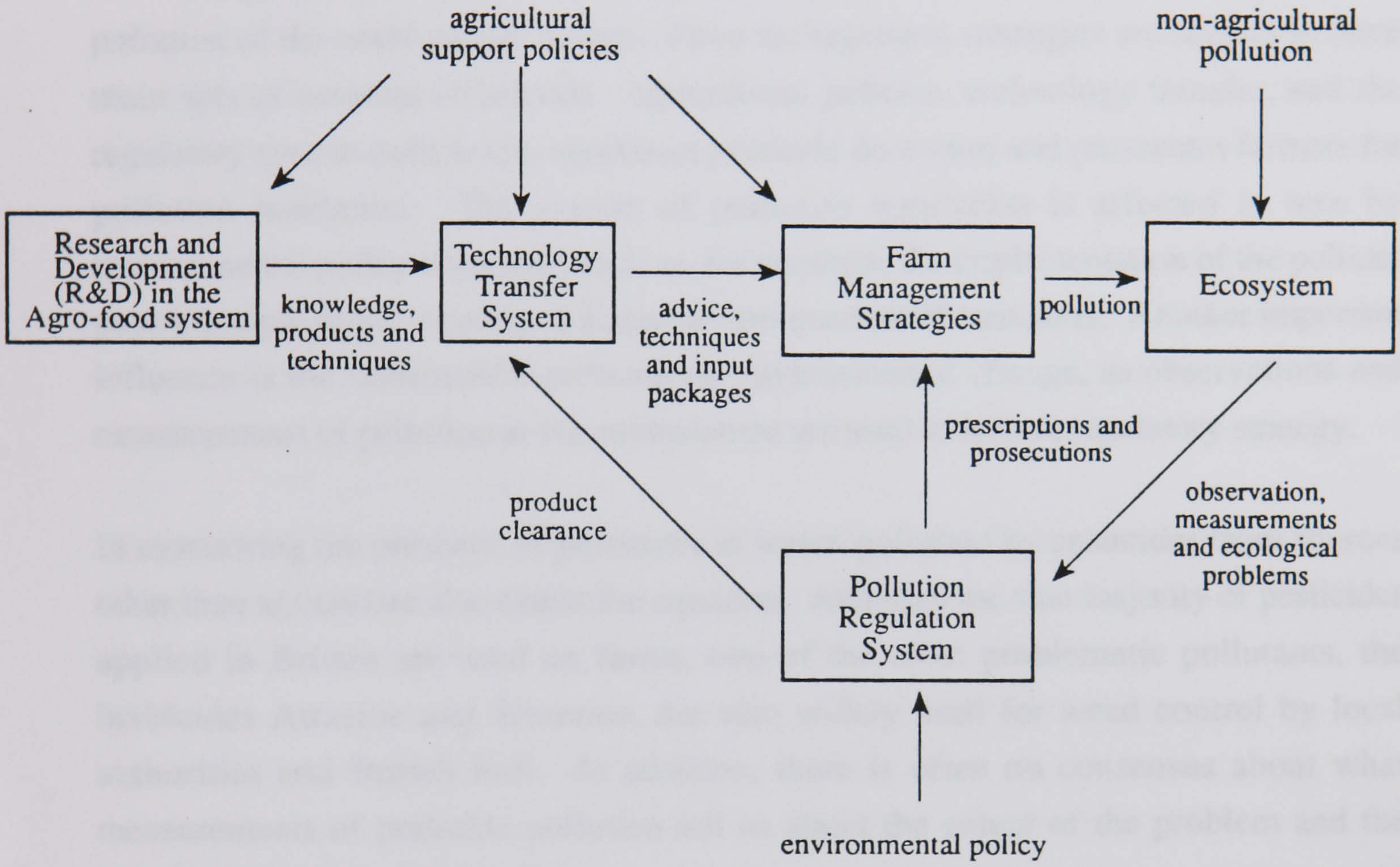


Figure II - The Pesticide 'Pollution Production Process'



Source: Developed from Lowe *et al.*, 1990a, p.64.

agro-food system. New products enter the technology transfer system where they are subject to some regulatory control (including examination of their potential to cause pollution) prior to their clearance. Once authorised for the market, they can be used on farms. Adoption of particular pesticides will be influenced by the advice farmers receive and the marketing strategies of input suppliers, some of whom have sought to introduce new technologies in mutually-dependent packages (including seeds, growth regulators, pesticides and spraying technologies).

It is through the use of these technologies, as part of farm management strategies, that pollution of the environment occurs. Farm management strategies are subject to three main sets of external influences - agricultural policies, technology transfer, and the regulatory system (which sets maximum pesticide dose rates and prosecutes farmers for pollution incidents). The system of pollution regulation is affected in turn by environmental policy objectives such as, for example, the implementation of the polluter pays principle or the meeting of European environmental standards. Another important influence is the information gathered on environmental change, as observations and measurements of pollution in the environment are used to inform regulatory strategy.

In monitoring the presence of pesticides in water, pollution by pesticides from sources other than agriculture also enters the equation. Although the vast majority of pesticides applied in Britain are used on farms, two of the most problematic pollutants, the herbicides Atrazine and Simazine, are also widely used for weed control by local authorities and British Rail. In addition, there is often no consensus about what measurements of pesticide pollution tell us about the extent of the problem and the causal processes underlying it.

As Figure II illustrates, agricultural policies influence several elements in the system. In the early post-war period when the drive for expansion in agricultural output was at its most intense, the state intervened directly in R&D by creating and expanding public sector agricultural research establishments. It also provided incentives for the adoption of new technologies on farms through grants and subsidies, through the establishment of a public agricultural advisory service committed to technological advance, and indirectly via a support system based on guaranteed prices. These interventions have been described as helping to constitute a 'productivist regime', usually taken to refer to

> "the network of institutions oriented to boosting food production from domestic sources...[including]...not only the Ministry of Agriculture and other state agencies but the assemblage of input suppliers, financial institutions, R&D centres etc., which facilitated the continued expansion of agricultural production" (Lowe *et al.*, 1993, p.221).

As this regime entered a period of crisis in the 1980s, so the relationship between agricultural policy and elements of the pesticide pollution system have been subject to important changes. For example, the state has gradually withdrawn its support for agricultural R&D, and the Agricultural Development and Advisory Service (ADAS) has been obliged to charge for most of its services to farmers (but not its 'public good' advice on conservation and environmental protection). In response to the budgetary crisis in the Common Agricultural Policy, price support has gradually been reduced and combined with sets of measures designed to limit production.

Two points arise from this conceptualisation of the pesticide pollution process. First, the role of agricultural policy has to be an important focus for the thesis. Second, the historical dynamic to change must be treated as central to the analysis. The relations between the boxes in Figure II are not static, but subject to important changes as a result of the shifting position of agriculture within national and European economies and political systems. For example, in recent years, environmental policy has increasingly influenced the whole process. Combined with improved techniques for monitoring environmental change, this shift in public policy has strengthened the influence of pollution regulation over the technology transfer system and farm management strategies. Thus, changes in the nature of the relations portrayed in Figure II require investigation *as a whole*, and these form the primary focus of the first part of the thesis. But what of the role of the farmer in this complex ?

iii) Farmers' Actions in Context

Attempting to understand the role of the farmer in the pesticide pollution process raises the question of 'structure' and 'agency' common to much social science enquiry. Farmers are obligatory actors, for what they do in their fields (in using pesticides) is pivotal to pesticide pollution. However, assuming as many commentators do that farmers are 'policy dopes', forced by the state onto the pesticide treadmill, imposes a categorical logic which leaves us poorly equipped to make sense of local and farm-specific influences on pollution, despite the need to deliver many of the objectives of environmental regulation at the farm level (Potter, 1985; 1986). Neither structuralist nor behavioural explanations can ever be definitive, and it is a matter of debate whether exhaustive cause-and-effect explanatory models can ever be satisfactorily constructed. As will be argued in Chapter 1, however, it is possible to address this dilemma through the conceptualisation of 'action in context'. This approach has been applied to understanding rural change, specifically through the prism of the rural land development process (Marsden *et al.*, 1993; Lowe *et al.*, 1993) and allows researchers "to take seriously the practices of the key actors while recognising that they are not free to do as they wish" (Marsden *et al.*, 1993, p.190). Action in context requires the examination of not only farmers' values and behaviour, but also the context, especially the role of other actors, within which they operate (as illustrated in Figure II) and how this changes over time.

The pesticide pollution process is an emergent and ever-changing phenomenon. Although the strategies of its different actors mesh together, outcomes cannot be reduced to the strategy of any one actor, in the same way that a game of chess cannot be reduced to the strategy of either player alone. In particular, the development and diffusion of pesticide technologies is influenced by more than just the strategies of pesticide manufacturers or farmers. Rather, it is in the interplay between different actors that, for example, pesticides are adopted and pollution is detected. These interactions take place in a social context, bringing us to the core dilemma of social theory which 'action in context' seeks to address: how is it that actors are both shaped by and yet help to shape the context in which they find themselves ?

The context for pesticide use in Britain has rapidly changed in recent decades. Only 60 years ago pesticides were hardly used. Now they are the mainstay of crop protection. The thesis argues that in order to understand the 'success' of pesticides and how such technologies become obdurate, we have to address how technological change is influenced by social processes. Here, Bijker and Law (1992) have argued that:

> "strategies for realizing obduracy [of technologies] comprise efficient combinations of delegating and policing the delegates. The dialectic of action and structure turns on this double requirement. If the strategies for delegating and controlling are successfully deployed, an institution results, an arrangement is stabilized, a structure emerges" (p.299).

This means that what appears from one perspective to be a successful technology may be a failing artefact from another. Success depends upon enrolling other actors to adopt particular representations (of the world, of actors and of the viability of technologies) in networks (Callon, 1986; Callon and Law, 1989). The building of networks cannot be detached from the strategies of actors, but neither can it be reduced to these. Thus,

> "from the standpoint of any particular actor, the structure and the actors defined within it represent a more or less accurately pictured geography of enablement and constraint" (Bijker and Law, 1992, p.300).

Some relations are easier to create and maintain than others, but all relations that make up 'structure' are an emergent consequence of actors' strategies and other actions and events.

In thinking about the context in which farmers use pesticides (and water is polluted), and if reductionism is to be avoided, what can be said about the geography of enablement and constraint that makes up the context ? How does the context affect farmers' strategies, and what leads particular groupings of socio-technical elements to display particular obduracy in certain contexts ?

The concepts, techniques and resources used by social actors (in this case, farmers) combine explicit theory, tacit knowledge, general engineering practice, cultural values, devices, and material networks used in a community. These are simultaneously framed in the social *and* technical. Crucially, actors' meanings and the ways in which they understand their positions in their contexts provide the bounds within which they act (and, in this case, within which they adopt and use pesticide technologies). Bijker and Law (1992) call this the 'technological frame'. These contours help structure relations, be they social or technical, and serve as a bridge between structure and agency. Thus, the ways in which actors are moulded by and implicated in networks of relations can be used to help explain action; networks of relations (and networks of resources) enable certain courses of action while constraining others.

The concept of a 'technological frame' can provide a model of the patterns that arise when social groups are constituted and interact with one another and can help point to how some sets of socio-technical arrangements become obdurate while others remain malleable. Moreover, certain technologies and their carriers may be more 'flexibly' used in their early stages but later develop to a point at which they are relatively insensitive to, but exercise great influence over, their environments. This has been suggested by historians of science who have looked at the motor car and the electricity supply system (Hughes, 1983; 1987). In short, technologies seem to take on a life (or momentum) of their own as they begin to affect the social world around them. In the analogy of the motor car, for example, roads have to be built, materials for road-building extracted, traffic flow systems modernised, safety mechanisms developed and so on. The processes through which technologies become widely accepted and adopted can help us to examine the extent to which actors are shaped by or implicated in particular networks of relations, be they economic relations, commitments to expertise and skills or so on. They are, however, patterned relations, and they can add to the obduracy or momentum of the socio-technical system.

iv) The Structure of the Thesis

This brief theoretical discussion highlights the focus of analysis to be employed in examining the questions about pesticide use and pollution outlined above. The main questions are: i) why since the Second World War have pesticides become such an important element of farming practice in Britain ? ii) how has the pesticide pollution of water emerged as a 'problem' ? iii) how do farmers decide which chemicals to use and precisely how to use them ? and iv) what are the implications for farming practice of regulations to tackle pesticide pollution ? The point of departure is that, although much of our language and practices encourage us to treat technology and society as if they are quite separate from each other, technology is never purely technological. It is also social. At the same time, the social is never purely social. It is also technological.

The thesis seeks to make an original contribution to our knowledge and understanding in a number of ways. *First*, in presenting the first sociologically-derived analysis of the problem of pesticide pollution of water in Britain, it highlights the social shaping of technological change and associated environmental outcomes. In turn, it points to the importance of social science perspectives in explaining the underlying *causes* of environmental problems and to the development of solutions to them. Moreover, from the specific case of pesticide pollution, the thesis improves our general understanding of how contemporary technological change in agriculture proceeds and is organised. *Second*, in developing an 'action in context' perspective on pesticide use on the farm, the thesis seeks to overcome the pitfalls of the structure-agency duality common to social science and, in doing so, provides an enhanced understanding of farmers' risk-taking strategies in relation to the environment. Furthermore, it represents the first attempt to use 'action in context' to address the use of a particular *technology*. *Third*, the thesis makes a contribution to the social science debates about the role of farmer action (Lowe *et al.*, 1992b) in environmental change. Although pesticide pollution is often seen as a technical issue requiring technical solutions, it is what individual farmers do that affects environments. The thesis attempts to fill a gap in the literature between structuralist and behavioural perspectives by focusing on *negotiated* action, this being the outcome of interactions between farmers and other actors in networks.

In this research, therefore, a wider relevance is sought which goes beyond conceptual debates in the study of agriculture and the environment. Most importantly, an improved understanding of how and why farmers do what they do ought to inform the development of regulatory strategies. Reducing the contamination of water with pesticides requires that we understand the causal processes underlying pesticide use and the complexity of factors influencing what farmers do.

Theoretical approaches that might be employed to address the central questions of the thesis are reviewed in Chapter 1 and a conceptual framework is developed. Here, the farmer has been positioned within a context - the pesticide pollution process. This has an historical dimension which is crucial to any understanding of its current form. In Part II (Chapters 2 and 3), an account of the development of the pesticide pollution process is presented. Particular attention is paid to the role of, and philosophy behind, agricultural policy in fostering pesticide use, and the ways in which water pollution problems arising from pesticide use have been constructed and contested by different groups. Of specific significance is the current uncertainty surrounding the objectives of agricultural policy which in turn is calling into question assumptions about the role of pesticides which have prevailed for forty years in Britain and elsewhere[4].

Part III of the thesis contains an empirical examination of the farmer as producer of agricultural commodities, pesticide user and polluter. From a survey of cereal producers in the catchment of the Bedford Ouse in Bedfordshire and Buckinghamshire, the thesis explores how pesticide practices result from the interactions between farmers and other actors, especially those supplying and providing advice about pesticides. Chapter 4 introduces the local context with a description of agricultural and environmental changes in the catchment and describes the methodology employed during the local fieldwork. In Chapter 5 the restructuring processes being experienced by cereal producers and their changing pesticide practices are examined. Chapter 6 takes a detailed look at the processes of negotiation which surround decisions about pesticide use, and assesses the possibilities of devising strategies to reduce herbicide usage in particular. Chapter 7 further examines some of these issues, including how practices vary in relation to the mix of enterprises on the farm and the family's farming strategy. It also explores how farmers represent pollution problems and their roles in creating them and how they understand the roles of the relevant regulatory authorities, before going on to assess the possible implications of different sets of measures designed to address the pollution problem.

[4] At one extreme, in countries such as the Netherlands and Denmark, policies are now in place which seek to reduce the quantity of pesticides applied by up to 50% by the year 2000 (Baldock and Bennett, 1991). In Britain, the Government has stated its objective of reducing dependence on pesticides in agriculture to the minimum necessary (DoE, 1990, p.179), although there are as yet no specific regulatory mechanisms which seek explicitly to *reduce* the quantity of pesticides applied (Ward *et al.*, 1993).

CHAPTER 1:

CONCEPTUALISING TECHNOLOGICAL CHANGE IN AGRICULTURE

1.1 Introduction

It is widely acknowledged that agriculture's environmental problems are an indictment of the products and practices employed in the production process. In order to comprehend more fully how farming practices have led to environmental change it is necessary to understand how technological change has evolved in the context of agrarian development under advanced capitalism.

Here, the notion of technological determinism is firmly rejected. Technological change is not autonomous from society and technologies are not driven by any 'internal logic'. Rather, they are moulded by and contingent upon their social context. Newby and Utting make the same point in their analysis of the technological transformation of British agriculture since the 1940s. They argue that technological change has not been, as is often suggested,

> "the product of the 'hidden hand' of the market, but of quite deliberate policy decisions, consciously pursued and publicly encouraged" (1984, p.261).

In order to understand how pesticide technologies have become of such importance to arable farming in Britain, leading to problems of water pollution, the evolving context for their use has first to be examined. This context was conceptualised in the Introduction as a network of relations surrounding the farmer. Pollution occurs because of the workings of a socio-technical system (Figure II, p.19) in which the actions of farmers are not wholly under their control. As argued elsewhere;

> "actors take decisions and act upon them, but the decisions and actions taken depend on the social context and the activities of other actors involved. In this sense, the context has a reality and a dynamic all of its own" (Marsden *et al.*, 1993, p.163).

In this chapter the relationships between farmers' adoption and use of technologies and their wider social context is explored. First, the different ways that social scientists have approached technological change in agriculture is examined. Not only has the nature of farming technologies been transformed since the 1930s, but so has the way that technological change is represented and understood. Where once mechanisation and the application of chemical technologies were seen as indicative of 'progress' and 'development', subsequent recognition of the social and ecological consequences of the use of new technologies has brought such assumptions into question.

Approaches to the study of technological change in agriculture can be broadly divided into 'behavioural' approaches which attribute a significant role to human agency, and 'structuralist' approaches which tend to attribute a determining role to the political and economic 'system' within which farmers manage their land. In the latter part of the chapter it will be argued that neither behavioural nor structuralist approaches are alone adequate and a 'middle path' employing the concept of 'action in context' will be adopted and justified.

1.2 Behavioural Approaches to Technological Change in Agriculture

Until the late 1970s, the classical diffusion model dominated social science research into technological change. The model sought to explain how farmers adopted new products and practices, almost all of which were directed at increasing productivity or farming efficiency. The adoption process was conceptualised as a series of stages typified by awareness of the innovation, the collection of information, its evaluation, a trial period and then adoption. In this linear system, scientists would develop new technologies and extension agents would disseminate them to farmers. Research findings indicated that adoption was characterised by a logistical growth (or "S") curve, and farmers were classified as innovators, early adopters, early majority, late majority and laggards according to the stage on the curve at which they adopted a technology (Rogers, 1962). Criticisms of the model first appeared in the late 1960s.

The principal criticism was that the model's application had been uncritical, if not promotional, towards technological change (Stockdale, 1977; Goss, 1979). Innovations "were unquestionably viewed as improvements" (Fliegel and van Es, 1983, p.14), and as Buttel *et al.* explained, researchers

> "tended to adopt the language of their agricultural experiment stations by referring to the technologies they studied as "improved" or "recommended". Most such studies were therefore couched in terms of how the new knowledge of diffusion-adoption would enable... [increases in]...the rate of adoption of these new, improved, and recommended technologies" (1990, p.47).

Even among those social scientists who used the approach its shortcomings became a cause for concern. One study found that the adoption of environmental innovations, such as contour farming, terracing and the use of reduced tillage, followed a quite different pattern from 'commercial innovations', and concluded that the classical diffusion model "may have provided within rural sociology a field of knowledge with a narrow empirical foundation on which to base its generalisations" (Pampel and van Es, 1977, p.69). On the basis of Third World experiences, Goss (1979) reinforced these criticisms and noted that the model failed to account for the distributional effects of diffusion. Further, "there was scant attention given to sociological theory...and the overriding tendency was towards raw empiricism" (p.756). Stockdale (1977) questioned the impacts of new agricultural technologies on the natural environment, warning that the role of technology in transforming American agriculture was widely held up to be a model for other nations to follow, although there had been little research into the ecological consequences of this energy intensive, high technology model of development.

More recently, Busch *et al.* have highlighted several conceptual problems with the model. Most important was its failure to distinguish between 'scientific' and 'everyday' rationalities. For example, agricultural science had traditionally been concerned with finding the optimal *means* of achieving the *end* of greater productivity, but the end itself was not called into question. The decision to increase productivity was "the proper subject of philosophy or politics but not of science" (Busch *et al.*, 1991, p.42). By comparison, the ends and means of farmers in their everyday situations are much more varied and complex, and calculations about what might be optimal solutions are likely to give way to what appears most appropriate given a range of constraints. Unfortunately, the implicit assumption in most studies was that both scientists and farmers acted with the same 'rationalities'. Busch *et al.* list a series of other questionable assumptions implicit in the model, including 'ontological monism'[1] and the denigration of 'the traditional' as erroneous in the face of 'modernity'[2].

A further strand of work has made its focus the attitudes and actions of individual actors. Farmers' attitudes to new technologies and environmental issues have been

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[1] Ontological monism is the assumption that there is a single social and physical world.

[2] Neo-classical economic analyses of technological change have also contained assumptions about innovation and diffusion. Historically, the economics profession tended to neglect technological change as a focus for inquiry, treating it as a 'residual' or 'exogenous' factor. Jewkes *et al.* (1956) attributed this neglect to three factors: an ignorance of science and technology issues among economists; an absence of statistics; and a preoccupation with cyclical fluctuations and unemployment within national economies. However, among those economists with an interest in innovation, debates in the early post-war period centred on the crude dichotomy of 'demand-pull' versus 'technology-push', and linear conceptualisations of the innovative process characterised by a top-down 'flow' from science, to R&D, design, production and marketing.

The limits of seeing technological change as characterised by linear processes are now more widely recognised within the social sciences, and it is generally acknowledged - even among economists - that scientific endeavour, demand and institutional pressures interact in more complex ways to shape patterns of technological change (Dosi, 1982; Dosi *et al.*, 1988; Orsenigo, 1989). The nature of these interactions and how they can be conceptualised will be explored in more detail in Section 1.7.

examined in a series of studies (ADAS, 1976; Worthington, 1979; Social Research Consultancy, 1982; MacDonald, 1984), some of which have been little more than opinion polls. They often assumed that a basic divide exits between modern (or progressive) farmers and traditional (or conservative) ones, and sought to identify and measure the different attitudes characteristic of the two groups. Moreover, implicit in many attitudinal studies is the assumption that attitudes *determine* behaviour.

Two studies of farmers' attitudes in Britain (Tait, 1976; Carr, 1988; Carr and Tait, 1990) have specifically addressed the question of pesticide use. Tait's analysis of the factors affecting the production and usage of pesticides in the UK was conducted at a time when the quantity of pesticides being applied to crops in Britain was rising rapidly. Rooted in a socio-psychological and empirical tradition, the study aimed to identify the major parameters of farmers' 'decision-making frameworks'. Statistical analysis revealed that the traditional economic assumption, that farmers seek to maximise profits, could not be supported. Instead, farmers' attitudes towards risk exerted "a considerable effect" on pesticide usage (p.155), with more risk-averse farmers being more reliant on routinised chemical crop protection. Furthermore, many farmers expressed regret at the extent of their dependence on chemicals for crop protection.

Carr's study (1988) employed similar techniques to examine farmers' attitudes to a range of environmental issues including pesticide use. Statistical analysis revealed a poor correlation between *attitudes* to using pesticides and actual pesticide use. Farmers' attitudes to pesticide use were, however, found to correlate with their subjective assessments of their own pesticide usage compared to other farmers. Carr, therefore, suggested that farmers might be encouraged to reduce pesticide usage if they were presented with comparisons of their own use with that of other farmers. This disjuncture between farmers' attitudes and what they do is echoed in other attitudinal studies, particularly those concerning conservation (Newby *et al.*, 1977). In particular, many farmers regretted the environmental impact of their practices but felt they had little alternative. This has helped shift attention among researchers away from individual behaviour to structural factors such as the influence of agricultural policy.

To conclude, behavioural analyses frequently suffer from conceptual problems. Most important is the lack of critical attention paid to where agricultural technologies come from, and how and by whom they are produced and promoted. Behavioural studies use a classic science-based notion of rational action and often fail to explicitly address the social, political and economic context within which farmers operate. Action is assessed outside its context. Farmers are assumed to be free agents, able to pick and choose technologies as they wish and according to their own needs. Little attention is paid to the constraints and pressures that might compel farmers to adopt, as embodied, for example, in the theory of the technological treadmill.

1.3 The Theory of the Treadmill

The notion of the 'treadmill' was first introduced by Cochrane, an American agricultural economist, in 1958. He drew on findings from research into the diffusion and adoption of agricultural innovations undertaken by rural sociologists which suggested that it was the more entrepreneurial and non-risk-averse farmers who tended to be the first to adopt new technologies. He argued that these early adopters then benefitted from lower than average unit costs of production, often associated with an increase in output, and increased net returns. In the period when any new technique has only been adopted by a few farmers, total output is not noticeably increased and the price of the commodity does not fall (Cochrane, 1958; 1979).

The net incomes of the few early adopters rise and more farmers are then attracted to the technique. However, once adoption has become widespread, the situation is transformed. Total output of the commodity increases markedly and so its price tends to fall. Increases in net returns, such as they are, are often largely capitalised into the value of fixed assets, such as land. Land prices, and sometimes rents, may then rise, raising the unit cost of production. This, combined with the falling commodity price, means that the financial benefits of adopting the new technique vanish. Thus early adopters take up the technology to increase returns, while it is those that Cochrane describes as 'Mr Average Farmer' who find themselves on the treadmill. More and more are obliged to adopt the new technology because the price of the commodity is declining. They are *forced* to adopt in order to reduce costs and stay in business.

Cochrane's theory has been important in conceptualising the role of technological change in agrarian development. According to Buttel *et al.* (1990, p.130), one reason why the theory has been so widely accepted as an "orienting perspective" is because it draws upon linked knowledge from a range of research areas. The theory has enjoyed particular favour among exponents of what Friedland *et al.* (1991) have called the 'new political economy of agriculture' which developed in North America and Europe in the 1980s (Marsden *et al.*, 1986; Goodman *et al.*, 1987; Kloppenburg, 1988; Friedmann and McMichael, 1989). The treadmill theory is seen as providing insights into the transformation of agriculture by off-farm capitals. The idea that farmers may be forced to adopt new products and practices, thus becoming locked into new systems of production, found resonance with those keen to point to the concentration of economic power among a small number of agri-business industries.

The technological treadmill requires critical re-evaluation because the international political and economic conditions shaping the modern agro-food system are very different from those of the 1950s when Cochrane's theory was devised (Ward, 1993). The main concern of the immediate post-war period was the uneven *uptake* of new agricultural technologies, with those farmers not adopting being seen as part of the 'problem' of rural development. Cochrane, on the other hand, used the term to criticise the direction of agricultural development because of his concerns for its *social* consequences. He suggests the treadmill "fostered a cannibalistic process in which the large aggressive, innovative farmers gobbled up the productive assets of the smaller, less efficient less aggressive farmers" (Cochrane, 1979, p.405).

A major weakness of Cochrane's theory is his failure to address how agricultural technology is produced and diffused (Buttel *et al.*, 1990). Research by Friedland *et al.* (1981) showed that the social organisation of different agricultural commodity systems varies and so, therefore, does the structural context for technological change. The introduction of new agricultural technologies benefit different groups within commodity complexes in different ways. For example, dramatic, transformational technological change in the US tomato industry followed changes in the availability of cheap labour in the 1960s, yet similar shifts in the labour supply resulted only in incremental technological changes in the lettuce industry. Friedland *et al.* demonstrated how this was because the rate and nature of technological change was influenced by the supply and control of labour and the economic structure of the commodity system. Therefore, the specific social and historical contexts are important in understanding the production *and* consumption of new agricultural technologies. In the light of these insights, any conceptualisation of the use of technologies in the 1990s needs to be sensitive to the socio-political and economic context within which agricultural technologies are produced.

Further problems with Cochrane's theory arise from the specific historical context in which the theory is set. One problem concerns the assumption that farmers are solely food producers. This renders the theory much less applicable to those numerous parts of the advanced capitalist world where pluriactivity as a household survival strategy has become commonplace, and farm households have developed extensive links with the non-agricultural economy. For example, in the United States the proportion of farm family income derived from non-farm sources rose from 26% in 1940 to 40% in 1960, and to over 60% by the mid-1980s (Ahearn *et al.*, 1985). Gasson (1990) has found evidence of broadly comparable increases in Canada, Sweden and Japan. Where the farm business contributes only part of the farm household finances because of the role of non-agricultural income, patterns of adoption of new agricultural technologies may differ. Businesses may not be run simply to maximise economic returns. Pluriactive farm households may seek to maintain a cherished agricultural life-style and survival or accumulation may be sought through a *combination* of agricultural and non-agricultural activities. Such pluriactive strategies often emphasise flexibility and the minimisation of borrowing rather than maximising farm business profitability (Marsden *et al.*, 1992a).

Finally, the treadmill theory implies passivity on the part of farmers. Uptake of new technologies is readily recorded (often from agricultural statistics, such as the number of machines etc.) but resistance to change is not. Absence of adoption is deemed to be 'sloth' or 'laggardly', although differences in farm-level responses may be shaped as much by the variability of farmers' values, or 'logics of production' (van der Ploeg, 1990). In effect, Cochrane's model tends to assume mechanistic 'responses' by individual farmers to external market and technological conditions, a position denied by Hawkins' (1991) research into dairy and potato production in Cheshire. Little allowance is made for independent judgement - even by the actor most involved.

1.4 Political Economy and Technology

Political economists in the Marxist tradition have viewed technological change as a process which takes place in response to the needs of industrial capital. Innovations are seen as produced within social and economic structures which, themselves, drive technological change through the incentive to accumulate. The producers of agricultural technologies seek to appropriate surplus value from the farm production process by promoting the adoption of manufactured industrial inputs. Accumulation becomes concentrated in the oligopolistic agricultural supply industries and farm production is transformed along an industrial trajectory. Political economists have, therefore, frequently asked why, under these conditions of technological change, agriculture remains dominated by small family businesses.

Three lines of argument can be identified. Firstly, Friedmann (1986) argues that it is the social relations of agricultural production specific to the farm family that are the key to the persistence of family farming. Secondly, Mann and Dickinson (1978) suggest that the most important barrier to the capitalist development of agriculture is the disjuncture between 'production time' and 'labour time' which prevent the routinisation of the agricultural labour process and makes agriculture less profitable for capital than other industries. Thirdly, Goodman *et al.* (1987) suggest the key to agriculture's uniqueness lies in the biological basis of the production process. Nature's constraints to capitalism, represented by the biological conversion of energy, have meant that the transformation of agricultural production under capitalism has been characterised by two processes which Goodman *et al.* call *appropriationism* and *substitutionism.* Technological change is a critical feature of both processes. They define appropriationism as the

> "discontinuous but persistent undermining of discrete elements of the agricultural production process, their transformation into industrial activities, and their re-incorporation into agriculture as inputs" (1987, p.2).

The replacement of broadcast sowing by the seed drill, the horse by the tractor, and manure by synthetic chemical fertilizers are examples of appropriationism. At the same time, substitutionism takes place as a parallel process. Substitutionism is defined as a similarly discontinuous but permanent process by which

> "industrial activity account[s] for a steadily rising proportion of value added [and] the agricultural product, after first being reduced to an industrial input, increasingly suffers replacement by non-agricultural components" (1987, p.2).

This conceptualisation places technological change in a central position in the transformation of capitalist agriculture. Industrial capital seeks progressively to appropriate the agricultural production process in order to create sectors of accumulation through technological change.

While Goodman *et al.*'s theory has become a widely accepted account of agro-industrial development within neo-Marxist agrarian political economy, and has provided a particularly useful conceptualisation of the role of emerging biotechnologies in the food system, it has been the subject of post-structuralist critiques which have centred on its inability to deal with empirical diversity in agriculture (Whatmore, 1991, p.18; van der Ploeg, 1990).

The theme of differentiation amongst farm businesses was explored by researchers studying the restructuring of contemporary English agriculture in the mid-1980s. A theoretically based typology was developed by Whatmore *et al.*, (1987a;b) in order to help to understand the effects on farm businesses of external pressures from wider off-farm circuits of capital. It was argued that the technological treadmill reflected "the central mechanism" by which formal subsumption of production relations takes place (1987a, p.28), but at the same time it widened the terms of reference beyond technology to include credit and financial relations and the labour process.

1.5 Technology and the Environment: The Treadmill as Metaphor

With increasing concern since the 1970s about the environmental consequences of technological change in agriculture, the notion of a treadmill has been used, particularly by environmental groups, to explain agricultural intensification and associated environmental change. Two important critiques of agricultural policy in the early 1990s used the term as a metaphor to illustrate the idea that farmers are being forced to adopt more new technologies because of the pressures of the system within which they operate[3].

In 1991, Friends of the Earth published their environmental review of agricultural policy entitled *Off the Treadmill.* It began with the statement;

> "It is over a decade since the Royal Commission on Environmental Pollution noted that some farmers "feel themselves to be on a treadmill with regard to pesticide usage - compelled by circumstances to depend on chemicals which they as countrymen, ultimately find disturbing". Yet in the intervening years, the farming 'treadmill' has grown bigger, faster, and even more unbalanced" (Friends of the Earth, 1991, p.1).

The treadmill term is used here to refer to farmers' increasing dependency on pesticides and chemical fertilizers. Central to this conceptualisation is the notion that through the use of pesticides farmers disrupt ecosystems and consequently need to use ever more chemicals to maintain effective pest control. Either pests develop resistance to pesticides or new types of pests are unintentionally created. In this context, the treadmill concept has a strong ecological dynamic.

This idea has also been used recently in a study which explains how farmers are *'pushed onto'* and become *'caught on'* the treadmill (Clunies-Ross and Hildyard, 1992). Although the study takes fertilizer and pesticide use as the main illustration of the operation of the treadmill, the idea is also applied in a much broader form. With little regard to farmers being at all in control of their own actions, they argue that

> "Squeezed by prices, encouraged by advice and training, controlled by regulation, limited by research, and trapped by peer pressure, farmers have had little choice but to adopt more and more intensive systems" (Clunies-Ross and Hildyard, 1992, p.59).

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[3] The term 'treadmill' has also been used in a wider context to explain the relationship between economic growth and environmental change. Schnaiberg (1980), in seeking to examine which institutional traits of modern society can be held responsible for environmental problems, describes a 'treadmill of production', explained in terms of the capitalistic character of production organisation. He argues that "the basic social force driving the treadmill is the inherent nature of competition and concentration of capital...[and that]...increasing the speed of this treadmill involves increased environmental withdrawals" (Schnaiberg, 1980, p.230).

Under these circumstances, the political and economic conditions for agriculture are brought into the equation, with the key processes being loss of control over farm inputs, increasing debt, increasing concentration of land holdings, increasing corporate control over the food industry, and declining bargaining power for farmers in the market place. Therefore, to the ecological dynamic can be added political and economic dimensions[4].

Clunies-Ross and Hildyard explain how they see 'the chemical treadmill' at work (1992, p.61). They argue that since the 1950s there has been a dramatic increase in both the quantity of agrochemicals used in the developed world, and the number of different pesticides available. For example, in the US, the use of manufactured nitrogen quadrupled between 1961 and 1981, and the amount of pesticide active ingredients increased by 170 per cent over the same period, whilst the acreage under cultivation remained relatively constant. These changes have arisen because manufactured fertilizers have raised yields, and made it no longer necessary to rotate crops and livestock to maintain soil fertility. Pesticides have made monocropping first possible, and then the accepted norm.

As production has increased, so agricultural commodity prices have come down. Those who did not adopt new seeds, fertilizers and pesticides tended to be squeezed out of business, while those that did "stepped onto the chemical treadmill" (p.61). However,

> "Getting off the chemical treadmill has never been easy. The cost-price squeeze which encouraged farmers onto the treadmill has increased rather than decreased in intensity. Farm gate prices have tended to fall in real terms, whilst the cost of inputs has gone up, with the result that farmers have to strive for higher and higher yields in order to make a profit" (1992, p.61).

In addition to the economic necessities of adopting intensive practices, Clunies-Ross and Hildyard also argue that farmers have become locked into particular production practices in physical terms. The replacement of manure by manufactured fertilizers means that levels of organic matter in the soil are reduced, along with the availability of

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4 The term 'treadmill' is also regularly used in the work of social scientists looking at agricultural change. For example, Pile uses the term 'treadmill' in a range of contexts to explain the adoption of different survival strategies on farms. He suggests that "the treadmill metaphor is useful because farmers themselves believe that they are struggling within a labour treadmill, involving both work and technology" (Pile, 1991, p.264). He goes on to discuss the labour treadmill, the technological treadmill, the treadmill of farm management and the financial treadmill. To this list can be added "the vicious treadmill of cut-throat competition" (Woods, 1992, p.14) and "the treadmill of competitive innovation" (Goodman and Redclift, 1991, p.102).

essential trace elements such as magnesium, zinc and copper. Farmers have had to apply more and more manufactured fertilizers to compensate, but with the decreasing likelihood that yields will increase[5].

In the case of pesticides, the treadmill effect arises because of pest resistance, whereby pesticides lead to more pest infestations by killing a pest's natural enemies. Also, pesticides can disrupt the metabolism of plants, causing proteins to break down and making them increasingly susceptible to attack by pests. Because spraying programmes rarely totally eradicate a whole population of pests at once, some will inevitably survive, passing on their immunity to the next generation. The problem of increasing immunity then fosters an even greater dependence on newer chemical technologies.

Clunies-Ross and Hildyard's report concentrates on issues of pest resistance and soil properties and so privileges physical dependencies in soils and ecosystems over the economic and social processes locking farmers into particular development trajectories. Their account can also be criticised because of its oversimplified treatment of the use and impacts of agrochemicals. Thus, their notion of a pesticide treadmill, whilst evocative of the farmer's dilemma in adopting chemical technologies, is too narrow in its scope. The term 'treadmill' makes a good metaphor for the combined sets of pressures which have encouraged agricultural intensification, particularly as a tool in environmental campaigning, for it helps draw attention to the role of public policy in shaping agricultural change. However, sets of different economic, political and ecological processes and influences are all conflated under the banner of the 'treadmill' leaving the concept analytically weak. It infers an element of compulsion in that farmers are deemed to be *forced* to continually adopt new technologies, but adds little to our understanding of the differentiation and variability of these processes evident in the empirical literature on diffusion and adoption.

1.6 Technology and Regulation Theory

Macro changes driving the restructuring of agriculture have become one of the central concerns of a group of commentators who have used the ideas of the French 'regulation' (or regulationist) school (Aglietta, 1979; Lipietz, 1987). Regulation theory provides a useful ordering device for understanding the evolving context for technological change in agriculture. Its focus of analysis is the institutions and structures through which society is organised, produced and reproduced, and its central

5 According to Clunies-Ross and Hildyard (1992, p.62), "twenty years ago, farmers in the US corn belt could have expected a tonne of fertilizer to add 15 to 20 tonnes to their grain harvest. Today the same tonne can only increase production by about 5 to 10 tonnes".

tenet is that capitalism develops in the form of a succession of periods, each with specific institutional frameworks and social norms. These frameworks are conceptualised as 'regimes of accumulation' - a notion developed in response to emerging evidence of radical changes in labour processes, consumer habits, geographical and geopolitical configurations, and in state powers and practices, particularly since the 1970s[6].

The *extensive* regime (Figure 1.1) dominated from the late nineteenth century until the First World War and was characterised by incremental growth, rapidly growing demand, and the concentration of accumulation and technological change in heavy producer goods industries. The corresponding mode of social regulation (MSR) for this regime has been termed the mode of *competitive regulation* (Tickell and Peck, 1992), an economically liberal and non-interventionist MSR at the level of the nation state. Wages were negotiated by individual firms and were subject to market fluctuations. Internationally, this MSR was characterised by British hegemony and the gold standard. The structure of the extensive regime of accumulation altered after 1918, particularly as a result of technological change in industries producing consumer goods. Demand, however, was not sufficient to maintain the pattern of accumulation, a deficiency that led to the economic crisis of the 1930s.

The 1920s and 1930s saw a transition between the extensive regime and the intensive ('Fordist') regime which succeeded it. After the Second World War, labour productivity in both capital and consumer goods industries increased significantly, leading to massive increases in real wages and triggering the formation of mass markets for standardised consumer goods. Accumulation under the extensive regime had been prone to cyclical recessions, but intensive accumulation represented a more robust growth model, and cyclical downturns between 1950 and 1973 brought only a slowdown in rates of growth (de Vroey, 1984). Accumulation under this regime is

[6] The regulationist school's basic argument can be briefly summarised (from Aglietta, 1979; Lipietz, 1986; 1987) as follows. The stabilisation, over a long period, of the allocation of the net product between consumption and accumulation can be characterised as a regime of accumulation. This implies some correspondence between the transformation of the conditions of production and the conditions of reproduction of wage earners. If the schema of reproduction are coherent, then a particular system of accumulation can exist and be sustained. However, for this to be so, and for the regime to be maintained, the actions of a range of individuals and agencies, such as capitalists, workers, financiers, civil servants and so on, have to be brought into some kind of configuration. According to Lipietz there must exist, "a materialisation of the regime of accumulation taking the form of norms, habits, laws, regulating networks and so on that ensure the unity of the process, *i.e.* the appropriate consistency of individual behaviours with the schema of reproduction. This body of interiorised rules and social processes is called the *mode of regulation*" (Lipietz, 1986, p.19). Modes of regulation, therefore, can be seen as the means of institutionalising struggles and containing them within parameters compatible with maintaining accumulation. Two regimes of accumulation are identified in the twentieth century: the extensive regime and the intensive (or Fordist) regime, separated by intervening periods of structural crisis.

Figure 1.1 - Phases of Regulation and Accumulation in the Twentieth Century

Image removed for copyright reasons

Source: Tickell and Peck, 1992, p.194.

termed 'intensive' because surplus is not extracted from the production processes in an *absolute* sense, through lengthening the working day or the number of workers, but rather through *intensifying* the production process. *Relative* surplus value is then radically increased through the use of assembly lines and capital equipment to increase the amount of production per worker. It is this emphasis on assembly line type production processes that has spawned the term 'Fordism'[7].

The intensive regime began to destabilise during the late 1960s following a reduction in the rate of productivity growth in the US and northern Europe. Leading industrial sectors had reached their technical limits, while real wages and capital intensification rose and investment in consumer goods industries slowed down. The structural crisis presented by Fordism became apparent by the mid-1970s, exacerbated by the oil price rises of 1973 and the subsequent debt burden.

Regulation theory has been used to describe the post-war capitalist development of western agriculture (Kenney *et al.*, 1989; Friedman and McMichael, 1989; Goodman and Redclift, 1991; Marsden *et al.*, 1993), and writers have drawn rural parallels between the evolution of the post-war modern agro-food system and industrial 'Fordism'. For example, Goodman and Redclift (1991) argue that two key processes have shaped the structure and development of the post-war agro-food system. First, during the Fordist regime of accumulation, agriculture provided cheap food to an urban industrial workforce, in turn enabling a higher proportion of household income to be spent on non-food consumption, and further integrating the industrial working class into the market for mass produced goods. Set within this context of capital accumulation, their second theme is one of accumulation inside the agro-food sector itself. The pattern of accumulation, they argue, is shaped by the biological constraints of the agricultural production process and human food consumption requirements.

Two processes were crucial during the post-war period. The first was the need of capital to develop new markets for commodities and labour in the western world. The second was the mutual interests of a scientific community and agro-industrial capital to adopt a high technology model of agricultural production and development. It was the establishment of a particular technology/policy model in the aftermath of the Second World War in the US and Europe, that facilitated this development trajectory and the role of chemical technologies within it (see Chapter 2). Goodman and Redclift refer to

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[7] 'Fordism', the regulationists argue, is a particular regime of accumulation based upon the expansion of domestic markets for mass-produced goods in advanced capitalist states. It necessitates the progressive adoption of mass consumption by the industrial working class. The corresponding institutional context for Fordism was one of Keynesian policies of full employment and corporatist politics.

the model as a "treadmill of competitive innovation" (1991, p.102), arguing that its defining characteristic is the "symbiosis" between the state, agro-industrial capital and agricultural science, which "is at the root of the transformation and current economic and environmental crisis of modern agriculture" (1991, p.103).

The regulationist approach to the evolution of capitalism does not provide a single, consistent theory, but is an umbrella term for an ongoing research agenda within contemporary political economy (Jessop, 1990)[8]. It has been criticised for its failure to provide a clear definition of regulation itself (Jessop, 1990, p.176, but see Marden, 1992), and there is not much agreement about the object of regulation, reflected in "the lack of unanimity among regulation theorists when they answer the question: what is to be regulated ?" (Jessop, 1990, p.177). Furthermore, regulation theory has been criticised for being too concerned with systems of accumulation, with insufficient attention being paid to the associated modes of social regulation (Peck and Tickell, 1992; Tickell and Peck, 1992).

The point of greatest contention has been over what follows Fordism. Has capitalism entered a new phase of development that can be characterised as a regime of flexible (post-Fordist) accumulation (see Harvey, 1989) or are we in a period where the structural crisis of Fordism is still being played out (Hyman, 1988; Dunford, 1990) ? That this debate remains unresolved need not, however, undermine regulation theory's explanatory power in helping to understand *historical* changes in the nature of capitalist development. In support of the approach, Harvey argues that its strength lies in its focus on the

> "the complex interrelations, habits, political practices, and cultural forms that allow a highly dynamic, and, consequently unstable, capitalist system to acquire sufficient semblance of order to function coherently at least for a certain period of time" (1989, p.122).

Whilst it is not the aim of this thesis to improve upon regulation theory's account of the transformation of capitalism, the key question that is of concern here is how applicable is the approach to understanding patterns of change in the agricultural sectors of advanced capitalist economies ?

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8 Identifying seven different schools within the regulation approach, Jessop has described its distinctive features. Regulation theory, he asserts; "works with a realist ontology and epistemology; adopts the method of 'articulation' in theory construction; operates within a general Marxist tradition of historical materialism with its interest in the political economy of capitalism and the anatomy of bourgeois society; and is especially concerned with the changing forms and mechanisms (institutions, networks, procedures, modes of calculation and norms) in and through which the expanded reproduction of capital as a social relation is secured" (Jessop, 1990, p.204).

It is only recently that agricultural development under capitalism has been scrutinised using regulationist concepts (Kenney *et al.*, 1989; Friedmann and McMichael, 1989; Sauer, 1990; Goodman and Redclift, 1991; Marsden *et al.*, 1993). These studies highlight the resonance between the nature of the development of the modern agro-food system and of capitalist development more generally. Put briefly, extensive capitalist accumulation is a model of development in which increases in output are achieved through quantitative increases in the volume of inputs, while intensive accumulation achieves increases in output through improvements in the efficiency with which inputs are used[9].

Similar shifts from an extensive to an intensive form of accumulation have been discerned in the agro-food system. For example, Friedmann and McMichael (1989) use the concept of food regimes to link international relations of food production and consumption to broader regimes of accumulation identified by the regulationist school (see also Friedmann, 1993)[10]. Such a framework highlights three main points. First, the direction of agricultural development is largely determined by the non-agricultural economy. Second, the current crisis in agriculture parallels the crisis in capitalism, the roots of both lying in the New Deal and immediate post-war eras. Third, the political economy of the agro-food system now depends upon inseparable links between agriculture and non-agricultural industries. The framework also helps underscore the most important processes shaping agricultural change: the integration of farm businesses and households into wider circuits of production and consumption; the effects on agriculture of external economic processes such as the development of new technologies and markets; and the role of the state and agro-industrial interests (Kenney *et al.*, 1989).

During the inter-war period, agriculture's role was to continue to provide cheap food. This role acquired a new significance during the intensive regime because industrial wages became linked to productivity gains through the process of collective bargaining, a key characteristic of the Fordist mode of social regulation. Cheap food policies

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[9] In truth, both strategies usually co-exist, although one may be dominant. Thus, as Dunford (1990, p.310) puts it, "an age of intensive accumulation is one in which intensive methods predominate".

[10] The first food regime was centred on European imports of wheat and meat from the settler states between 1870 and 1914. In turn, settler states imported manufactured goods, labour and capital from Europe. This regime became the key to the creation and development of a system of capitalist economies governed by independent nation states, and was also instrumental in shaping relations between agriculture and industry. The second food regime, which spanned more than three decades after the Second World War, was characterised by strong state protection for agriculture and the organisation of the world economy under US hegemony. The state system was extended to former colonies in Africa, Asia and Latin America, whilst at the same time agricultural sectors in the advanced capitalist world experienced transnational restructuring by agro-food capitals.

increased household purchasing power among the urban industrial workforce. As Goodman and Redclift point out,

> "The maintenance of inter-sectoral terms of trade favourable to the urban sectors remained important throughout the inter-war period, and constituted the principal aim of state agricultural policy in supporting the accumulation process" (1991, p.87).

It is in this context that Goodman and Redclift's 'minor' theme of accumulation *within* the agri-food system is played out. The pattern of accumulation has been critically influenced by the 'dual biological constraints' inherent in food production associated with the nature of agricultural production and human food consumption requirements. These constraints also set the limits to the development of a Fordist' agriculture in the strict sense[11].

Goodman *et al.*'s (1987) conceptualisation of appropriationsim and substitutionism under these conditions recognises that accumulation in the agro-food system has required that industrialization take a markedly different path from other production sectors. The biological production-consumption cycle has meant that the transformation of the agricultural production process by industrial capitals (appropriationism) has been partial and historically discontinuous. Most innovations have been introduced by capitals located outside the production process, with agricultural input sectors becoming autonomous sources of innovation. According to Goodman and Redclift,

> "The key point to recognize is that biological constraints (photosynthesis, gestation, species diversity, land as space, etc.) have led to the *fragmentation* of the innovation process, whose origins and dynamic lie outside direct agricultural production" (1991, p.91, emphasis in original).

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[11] Labelling the intensive regime of accumulation as the 'Fordist' era has prompted debate over whether agricultural production in the post-war period can be characterised as Fordist in nature (Kenney *et al.*, 1989; Sauer, 1990; Goodman and Redclift, 1991). The relationship between the mode of consumption and production was underpinned by corporatist politics and similar features can be discerned in the agricultural sphere. However, while writers have conceptualised the technology/policy model of agricultural development as the rural complement to industrial Fordism, Goodman and Redclift (1991) have sounded a note of caution. They argue that "the attempt to equate agriculture and industry is misguided" (p.100). Because of the individualistic and entrepreneurial nature of the agricultural labour process, there has continued to be scope for practising 'the art of farming'. Also, the biological constraints to agricultural production have prevented capital from directly subsuming the production process. In effect, agriculture has resisted Fordist principles of productive organisation. Fordism is, however, useful when thinking of the food system as a whole. For the downstream food processing and manufacturing sectors, agricultural commodities have tended to become reduced to interchangeable inputs, and the catering and fast-food sectors have become characterised by mass-produced, standardised products and unskilled labour. So, taking on board Goodman and Redclift's reservations, it is better to think in terms of either a Fordist 'food' system, or agriculture under the Fordist regime of capitalist accumulation, rather than a Fordist agriculture *per se*.

Technological change has, however, left what Goodman and Redclift call the fundamental technical base of agricultural production more or less the same, and farm production remains largely tied to the technological and organisational capacity of family producers. Changes have, of course, occurred. Average farm size has increased since the 1930s, and technological change has developed rapidly, mainly as a result of the system of government support and intervention. Moreover, Goodman and Redclift go on to acknowledge how

> "the social transformation of agriculture is due less to the revolutionary nature of innovation per se than the institutional incentives to early adoption and technological competition introduced by the state....In large part, social differentiation and restructuring have been politically engineered rather than the result of ineluctable technological advances of scale in production" (1991, p.93).

Regulationist approaches provide useful insights into the processes driving aggregate agricultural changes in advanced economies. Crucially, regulation theory helps link the processes encouraging technological change in agriculture to the efforts of states to sustain accumulation in the wider capitalist economy. In emphasising the role of the state, it also highlights the social contextualisation of technological change in agriculture and provides helpful conceptual tools and frameworks for exploring the changing context within which individual farmers manage their businesses. However, regulation theory is of less use in assessing change on individual farms. It has been used to impose a categorical logic upon local action, representing restructuring processes as coherent and determined by the structural requirements of capital accumulation (Munton, 1992; Whatmore, 1994). This leaves a difficulty in dealing with the empirical diversity that remains characteristic of advanced capitalist agriculture (van der Ploeg, 1990) and raises the familiar dilemma of demarking structural change from human agency.

1.7 Bridging the Structure-Agency Duality

The conceptual problems of the structure/agency duality are common in social science. In agrarian political economy, interest in macro processes was reflected in a shift in focus from the household, to wider political and economic structures, to the capitalist transformation of family farming. Much of the concern during the 1980s centred on processes of externalisation and the commoditization of farm-based production (van der Ploeg, 1985; Long *et al.*, 1986) and focused on the ways in which family households and farm businesses become tied into the wider market economy. Concern about the variability of individual responses suggests the need for micro-sociological perspectives, but without losing a sense of context. Early attempts to integrate structure and agency have mostly tended to allow one to dominate over the other, but more recently theorists have attempted to chart a middle course, with Giddens's (1984) 'structuration' theory, for example, recombining the mutually dependent structure and agency.

Political economy approaches to understanding change on farms can be criticised for their undue concern with structure and the limited attention they pay to agency. Moreover, they are prone to making unwarranted assumptions about people's material interests and how these determine behaviour (Callon, 1986; Hindess, 1986; Schwarz and Thompson, 1990). Attention needs to be drawn to what actors know, how they come to know it, and what they do on the basis of their knowledge (Schwarz and Thompson, 1990). Such a 'socio-cultural' approach, the origins of which lie in the sociology of knowledge, need not deny the insights of political economy. It suggests instead that its constructs, such as subsumption (Whatmore *et al.*, 1987a) or appropriationism and substitutionism (Goodman *et al.*, 1987), should be treated as frameworks providing the context for action which are, in turn, mediated by action. They are not rigid determinants. Changes on farms result from choices *and* constraints, which a more 'actor-oriented' approach can help explicate.

The use of more 'actor-oriented' approaches does, however, beg other important methodological questions. Of particular interest is the accretion of knowledge and information, and its mediation and use on farms. The evidence we have suggests that farmers are bombarded by, and seek, advice from off the farm (Tait, 1978; 1985; Eldon, 1988), but they continually reinterpret such advice in the light of their experience and the objectives of the farm household. Two related concepts are especially useful in linking together knowledge systems and the notion of interests contained in political economy. These are 'negotiation' and 'strategy'. The former seeks to capture the *process* of mediation, or the manner in which farmers interpret and endeavour to fashion the external advice they seek and receive. As Long argues, negotiation takes place at the 'interface' between "social actors with conflicting or diverging interests and values," and it "sensitizes the researcher to the importance of exploring how discrepancies of social interest, cultural interpretation, knowledge and power are mediated and perpetuated or transformed at critical points of linkage or confrontation" (Long, 1989, p.221). As a concept, negotiation challenges the distinction between structure and agency and the one-way relationship between them sometimes assumed in political economy. It accommodates individual choice without disregarding structural influences, making the process of mediation the focus of enquiry without pre-judging what the 'real' interests of farming households may be.

Nonetheless, negotiation is not a random or unstructured process. It would be wrong to assume that some notion of 'strategy', (*i.e.* a set of farm household aspirations and objectives), is absent even if negotiated outcomes cannot always be anticipated from the strategy outlined. Thus, negotiation incorporates aspects of conscious reflection, rationality and constrained choice, all of which are embedded in the concept of strategy (Redclift, 1986; Crow, 1989).

Strategy has been used as a means of bridging the structure/agency dichotomy in social science (Giddens, 1979; Crow, 1989), and in analyses of farming change the concept has been frequently but loosely employed to incorporate the notion of individual or family-based *responses* to external constraints (Redclift, 1986; Gasson, 1986; Marsden *et al.*, 1989; Pile, 1991). That the term is so widely used indicates, according to Crow, (1989, p.19), its perceived utility in understanding social action. However, consideration must be given to what constitutes a strategy. Crow suggests that "normally it is taken to imply the presence of conscious and rational decisions involving a long-term perspective" (p.19). But confusion can arise from the labels attached to strategies (such as 'coping' or 'survival' strategies), particularly when social scientists "impute objectives which the actors to whom they are imputed would not necessarily recognise" (p.20). There is also a danger that 'strategy' can be used to emphasise choice and play down constraint.

One recent attempt to utilise the concept of strategy in understanding agricultural change is that of Pile (1990a;b; 1991; 1992). He argues that farmers' survival strategies develop from their individual motivations and their attitudes towards social processes (*i.e.* the way they read history). Given that strategies are constrained by structural relationships, Pile (1991) suggests that what is important is how farmers understand and give meaning to their structural relationships. He argues that "farmers'... survival strategies [are] conditioned by their individual readings of the general circumstances which they all face" (p.272). Such a conceptualisation brings to the fore the issue of how farmers 'see the world'[12].

The concepts of strategy and negotiation can be used as a path through the structure/agency dualism, but this still leaves open the question of what structure amounts to and how 'constraint' is exercised. An examination of power helps shed

[12] Pile's study is preoccuppied with *farmers' survival strategies* although there is a question of whose strategy is the focus for analysis. Much has been made of the link between farm family household and farm business (Gasson *et al.*, 1988; Gasson and Errington, 1993), and it has been shown that the family's aspirations are important in determining the direction of farm business development. Strategies could be expected to be negotiated within farm families and may involve actions intended to achieve more than just survival. Therefore, the term *family's farming strategy* is preferred here.

light on this question and also helps clarify the concepts of strategy and negotiation. According to Latour (1986; 1987), who is keen to overturn some of the common assumptions about the roles of 'power' and 'society' in social science, power ought not to be seen as something that is *possessed*. It must instead be treated as a *consequence*, not a *cause*, of action. By comparing a diffusion model of power, where actors derive power from some central source, with a translation model, where "power is composed here and now by enrolling many actors in a given political and social scheme" (1986, p.264), Latour argues that power is an *outcome* of action. "No matter how much power one appears to accumulate, it is always necessary to obtain it from the others who are doing the action" (p.276). Representations and enrollment, therefore, become central to the analysis and

> "a constant debate will rage about who obeys and who is obeyed. In these continuous struggles there will be as many definitions of "the whole picture" as their are actors striving to enrol and/or be enrolled" (1986, p.274).

Such a stance is contentious because it means that society and social science come into question, primarily because of the tendency to treat effects as causes. As Latour argues, social science, as a science of society, has tended to

> "use notions of 'power' and 'capital' when these have to be locally *composed*; it will talk of 'classes', 'ranks' and 'values' when these are the outcome of a continuous debate on how to classify, to rank and to evaluate; it will try to make society hang together with 'hierarchies', 'professions', 'institutions' or 'organisations' whereas the practical details that make it possible for these entities to last for more than a minute will escape attention" (1986, p.277, emphasis in original).

Such a perspective on social action and power relations has been incorporated in the 'action in context' approach. This is discussed in the next section and the notion of farmers as embedded in a dynamic network of relations that were characterised in the introduction as a 'pollution production process' is developed in this light. The network of relations provides the (evolving) context within which farmers pesticide practices must be set.

1.8 Action in Context

Pesticide pollution occurs in specific places as a result of the actions of individual actors. Concepts are, therefore, required to understand what individual farmers are doing and why, that can be accounted for through a 'bottom up' approach.

Action in context (AIC) is an approach developed as part of a recent research programme investigating the social and economic restructuring of rural Britain through analyses of the rural land development process (Marsden *et al.*, 1993). Research at local, national and transnational levels demonstrated how economic actors, the regulatory planning system and local political configurations, all play roles in shaping specific development processes, and although outcomes were locally-rooted, the processes governing them need not always be so. For the researchers, complex conceptual questions followed from this, including

> "what kinds of relationships might we expect to find between economic and political actors operating at the national and transnational levels, and such actors operating locally ? How do the forces of economic change interact with regulatory powers to condition local outcomes ? What scope do locally based actors have to resist or significantly alter such outcomes ?" (Marsden *et al.*, 1993, p.129).

Given the theoretical gap between locally-based analyses and structural processes, the AIC approach tries to handle a range of economic, political and cultural processes which underlie social action in particular places (Marsden *et al.*, 1993; Murdoch *et al.*, 1992; Murdoch and Marsden, 1994). AIC was also born out of a concern that much of the so-called restructuring debate in human geography and other social sciences had, during the 1980s, erred on the side of structuralism.

One important influence on the development of the AIC approach was that of the sociology of translation, a body of work by a mainly French school of sociologists of science. Callon *et al.* (1985, p.10) describe the aim of such studies as being to analyse the creation of "categories and linkages and ... the way in which some are successfully imposed while others are not". One of the most widely cited examples of this approach is a case study of the controversy amongst scientists and the scallop fishermen of St. Brieuc Bay in northern France (Callon, 1986; Callon and Law, 1989). It focuses on how one group of actors is able to get others to comply with its position, how its position is sustained, and how various consequences arise. During any period of contestation about change, a network of relationships is constructed. Four different stages (or what Callon calls 'moments of translation') are identified during which the different actors seek to define each other's identities and establish the possibilities of interaction and the margins of manoeuvre. In Callon's case study, three scientists present new knowledge acquired from a visit to Japan, as the best way in which the problem of St. Brieuc's depleting scallop stocks can be solved, and then seek to construct a network of actors to achieve this.

The first moment of translation ('problematisation') occurs when the scientists seek to define the nature of the problem and bring other actors into play on their terms. The second moment ('interessement') is when the scientists try to consolidate the network they have created by convincing others of their views and so enlisting allies. The third moment ('enrollment') represents the point at which the network is operationalised following negotiations about how the different identities within the network are to be fixed. Fourth comes 'mobilisation', when the representations of interest made by the lead actors are fixed throughout the network and legitimised. Through each of these phases of building and stabilizing the network, the issue of representation (*i.e.* the *definition* of the nature of the problem) is crucial. The strength of the network depends not only on the relationships between actors but also on the legitimacy of their representations.

Approaching social action in this way allows identities and interests to be viewed not as pre-given but as emerging out of the interactions between different actors. In particular, power becomes an *outcome* of action rather than a *cause* (Latour, 1986). As Callon (1986, p.224) explains

> "understanding what sociologists generally call power relationships means describing the way in which actors are defined, associated and simultaneously obliged to remain faithful to their alliances. The repertoire of translation...permits an exploration of how a few obtain the right to express and to represent the many silent actors of the social and natural worlds they have mobilised".

Callon's study and his 'moments of translation' can be treated as an exemplar[13], whilst recognising that it "provides a useful corrective to the earlier concentration on structuralist analysis" (Marsden *et al.*, 1993, p.145). This is especially because the focus for analysis becomes the means by which interests and objectives are constructed, represented and come into effect. Drawing on Massey's (1984) geological metaphor, describing the way that localities are constructed through successive rounds of investment over time, Marsden *et al.* argue that past practices within networks "provide the 'standing conditions' for present and future actions". These conditions usually take the form of rules and resources. Rules need not be fixed and absolute in their effects, and there can be discretion in their interpretation and implementation. Furthermore, the distribution of resources is not fixed. Although it will be conditioned by past practices, alliances have to be continually "forged and maintained [and]...representations have to be legitimized and acted upon" (1993, p.152).

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13 That is to say, these moments of translation provide a model or scheme, although not all are necessary or necessarily occur in the above order.

Adopting the AIC perspective for the research presented here requires that local pesticide practices be considered as the *outcomes* of power relations meeting in places. It allows the focus of analysis to be the methods adopted by actors (in context) in formulating and seeking to achieve their objectives. The implications for this methodological approach are explored in more detail below.

a) 'Context' and Technology.

Marsden *et al.*'s work looked at the socio-political relationships surrounding rural land development processes, but left the role of technology unexamined. Here, the adoption and use of agricultural technologies are central to the enquiry. How, therefore, can AIC be best employed to help understand the use of pesticides and the emergence of a pesticide pollution 'problem'?

There has been a recent upsurge of interest in the social relations surrounding the adoption and use of technologies among those working in the sociology of translation and actor-network traditions (Bijker *et al.*, 1987; Bijker and Law, 1992; Law, 1991; Callon, 1991; Latour, 1991). This work provides a valuable perspective on the social shaping of technology, but first, it is useful to define technology more explicitly.

Technology itself is a 'slippery' term. Here, following MacKenzie and Wajcman (1985), technology will be taken to cover three components. First, technology comprises *physical objects* or *artefacts* such as, for example, pesticides, spraying machinery, tractors and so on. Second, 'technology' may refer to *activities* or *processes*, such as, for example, crop spraying, cultivation and harvesting. Third, 'technology' can refer to what people *know* as well as what they do, in that technologies are meaningless without the 'know-how' to use them. Given the firm rejection of technological determinism, with its assumptions about technological 'progress' being an autonomous process operating outside of society, the questions that follow are: what shapes technology and technological change ? And what are the various pathways and mechanisms through which society influences technologies and technological change ?

If we first turn to the 'context' side of the action in context approach, work in the sociology of science and technology has stressed the importance of the different but interlocking elements of physical artefacts, institutions and their environment (Hughes, 1983; 1987; 1988; Dosi, 1982). In doing so, it draws together technical, social, economic and political aspects, all within a 'technological system'. According to

Hughes (1987, p.52), "because components of a technological system interact, their characteristics derive from the system". Thus management of a system often chooses technical components that support the structure, or organisational form, of management. He goes on:

> "technological systems solve problems or fulfill goals using whatever means are available and appropriate; the problems have to do mostly with reordering the physical world in ways considered useful or desirable, at least by those designing or employing the technological system" (Hughes, 1987, p.53).

Systems are built, maintained and consolidated by protagonists. Crucially, however, Hughes, whose work has examined the evolution of national electricity supply industries, identifies 'momentum' as a key characteristic such systems can acquire. As he explains:

> "Technological systems, even after prolonged growth and consolidation, do not become autonomous; they acquire momentum. They have a mass of technical and organisational components; they possess direction, or goals; and they display a rate of growth suggesting velocity. A high level of momentum often causes observers to assume that a technological system has become autonomous" (1987, p.76).

Thus mature technological systems "have a quality that is analogous...to inertia of motion" (p.76) and this arises from the various groups of actors who may have vested interests in the growth and durability of the system, including managers, owners, politicians, manufacturing corporations, research laboratories, sections of scientific and technical societies, educational institutions and regulatory bodies. In turn, communities of practitioners can maintain traditions of technological practice, adding to the momentum of a technological system.

Momentum also suggests the notion of a technological 'trajectory'. Such ideas have been the concern of a group of neo-Schumpeterian economists who have examined technological change from an evolutionary perspective (Dosi, 1982; Nelson and Winter, 1982; Orsenigo, 1989; van den Belt and Rip, 1987). Rejecting neo-classical approaches to technological change with their assumptions about 'perfect rationality' and 'profit maximisation', the evolutionary approach sees firms as loosely structured clusters of routines, with the outcomes of routines being determined by either competitive markets or, more usually, by the influence of government policy or institutional arrangements. Nelson and Winter (1982) argue that technological development is often patterned in the form of a *technological regime*, or what Dosi (1982) calls a *technological paradigm*. This concept is cognitive and relates to "technicians' beliefs about what is feasible and at least worth attempting" (Nelson and

Winter, 1982, p.258)[14]. A paradigm contains a dominant definition of the relevant problem that must be tackled, the tasks to be fulfilled, a pattern of inquiry, the material technology to be used, and types of basic artefacts to be developed and improved. These help structure or channel innovation and so give rise to *technological trajectories*. This implies that existing technologies provide an important set of preconditions for new technologies, although not, of course, that existing technology wholly determines innovation.

There is a danger of seeing technologists taking one innovation and simply developing new versions of it as part of a mechanistic trajectory. However, rather than simply being a rule to be followed mechanically, paradigms were always argued by Kuhn to be resources to be used and drawn upon (MacKenzie and Wajcman, 1985, p.11). Thus, trajectories are never 'natural' or predetermined, but subject to social shaping.

The fact that, as Callon (1991, p.132) puts it, "technology both creates systems which close off other options and generates novel, unpredictable and indeed previously unthinkable options" leads us to ask how systems are created and how options are closed off. These questions will guide the 'context' side of the action in context approach adopted in this thesis (Chapters 2-4). Pesticide pollution occurs because of the way that pesticides are employed in agriculture. Can the development and adoption of pesticides be characterised as a technological system within a particular paradigm with a trajectory or even momentum of its own ? And if so, how does this momentum manifest itself within the networks of actors involved ?

b) 'Action' and Technology

Turning to the 'action' side of the action in context approach, and how technology might be brought into the equation, Callon argues that while economics suggests that consumers and producers enter (market) relationships via the product, and sociology suggests that actors can only be defined in terms of their inter-relationships, these can be brought together as two parts of the same puzzle. He concludes that "actors define one another in interaction - in the intermediaries that they put into circulation" (1991, p.135), with intermediaries being texts (reports, notes, files etc.), technical artefacts (instruments, machines, pesticides, consumer goods), humans (including their skills and knowledge), and money. Intermediaries help compose networks by giving them

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[14] Dosi's technological paradigm concept (1982) is an extension of Kuhn's notion of scientific paradigms (Kuhn, 1970). In one sense, a paradigm is an exemplar, but in another sense, it forms an "entire constellation of beliefs, values, techniques and so on shared by the members of a given [scientific] community" (Kuhn, 1970, p.175).

form. Thus, a technical object such as a pesticide "may be treated as a programme of action co-ordinating a network of roles" (p.136).

As the artefact moves from actor to actor, so not only does it give form to the network, but also contributes to the network's definition and the definition of the actors. Because networks are defined both by the actors and by the circulation of intermediaries, implicit in their definition is translation, that is, intermediaries (artefacts) ascribe roles to those who receive them. The circulation of pesticides helps to define farmers as pesticide users. As Callon (1991, p.143) puts it, "A translates B. To say this is to say that A defines B". But are translations reversible or irreversible ?

Callon suggests that the degree of irreversibility of a translation depends on two things: the extent to which it is subsequently possible to go back to a point where a particular translation was only one amongst others, and the extent to which it shapes and determines subsequent translations (1991, p.150). Here we begin to see the link with technological paradigms and trajectories. Moreover, the irreversibility of a translation is accompanied and measured by *normalisation*. As Callon explains:

> "Normalisation makes a series of links predictable, limits fluctuations, aligns actors and intermediaries, and cuts down the number of translations and the amount of information put into circulation. It operates by standardising interfaces - that is, by standardising and constraining actors and intermediaries" (1991, p.151).

Normalisation implies that the use of technologies becomes standardised and routinised. In Bijker and Law's (1992) words, technologies become 'obdurate'. Definitions of what the 'problem' is and its optimal technical solution become stabilised and unquestioned. Thus, with normalisation, standardisation and irreversibility in techno-economic networks comes constraint, as networks become "heavy with norms" (Callon, 1991, p.151).

Adopting the action in context approach to the study of farmers and pesticide pollution would, therefore, involve a search for linkages between actors, and between actors and technical artefacts, within networks. The important questions thus become how are networks constructed ? and what representations and translations prevail within them ? This perspective does not mean that individual human agency reigns supreme. Rather, the identification of different 'norms' and 'visions of the world' ought to help highlight the irreversibility or otherwise of networks and the ways in which the context is reproduced through action.

1.9 Conclusions

The questions which guide the thesis concern the historical causes of increasing pesticide use in Britain, the emergence of a water pollution problem, and the ways that farmers' current understandings and practices are constructed. In addressing these questions, the action in context approach offers several conceptual advantages over the earlier approaches to technological change discussed in the chapter. It enables local action to be situated in its historical and structural context and in the light of prevailing technological paradigms. Current technological arrangements and pesticide practices are seen, in part, as the outcomes of past rounds of technological choices. In turn, the influences upon these past choices are brought into the analysis. Farmers become not wholly constrained actors, as they are in the theory of the treadmill; nor wholly free agents, but actors faced with choices and constraints. In this sense, while farm families may pursue their strategic objectives, and in doing so make decisions about how technology should best be employed on farms, their actions and objectives will continually have to be mediated and negotiated with other actors and in the light of changing structural conditions. Mapping this 'geography of enablement and constraint' also raises questions about what farmers know and how they come to know it.

In describing the evolving context for technological change and pesticide use in British agriculture, regulationist concepts provide a helpful ordering framework. This is especially so because the regulationist perspective allows agricultural development and the role of technological change to be set within the context of the evolution of wider capitalist processes.

The perspective also highlights the role of the state in 'regulating' the relations between production and consumption in order to sustain capitalist accumulation. In doing so, we are able to point to the (social) influences shaping the direction of technological change and, in this case, the role of the state in stimulating the production of new technologies. This marks an important improvement upon earlier models of technological change in agriculture such as the diffusion-adoption model and the theory of the treadmill, both of which paid scant attention to how and why new agricultural technologies were produced.

Regulationist perspectives alone leave us poorly equipped to deal with local diversity, however. Local and farm-level change cannot be simply 'read off' from changes in the regime of accumulation, although as Whatmore (1994) points out, there has been a tendency in the recent literature to use regulation theory in this way to impose 'categorical logics' on action. Rather, the ways in which actors understand their positions in their contexts provide the bounds within which they act and their links and relations with other actors are crucial.

Finally, in examining how the use of pesticide technologies has led to contamination of the water environment, we enter several realms which have previously tended to be studied separately. Issues of scientific research and the development of technical artefacts are brought together with questions about how and why farmers act as they do in the social world. In turn, the concern is to understand local social action but in the context of macro-processes of change. Employing an action in context approach ought to provide a means of establishing the *reciprocity* of the technical and the social as well as of action and context. The technical shapes the social and vice versa, while action shapes and is shaped by context.

What are the methodological implications of this discussion for looking at the development and adoption of pesticide technologies in British agriculture and the emergence of a water pollution 'problem' ? An AIC approach requires that the context and its historical evolution be examined first. The notion of a technology/policy model of agricultural development was introduced by Goodman and Redclift (1991) to explain the technological changes of the post-war period. This model will be examined in the British context in Chapters 2 and 3, with particular attention paid to the development, promotion and use of pesticides. Of crucial importance will be the formation of a particular technological system (or paradigm), its evolution along a trajectory and the development of momentum.

CHAPTER 2:
THE TECHNOLOGY/POLICY MODEL IN BRITIAN

2.1 Introduction: The Evolution of Agricultural Policy

In Chapter 1 it was argued that technological change in agriculture has not been an autonomous process, with its roots in the realm of objective scientific endeavour and its functions operating outside of social control processes. Rather, British agricultural development since the 1940s has been shaped by government effecting a particular development model. But how was this 'model' constructed ? And how was the adoption of new farming technologies, such as pesticides, encouraged ?

According to Goodman and Redclift, the roots of the modern agro-food system lie in the US during the New Deal period, with the establishment of a technology/policy model that was "central to the food system's development" and the "motor" for change (1991, p.86). They argue that two main themes interact "like major and minor chords" (p.87) to establish the structure of the food system and the direction of its development. The major theme concerns the role of agriculture in the resurrection of industrial capitalism in a period of recession. The minor theme concerns the pattern of accumulation *within* the agro-food system.

The technological transformation that took place in British agriculture arose slightly later than, but in parallel to, the New Deal, created by its own, albeit different institutional incentives. The state engineered the move to chemical crop protection as part of its broader strategy. In order to understand this process, this chapter examines the actions and policies of the state in regulating agriculture's role in the expansion of industrial capitalism in Britain. While the focus of analysis is the development of chemical crop protection, particular attention will be paid to herbicides over other types of pesticide because they have been most important in the water pollution problems of the 1980s.

2.2 British Agricultural Development, 1860-1944

The economic experiences of the preceding decades were crucial in shaping the direction of agricultural development in Britain after the Second World War. Marsden *et al.* (1993) identify two phases in Britain's economic relations which broadly equate with the regulationist schools' two regimes of accumulation - the Imperial food order, dominated by Britain from the 1860s to the 1930s; and the post-war 'Atlanticist' food order, dominated by the US. During the former regime, the mode of consumption was characterised by the reproduction of the labour force, underpinned by the role of staple foodstuffs and non-commoditized domestic labour, including food preparation.

Before 1914, accumulation in industrial capitalism depended on the expansion of the colonial powers' overseas markets. Agricultural production grew largely by extending its frontiers, helped by technological change in transport and communications. Globally, the area of cropland rose by 250 million acres between 1840 and 1888, with about half of this increase located in the US (Hobsbawm, 1979). This expansion redefined the relations between agriculture and industry, primarily because Europe's industrial base was no longer dependent on domestic agriculture, and local harvest crises had less and less impact on economic activity. As necessary, more food was imported from elsewhere.

After 1870, the full impact of this agricultural expansion was felt. World grain prices declined markedly during the last quarter of the nineteenth century as world output rose rapidly. Responses to the problem varied. In Britain, an ideological commitment in government to free-trade let many farmers fail, while France and Germany erected protectionist barriers. By the end of the nineteenth century, this had left Britain heavily dependent on overseas supplies of food, with three-quarters of its consumption of wheat and cheese and half its meat imported. Britain's trade relations had developed initially from traditional colonial relations, based on the import of primary goods and the export of infrastructural and capital goods. Gradually, protected colonial markets were opened up to free world trade, hinged around Britain's global economic hegemony. With its naval and economic power, diplomacy, and financial infrastructure with sterling as the international currency, Britain was instrumental in establishing the first unified, price-regulated world market (McMichael, 1985). However, at home the free trade philosophy left British agriculture vulnerable to world market price trends. Low grain prices meant that wheat producers in the UK suffered most from increasing world trade as imports from Argentina, India, Canada and Australia rapidly increased. In the late 1850s, Britain had imported 1 million tons of grain per year but this had increased to 5 million tons by 1914, three times the amount produced at home (Sayer, 1967, p.108)[1].

The state left agriculture's fate to be determined by the market, and as a result, the proportion of the working population employed in agriculture dropped from 18% in 1861 to 8% in 1911 (Tracy, 1982, p.53). State support for agriculture was only

[1] During this period changes in trade and agricultural policies were accompanied by technological changes in agricultural production, including the emergence of industrialised agricultural input sectors producing machinery and manufactured fertilizers. The diffusion of tractors and combine harvesters in the US increased labour productivity, such that the man-hours per acre required for wheat cultivation declined from 56 in 1800, to 35 in 1840 and to 15 by 1900 (Rasmussen, 1962).

introduced during the war in 1916 following bad weather and increased activity by German submarines. A system of county committees was established to direct agricultural production, along with modest price guarantees. Prices continued to rise after the end of the war, and were 25% higher than their 1918 levels by April 1920. Intervention brought security to agriculture but inflation meant that financial liability to the Exchequer was not great. However, the world market collapsed in 1920 and as the demands on the state to guarantee prices increased, the Corn Production Acts (Repeal) Act was introduced in August 1921 cancelling all price guarantees, an episode which has gone down in farming history as the 'Great Betrayal' (Self and Storing, 1962, p.18).

The state's role remained limited throughout the 1920s. It held to the policy of laissez-faire and it was not until the economic slump of 1929-32 that agricultural policy changed significantly. British farmers were vulnerable to falling farm prices at the end of the 1920s, and to increasing imports, which had risen to 35% above normal 1920s levels by the end of 1931 (Tracy, 1982, p.159). The politics of the free trade versus tariff reform debate also shifted during the depression in favour of the latter. Protectionist countries had experienced more favourable economic fortunes while recovery was slow and difficult in Britain. Most western industrialised nations had introduced measures to stabilise domestic agricultural markets. In Britain, intervention during the early 1930s took four main forms: marketing reorganisation and the regulation of home produced supplies; regulation of imports; subsidies and price insurance; and measures to increase efficiency and reduce costs of production (Murray, 1955, p.28). According to Marsden *et al.*, this move from a laissez-faire agricultural policy in Britain during the early 1930s

> "was part of a more general change in the management of national economies in response to the Great Depression and its undermining of the classical liberal orthodoxies of public finance" (1993, p.50).

Following the Wheat Act of 1932, deficiency payments were agreed for wheat producers[2], and between 1932 and 1938 the area under wheat in the UK expanded from 1.3 million to 1.9 million acres (Tracy, 1982, p.168). The system was extended to producers of barley and oats under the 1937 Agriculture Act. The result of these subsidy schemes was a slow but uneven improvement in prices for agricultural produce after 1935 (see Table 2.1) and, by 1939, almost all the main commodities produced by British agriculture were benefiting from guaranteed pricing schemes. Seventeen

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[2] Deficiency payments are a payment to the producer equivalent to the difference between the average price received in the market and a standard rate set by the Government. The Wheat Act of 1932 set this standard rate for wheat at 10 shillings per hundred weight.

Table 2.1 - Agricultural Price Indices for England and Wales, 1930-1938

Image removed for copyright reasons

Source: Tracy, 1982, p.169.

marketing boards and producer associations had also been established, such that the state had become heavily involved in regulating and guiding agricultural production. However, technological change proceeded relatively slowly. For example, although tractors had been available for some years, in 1939, there were still 650,000 horses used on British farms (Sayer, 1967, p.120).

The 'drift' into intervention in agriculture became much more marked with the outbreak of the Second World War. In October 1939, the Minister of Agriculture announced that the Government would purchase farm products at fixed prices and so provided farmers with a guaranteed market and prices for their principal products (Hansard, October 1939, Vol. 352, Col. 7). A range of further measures were taken. A Ministry of Food was established, which became the sole buyer and importer of all principal foodstuffs. Food rationing was introduced, and a 'dig for victory' campaign launched, whereby grants of £2 per acre were paid to encourage farmers to plough up permanent pasture for cropping. Only a third of farmland was ploughed in 1939 with two thirds under permanent grass. By 1945, these proportions were reversed.

A local committee structure was established to direct farm production at the local level. This, coupled with the system of subsidies, also helped to increase grass output by two-thirds between 1938-39 and 1941-42 (Bowers, 1985, p.66). Farming prospered under the new system of state subsidies, and, as Marsden *et al.* point out,

> "this experience of a state-managed expansion of output proved a formative one for farmers and government alike. With Britain's unique dependence on imported food once more exposed by a world war, the seal was set on this new partnership" (1993, p.51).

The success of the package of policies prompted an extension of the system of guaranteed prices in 1944, initially for four years after the end of the war, despite the increasing financial commitment to agriculture which this involved. Between 1938-39 and 1944-45, state expenditure on agricultural support rose from £11.5 million to £61.4 million (Murray, 1955, p.323).

The experience of the 1930s' depression and the war economy fundamentally altered public and political attitudes towards the relationship between state, economy and society, and led to a new conception of the role of government in managing the economy including agriculture. Intervention and planned production to achieve public, welfarist goals became more generally accepted, and there was little disagreement between the main political parties over the need to intervene to support agriculture (Flynn, 1986). This interventionist ideology had also dominated the report of the Scott

Committee on Land Utilisation in Rural Areas (Scott Committee, 1942). It concluded that a prosperous rural economy depended upon a prosperous agriculture and advocated support for farming as a means of preserving the countryside and maintaining rural services.

By 1944, the key actors involved in formulating agricultural policy were looking as to how policy might best develop after the end of the war. A declaration on 'Post War Agricultural Policy' was issued by, among others, the NFU, the Royal Agricultural Society of England, the Country Landowners Association, the National Union of Agricultural Workers, the Transport and General Workers Union, the Institution of Chartered Surveyors and the Councils of Agriculture for England and Wales. The declaration, which provided the basis for the 1947 Agriculture Act, called for guaranteed prices and protection for farmers after the war. It stated that,

> "It is essential on national grounds that British agriculture should be maintained in a healthy condition, sufficiently prosperous to ensure a stable level of prices which will yield a reasonable return to the producer and on the capital employed in the industry, and a scale of wages sufficient to ensure a standard of living comparable to that of urban workers ... [Furthermore] ... There should be a definite relation between the price level and the costs of production....In return for a guaranteed price level, all owners and occupiers of rural land must accept an obligation to maintain a reasonable standard of good husbandry and good estate management and submit to the necessary measure of direction and guidance subject to provision for appeal to an important tribunal" (quoted in NFU, 1945, Appendix A).

A broad consensus over the future direction of agricultural policy after the end of the war emerged and widespread public support was expressed for protecting agriculture following its wartime role and the threat of world food shortages in the immediate post-war years.

At the same time, Britain's economic relations with the US became a major factor in the post-war global economic order[3]. Britain experienced a shortage of both food and dollars immediately after the war, and was unable to buy all its food requirements on the world's markets. To save dollars and to help address the massive balance of payments deficit, extra monies were provided to encourage increased agricultural

[3] The US sought more liberal trading conditions and Britain's trading arrangements became the main target for reform. This was achieved during negotiations over post-war commercial and monetary policy and over the terms of Britain's dollar loan to fund the Labour Government's welfare reforms. From the US point of view, "the loan was meant to prise open the sterling area and curb the Labour Government's enthusiasm for intervention" (Booth, 1990, p.147). The loan, agreed in December 1945, was smaller than had been hoped for in Britain. It was also interest bearing and was dependent on sterling convertibility, sterling balances, import policy and the ratification of the Bretton Woods agreement.

production whilst demand for food continued to be controlled through rationing. An official in the Treasury wrote to the Ministry of Agriculture observing that

> "the prospect of a dollar shortage has created the greatest opportunity for British agriculture that has occurred in a time of peace for a hundred years.... [W]e are now in the position where agriculture will be under fire for not expanding enough....In these circumstances the time may come when certain advances which have hitherto been regarded as visionary may become practical politics" (quoted in Smith, 1989).

2.3 The Production of Agricultural Technologies, 1860-1944

As part of the British state's 'drift' towards a more interventionist agricultural policy, greater efforts were made to promote agricultural research and development (R&D). From the late 1500s to the agricultural revolution, technological change in agriculture had depended on individual enterprise and capital. The upper and middle classes with interests in land, as land owners, and science, as a 'gentlemanly' pursuit, were on occasion combined in the pragmatic pursuit of profit. In the first half of the nineteenth century, agricultural science became more strongly associated with the wider farming community, primarily through the application of findings from agricultural science to farms. Farmers began to look more to agricultural science for solutions to their problems. In public policy, educating agriculturalists remained separate from the search for *new* knowledge, the former funded by state money, the latter still relying almost exclusively on private sponsorship (Hawkins, 1991). However, in 1909 a Development Commission was established in the belief that the application of agricultural science could help the process of rural development more generally. A series of twelve research institutes were established, each specialising in a particular field of agriculture (Brassley, 1991).

British concern for self-sufficiency in temperate food products during the two World Wars provided a further important spur to the development of agricultural science. In 1914 the first advisory system, the Provincial Advisory System, was set up. Throughout the interwar years a permissive rather than a statutory advisory service was offered providing farmers with limited and uneven access to the fruits of scientific research. The adoption of new technology depended primarily on individual farmers and their access to land and capital as well as education. As Munton *et al.* argue

> "Effectively, the system had little to offer the numerous small, under capitalised farms, which made up the majority of farming businesses at the time, and which were managed on the basis of minimising expenditure of all kinds" (1990, p.115).

By the end of the Second World War, however, this system was ripe for overhaul, particularly because there existed a new commitment to a dynamic agricultural R&D sector which would promote the adoption of new products and practices. Agricultural science and the *production* of new technologies were placed at the heart of the new development model. Important among the new technologies were farming chemicals, although advances in this field - spasmodic and unco-ordinated as they were - had a longer history.

The first modern chemical treatments in crop husbandry, primarily insecticides and fungicides, can be traced to France in the 1880s, although the development of herbicides originated in the UK and US in the 1930s. Chemical methods of crop protection developed in close association with wider developments in the biological and chemical sciences. Before 1850, the rate of scientific advance in crop protection was "almost imperceptible" (Lever, 1990, p.44), and it was not until the century following 1850 that the foundations of modern crop protection chemistry were laid.

The first fungicide was developed in the late 1840s following observations that sulphur could control vine powdery mildew. A routine dusting programme evolved in France during the 1850s where fine, dry sulphur was applied to vines. In 1885 Pierre Milldardet discovered that the Bordeaux mixture (copper sulphate and lime) was effective in reducing vine downy mildew (*Plasmopora viticola*) and its application became standard practice in vineyards for a century. The success of the Bordeaux mixture prompted worldwide trials on a range of crops. In particular, strong links were forged between scientists in the US and France and in 1886 a section devoted to vegetable pathology was established as part of the Botany Division in the United States Department of Agriculture. US trials concentrated on minimising spraying costs and the timing of applications of the French fungicide. The 1888 Hatch Act set up State Agricultural Experiment Stations and Land Grant Colleges in each state, facilitating expansion of Federal Government sponsored research into crop protection. A year later, in the UK, the establishment of the Board of Agriculture provided a similar foundation for crop protection research.

By the 1880s insecticides began to have significant impacts on agricultural production practices, initially in horticulture, although the use of chemicals such as sulphur to control insect pests can be traced back centuries (Green, 1976). Fruit growers in the US began using spray oils made from kerosene, soap and water which killed insect pests by suffocation. This became standard practice in the US during the 1890s and the sprays were first employed in the UK in 1885.

Up until the 1930s, most of the pesticides introduced were fungicides, with the dithiocarbamates produced by Rohm & Haas and DuPont being the most important. DuPont had begun R&D in dithiocarbamates in the late 1920s, but their derivatives proved very expensive and it took DuPont and Rohm & Haas six years to develop a commercially viable manufacturing process. During the 1930s around 80% of new products introduced were fungicides (Achilladelis *et al.*, 1987). By the early 1930s, many of the American and European chemical companies had become more research orientated, partly because of the encouragement given by governments to agricultural R&D and the establishment of state agricultural institutes with which companies developed close links. Academic researchers interested in linking chemical structure to biological activity were soon attracted to these new, well-financed institutions.

The systematic search for pesticides began in earnest during the 1930s (Archilladelis *et al.*, 1987). Much of this research involved the haphazard testing of chemicals to see if they held any pesticidal attributes. ICI, which had established the world's first commercial agricultural research station devoted to crop production and protection at Jealott's Hill, Berkshire in 1928, began testing chemicals almost at random in 1934 (Peacock, 1978). A member of the ICI team which developed Lindane described the process as follows,

> "We investigated several thousand organic and other chemicals prepared in our various laboratories ... investigating the toxicity of chemicals by determining the concentration necessary to obtain a 50% kill of a series of standard insects" (Slade, 1945, p.314).

The first breakthrough in the development of synthetic insecticides did not come until the late 1930s with the discovery of the organochlorine compounds, the most famous of which is DDT. First synthesised in 1873, DDT's insecticidal attributes were discovered by Paul Muller, a Swiss entomologist, in 1939.

The development of herbicides came relatively late in crop protection history. In 1897 it had been discovered in France that a 2% solution of copper sulphate killed charlock (*Sinapis alba*) in wheat without damaging the crop, but the most important breakthrough came in the 1930s with the development of 'hormone' weedkillers (Lever, 1990). Herbicide development had been closely linked to research into plant growth substances and the first growth hormone was isolated in 1926. The idea that plant growth could be modified by controlling biochemical processes excited the young but growing chemical industry and particularly those companies which were developing artificial fertilizers. In the UK, ICI started to test numerous chemicals as potential growth regulators but met with little initial success.

The Second World War provided a major impetus to research into agrochemicals with the main aims being to increase domestic self-sufficiency in food production and to find ways of destroying the enemy's crops. ICI produced 1-napthyl acetic acid (NAA) and in experiments in 1940 attempted to kill wheat and oats. Findings led instead to an exploration of the selective weed control properties of NAA, an area of research also taking place at Rothamsted Experimental Station in Hertfordshire. ICI and Rothamsted's efforts were co-ordinated through the Agricultural Research Council under tight wartime security with the aim of developing a crop destruction weapon against sugar beet. After field trials in 1944, the NAA derivative MCPA was launched in the UK in 1945 as the first 'scientifically produced' selective herbicide (Achilladelis *et al.*, 1987; Lever, 1990).

Research also progressed in the United States. The National Academy of Sciences' War Research Committee was interested in using plant hormones as crop destruction weapons, foreshadowing the use of 'agent orange' in Vietnam in the 1960s. NAA's chemical relative, 2,4-D was of particular interest because of its selective weedkilling properties, and the US chemical company, AmChem, patented the methods and compositions for killing weeds covering halogenated phenoxy monocarboxylic aliphatic acids in 1944 and marketed 2,4-D as 'Weedone' in 1945.

It is significant that MCPA and 2,4-D first became available in Britain in the immediate post-war period. Both helped revolutionise weed control in cereal cropping, in particular. They allowed farmers to abandon the use of wide rows and horse hoeing, which until then had been the only means of keeping weeds in cereals under control, and led to important improvements in yields. But for the chemical revolution to take place, much more was required than simply the development of new chemicals. Farmers had to be actively encouraged to adopt new practices, and to achieve this a new long-term policy framework was required for British agriculture.

2.4 The Technology/Policy Model and the Use of Pesticides, 1945-1980s

The direction agricultural policy was to take in Britain at the end of the Second World War was crucially influenced by the experiences of the 1920s and 1930s. Farming interests were anxious not to see a repeat of the 'Great Betrayal' of 1921, and the war-time Government had drawn up details of possible legislation for post-war agriculture. The incoming Labour Government of 1945 therefore had a ready-made policy that was likely to receive widespread public and political support.

In 1946 the new Minister of Agriculture made the Government's position clear. He said,

> "The adjustment of commodity prices is the only satisfactory method which can be generally applied to effect changes in the level of farming profitability, in spite of the admitted inequalities between farmer and farmer which it produces" (Hansard, 21 November 1946, Vol. 430, Col. 1027).

Commodity prices were to be fixed in the light of changing farm incomes compared to other sectors, at an Annual Price Review, and the war-time system of guaranteed prices was to be continued at least for the time being. However, during the preparation of the post-war legislation, international considerations became more and more important. A world grain shortage acutely affected Britain, a nation already obliged to supply food to India and to the British zone in Germany, and bread rationing had to be introduced. By late 1946, it became apparent that the US loan would only last half as long as had been expected and the requirement to make sterling freely convertible into dollars would compound the food and financial crisis. Domestic food supplies needed to be increased as rapidly as possible, particularly to save dollars. Agricultural policy became inextricably linked with the dollar crisis. The Prime Minister, Clement Attlee, said in the House of Commons debate on the King's Speech in 1946

> "it is vitally important that we protect our balance of payments position...[one measure aimed at this]... is the efficient organisation of agriculture. We must make full use of our land. We must have a prosperous agriculture" (Hansard, 12th November 1946, Vol. 430, Cols. 35-36).

Subsequently, the objectives of the 1947 Agriculture Act were outlined in its preamble as

> "promoting and maintaining by the provision of guaranteed prices and assured markets ... a stable and efficient agricultural industry capable of producing such part of the nation's food and other agricultural produce as it is desirable to produce in the UK and of producing it at minimum prices consistently with proper renumeration and living conditions for farmers and workers in agriculture and an adequate return on capital invested in the industry" (quoted in Kirk, 1979, p.47).

While it was agreed that nothing short of guaranteed markets and prices would ensure stability in agriculture, the only *quid pro quo* required from farmers was that they strive to maximise efficiency and thus maximise value for (taxpayers') money. In addition to providing farmers with guaranteed prices and markets for all that they could produce, the 1947 Act required that they abide by 'rules of good husbandry'. Failure to comply rendered them liable to supervision orders and, if they failed to improve, notices to quit.

Between 1947 and 1952, 5000 farmers were placed under supervision orders and 400 were dispossessed (Lowe *et al.*, 1986, p.41)[4]. It was the reconstituted county committees who carried out these measures, acting as the Ministry of Agriculture's local agent. One amendment to the Act, suggested by the House of Lords, was that farmers under supervision of the county agricultural war executive committees should not be advised to "alter the character of the holding" (Hansard 4th August 1947, Vol. 441, Col. 1108-59), but this was rejected on the grounds that it would then be impossible for these farmers to adopt new practices in agriculture. During all the Parliamentary discussions surrounding the Bill, only one MP, Mr Vane, raised the point that there might be "some conflict between the interests of food production and those of good estate management" (Hansard, 4th August 1947, Vol. 441, Col. 1136).

The multi-faceted state intervention in agriculture embodied in the 1947 Act was unprecedented and transformed farming "into a sort of ward of the state, much like a nationalised industry was contemplated" (Kirk, 1979, p.47). The emphasis on stimulating production and the adoption of new farming practices effectively set what Cochrane (1958) describes as the 'treadmill' in motion (see Chapter 1). Although by the late 1940s the widespread application of agrochemicals in general, and herbicides in particular, were still practices of the future, the principles of weed and pest control were becoming integral to notions of good husbandry. These notions were outlined in the 1947 Act as follows

"(a) permanent pasture should be properly mown or grazed and maintained in a good state of cultivation and fertility and in good condition;

(b) the manner in which arable land is cropped should be such as to maintain that land clean and in a good state of cultivation and fertility and in good condition;

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[4] The removal of 'bad' farmers from the land saw state intervention in agriculture at its most extreme and was a measure that attracted much controversy in the House of Commons in the late 1940s. One MP, Sir Walden Smithers, referred to dispossession as "this tyrannical treatment of British subjects" (Hansard 28th April 1947, Vol. 436, Col. 1527). In a written answer, the Minister of Agriculture, Thomas Williams, explained; "The procedure is that county war executive committees make every effort to induce inefficient farmers to improve their work and methods, and they offer all possible guidance and assistance before resorting to drastic action. When, however, they conclude that there is no alternative to the taking of possession or the termination of the tenancy of a holding in the interests of food production, and when the Land Commissioner, acting on my behalf, is satisfied that there is a *prima facie* case, the farmer is informed of the committee's intention to apply for my consent to the taking possession of his land or the termination of his tenancy, as the case may be, and of the grounds upon which they are acting" (Hansard 18th November 1946, Vol. 430, Col. 19). Mr Gerald Williams MP complained in the House; "Is not the Minister aware that they [dispossessed farmers] were dispossessed because of the compulsory orders for cropping, which they could not carry out, and that if they were given the tools they could produce more food on these holdings ?" but the Minister replied; "No, Sir, I am only aware of the fact that they were dispossessed because of bad farming" (Hansard, 3rd February 1947, Vol. 432, Col. 1394).

(c) the unit should be properly stocked where the system of farming practised requires the keeping of livestock, and an efficient standard of management of livestock should be maintained where livestock are kept and of breeding where the breeding of livestock is carried out;

(d) the necessary steps should be taken to secure and maintain crops and livestock free from disease and from infestation by insects and other pests;

(e) the necessary steps should be taken for the protection and preservation of crops harvested or lifted, or in course of being harvested or lifted;

(f) the necessary work of maintenance and repair should be carried out".

(Agriculture Act, 1947, Section 2, Para. 11).

The Act also contained a section on 'Pest and Weed Control' which, though primarily concerned with farmers' responsibility for the prevention of damage done by rabbits, also contained provisions "for securing the destruction of injurious weeds" (Section 4, Para. 102). In effect, the fight against all types of pest on farmland, including weeds, became embodied in policy, and if farmers did not fulfil their duties to ensure 'clean' fields, they risked being placed under supervision orders and even being dispossessed.

More generally, the farming community's concerns of the day were reflected in the House of Commons Parliamentary questions and debates, and a reading of Hansard reveals the way agricultural development was represented. In particular, it identifies the emerging emphasis on the widespread adoption of new farming technologies and practices. For example, throughout 1948 the Minister of Agriculture was regularly questioned about the shortage of manufactured fertilizers or machinery. Mr S. Dye MP asked the Minister if he was

> "satisfied there are a sufficient number of spraying machines and supply of materials to destroy all annual weeds in corn and other crops to assist increased yields of crops per acre ?" (Hansard 7th July 1948, Vol. 451, Col. 1625).

The lack of spraying machines was seen as a major constraint on the expansion of agricultural production (Makepeace, 1980; Southcombe, 1980). It was later suggested that because even average sized farms could not afford spraying machines, the county agricultural committees could help farmers with spraying by either spraying under contract or by hiring out their machines (Hansard Vol. 454, Col. 164). There was also an increased emphasis on stimulating arable production, and in June 1948, the Government used its new powers under Section 25 of the Act to give directions to farmers to keep not more than a specified acreage of their land under permanent or temporary grassland.

In a Parliamentary debate on agriculture in July 1948, 11 months after the expansion programme had been launched, weed control continued to be a concern. Mr J. Alpass, the MP for Thornbury, said in his speech

> "this question of the control and elimination of weeds is not tackled sufficiently thoroughly. In my opinion it is done in too much of a casual fashion. It is not merely the man who neglects his duty in this respect who suffers; it is often the adjoining farmer. A little while ago I went round a certain part of my county and on some of the finest land....I was horrified to see fields covered with thistles. I think the attention of the county agricultural committee should be drawn to that and that this question of the elimination of weeds should be tackled in a much more serious fashion" (Hansard 20th July 1948, Vol. 454, Col. 298).

The enthusiasm for new technological options to improve productivity in agriculture was shared by many speakers in the debate. The MP for Wrexham, Mr Richards, explained

> "There is no doubt at all, I think, that a revolution has taken place in agriculture since the beginning of the war. The revolution, of course, is not entirely the result of the war. I think that when history comes to be written, the roots of the changes will be found in the work of scientists at Rothamsted, Cockle Park and Aberystwyth" (Hansard 20th July 1948, Vol. 454, Col. 303).

Similarly, in looking to the future, the path for agriculture seemed clear. Sir Ian Fraser, the MP for Lonsdale, said

> "I am one of those who believe that ordered mechanisation is perhaps the only way that eventually our agriculture can become completely self-sustaining, and therefore I want to see every possible effort made towards encouraging and increasing mechanisation of every kind" (Hansard 20th July 1948, Vol. 454, Cols. 309-10).

The period 1945-50 saw not only the construction of the productivist policy framework in Britain but also important steps in the development of new herbicides. In Britain, research concentrated on MCPA, while in the US, the focus was on 2,4-D using phenol, a cheap by-product from oil refining. These phenoxy acid compounds have since grown to be the world's main herbicides controlling weeds in cereals. By 1950, organic chemistry was established as an important scientific discipline with the potential to provide a range of useful agrochemicals to control the major fungus, insect and weed pests. These developments were promoted by a network of actors keen to provide a chemical, technological solution to the question of improving agricultural productivity.

New institutions were put in place to foster the technological revolution that it was felt was required. The Agricultural Research Council (ARC), originally set up in 1931, was given greater powers and resources to advise and assess the value of research in the agricultural sciences (Cooke, 1981; Foreman, 1989). Also, the National Agricultural Advisory Service (NAAS) was formed in 1946 from the County War Agricultural Executive Committees as a state advisory service to encourage the adoption of new practices through the provision of free advice. Through these two structures, innovation in agricultural technology and its extension to farms combined to provide the technical base for the productivist policy framework of the next forty years.

There was a strong sense of the public sector orchestrating the flow of technologies from publicly-funded scientific institutes via the advisory services to farmers. NAAS advisors were vigorous in their pursuit of the latest developments in agricultural science and widely promoted their adoption by farmers (McCann, 1989; Dancey, 1993). During the debate on the 1944 Agriculture Bill and the provision of a state advisory service, the then Minister of Agriculture had said,

> "no one will dispute, I am sure, the need for an adequate service of advice to agriculture. We want to try and ensure that everybody is in a position to know all about the latest developments in agricultural science. We also need...the practice of all the best farmers [to] become the practice of all. I have been encouraged in all this by the keenness of the farmers to take advantage of the additional advice that we have been able to give them, and also their readiness to emulate the more progressive farmers and by that success which has attended their efforts. That provides a justification for the suggestion we are making that we should continue, in peacetime, what has proved to be so successful in wartime" (quoted in Dancey, 1993, pp.377-378).

The unanimity of purpose that had existed during wartime between the state, agricultural science, commercial companies and the farming community continued after the war. Nowhere was this more so than in the diffusion of weed control technologies.

During wartime, field investigations into MCPA and 2,4-D had been undertaken jointly by an ARC-funded research team, the Norfolk Agricultural Executive Committee and ICI (Lockheart *et al.*, 1990), and the spirit of partnership and co-operation continued after the war. The origins of the chemical paradigm for weed control lay in the unity of purpose of this period when herbicides, in particular, became seen as the 'common sense' route for future crop protection amongst the key actors of the time.

The ARC-financed team examining herbicides was reorganised in 1950 and became the ARC's Unit of Experimental Agronomy, based at Oxford University's Department of Agriculture. One aim of the Unit was "to promote communication and collaboration between the main organisations concerned with the exciting development of chemical weed control" (Fryer, 1982, p.78). It was soon realised that the rapidly increasing importance of chemical weed control in agriculture required that a permanent and enlarged centre for weed research be established with facilities for field and laboratory-based experimental work. Accordingly, the ARC bought an Oxfordshire farm where the Weed Research Organisation (WRO) was established in 1960. Research continued at Oxford University into the chemistry and physiology of herbicidal action, while the WRO concentrated on the practical use of herbicides and providing "a focus for weed control interests in [Britain]" (ARC, 1965, p.4). By 1964, the unit had a staff complement of 70, and this had risen to 170 by 1980 (ARC, 1982).

A key feature of the WRO, and one which underlines the sense of the public sector orchestrating the flow of new innovations from science to the farm, was its emphasis on liaison with other government organisations, especially the NAAS. Two senior NAAS officers were permanently stationed at the WRO with full access to all its research and information (ARC, 1965). The task of these 'Liaison Officers' was to keep abreast of advances in chemical crop protection and to facilitate the flow of up-to-date techniques onto farms via local NAAS officers (McCann, 1989, p.55). Typically, they would deal with between 300 and 400 individual technical queries from NAAS district and county staff each year, but would also organise series of national trials on behalf of the NAAS. For example, in 1964 five trials demonstrating the use of pre-emergent herbicides in spring-sown cereals were organised by the WRO/NAAS Liaison Officers to show farmers how pre-emergent treatment could produce better crop yields than post-emergent sprays. Liaison Officers were also responsible for writing much of the advisory literature on weed control published by the NAAS and acted as its representatives on the British Weed Control Council.

The philosophy and activities of the WRO were firmly rooted in the chemical paradigm for crop protection and its dominance was reinforced by the "very close links...between WRO and individual manufacturers" (ARC, 1982, p.6). These links had been formalised at a meeting at the Ministry of Agriculture in 1952 involving 40 participants from the Unit of Experimental Agronomy, the major pesticide manufacturers and the public agricultural research institutes. It was agreed that five topics required attention:

> "(i) dissemination of information on weed control, *especially between industry and official bodies*; (ii) means of educating public opinion on weed control and spraying matters; (iii) the possibility of holding national or possibly regional conferences on weed control; (iv) economic aspects of weed control; (v) the possibility of arranging a co-ordinated programme of experiments and observational studies" (Fryer, 1982, p.79, emphasis added).

To meet these ends, the British Weed Control Council was formed in 1953 and provided an important arena where links between herbicide manufacturers, public R&D scientists and public advisory officials could be maintained and networks strengthened.

The NAAS acted as an important agent of agricultural change in the post-war period and helped encourage the diffusion of new technologies. Central to what Dancey (1993, p.379) calls this "potent force for change" was the District Officer. NAAS District Officers were normally required to a hold a degree in agriculture and were typically responsible for an area covered by approximately 1000 holdings[5]. District Officers were supported by an array of specialist advice and research services at the county, regional and national levels.

The network of R&D and advice promoting new chemical methods was extremely effective (McCann, 1989; Dancey, 1993), helped by the favourable economics of switching to using pesticides on farms. The switch to chemicals was made across much of the western world. Internationally, the post-war growth of the agrochemical industry was staggering, with the world market for crop protection chemicals increasing from around \$700 million in 1945 to around \$2500 million by the early 1960s, \$4500 million in the early 1970s and \$10,000 million by 1980 all at 1979 prices (Braunholtz, 1982). In Britain, the post-war developments in chemical crop protection were quickly taken up by farmers. Although no data exist on the area treated or the volume of pesticides applied, Table 2.2 shows the rising number of spraying machines in use over this period. Between 1942 and 1946, the number of ground crop sprayers in use in England and Wales more than doubled from 1,600 to 3,455 and in the immediate aftermath of the 1947 Agriculture Act there was a three-fold increase to 9,330 sprayers by 1952. Change accelerated in the 1950s, with a more than five-fold increase in the number of sprayers from 9,330 to 49,075 by 1959. By the late 1970s the number of sprayers had almost doubled again to 90,000 while over the same period their scale had also increased (Southcombe, 1980).

The policy framework established by the 1947 Act operated without major change until 1951 when a Conservative Government replaced Labour. Net output from agriculture had rapidly increased, as had state expenditure on farm support. The Conservatives abolished food rationing in 1954 and ceased subsidies on food consumption. However, the policy of agricultural expansion continued. Deficiency payments were reintroduced in an attempt to restore some semblance of a free market but within a strategy of maintaining price support through the Annual Price Review.

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[5] In 1957 it was agreed that a new target of one advisor per 500 holdings of 15 acres or more should be

Table 2.2 - The Number of Ground Crop Sprayers in Use in England and Wales, 1942-1959 (1)

Image removed for copyright reasons

Source: Laverton, 1962, p.38.

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strived for.

Internal market prices were still determined by world market prices and these began to fall in the mid-1950s, increasing the liabilities of the Exchequer which had to make up the difference through deficiency payments. The Government's response was to make expansion more selective, with particular emphasis on beef, sheepmeat and home-produced feedstuffs, and with less support for the production of milk, pigs and eggs (Hansard, 15 March 1956, Vol. 55, Col. 559). The focus also switched from increasing output to encouraging improvements in efficiency and containing the costs of price support. Although these changes meant that the 1956 Review was the first not to be agreed by the farming unions, the 1957 Agriculture Act satisfied farming interests because it reaffirmed the principle of state support for agriculture, at least for the medium term.

The Act stipulated that the guaranteed prices of each commodity would be maintained at not less than 96% of the previous year's level and, for livestock products, that reductions should not exceed 9% over a three year period. At the same time, the total value of the guarantees and production grants could not fall below 97.5% of the value of the preceding year. This gave farmers some assurance yet allowed the state the freedom gradually to reduce subsidies. The Minister of Agriculture said that the policy aimed to

> "promote the long term economic efficiency and competitiveness of the industry. It is not a measure to enable less-successful farmers to stay in business; far less is it a measure to perpetuate the existing patterns of production" (Hansard, 25 March 1957, Vol. 567, Col. 808).

The state's main concern in the late 1950s was to prevent a rapid increase in the total amount of state support on price guarantees, subsidies and grants. This objective was achieved in that state support for agriculture rose only slowly from £227 million to £250 million between 1956 and 1960 (Annual Review, Cmnd. 2621, 1965).

The emphasis on efficiency from the mid-1950s onwards prompted a 'two-pronged' approach to implementing agricultural policy (Marsden *et al.*, 1993, p.55). This consisted, first, of the direct public financing of agricultural R&D and education, and a state advisory service, all of which helped to emphasise the development and promotion of technologies that saved labour and raised yields. The second prong was the orientation of support policy towards encouraging farmers to take up new technologies, both directly through capital grants and input subsidies, and indirectly through the steady but gradual squeeze on guaranteed prices. After 1951, the additions to guarantees were typically less than the increase in the costs of production, and were sometimes negative (see Table 2.3), such that the only way farm incomes could be

Table 2.3 - Increases in Guarantees and Changing Costs for Review Products

£m

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Source: Bowers, 1985, p.69.

* - Because of changes in the system of protection these figures are not comparable with previous years.

improved was through increased efficiency. It was through this 'cost-price squeeze' that the inducement to take up new chemical technologies as an integral part of cropping practices became stronger. At the same time, the competitive pressures described by Cochrane (1979) as the 'treadmill' became more evident.

Between 1950 and 1959 the promise of agricultural expansion throughout the advanced capitalist world raised the confidence of the agrochemical industry and the rate of innovation increased. During the decade, 140 new agrochemical products were introduced, and of these, 85 were insecticides, 35 were herbicides, and 20 were fungicides (Achilladelis, *et al.*, 1987).

The early 1960s was a period when the chemical paradigm gained even greater legitimacy and the technological trajectory it was encouraging came of age. The newly expanded WRO was turning its attention to prophylactic, pre-emergent herbicide use and the new types of rotations this allowed. Moreover, these developments were taking place in an atmosphere of renewed scientific and technological vigour as the wonders of chemical science and technology were being raised in the national public and political consciousness. It was in 1963 that Harold Wilson, the 'Prime Minister-in-waiting', delivered his speech to the Labour Party Conference in Scarborough which praised science as an agent of change. He called for the mobilisation of scientific research to meet the needs of technological development and argued that "in the Cabinet room and the boardroom alike those charged with the control of our affairs must be ready to think and to speak in the language of our scientific age" (quoted in Pimlott, 1992, p.304). In such an atmosphere, the protagonists of crop protection's chemical strategy became part of a wider national effort to apply science and technology to the project of economic development[6].

World market prices for agricultural commodities fell further in the early 1960s, and because of the state's long term assurances to agriculture contained in the 1957 Act, the cost of meeting price guarantees rose from £151.2 million to £225.5 million between 1961 and 1962 (Annual Review 1965, Cmnd. 2621). In response, attempts were made to limit production for some commodities, but the policy of 'selective expansion' continued. The new Labour Government of 1964 saw a crucial role for agriculture, spelt out in the 1965 National Plan, which said

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[6] Coincidentally, Wilson's speech came only months after the publication in Britain of Rachel Carson's book, *Silent Spring* (1963), which pointed to the disturbing ecological consequences of pesticide use for the first time (see next Chapter). Carson's evidence was drawn primarily from the experience of insecticide use in the US, and did little to undermine faith amongst scientists and policy-makers in the use of herbicides to control weeds in Britain. It did, however, sow the first seeds of doubt over agriculture's 'dependence' on chemical methods.

> "First it will help through increased production to meet the growth in demand. This will ease the pressure on our bill for imports of temperate agricultural produce. Secondly, by improving its labour productivity more rapidly than the increase in production, agriculture will continue to release substantial manpower resources and so help in closing the manpower gap extended during the plan period" (The National Plan, Cmnd. 2764, 1965).

However, a significant change in policy was signalled at the 1965 Price Review when the Government said that agriculture would "be expected to absorb ... through its increasing productivity, a large part of its increased costs " (Hansard, 17 March 1965, Vol. 508, Col. 1289). It was later calculated that at this review the additions to guaranteed prices fell short of agriculture's rising costs of production by £18.5 million (Winegarten and Acland-Hood, 1978). Such a shortfall only served to tighten the cost-price squeeze and thus intensify the search for efficiency gains in order to maintain farm incomes.

Despite the under-recoupment of agriculture's costs at the reviews of 1966, 1968, 1969, output continued to expand, and by 1969 stood at more than twice its pre-war level. Moreover, support measures became increasingly characterised by import restrictions to prevent 'dumping' in the UK. These had the affect of pushing the cost of agricultural support more firmly onto the consumer via higher food prices, and at the same time giving the appearance of decreasing levels of expenditure.

By the 1960s, herbicides had become the most important of the crop protection chemicals in terms of the number of innovations and the value of total sales. One hundred and ten new herbicides were introduced between 1960 and 1969 compared with 96 new insecticides and 50 new fungicides. Strong market demand for herbicides continued through the 1970s when 70 new products were introduced, compared to 60 new insecticides and 42 new fungicides (Achilladelis, *et al.*, 1987). Herbicides were also becoming more widely applied. For example, by 1969, 65% of the UK's cereal acreage was treated with them, and this rose to 94% by 1975 (Grigg, 1989, p.74). 'Demand' did not materialise from thin air, however, and cannot be used on its own to provide an 'explanation' of rising pesticide use. Rather, demand had to be continually created and stimulated. The cost-price squeeze provided an economic stimulus to search for efficiency gains, but in addition, during the 1960s agrochemical companies targeted 'lead' farmers considered as local opinion-formers. They were provided with pesticides at greatly reduced prices, or even free of charge, in order to encourage the adoption of new chemical products (Tait, 1976).

The cost-price squeeze is widely evoked in the literature as a standard economic explanation of the widespread uptake of new agricultural technologies (Munton *et al.*, 1990; Goodman and Redclift, 1991; Clunies-Ross and Hildyard, 1992). However, there remains a question mark over whether farmers can be said to have been 'forced' to adopt new technologies, and this question has been posed by economists who prefer to conceptualise farmers as 'active profit seekers' rather than as passive or even reluctant agents of change (see Allanson *et al.*, 1994, pp.20-21). Once the chemical paradigm was firmly established, pesticide technologies would have become progressively more attractive to farmers as active profit seekers. Evolutionary economists of technological change have pointed to several reasons for what might be termed the 'increasing returns to adoption', all of which help reinforce technological trajectories (Arthur, 1988). These arguments can be applied to the diffusion of pesticides. First, the more any pesticide is used, the more is learned about its efficacy, making it more attractive to adopt. Second, technologies often offer advantages in 'going along' with other adopters as networks of users benefit from similar advisory and support services. Third, the expansion of the agrochemical market meant that the unit costs of producing pesticides fell as manufacturers benefitted from scale economies (Achilladelis, *et al.*, 1987). Fourth, pesticides that are more widely used often enjoy the advantage of being better known and better understood, making their adoption more attractive, especially to the risk-averse. Fifth, as pesticides are adopted, other technologies become part of their infrastructure. Thus, once a farmer has a spraying machine, a spray operator, a pesticide store and so on, alternative technologies are placed at a greater disadvantage.

These factors do not fundamentally undermine the argument that the cost-price squeeze stimulated change, and it can still be viewed as a 'push' factor. However, its influence is likely to have been far less pronounced than recent political economy accounts suggest. The prevailing view expressed by politicians and advisors during the 1950s was that farmers were required to improve efficiency. Even as 'active profit seekers', farmers faced choices about how best to achieve this, and these choices were made in the particular social and technological context of the day. This context was one of rapid modernisation and a progressive chemical paradigm combined with the increasing economic attractiveness of switching to the new technological system.

The growing importance of herbicides in crop production signalled an important turning point in farming practice, and provided a significant trigger to further intensification in the arable sector. Before the availability of herbicides, weed populations were kept down by means of crop rotations and cultivations so that no one weed species could benefit from a consistently favourable environment. By the late 1940s, arable farmers had generally reached a "high level of efficiency in weed control" using rotations

(Lockheart *et al.*, 1990, p.45). Until the 1950s, the emphasis had been on incorporating herbicides into existing husbandry systems that were basically unchanged. Their use merely replaced the hoe, harrow and sickle. However, during the 1960s, herbicides began to be used as part of a far more fundamental change in crop husbandry and themselves became "an integral part of the production process" (Robinson, 1980, p.299). This change arose from their unique ability to kill off vegetation on a large scale without relying on cultivations, enabling farmers to grow a succession of cereal crops without recourse to the plough. Seed could be drilled directly into the stubble of the previous crop with weed growth having already been killed by spraying (Fryer, 1964, p.524). The move from rotations to continuous cereal cropping profoundly altered arable farming. Until the 1950s it "continued to be regarded as bad farming to grow more than two straw crops in succession" (Elliott, 1980, p.288) because of the increased risk of weed infestation. The use of herbicides, however, transformed cereals from a 'fouling' crop to a 'cleaning' crop (Robinson, 1980). As a result, by the late 1960s "rotation was considered an old fashioned word" with many believing that "farmers could have an almost complete freedom of cropping so far as weed control was concerned" (Elliott, 1980, p.288).

Herbicides have meant that there has been little need to return to rotational husbandry for weed control, despite the continued presence of grass weeds (Chancellor, 1980). Since the late 1960s and 1970s, farmers have switched from spring-sown cereals to more productive winter cereals - a switch made possible by the ability of herbicides to tackle the increased threat from grass weeds. Cereal producers have also been able to sustain programmes of continuous autumn-sown crops (Makepeace, 1980), using minimum tillage and direct drilling to speed up sowing, although this strategy has also "entailed a greater commitment to herbicides for weed control" (Lockheart *et al.*, 1990, p.46).

Another important factor accounting for the increasing importance of herbicides, particularly in the US, was the development of plant breeding and hybridisation techniques (Kloppenburg, 1988; Goodman and Wilkinson, 1990; Goodman and Redclift, 1991). Chemical and farm equipment companies began to plan plant breeding research in order to develop 'packages' of mechanical, chemical and genetic innovations, thus establishing a radical new 'style' of agro-industrial innovation and development. The relationship between innovations in seeds and pesticides is a long standing one. Kloppenburg (1984; 1988) has shown, for example, how the hybridisation of corn was instrumental in facilitating the expansion of other branches of the agricultural supply industries, such as machinery and pesticide manufacturing. The noted corn breeder, George Sprague, observed that

> "the objective in plant breeding is to develop, identify and propagate new genotypes which will produce economic yield increases under some *specified management system* (Sprague, quoted in Kloppenburg, 1984, p.302 [Emphasis added by Kloppenburg].

This management system presupposed mechanisation and the application of pesticides. Indeed, hybrids were developed by breeders that were suited to higher levels of chemical application. The density at which corn was planted doubled between the mid-1930s and 1978, but higher plant densities meant greater vulnerability to insect, weed and fungal build up which, in turn, encouraged the greater use of pesticides. According to Kloppenburg, the corn crop accounted for a third of US herbicide sales by the early 1980s and "has been a major contributor to the historical increase in the intensity of chemical use in American agriculture" (1984, p.303).

In Britain, the overall direction of agricultural policy pursued through the 1950s and 1960s was maintained by the incoming Conservative Government of 1970 which was also planning for EEC entry. The policy aims of the time were summed up in the 1972 Annual Review which said that

> "Our share of the enlarged EEC market including our own home market will depend on the competitiveness of our farmers. This means that we should aim to improve the already good record of productivity gain in our agricultural industry from the start of transition [to the Common Agricultural Policy] by stimulating the investment which is needed for expansion and by securing the advantages of increased scale" (Annual Review 1972, Cmnd. 4928, p.5).

Policy trends in the 1950s and 1960s, particularly the drift into tariffs on agricultural imports, prepared British agriculture for entry into the EEC's Common Agricultural Policy (CAP). Bowers (1985, p.73) has gone so far as to say that "entry to the EEC can be seen as the logical culmination of UK agricultural policy in the 1960s." The CAP originated in Article 39 of the Treaty of Rome which stipulated that the CAP should

> "(a) increase agricultural productivity by promoting technical progress and by ensuring the rational development of agricultural production and the optimum utilisation of the factors of production, in particular labour;
>
> (b) ensure a fair standard of living for the agricultural community, in particular by increasing the individual earnings of persons engaged in agriculture;
>
> (c) stabilise markets;
>
> (d) ensure the availability of supplies;

(e) ensure that supplies reach consumers at reasonable prices" (Commission of the European Communities, 1987, p.18).

Under the CAP, support measures for most crops including cereals took two forms:

"(i) intervention measures on the internal market which, depending on their economic nature, may be subdivided into aids for public and private storage, withdrawals and similar operations, price compensation measures and guidance premiums;

(ii) refunds on exports to non-member countries" (Commission of the European Communities, 1987, pp.47-48).

National intervention agencies, acting as agents of the Community, would buy any excess produce at a minimum price and put this surplus into store until it could be released. Also, import prices were fixed by being subject to a variable levy which moved in accordance with world market prices[7].

For the formulators of British agricultural policy, entry into the CAP was, therefore, more a process of continuity rather than one of change, and provided an opportunity to compete effectively within a much larger 'domestic' market. The Labour Government published a broad policy statement in 1975 entitled *Food From Our Own Resources*, which stated that

> "the Government take the view that a continuing expansion of food production in Britain will be in the national interest. It is mainly the cost in sterling terms of alternative supplies from abroad which determines whether expansion of home production is economically worthwhile ... but the objective of Government policy will be to provide farmers with a prospect of stability in their returns at levels encouraging the greater home production which would give the country an insurance against periods of shortage and higher prices" (MAFF, 1975, Cmnd. 6020, Para. 4).

The transition period for Britain's entry into the EC ended in 1978. Even then, the policy of agricultural expansion remained intact, gaining further credibility in 1979 with the publication of *Farming and the Nation*, a White Paper which outlined further expansion over a five year period, despite evidence of looming surpluses for most major commodities within the EC (MAFF, 1979).

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[7] In addition to these price controls, the CAP also contained structural measures. Directive 72/159/EEC enabled the payment of grant aid for investment for the implementation of an approved development plan, was aimed at farm 'modernisation', and was implemented in the UK through the Farm and Horticultural Development Scheme. Directive 72/160/EEC was intended to encourage small farmers to retire and amalgamate holdings into full-time farms, and Directive 75/268/EEC introduced specific types of compensatory payments to farmers in 'Less Favoured' hill and mountain areas.

2.5 The Social Shaping of Pesticide Use in Britain

The thirty years from 1950 to 1980 saw a chemical revolution in British agriculture. Production practices were transformed and the use of pesticides in general, and herbicides in particular, became the mainstay of arable crop protection. Using the language of Hughes (1983; 1987), a technological system came into being bringing with it a paradigm (and a trajectory) of its own. Dominant within this paradigm was the view that pest problems in arable farming were best tackled through chemical treatment, and so scientific effort was to be devoted to continually improving the efficacy of pesticide use in this context. A network of actors had a common interest in maintaining the technological system associated with the productivist model. The network included the state - which wanted to contain the costs of price support by encouraging improvements in agricultural efficiency; the agricultural scientists from both the public and private sectors - whose role it was to produce the new chemicals and the optimal means of applying them; and agro-industrial capitals -including those farmers prepared to adopt, modernise and accumulate, and the manufacturers of agrochemicals and spraying machinery who saw their markets and profits grow.

Between 1948 and 1982, total sales of pesticides in the UK rose from £70 million to £542 million (both at 1982 prices), almost an 8-fold increase in real terms. In addition, the number of different pesticide products available to farmers rose from 216 to 700 (DoE, 1983, p.3). By 1982, over 31,000 tonnes of active ingredient of pesticide were being applied to more than 3.8 million hectares. This was also the year that the loading (or dosage) of pesticide reached its peak at an average of 8.25kg of active ingredient per hectare (see Table 2.4).

The greater use of pesticides contributed to improvements in yields, along with the development of high yielding and disease-resistant varieties, and the increasing use of fertilizers. Before 1939, the average yield of wheat, for example, was little more than 2 tonnes/ha but by the late 1980s had risen to more than 6 tonnes/ha, representing an annual increase of around 2.6% (Britton, 1990). It has been estimated that half of this increase in yield was due to improvements in the usage of pesticides (Stanley and Hardy, 1984).

But just as important as the widespread use of pesticides was their importance in transforming practices on farms. For example, there has been an increasing emphasis since the late 1960s on growing winter wheat and, more recently, a change from spring sown to autumn sown barley, both of which have been made possible by the availability of pesticides. Moreover, applications of pesticide, and especially

Table 2.4 - Pesticide Usage on Arable Crops in England and Wales[1]

Chemical Group	(Tonnes of active ingredient) 1974[2]	1977	1982	1988	1993[3]
Insecticides	(286.7)	520.4	591.8	490.3	523.6
Molluscicides		19.3	203.3	164.7	101.1
Seed treatments	540.4	524.1	266.9	388.0	286.3
Fungicides	1090.6	1402.1	3542.6	5099.9	5817.4
Herbicides	13683.3	17275.2	24228.5	16294.5	8376.0[4]
Growth regulators	71.0	238.9	1109.3	1771.1	2641.5
Total pesticides	15672.1	20025.8	31390.4	27216.6	17745.9
Area grown (000 ha)	3839.5	3765.8	3800.7	4025.4	4569.7
Loading (kg/ha)	4.08	5.31	8.25	6.76	3.88[4]

Notes

1. The data are from MAFF's Pesticide Usage Survey (Sly, 1977; 1981; Davis *et al.*, 1990; 1993; see also Pitman, 1992). There have been six surveys of pesticide usage on arable crops in England and Wales (in 1974, 1977, 1982, 1988, 1990 and 1992). The two most recent surveys include Scotland. Arable crops are defined as cereals, potatoes, peas and beans, oilseed rape and linseed.

2. For 1974 the figure listed in parenthesis against insecticides is a combined total for insecticides and molluscicides.

3. The data for 1992 covers England, Wales and Scotland, which includes around 10% of Britain's agricultural land area treated with pesticides.

4. The reduction in the weight of active ingredient applied, particularly for herbicides, and the falling pesticide 'loading' during the 1980s is not necessarily an indicator of declining pesticide use. It is what Beaumont (1993, p.195) calls a "phantom" reduction. Indeed, the area treated with pesticides in Britain has continued to increase (Davis, *et al.*, 1993). According to the officials who carry out the Pesticide Usage Survey, the figures indicate a shift to much more potent products which can be applied to crops at lower weights of active ingredient per hectare.

herbicides, have become more routinized and prophylactic in nature as farmers simplify and standardise crop management strategies. This shift has been helped by the availability since the 1960s of pre-emergent herbicides which are sprayed onto, and linger in, the soil killing weeds as they emerge. As a result of the favourable economics of pesticide use[8], the chemical option has become standard practice. A series of factors have also helped to close off other non-chemical options. *First* is the increasing reliance among farmers upon the crop protection advice of technical advisors from off the farm. This will be examined in more detail in Chapter 6. *Second*, the routinisation of spraying strategies, and the widely-acknowledged reliability of pre-emergent herbicides in particular, makes for a much less complicated pest control strategy with less risk of subsequent problems in the crop. The preventative use of pesticides as an 'insurance' against the risk of pest problems saves farmers having to modify crop husbandry strategies in more reactive ways after problems have appeared.

It can be seen from the analysis presented in this chapter that the widespread adoption of pesticides in British agriculture has evolved in the context of a particular agricultural policy devoted to increasing efficiency via gains in productivity. Indeed, the development of pesticide technologies, and the concern to limit the costs of agricultural support, have meant that pesticide use and agricultural policy have 'co-evolved'. Moreover, British agricultural policy has to be seen in the context of the development of international capitalism. As the regulationists have suggested, the post-war period was characterised by intensive accumulation with land and labour being exploited at increasing intensities. Pesticides have been a key technology in this process. They have been instrumental in delivering productivity gains in agriculture, helping Britain along the path of self-sufficiency in temperate food products while at the same time easing balance of payments pressures. In turn, a powerful alliance of interests involving the state, agro-industrial capitals and agricultural scientists were keen to develop and maintain a technological system which fostered chemical cropping options.

It was not until the 1980s that the contradictions inherent in this development model came to the fore. Concerns about the environmental consequences of an increasing dependence on pesticide use in agriculture were first expressed in the 1960s (Carson, 1963), but it took the budgetary difficulties of the late 1970s and 1980s to expose the technology/policy model to a crisis of legitimacy. This crisis was compounded by an increasingly sophisticated environmental critique of modern agricultural practices. It was in this context that the EC's Drinking Water Directive first highlighted the problem of pesticide pollution of watercourses.

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[8] By the late 1960s it was estimated that farmers were able to gain £5 in benefits for every £1 invested in pesticides (Strickland, 1970).

CHAPTER 3:

THE MODEL IN CRISIS: POST-PRODUCTIVISM AND PESTICIDE POLLUTION

3.1 Introduction: The International Farm Crisis and the British Experience

Since the 1970s, the productivist technology/policy model has been in crisis and the problem of pesticide pollution of water has emerged in a context quite different from that in which pesticide use was first encouraged. This chapter examines the origins of the crisis and the implications for agriculture in Britain, before going on to discuss the emergence and constitution of the pesticide pollution 'problem' in the light of mounting economic, political and environmental pressures within the agro-food system.

The farm crisis of the 1980s in Britain resulted from economic and regulatory changes in the international food system which undermined the stability of the post-war food order, brought increased competition in world markets, and exposed the productivist model to a crisis of *legitimacy*. In turn, British agriculture was being 'repositioned', both vertically in the food system and horizontally through new competing demands on rural space (Marsden *et al.*, 1990a, p.12). While the origins of the British crisis can be traced back to international changes, its national expression has been influenced by a range of political, social and ideological trends particular to the British experience.

Internationally, the farm crisis has been an "expression of structural tendencies, inherited from an earlier period" (Goodman and Redclift, 1990, p.19). The three decades after the Second World War were characterised by US hegemony in the global agro-food system (Friedmann and McMichael, 1989; Tubiana, 1989), but the technology/policy model became a victim of its own success and brought instability to the international regulatory system[1]. Rising agricultural productivity in advanced industrial nations replaced the fears of the early 1970s about world food shortages with new concerns about over-production, trade wars and the budgetary and environmental costs of agricultural support. Goodman and Redclift (1989, p.6), bringing together the

[1] Since the late 1970s, studies have pointed to the closer integration of national food markets, the international standardisation of technologies for the production and consumption of food, and the rise to prominence of multi-national food manufacturing and agribusiness companies with their own global marketing and development strategies, all of which have globalised and yet destabilised the international agro-food system (Marsden *et al.*, 1990a; Goodman and Redclift, 1991; McMichael and Myhre, 1991; Munton, 1992). 'Globalisation' of the agro-food system has taken place at a time when patterns of production and accumulation in the capitalist world economy as a whole have themselves become increasingly globalised (Dicken, 1992).

apparently fragmented events surrounding the international farm crisis, identify four main components. These are:

(a) the development in the United States of a model of technological innovation and market intervention for agriculture and its international dissemination;

(b) the breakdown of the post-war system of regulation of world agricultural trade managed by the United States;

(c) the crisis of political representation and legitimation between farmers' organisations and the state; and

(d) the failure to anticipate or contain the environmental problems associated with the new agricultural technology/policy model.

The first component was examined from a British perspective in Chapter 2. The remaining three will be briefly explored here before going on to look in more detail at the expression of the crisis in Britain.

During the 1950s and 1960s, world agricultural markets enjoyed a period of unprecedented stability under a system ('regime', or 'international food order') managed by the US with its roots in the Bretton Woods agreement. The US share of world agricultural markets grew and by 1970 accounted for nearly 35% of wheat exports, 50% of maize, 90% of soyabean and 30% of cattle-cake (Tubiana, 1989, p.25). This dominance, along with American domestic production control mechanisms, such as set-aside and storage schemes, concessionary export sales and food aid, kept markets stable and basic food prices low. For example, the variance between average annual US export prices was 0.06 between 1963 and 1972, and 0.20 between 1972 and 1983 (Tubiana, 1989, p.43), an exceptional level of stability because agricultural markets tend by their very nature to be unstable given the biological constraints on production and the atomistic structure of the industry.

The adoption of the technology/policy model in other advanced economies meant that the US dominance of world commodity markets came under threat. In particular, agricultural output grew rapidly in Europe under the powerful production incentives of the Common Agricultural Policy. From the 1970s, the EC increased exports to solve its own problems of surplus production, and although US and EC export strategies were sustainable until the mid-1970s because of world food shortages, commodity markets became more volatile in the 1980s. Competition between the two agricultural 'super powers' ended the market stability of the 1950s and 1960s, and made multi-lateral trade agreements more difficult to manage, leading to rising protectionism[2].

As well as sparking controversies amongst trade blocs, agricultural over-production also undermined the legitimacy of the productivist policy framework. The idea of subsidising farmers to produce food which then had to be stored became increasingly difficult to defend. Moreover, surpluses were subsequently exported at subsidised rates, disrupting world food trade and undermining Third World agriculture. Agricultural policy reform assumed a much higher profile on the political agendas of western countries and pressure to cut subsidies mounted[3].

It was from within the context of these international geopolitical trade negotiations that individual nation states addressed their own 'farm problems'. Because the international farm crisis is, above all, a structural crisis, its effects are similar across capitalist countries - rising farm bankruptcies, falling farm incomes and lower returns on capital. These trends have, however, been played out in different ways in different national contexts. In the US in the 1970s, agriculture was protected from instability because of increasing exports, favourable world market prices and farm support programmes. Stability created confidence and farmers borrowed to invest in land and equipment. After real interest rates rose sharply in the late 1970s, highly leveraged producers, were caught in a debt trap which led to collapsing land values, declining farm prices and increased numbers of bankruptcies. Similar problems have been faced in the EC, although different banking systems have made producers less vulnerable to bankruptcies than in the US. However, declining economic fortunes have been compounded by policy measures to tackle over-production, such as milk quotas.

Agriculture's economic troubles have also posed problems for farmers' organisations. The number of farmers has declined, their economic power has been weakened, and food surpluses and the high cost of subsidies have undermined the public and political support for farming of the early post-war decades. These difficulties have come at a time of rising urban unemployment and the emergence of neo-liberal economic policies in many western countries, both of which have led to an increasing questioning of the legitimacy of state support for agriculture.

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2 Multi-lateral arrangements were replaced by bilateral agreements, with trade negotiated on a contract by contract basis, with a plethora of different credit terms, making it increasingly difficult even to establish a 'world market price' for some commodities. Under these more flexible conditions, both the EC and the US have tended to adopt much more aggressive trade policies (Goodman and Redclift, 1989, p.10; Friedmann, 1982; 1991; 1993; Buttel, 1989; Tubiana, 1989).

3 The Uruguay Round of the GATT negotiations represents an attempt to address these problems at the global level. That these talks went on for over six years is a measure of the intractability and complexity of the farm crisis, as well as a sign that the crisis has also been one of political legitimacy.

Environmental problems associated with the technology/policy model also undermined public and political support for farmers. Most prominent have been the loss of important wildlife habitats and valued rural landscapes and the pollution of water. Soil compaction and erosion have also resulted from specialised, intensive and mechanised production practices, and there has been an increase in the levels of toxic residues in foods. Together, these problems have undermined the notion of farmers as working closely with nature producing the nation's food, replacing it with a public image of farmers as highly subsidised polluters and destroyers of the countryside.

These changes provided the broad political context for the British experience, but the pattern of farm change has also been strongly influenced by the repositioning of agriculture within the food system and the rural economy, which meant farmers had to face two further structural challenges. The *first* concerns their weakening economic position as food producers within the food system. Farmers are receiving a declining share of the value-added created by the system and, at the same time, their husbandry practices are being increasingly influenced by off-farm interests. This is occurring indirectly, through the uptake of ever-more specialised technologies, and directly as a result of the growing number of contractual arrangements between farmers and food processors and retailers.

The *second* challenge arises from the growing consumption demands being placed on rural areas. These have led to the tighter environmental regulation of agricultural practices, which in Britain ranges from incentives to retain 'traditional' farming landscapes, to requirements to change existing practices to prevent water pollution (Lowe *et al.*, 1992b). Tighter regulation reflects a growing general commitment to green issues as well as a changing perception of the purpose of rural areas, characterised by a shift from food production to meeting the rising demands for rural living space, recreation and conservation. It is to a more detailed discussion of these two challenges that we now turn.

In Britain, agriculture enjoyed relatively favourable economic fortunes during the early 1970s as a result of the transition to the Common Agricultural Policy. However, real full-time farm incomes dropped by 35% between 1970 and 1980 (Howarth, 1985), at a time when the cost of agricultural support trebled at current prices. After 1980, agriculture only partially recovered and by 1985 incomes had dropped again to three-quarters of their 1980 level in real terms, and only half their 1970 level (Harrison, 1989; Hill, 1990). Indebtedness also rose. Total liabilities grew from £3.8 billion in 1979 to £10.7 billion in 1991, and total liabilities as a proportion of total assets increased from 8.5% to 18.5% over the same period (Johnson, 1986; MAFF, 1992). In addition, more investment now comes from borrowed finance capital than re-invested profits.

At the same time as real farm gate prices have declined, the share of total value added in the food system that farmers have been able to capture has been diminishing. By the mid-1980s, the farm sector was receiving little over 15% of total value added in food production (Harvey, 1987). Farms have been increasingly tied to input sectors through the development of credit links (Marsden *et al.*, 1990b), and at the same time, food retailers and processors have been able to achieve more favourable market relations with farmers as a result of their oligopolistic powers[4].

In the late 1980s, farming groups began to point to the increasing power of supermarkets as being in part responsible for their own declining economic fortunes. Reluctant to invest in the farm sector, British food retailers have also been able to extend control over the production process and achieve the market relations they desire through 'contract farming'. This allows retailers to emphasise quality standards and influence the timing of planting, spraying and harvesting of crops[5]. While contract farming represents opportunities as well as threats to farmers, the premiums offered for meeting quality targets are often not high enough to warrant the specified changes in farming practices. Harvey notes the problem for farmers to be "that higher quality may become the expected norm for which no premium is payable" (1987, p.155), locking farmers into a 'quality treadmill'. Retailers acknowledge that regulating the food production process is one of the principal ways that they can maintain food quality. The Director of Quality Assurance for Safeway, the UK's 3rd largest food retailer, has pointed out that the role of the retailers in meeting food safety concerns "is to ensure that the product will be produced under satisfactory conditions and to a satisfactory specification" (Cumming, 1990, p.62). According to Harvey (1987, p.156), the requirement that farmers meet retailers' stipulations "will determine their future profitability as much as policy decisions in the EC".

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4 Since the mid-1960s, there has been what Wrigley (1987, p.1284) describes as "a fundamental shift in the balance of power in the industry away from the suppliers or manufacturers of grocery items and towards the rapidly expanding retail corporations". The 1980s have seen the increasing dominance of five companies whose combined share of total grocery sales has risen from 43% in 1984 to 61% in 1990 (Wrigley, 1992). This economic power is unusual in international terms, with Britain's largest food retailers, by the mid-1980s, enjoying "profit levels, employment levels, and sheer market and political power sufficient to rival the traditional giants of UK manufacturing industry" (Wrigley, 1987, p.1285).

5 In Britain, contract farming - where a farmer is contracted to produce exclusively for food retailing or manufacturing companies - has become more common since the early 1970s, such that, according to Clunies-Ross and Hildyard (1992, p.69), "most of the poultry, eggs, pork and bacon, and over 90% of vegetables like peas and beans are grown to the order and specification of the food industry".

Farming groups, complaining about the so-called 'profitability gap' between farming and food retailing, have noted that between 1980 and 1990, the retail prices index rose by 106%, food prices increased by 71%, and yet prices received at the farm gate only grew by 46% (Agricultural Supply Industry, 1990a). This prompted complaints that "the big five supermarket chains make more profit than the whole of British agriculture" (The Independent, 1990), because they "are able to dictate totally what products they require and to a large extent what price they will pay" (Croft, 1991, p.14)[6].

The trends identified above help to explain why one of the most consistent features of change in rural Britain has been the retreat of agriculture. Agriculture has long been in decline as an economic force[7]. By 1981, manufacturing employment had outstripped agricultural employment in rural areas and the service sector became the source of work for most rural residents (Marsden *et al.*, 1991). Moreover, a shift in political power and the way the countryside is represented in debates over the future of rural Britain is discernible, with the traditional dominance of production interests being replaced by consumption interests. This shift, according to Lowe *et al.* (1990b), involves

> "a growing awareness of 'green' issues and the effects of increased affluence on patterns of consumption which together have led to pressure for environmental and 'quality of life' considerations to be incorporated into large areas of public and private decision making. In the context of the use of rural space, the result has been to emphasise the importance of demands for housing, leisure and amenity at the expense of the more traditional concerns of food and fibre production".

The move towards a 'post-productivist' rural Britain in which agriculture plays a diminished role has also been reflected in agricultural policy. The Government's response to the declining economic fortunes of agriculture has been to promote the diversification of farm businesses, helping to accelerate social change in the countryside. More people have wanted to move from urban to rural areas, and this has coincided with efforts in agriculture to find new, non-farming uses for land and buildings (Watkins and Winter, 1988; Kneale *et al.*, 1992).

Such changes often leave farmers feeling that their position has been undermined by new social groups moving into the countryside (Ward *et al.*, 1994). Farm

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6 Supermarkets were also accused of changing the specifications of fruit and vegetables during a contract, without any discussion with the producer, introducing sale or return clauses in supply contracts for highly perishable products, and delaying payments to suppliers (Richardson, 1991; Davies, 1992).

7 The shedding of labour from farms has been going on for at least 150 years, but between 1950 and 1990 the numbers employed in British agriculture fell from almost 1 million to under 300,000 (Body, 1991, p.114). At the same time, agriculture's contribution to rural employment and regional economies more generally has steadily diminished.

diversification and the conversion of barns means that many farmers now have new neighbours with quite different perceptions of the function of the countryside. This can lead to direct pressure to change their farming practices. More generally, there is a perception amongst farmers that social change is diminishing their autonomy. Middle class newcomers are often viewed as the harbingers of new values and procedures by which farming will be increasingly judged by society at large. It is against this background of declining public and political support, coupled with increasing 'informal' regulation driven by social change in the countryside, that the farmers' experience of the farm crisis in Britain must be set.

A sense of alienation and growing frustration is developing amongst a farming community that has seen the goalposts of public policy moved dramatically. The certainty of the productivist era has been replaced by the ambiguities of an agricultural and rural policy which has sought to contain the costs of production support, promote farm diversification, and provide increased protection for the rural environment. While the farm crisis has been primarily an economic one, this has been accompanied by a crisis of legitimacy. Indeed, the two processes are mutually reinforcing, and further compounded when linked to the growing concern about the condition of the farmed environment.

3.2 Agriculture's Ecological Crisis in Britain

The agriculture-environment debate in Britain dates back at least to the early 1960s and concerns about the impact of pesticides on wildlife. By the early 1970s, concerns had broadened to the loss of wildlife habitats arising from rationalisation of the farmed landscape. Fears were originally expressed in terms of the threat to wildlife, but environmental groups began to call also for the protection of attractive rural landscapes.

Farming practices since the 1950s had reduced the diversity of habitats. Most damaging were the removal of hedgerows, the ploughing up of uncultivated field margins, the reclamation of scrub and woodlands, the reduction in rotations and fallows, the replacement of permanent pasture by leys and arable cropping, land drainage and the elimination of standing water and farm ponds, and the treatment of grassland and arable land with selective herbicides and insecticides. The rate of loss reached epidemic proportions during the 1960s when about 10,000 miles of hedgerow were being removed each year, radically altering the landscape of large tracts of lowland Britain (Countryside Commission, 1977)[8].

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[8] More recent survey work by the Countryside Commission and the Department of the Environment suggests the annual rate of hedgerow removal in England and Wales was 2900 miles a year between

Hedgerows often became redundant following the shift from mixed farming to specialised arable production, losing their purpose as livestock barriers, and the use of larger farm machinery required larger, more rectangular fields. In a process which closely parallels that causing pesticide pollution, hedgerows were removed because of

> "the effect of a system which systematically establishes financial inducements to erode the countryside, offers no reward to offset market failures and increases the penalties imposed...on farmers who may want to farm in a way which enhances and enriches the rural environment" (Cheshire, 1985, p.15).

Landscape change became a highly-charged issue during the 1970s as accumulating evidence emerged of the scale of change since the 1940s (Westmacott and Worthington, 1974; 1984; Barr *et al.*, 1986; Countryside Commission/Huntings, 1986). This evidence allowed pressure groups, such as the Council for the Protection for Rural England, to bring the issue to wider public attention, and to ask more fundamental questions about the relations between agriculture and the environment.

The farming lobby's first response to the environmental critique was to blame bad or 'maverick' farmers (Cox and Lowe 1983, p.65), preferring to draw attention to the good stewardship of most farmers and the efficiency of the industry as a whole. However, as the rate and scale of change became evident, the notion of 'maverick' farmers as solely responsible became inadequate, especially as studies of farmers' attitudes to conservation revealed many who regretted the environmental changes they had made but feeling that they had little alternative (ADAS, 1976; LeVay, 1979; Worthington, 1979; Social Research Consultancy, 1982; MacDonald, 1984; MAFF, 1985; MORI, 1987). This evidence shifted attention from individual behaviour to structural factors (Newby *et al.*, 1977). Agricultural policy was blamed for environmental change, with the central tenet of the 'policy thesis' being that policy had provided farmers with access to guaranteed markets, fixed prices, capital grants and an advisory service, conditions that created confidence, encouraged the specialisation and concentration of production, increased output, hastened the substitution of capital for labour, and led to a more intensive use of farmland.

1969 and 1980, rising to 4000 miles a year between 1980 and 1985 (Countryside Commission, 1986). Field boundaries provide important wildlife habitats for at least 20 species of mammals, 37 species of birds and 17 species of butterflies (Nature Conservancy Council, 1977), and so the combined impact of the removal of hedgerows with other aspects of the intensification of agricultural production has been the loss of, or damage to, many habitats and the increasing threat to the survival of some plant and animal species.

Despite broad agreement over these points, determining the precise significance and contribution of agricultural policy measures to environmental change has proved more difficult. There is a tendency to presume mechanistic responses by farmers to the economic signals provided by regulated markets, and then to make assumptions about the causes of environmental change on this basis. In an attempt to chart a midway course between the individualistic 'maverick thesis' and the macro approach of the 'policy thesis', Potter (1986; 1987) combined a macro-perspective on policy with farm-level impacts on land use change including 'family processes', such as succession, adaptability and the sets of values held by farmers. He suggested that "environmental damage may result from behaviour which is conditioned by investment norms and notions of what makes good farming practice" (1986, p.149). He categorised farmers on the basis of their investment style, identifying those who made systematic and programmed investments in land improvement as the harbingers of greatest change.

Given the wide variety of conditions on farms, these arguments represent a valuable palliative to the 'policy thesis'. Farmers manage their businesses within a range of constraints beyond their control, but exercise options within this range. This realisation prompted a series of studies in the late 1980s which integrated structural conditions with a focus upon the internal nature of farm businesses. These suggested that economic and policy conditions have demanded lower unit costs, achieved largely through more capital intensive production systems, with farmers obliged to adopt new cost-reducing technologies to offset falls in real prices (Munton *et al.*, 1987a;b; 1990).

During the late 1970s and 1980s, new concerns about industrialised agriculture's impact on watercourses came to the fore. The main agricultural water pollutants are pesticides, nitrates and livestock effluents. In England and Wales, the number of reported farm pollution incidents more than doubled during the 1980s, with the most frequent pollutants being cow slurry (55%) and silage effluent (20%) (National Rivers Authority, 1992, p.11). Pollution occurs when effluents are allowed to enter water courses, usually because of inadequate storage facilities or poor management. This has arisen primarily because a smaller number of farms now carry larger cattle herds, making safe disposal of effluents more difficult. The problem has been exacerbated by the switch from straw-based to slurry-based livestock housing systems and the concreting of farmyards. In addition, the increasing use of manufactured nitrogen fertilizers in farming is thought to have been in part responsible for rising nitrate levels in water. Similarly, numerous water supplies in Britain exceed the EC standard for pesticides (FoE, 1988).

The evolution of the controversies surrounding agricultural pollution have paralleled debates about farm landscape change. The initial response by farming interests has been to question the severity of the problem, and then to blame 'bad farmers'. It is only after strongly contested debates that the production system itself might come to be regarded as unsound. Indeed, it is only relatively recently that water pollution has become one of the most prominent environmental issues for agriculture. Lowe (1992) gives three reasons for the relatively late emergence of farm pollution as a public and political issue. *First*, water quality regulation prior to the 1980s had concentrated on urban and industrial sources, which meant that the lack of control over farming became more and more apparent, with pollution control oriented towards point source problems. Diffuse pollution creates a much more intractable regulatory problem. *Second*, the decline of heavy industries during the late 1970s and 1980s eased some of the long-standing air and water pollution problems in urban areas, leaving the agricultural sector more exposed to critical inquiry. *Third*, the growing recognition that agricultural policy provided an 'engine' for intensification led to a realisation that, unlike most other environmental problems, government support policies were implicated alongside market forces.

In the light of the series of environmental problems outlined above, an increasingly detailed environmental critique of the technology/policy model emerged. Goodman and Redclift argue that

> "the environmental effects of modern agriculture point to contradictions within the entire model on which the food system is based. Modern agriculture developed out of the partial separation of 'farming activities' from the natural resource base on which these activities were traditionally dependent" (1991, p.201).

The origins of the contradictions lay in the breakdown of the self-sustaining and cyclical patterns of farming practice of the pre-war period. The post-war transformation centred on industrial technologies that "[broke] into the cycle of renewal, failing to return to the resource base what has been removed from it" (1991, p.203).

3.3 The Implications of the Crisis for the Production and Use of Pesticides

The challenges for British agriculture described present farmers with conflicting messages. The demands of the food system seem to necessitate the adoption of increasingly sophisticated industrial technologies that commit farmers to financial relations with agro-food companies from which it is difficult to withdraw. The changing role for farming within the rural economy, on the other hand, requires that they take less risks with the environment and internalise some of the costs of the environmental disbenefits they cause. Pressures for market deregulation in agricultural commodities has grown (Arnold and Villian, 1990), but at the same time the demand for regulation of food quality and farming practices has increased. The pressure for improved regulation is reflected in the recent introduction of a straw burning ban, the withdrawal of some chemicals, and more rigorous effluent handling controls, changes which now constitute a significant source of business uncertainty, sometimes requiring substantial investment in fixed equipment, or major changes to farming practice (Lowe *et al.*, 1992a; Ward *et al.*, 1994).

The primary concern for farmers, however, is an economic one. Declining profitability has promoted a range of changes in the ways that farms are managed. At the most extreme, many farmers have left the industry and sold their businesses[9]. For those remaining, strategies have included the search for non-agricultural sources of income, the development or selling-off of land, the quest for greater efficiency in the use of inputs, or in some cases, increases in the scale or intensity of production. A key feature since the late 1980s, however, has been the growing economic risks faced by farmers[10].

The farm crisis has also brought state support for agricultural R&D under increasing pressure (Harvey, 1988). Public funding was cut and the private sector has been encouraged to play an increasing role in funding 'near market' research[11]. Since the early 1980s, the AFRC's 28 research stations and institutes have been either closed or

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[9] The number of holdings of at least 2ha in England and Wales fell from 206,000 in 1970 to 164,000 in 1986 (Britton, 1990, p.20).

[10] Harrison (1989) has categorised these risks into seven types. *First*, greater risks arise because of higher real interest rates and greater indebtedness than in the 1970s. *Second*, farmers have been less able to sell land and lease it back from financial institutions in order to relieve their debt burdens. During the 1970s, financial institutions were net purchasers of agricultural land (Munton, 1985), although this had been reversed by the mid-1980s. *Third*, rapidly rising land prices in the 1970s meant that many farm family members (usually brothers or sisters) who had been left farm assets demanded that their shares be paid in cash. This meant that farm operators had to 'buy out' family members, often borrowing from higher cost sources such as banks, rather than the more traditional within-family loans. *Fourth*, because farming has become far more heavily dependent on manufactured inputs, farmers become subject to additional price risks. *Fifth*, economic risks increase because the farmers' terms of trade continue to deteriorate as the costs of inputs rise while many farm commodities command lower real prices. *Sixth*, farm product prices since the late 1980s have been far more variable than during the early 1980s, thus increasing economic risks faced by the farmer. *Seventh*, farm incomes, in consequence, have become much more volatile than they were during the 1970s.

[11] State support for agricultural R&D remains significant compared to publicly funded research in other industries. In 1990/91, UK civil provision for R&D was £2.79billion, according to the Government's Chief Scientific Advisor, of which £246million may be attributed to agriculture and fisheries research by MAFF, the Departments of Agriculture in Northern Ireland and Scotland and AFRC, equating to around 9% of the total (Stewart, 1991). All Government funding of near market R&D was withdrawn by 1991/92, because of the Government's view that MAFF should "no longer act as a proxy-customer for applied R&D on behalf of industry" (Priorities Board, 1990, p.2). However, the tendency for near market research to be carried out collaboratively with the AFRC means that the public sector has still maintained partial directive responsibilities.

amalgamated into seven English and Welsh institutes, each with one or two main sites. Some 1643 jobs were lost between 1983 and 1988 representing a 34% reduction in the scientific workforce (AFRC, 1990). Industrial capital has become increasingly involved in funding near market research, and the AFRC's 'external' income from industry rose from £4M in 1983/84 to £16.5M in 1990/91 (ARFC, 1991a), and is projected to increase to £25 million by 1996/7 (AFRC, 1992).

There has also been a shift in emphasis during the 1980s away from R&D directed towards farm based production and towards 'public good' work (AFRC, 1989; Upton, 1991). Surplus production and environmental problems attracted criticism of the role of publicly funded agricultural R&D, which many saw as still being geared to increasing productivity through new technologies. Tudge, for example, complained that

> "not all research in food production is moving in directions that seem destined either to feed more people or to relieve pressure on domestic livestock or wildlife. Much, indeed, including much of the kind that is most likely to produce short-term profits, is moving in precisely the opposite direction" (Tudge, 1987, p.40).

In response, the AFRC began to stress its role in areas of public concern, emphasising its contribution to research into environmental and safety issues. However, despite the new emphasis on food safety and environmental studies (AFRC, 1991b; MAFF, 1992), forty years of research into yield-raising technologies have left their mark and an emphasis on improving productivity through the application of new technologies remains. Key actors in British agricultural R&D, such as politicians, agricultural economists and research scientists, many of whose interests lie in the maintenance of the productivist technology/policy model (Kloppenburg, 1991; 1992), are still wedded to this view. For example, in addressing a conference titled 'Agricultural and Food Research - Who Benefits ?' (see Wise, 1991), the theme of which was that R&D should drive 'efficiency' and 'competitiveness' in the agricultural sector, Professor William Stewart, Chief Scientific Advisor to the Cabinet Office, and formerly Secretary to the AFRC, said;

> "The key question of this symposium is "Who benefits from agricultural and food research and development ?" The answer, quite simply, is that the UK public has benefited. However, it would be counter-productive and complacent if we left it at that. We now have to ask: if UK agriculture and food production has been satisfied; if we are now able to compete with the best in the world, how do we ensure that this will remain to be the case not only today, but equally importantly, tomorrow ? We have only to look at the fertile lands of eastern Europe, performing sub-optimally at present. We note the improving agricultural production of our other European partners. We see the necessity to compete globally if we are to compete effectively. We are a small country, perched off the coast of continental Europe, remote from

> expanding areas of population growth, and we see the perturbations which GATT discussions have on our international competitiveness" (Stewart, 1991, p.8).

Stewart's initial tenet was challenged by Harvey at the same conference. Harvey suggested that it was not the public who gained because the sectors providing agriculture with its most important manufactured inputs are highly concentrated (see also Ward, 1990), and so firms are able to influence the prices charged for inputs. He said

> "Since these firms can set their prices, they could capture the benefits of technical change for themselves, rather than passing the benefits on to the producer in the form of lower prices" (Harvey, 1991, p.27).

Private corporations and multi-national companies play an increasing role in agricultural R&D. It has been estimated that in the combined field of agriculture and food R&D, annual public investment is exceeded by that of the private sector (Beck et al., 1990). The majority of new technology is produced by companies in the agricultural supply industries. Accurate figures for research spending on agriculture are deemed to be commercially sensitive and so are difficult to obtain, but data published in the company annual reports show that research expenditure in agriculture is a sizeable concern[12].

The concentrated structure of agricultural supply industries mean that considerable research effort is required to maintain a competitive edge in product development. In Britain four multi-national companies control over 60% of the pesticide market. By the late 1980s, ICI had the highest share with 19%, Schering held 16%, and Monsanto and Bayer 18% each (Ward, 1990). A small number of large firms supplying a large number of small farm businesses, leaves suppliers able to influence, and even set, the prices charged for inputs. They then capture much of the benefits of technological change themselves. Harvey (1991) argues that rapid technological development in the input sector is associated with increasing concentration, increasing spatial size of markets and increasing R&D investment, and suggests that the fortunes of the agricultural sector itself may have little impact on these processes.

The present unstable economic and political climate for agriculture has reduced profitability as sales of agrochemicals have declined. The fall in profitability has been

12 For example, in 1985 Unilever's research expenditure was £253M. Of the year's main research projects, all but two were related to food processing and handling (Unilever Company Annual Report, 1986). Similarly large budgets can be found in the annual reports of ICI and much of the agrochemical industry. For example, the newly merged companies of Schering and Hoescht to form AgroEvo will be spending £150 million per annum on pesticide related R&D (Davies and Whytock, 1994).

exacerbated by the high cost of bringing new products onto the market[13]. One strategy has been to strengthen links between innovation in seeds, plant genetics and agrochemicals (Kloppenburg, 1988; Goodman and Wilkinson, 1990). Seeds have "come to be recognised as the ideal vehicle for the delivery of agrochemicals to the field" (Kloppenburg, 1988, p.246). As a result, agrochemical companies have acquired seed and plant genetic research companies. According to Goodman and Wilkinson, these acquisition strategies recognise "that the seed is central to the marketing of the new plant biotechnologies....[and that] .... control over the technology incorporated in the seed can be used to extend markets for inorganic agrochemicals" (1990, p.139).

Major chemical, pharmaceutical and oil companies have bought more than 120 seed firms since the mid-1960s (Kenney *et al.*, 1983). The most recent wave of acquisitions since the mid-1980s has been driven by a need to consolidate market share in plant varieties in anticipation of biotechnological innovations (Goodman and Redclift, 1991, p.171), especially the possibility of developing varieties that are resistant to agrochemicals[14]. According to the Financial Times,

> "for ICI and its rivals, the aim is to create an agricultural package reaching from fertilizers, through pesticides to the plant itself, which can be tailor-made through genetic manipulation to fit the maker's system and no-one else's" (Financial Times, 13 June 1987).

For example, seeds have been dressed with chemicals which block herbicidal action so they can receive applications of herbicides after planting. Usually, treated seeds are only able to receive applications of those agrochemicals from the parent company of the seed firm. However, this still represents a *mechanical* union of seed and chemical. Biotechnology, on the other hand, gives rise to the possibility of a union at the *genetic* level, with seeds being genetically programmed to either respond to, or to require, the application of particular agrochemicals.

New products and practices have increasingly reached the farmer, not as public goods supplied by the state but in the form of commodities supplied by private interests. Agricultural R&D has facilitated a shift in emphasis from the farm into industrial

[13] For example, to create an adequate data package for official approval of a pesticide in the UK takes at least 8 years and costs at least £30 million (Marks, 1992).

[14] ICI took over Garst Seeds, the third largest US corn seed producer in 1985, Sinclair McGill, a leading UK seed firm in 1986, and Société Européenne de Semences in 1987, a takeover which placed ICI in the world's top ten seed producers. Other agrochemical companies in the world's top ten include Monsanto, Ciba-Geigy, Shell and Sandoz (Goodman and Wilkinson, 1990). ICI also unsuccessfully bid for the Plant Breeding Institute in Cambridge, which was privatised in 1987 and sold to Unilever. Concentration in the seed industry is likely to continue because the largest multi-nationals still only account for under 15% of total sales (Goodman and Redclift, 1991, p.172).

settings and R&D can therefore be understood as "an essential component of the contemporary dynamic of ... accumulation in the agricultural sector" (Kloppenburg 1988, p.35). Changes in the structure of agricultural R&D, therefore, hold important implications for farm-based production because technologies, in both product and advisory form, can be used to control production and markets (Hawkins, 1991).

The privatisation of agricultural science has led to closer collaboration between private companies, higher education and public sector research. For example, the AFRC aims to increase its research staff at universities from 9% in 1988 to 23% by the mid-1990s (AFRC, 1992). Industry and state institutes require the expertise of the bio-science departments at universities as they start to finance projects in less familiar fields. For example, ICI set up academic partnerships with 30 joint post-doctoral research schemes, 30 schemes with research councils, and with over 200 academic consultants in the late 1980s (ICI Company Annual Report, 1989). Universities are quite willing to aid this collaboration which provides extra income at a time of funding pressures.

Traditionally, politicians and research interests assumed that the main beneficiaries of new technologies would be farmers. As the farm has become a less important element of the agro-food complex, this assumption has been increasingly questioned. With declining farm incomes, farmers' willingness to adopt capital intensive technologies may have declined. However, the need of industrial capital to retain a market has meant that an innovative farming community is still required by the suppliers of agricultural technology. A number of strategies have become apparent. First, new technologies have been 'packaged' such that, for example, new seeds require the use of certain sprays. Second, credit and financial incentives via banks and leasing companies have been used to maintain innovation (Marsden *et al.*, 1990b). Finally, firms use technical specialists to advise farmers on the inputs to use (Hawkins, 1991; Ward and Munton, 1992). Even so, the economic squeeze of the 1980s has forced farmers to take a closer look at the efficiency with which inputs are used. The result has been that the quantity of pesticide applied in England and Wales (in terms of tonnes of active ingredient) fell between 1982 and 1988 by 13.3% (see Table 2.4 in Chapter 2). Although the quantity of fungicides applied grew by 44.0%, herbicides declined by 32.7% over the same period[15]. However, the increasing influence of the private sector in R&D and in the technology transfer system (Figure II, p.19) has helped maintain the importance of chemical crop protection strategies on the farm (see Chapter 6).

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15 It should be noted again that a decline in the *quantity* of pesticide applied in terms of tonnes of active ingredient need not necessarily imply a reduced risk of pollution because there has been a shift to more potent products. For this reason Beaumont (1993, p.195) suggests that the official statistics demonstrate only a 'phantom' reduction.

3.4 Pesticide Pollution of Water in Britain

The first concerns about the harmful environmental effects of pesticides came in the 1950s (Sheail, 1985, p.7). By 1956, deaths of wood pigeons and pheasants were being linked with pesticides used as seed-dressings, although wildlife losses were "generally dismissed as inevitable and localised, without any major or lasting effects on species populations" (Sheail, 1985, p.58). As evidence linking seed-dressings to bird deaths grew, pressure from conservation interests intensified and in 1962 a voluntary ban on their use was introduced[16]. But a serious debate on the future of pesticides was difficult to stimulate. As Sheail notes

> "It had been hard enough to persuade the sceptical and apathetic that the sudden losses of thousands of birds in 1960-61 were caused by pesticides; it was even more difficult to convince them of the more subtle dangers posed by the persistence of certain types of pesticide" (Sheail, 1985, p.86).

In 1963, the publication of the Rachel Carson's book, *Silent Spring*, caught the public imagination with its blistering attack on the indiscriminate use of pesticides and its claim that long term genetic and ecological problems could result from the build-up of residues. Crucially, she saw one of the key problems to be the dominance of chemistry over biological and ecological sciences, and wrote,

> "in my opinion the chemists and the engineers are leading us into very grave difficulties and the biologists are not making their views known with anything like the necessary effectiveness" (quoted in Sheail, 1985, p.88).

Carson's claims were supported by findings of high concentrations of DDT in bald eagles in the US, and soon became widely cited in calls for more stringent controls on pesticide use. The book marked an important turning point.

In Britain, the controversy that arose from the book prompted an investigation by the inter-departmental Advisory Committee on Poisonous Substances in 1963 into persistent organochlorine pesticides. The Government accepted the Committee's recommendations, banned the use of aldrin and dieldrin in sheep dips, sprays and fertilizers and began a review of the use of DDT.

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16 By this time, in California, Hunt and Bischoff (1960) had also established that residues of an insecticide could be found in fish populations, and residues were building up in the food chain.

The high public profile of pesticide pollution problems in the 1960s, coupled with fears about the threat to human health, led to a more general examination of pesticide usage in the scientific literature (Edwards, 1970; 1977; Irvine and Knights, 1974; Perring and Mellanby, 1977). A new type of treadmill - the pesticide treadmill - came to the fore. As Tait explains

> "the term treadmill implies a self-fuelling trend towards ever increasing and more expensive pesticide usage, and many of the factors driving this process are biological in origin" (Tait, 1981, p.230).

Specifically, the use of pesticides disrupts ecosystems leading to the use of more pesticides to maintain effective control. Either pests develop resistance or new pests are unintentionally created. For example, the use of a pesticide to control one pest can upset the ecological controls regulating other insect populations such that they become pests themselves, or the numbers of the pest's predators falls leading to a resurgence of the original pest later in the season (Metcalf, 1980). A combination of pesticide applications may then be required each year. Resistance is another important aspect of the ecological dynamic of the pesticide treadmill. Emerging evidence of pest resistance prompted the Royal Commission on Environmental Pollution (RCEP) to study the matter (RCEP, 1979, pp.47-50). It concluded

> "we are deeply concerned about the threat posed by the development of resistance to insecticides and fungicides and we are not convinced that the significance of this threat has been sufficiently appreciated by MAFF. We recommend that serious attention should be given to the development of strategies to combat pest resistance and to problems that would arise in introducing them" (1979, p.212).

The idea of a pesticide treadmill provided an ecological logic to help explain increasing pesticide use. However, while pest resistance and the emergence of new types of pest have been documented for individual pesticides and individual pests, there is still no scientific consensus on pest resistance as an *intrinsic* characteristic explaining increasing pesticide usage in general.

The problem of pollution of surface and groundwaters by agricultural pesticides did not materialise until the 1980s. The Royal Commission on Environmental Pollution, in its 1979 study of agriculture and pollution, devoted over a quarter of its report to looking at pesticides but water pollution was not specifically dealt with. Instead, the main foci for concern were risks to human health from pesticide residues in food, risks to farm workers from contact with sprays, and risks to wildlife from the cumulative effects in the food chain. The only threat to watercourses was perceived as coming from the careless disposal of pesticide containers or spray tank washings which, it was felt, could cause acute, but transient incidents (Tait, 1981). Otter has argued that it was an absence of good monitoring data that "generated an atmosphere of complacency" (1992, p.1).

Events during the 1980s have challenged this complacency, and the means by which agricultural pesticides pollute ground and surface waters is now the subject of much greater scientific effort (see, for example, Lawrence and Foster, 1987; Croll, 1991; Gomme *et al.*, 1991; 1992; RASE/ADAS, 1992; Greig-Smith *et al.*, 1992; RCEP, 1992; Walker, 1991). This change was set in train by the EC's Drinking Water Directive (80/778/EC), agreed in 1980. The Directive, which became law in Britain in 1985, set a very low maximum admissible concentration (MAC) level of 0.1μg/l for any individual pesticide and 0.5μg/l for total pesticides. These were the first legally-enforceable, numerical standards for pesticides in water in Britain. The Department of the Environment has subsequently provided its own list of toxicologically derived maximum concentrations which drinking water supplies must not exceed (DoE, 1989). Most of the DoE maxima are higher than the EC MACs, but meeting the EC MACs still remains the legal requirement and long term policy objective in Britain. In order to meet the MACs, considerable additional treatment will be required at waterworks and at high cost (Croll, 1991). Until treatment facilities are installed, water companies in Britain are exempted from legal action when the pesticide MACs are exceeded providing that (a) the DoE's toxicological limits are not also exceeded; (b) the water company gives an 'undertaking' under Section 19 of the Water Industry Act 1991 to meet the MAC by upgrading water treatment; and (c) the Secretary of State for the Environment has published Notices of Satisfaction[17].

The EC's MACs have been criticised by agriculturalists, the agrochemical industry and other commentators for having no toxicological basis (see, for example, GIFAP, 1990; British Agrochemicals Association, 1992; Eureau, 1992; Fawell, 1992; European Crop Protection Association, 1993). It is now not clear why the particular MAC levels were chosen. According to the Royal Commission

> "the limit of 0.1μg/l which applies to any individual pesticide is believed to be based on a one-time limit of detection for chlorinated insecticides. As such it was regarded as a surrogate zero" (RCEP, 1992, p.126).

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[17] These British arrangements were recently challenged in the High Court by Friends of the Earth who argued that they constituted a breach of the Directive and thus of European law. The Court upheld the validity of the Government's approach after affidavits from senior DoE officials indicated that at all times the Secretary of State had accepted the undertakings with the intention that ultimately the UK would comply with its obligations. In other words, the Court was convinced that meeting the MACs remained the objective of policy in the UK (Macrory, 1994).

Earlier limits had been devised by American and Canadian regulatory authorities in 1976 and 1978 respectively, based on pesticide toxicity. These were subsequently adopted by the World Health Organisation (WHO) in 1984 to guide national regulatory authorities in setting standards[18]. Most of the toxicological limits were higher than EC MACs and were used by the DoE to inform its own advisory limits. The British Government has been pressing the European Commission to review its MACs for pesticides in drinking water, driven partly by the high cost of treating water to remove pesticides (Maddox, 1992). Water companies claim that they will need to invest a total of £800 million in improved water treatment, and annual operating costs will rise by £80 million a year, if the MACs are not to be exceeded (ENDS, 1992a, p.9).

Crucially, the EC MACs have provided an authoritative norm. They have come to represent the very definition of pesticide pollution as a public problem, and a yardstick against which the extent of pesticide pollution in water can be measured. During the 1970s, water pollution from farming practices had become something of a non-problem. The water authorities acquiesced in the priority given by government to the expansion of food production over the curbing of farm pollution, and this led to a lack of effort in the monitoring of agricultural pollution. For example, schemes initiated by the former river boards to bring farm discharges under formal consent procedures were not pursued and the main river monitoring activities of the water authorities focused on major stretches affected by urban and industrial pollution. In any case, the periodic sampling procedures used were not designed to pick up the diffuse pollution typically caused by farming activities. Hence, there was a lack of information about the extent of farm pollution, completing a circle that, in effect, closed off the issue. The dearth of information meant, in turn, a lack of public awareness leading to little pressure on water authorities or policy-makers to address the issue, or on politicians to acknowledge its existence. What might be called the 'vicious circle of the non-problem' of farm pollution is depicted in Figure 3.1. It applies to the case of pesticide pollution but also to that of pollution from farm effluents[19].

It was, however, the introduction of the EC MACs and the monitoring required to demonstrate compliance that provided the opportunity for environmental groups to

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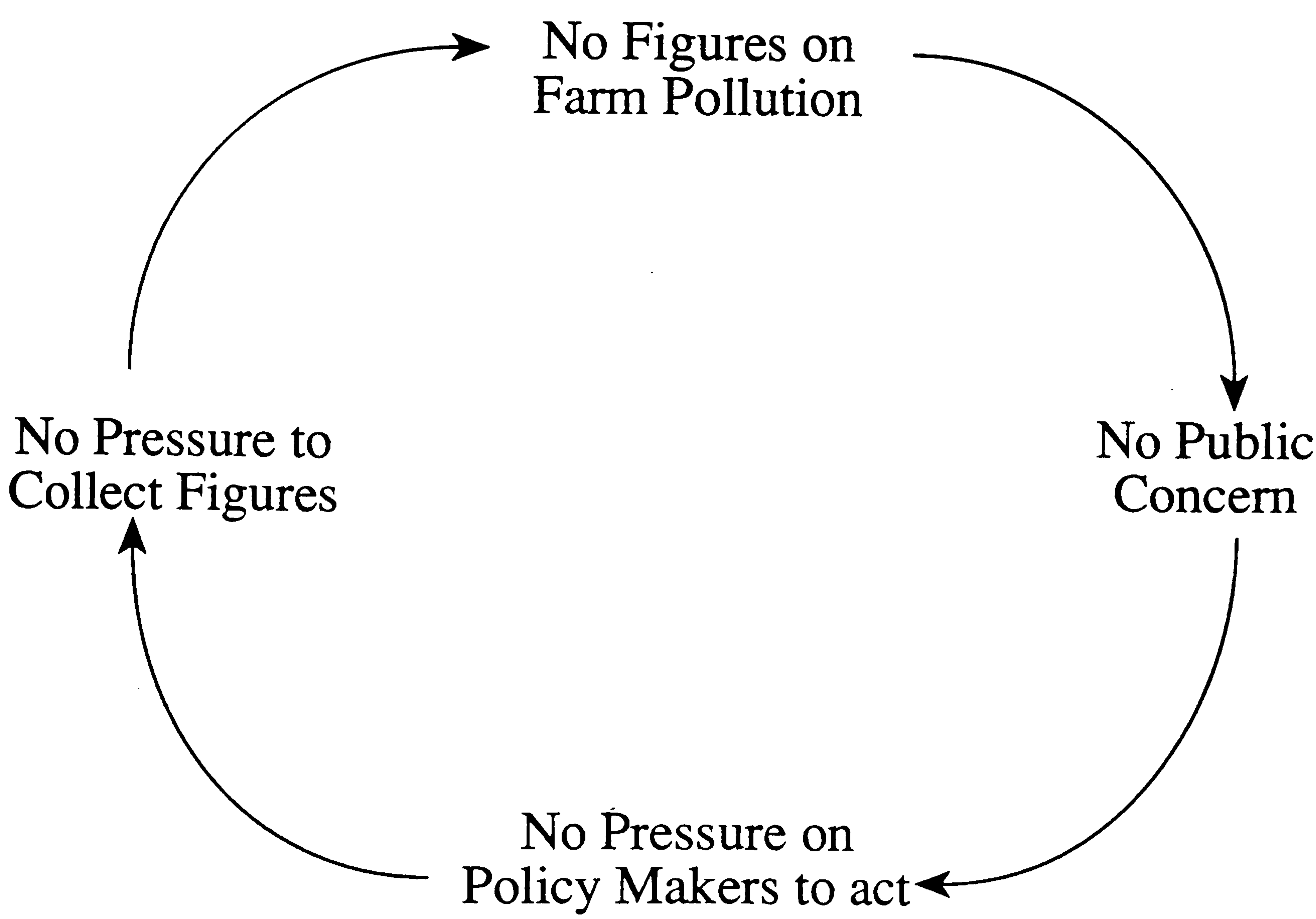
18 The WHO guideline values are set at levels designed to protect human health. As the RCEP emphasises, "they may not be suitable for the protection of aquatic life. Experience has shown this to be the case" (RCEP, 1992, p.126).

19 In the case of pollution from livestock effluents, social change in the countryside helped to break the circle and bring the issue to wider public attention (Ward *et al.*, 1994). Central to this process has been 'the farm pollution incident'. The gathering, collating and publicising of statistics on pollution incidents, often reported by concerned individuals among the new ruralites, have provided the missing numbers that have enabled farm pollution to become a public issue through becoming a 'measurable' problem (WAA/MAFF, 1986).

Figure 3.1 - Farm Pollution in the 1970s: The Vicious Circle of a Non-Problem



quantify the pesticide pollution 'problem' for the first time. Friends of the Earth had been monitoring the environmental impacts and health hazards of pesticide use during the early 1980s (Friends of the Earth, 1985; Rose, 1990). Incidents reported by members of the public and local FoE groups were collated in an effort to "show that a major problem of pesticide pollution exists" (FoE, 1985, p.ii). Many of the reported incidents involved people in the countryside suffering from contact with pesticides, but in a few cases pesticides had entered watercourses. However, the dearth of information on the extent of the threat to water from pesticides was severely limiting.

Other events in the mid-1980s combined to provide a setting within which pollution from farming practices gained a much higher profile. The mid-1980s saw the first recorded decline in river water quality at the national scale (DoE/Welsh Office, 1986), and this prompted a 1987 House of Commons Environment Committee to examine the pollution problem. The Committee concluded that growing farm pollution was an important contributory factor to declining river quality (House of Commons Environment Committee, 1987). This also came just when several environmental groups were becoming interested in water pollution and were keen to show that Britain was the 'Dirty Man of Europe' (Rose, 1990). Evidence of declining environmental quality was pursued as the achilles heel of the Thatcherite free-market and deregulatory philosophies, and the privatisation of the water industry gave a high-profile to such matters, specifically raising questions about how water quality should be regulated.

The EC's Drinking Water Directive also meant that, for the first time, data were available on the spread of pesticide contamination of water. This enabled FoE to narrow the scope of its pesticide campaign to look specifically at pesticides in drinking water. Water Authority records, collected to satisfy the Directive's monitoring requirements, were surveyed and data for pesticides in water were investigated for 10 Water Authorities and 28 Statutory Water Companies. The survey revealed that between July 1985 and June 1987, the EC's MAC for any single pesticide had been exceeded in 298 water supplies and the MAC for total pesticides had been exceeded 70 times (FoE, 1988). The worst affected region overall was East Anglia followed by Thames (see Table 3.1). The report, which subsequently informed a major feature in the Observer Magazine in August 1989 (Observer, 1989), brought the now measurable problem of pesticide pollution to wider public attention.

The data FoE published demonstrated for the first time the geographical spread of water pollution from pesticides (Figure 3.2). They showed that surface waters were under greater threat than groundwaters, and pointed to herbicides as the most common cause

Table 3.1 - The Regional Distribution of Pesticide Contamination of Drinking Water Supplies

Image removed for copyright reasons

Source: Friends of the Earth, 1988.

<u>Figure 3.2 - Areas Where Water Supplies Breach the EC Standard for Pesticides, 1988</u>

Image removed for copyright reasons

Source: The Observer, 1989.

of contamination. This finding was supported by evidence from scientific studies looking at the risks to water from pesticides (Lawrence and Foster, 1987; Croll, 1986; 1991). A study by the British Geological Survey in 1986 had recognised that accidental spillages and container disposals were not the only threats to water quality, and concluded that

> "The greatest threat to groundwater quality from the normal use of agricultural pesticides is likely to be associated with relatively soluble herbicides that are very widely and regularly applied for weed control in cereal production" (Lawrence and Foster, 1987, p.26).

The region with the greatest extent of cereal production is East Anglia. Surface and groundwaters were monitored for pesticides throughout the 1980s, firstly by the Anglian Water Authority and, after the privatisation of the water industry in 1989, by Anglian Water Services (Croll, 1986; 1991). By the early 1990s, the herbicides Atrazine, Simazine, Mecoprop, Isoproturon and Chlortoluron had been frequently found in surface waters in Britain at concentrations up to 0.5µg/l with a maximum of 11.5µg/l, over a hundred times the limit for drinking water (Croll, 1991). A routine monitoring programme began in the Anglian region in April 1985. After new methods suitable for the routine analysis of water for Chlortoluron, Isoproturon and four other herbicides became available in 1987 (Water Research Centre, 1987), these products were added to the list of pesticides to be routinely monitored.

By 1990, 700 water samples from Anglia region had been analysed and it was found that Isoproturon was the most frequently detected pesticide in surface waters, followed by Atrazine, Simazine, Chlortoluron and Mecoprop (see Table 3.2). The detected frequency of pesticide pollution of groundwaters was much less (Table 3.3), with Atrazine the most prevalent followed by Simazine and Isoproturon. Atrazine and Simazine are used widely outside agriculture, including for weed control on highway verges, railway land and industrial sites. The studies in the Anglian region found that "the quantities [of Atrazine and Simazine] used in agriculture (50 tonnes/annum) are much less than that required to produce the level of triazines detected" suggesting non-agricultural users were also to blame (Croll, 1991, p.392). This left Isoproturon as the most commonly detected pesticide in Anglian surface and groundwaters solely attributable to farming practices.

Isoproturon (IPU) is a pre-emergent herbicide used to kill grass weeds such as black grass and wild oats in cereal crops. It is a member of the urea family of herbicides and is applied directly onto the soil, usually in the autumn, before the crop has germinated. By inhibiting photosynthesis, IPU kills weeds that have either just germinated, or are

Table 3.2 - Pesticides Detected in Anglian Surface Waters

Image removed for copyright reasons

Source: Croll, 1991.

Table 3.3 - Pesticides Detected in Groundwaters

Image removed for copyright reasons

Source: Croll, 1991.

about to germinate at the time of spraying. First marketed in Britain in 1974, IPU is now a cheap, off-patent pesticide available under a range of brand names, the most common being Arelon, Javelin, Tolkan and Hytane (see Hassan, 1990).

MAFF's Pesticide Usage Surveys repeatedly reveal IPU as the most extensively used cereal herbicide in Britain. In 1992, 2,181,248 ha were treated with a total of almost 3,000 tonnes of active ingredient (Davis *et al.*, 1993, p.30). Of all the agrochemicals used in Britain, only sulphuric acid, used in heavy doses to kill off the tops of potato plants prior to harvest, is applied in greater quantities.

Pollution risks arise because IPU can persist in the soil for up to four months (Riley and Eagle, 1990, p.256). The availability and competitiveness of pre-emergent cereal herbicides like IPU made the switch to winter cereals technically feasible and economically viable (see pp.77-78). The switch also increased the risk of pollution in other ways. Research by Evans (1990) has demonstrated how the area of land in England and Wales sown to winter cereals increased by a factor of three between 1969 and the late 1980s, and found that it is land sown to winter cereals that is the most susceptible to soil erosion caused by run-off. More erosive rain falls in October and November when poorly covered ground is vulnerable to run-off and pre-emergent herbicides have been recently applied. Studies funded by MAFF in the late 1980s found IPU present in the waters of field drains at levels of 2.16μg/l (Greig-Smith *et al.*, 1992), and more recently, studies by ADAS and the Institute of Arable Crops Research detected levels of IPU in run-off water from fields at between 60 and 600μg/l, up to 6000 times the EC limit for drinking water (ENDS, 1992b, p.10). Because there has been little systematic monitoring of pesticides in water, evaluating the extent of the pollution problem remains difficult. Moreover, if water is not monitored for a particular pesticide, then any pollution will not be recorded. It is, therefore, very difficult to be certain about the *precise* extent of pollution by pesticides[20].

The collection and collation of data on pesticide pollution has become more standardised since the establishment of the Drinking Water Inspectorate (DWI) in 1990 following water privatisation. Annual reports are now compiled which contain the results of an annual technical audit of the quality of drinking water supplied by the 39 water companies in England and Wales (Drinking Water Inspectorate, 1991; 1992a; 1993). The 1992 audit found that 33 different pesticides were detected above 0.1μg/l in water

20 The limitations of pesticide pollution monitoring were well illustrated by the case of a pollution incident in Oxfordshire in 1991. A small quantity of Lindane was dumped into a sewer, but broad spectrum analysis carried out monthly failed to pick up the incident, and it was only when dead fish were spotted that samples were taken. Results showed Lindane present at 220μg/l in the effluent discharge and 3μg/l in the River Cherwell (ENDS, 1991, p.6).

supplied to customers compared with 34 in 1991 and 31 in 1990; and that 3.0% of analyses exceeded 0.1μg/l compared with 2.8% in 1991 and 2.1% in 1990 (Drinking Water Inspectorate, 1991; 1992a; 1993). However, it is unclear whether this increase arises from increasing pollution or more effectively targeted monitoring. In any case, its focus is on pesticides in drinking water supplies rather than pesticides in the general water environment. There remains no systematic, national monitoring schemes or publicly available data on pesticides in 'raw water'.

The causes of pesticide pollution and the precise mechanisms by which pesticides enter surface and groundwaters remain poorly understood and are now coming under closer scientific scrutiny (Kjolholt, 1990; Foster *et al.*, 1991; ENDS 1992b; Mattheissen *et al.*, 1992; Walker, 1991; Williams *et al.*, 1991; Carter, 1993). The ways in which pesticides pollute water are varied and complex (see Figure I, p.18). Surface waters are at risk from the inappropriate storage and disposal of pesticides on farms, and accidents usually take the form of a point source pollution incident with pesticides getting directly into streams or rivers. Surface waters can also be polluted during and after crops are sprayed, either through the spraying of pesticide directly onto water at field margins, or through the run-off of pesticide from the land surface, or through field drains.

The threat from run-off has been assessed as part of the 'Granta Catchment Pesticide Study' in Cambridgeshire, one of the most detailed studies of the movement of pesticides (Hennings *et al.*, 1988; Clark *et al.*, 1991; Gomme *et al.*, 1991; 1992). Findings suggest that much of the pesticide detected in rivers had been washed from the land, often via field drains. This means that most pollution would be expected to occur during and immediately after periods of rainfall as the pesticide gets washed in 'pulses' into rivers. It also explains the detection of peak pesticide concentrations in rivers orders of magnitude greater than their background concentrations (ENDS, 1992b).

Groundwaters tend to be at risk chiefly from the normal spraying of pesticides on land. Generally, between 10% and 40% of pesticides applied reach their target area (weeds or pests). A significant proportion remains in the soil, and this is greater for soil-applied pesticides than those aimed at plant leaves. Pre-emergent herbicides pose the greatest risks because they are applied in by far the greatest quantities and are applied directly onto, and linger in, the soil to kill weeds as they emerge (Foster *et al.*, 1991).

The science of detecting pesticides in water and tracing their movements in the environment is partial and uncertainties have left the issue open to contestation between different groups. In the main, the debate has centred on the applicability of the EC MACs. As a surrogate zero they embody the notion that pesticides have no place at all in drinking water. This remains the view of the EC (ENDS, 1993a, p.37) and is shared by environmental groups in Britain like Friends of the Earth (1993) and the SAFE (Sustainable Agriculture, Food and Environment) Alliance (SAFE Alliance, 1993).

In contrast, an alliance of actors has been pressing for the MACs to be changed, including the UK Government (1991), pesticide manufacturers (GIFAP, 1990; European Crop Protection Association, 1993) and the British and European water companies (Eureau, 1992). Their main challenges relate to the costs of implementation and the scientific basis of the MACs for protecting health. The MACs are argued to be 'unscientific' because they are not based on toxicological assessments of health risks.

Currently, when water supplies exceed the MAC, water companies have to install equipment to remove pesticides from supplies. The costs of this strategy run to hundreds of millions of pounds (see ENDS, 1992a). Other regulatory responses to the problem are being considered, however. For example, MAFF are conducting a large review of older pesticides using stricter standards than have been used in the past[21]. Moreover, since April 1992 the use of Atrazine and Simazine on non-cropped land has been banned by MAFF. The ban is viewed as a precedent because it is the first major regulatory decision to be influenced directly by the need to comply with the EC MACs rather than by conventional toxicological considerations (ENDS, 1992c, p.33).

Regulatory pressure on pesticides is likely to continue to increase, particularly in the light of agreements made by the Government at the Third International Conference on the Protection of the North Sea in 1990 (Beaumont, 1993) and the increasing interest in implementing policies for sustainable development (UK Government, 1994). It is possible that some of the more persistent and problematic pesticides, which were once approved, will be withdrawn from use. Furthermore, the concept of water protection zones has, since the mid-1980s, been gaining acceptance among policy makers and regulatory agencies (NRA, 1992; RCEP, 1992) who are beginning to consider tougher controls on the *use* of polluting pesticides in specific catchments (ENDS, 1990a; Barnden *et al.*, 1990; Farmers Weekly, 1990). This could follow the model of MAFF's Nitrate Sensitive Areas established in 1989, whereby particularly vulnerable catchments or aquifers are targeted for additional regulatory controls on farming practices in order to protect water quality. This strategy has the advantage of not penalising all farmers in order to solve the environmental problems of specific localities.

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21 As Otter has pointed out "The lack of analytical methodology to follow pesticide movements and fates in the environment has led to the assessments for approval purposes being based on simple models with little validation. Had we known how mobile the triazine herbicides are in the aquatic environment we would not have allowed the widespread uses they now enjoy" (Otter, 1992, p.1).

Water protection zones would mark a significant shift in the pattern of regulation. The focus for regulation has, until now, been the pesticide manufacturer, with chemicals tested before they are officially approved for sale. This means that farmers have been relatively free from regulations designed to prevent pesticide pollution, provided they abide by the manufacturers' instructions laid down on product labels. The lack of farmer-oriented regulation is in marked contrast to the regulation of livestock effluents where it is day-to-day farming practices that have been forced to change to meet stricter water pollution control regulations (Lowe *et al.*, 1992a). Although there are guidelines on how pesticides should be used (MAFF/HSE, 1990), these are poorly enforced (see Chapter 7). The introduction of water protection zones would, however, mean that the focus of regulation would shift to the farmer, and would increase the influence of environmental policy over the pesticide pollution process (see Figure II, p.19).

In the policy debates surrounding the pesticides in water issue a slow and still incomplete shift in the way the nature of the problem is understood can be observed. Traditionally, 'economy' and 'environment' have been considered as two separate spheres, which has meant that environmental problems such as pesticide pollution stand for themselves as isolated and detached phenomena. They are solved by means of environmental policy, typically through standard-setting and end-of-pipe technologies (such as treatment facilities to remove pesticides from supplies at waterworks).

More recently, however, the discourse surrounding 'sustainable development' has challenged this conception, and the economy and environment are becoming increasingly viewed as inseparable spheres. At a cognitive level, environmental problems are not isolated but impinge upon economic activity, requiring not only that the term 'economic' be redefined to include environmental costs, but also that policies focus not just on environmental consequences but on production processes and policies too. The implication is that agricultural pollution shifts from being a problem of unfortunate by-products of production to an indictment of unsound production systems. Thus, with pesticides in water there is an increasing recognition that a preventative pollution control policy requires the regulation of the ways that pesticides are used in production systems, rather than the current end-of-pipe water treatment approach (Beaumont, 1993; Friends of the Earth, 1993; Ward *et al.*, 1993).

3.5 Conclusions

This chapter has explained how the technology/policy model described in Chapter 2 entered a period of structural crisis in Britain and elsewhere. The crisis has more than an economic or budgetary dimension. Crucially, there has been an associated crisis of legitimacy, an important element of which has been a succession of environmental problems. In turn, an increasingly sophisticated environmental critique of the technology/policy model has emerged, and pesticide pollution has been constructed as a problem in this context.

In terms of the pesticide pollution production process illustrated in Figure II (p.19), the structural crisis has affected the nature of the relationship between agricultural support policies and R&D, technology transfer and farm management. Also, the state's retreat from funding agricultural R&D has enabled private companies to increase their influence over the production and diffusion of new agricultural technologies.

The 1980s saw the increasing influence of environmental policy and the system of pollution regulation within the pollution production process after monitoring of pesticides in water began to highlight the spread and levels of contamination. The importance of water monitoring strategies and the production of quantified 'measures' of contamination also demonstrate how what constitutes 'pollution' is itself socially-negotiated. It was the implementation of the EC's Drinking Water Directive that brought the issue to light in the first place. Thus, not only is technological change in agriculture socially shaped, but also the environmental impact and the construction of regulatory solutions can themselves only be fully understood in their social and historical context.

CHAPTER 4:
THE STUDY ARE AND FIELDWORK METHODOLOGY

4.1 Introduction

In this chapter the study area for the local empirical work, the Bedford Ouse catchment, is described, with particular attention paid to the historical evolution of its farming systems, the current agricultural structure, hydrology and local pesticide pollution problems. The methodology for the local empirical work is then explained.

The Bedford Ouse catchment was selected as the location for the study because it appears archetypical of the agricultural pesticide pollution issue in eastern England[1]. This archetypicality is not just a matter of numbers, although recorded levels of pesticide pollution are relatively high in national terms (see Croll, 1986; 1991; RCEP, 1992). More importantly, the catchment could serve as a prototype for the expression and construction of pesticide pollution issues and their regulatory solutions in a national context. In principle, the research could have been extended to other study areas but given constraints on time this would have meant sacrificing the level of detail thought appropriate. An intensive survey strategy was preferred to an extensive one because of the particular interest in processes rather than patterns of change. This choice has, however, meant that a particular type of challenge has had to be addressed: 'How do you know that the area chosen is typical of pesticide pollution problems ?'

Such a question implies that if the study area is not typical, then the study's findings cannot be extrapolated from the particular setting to the general issue of pesticide pollution. This issue has been addressed by Mitchell (1983) in relation to case studies. He argues that questions about typicality betray

> "a confusion between the procedures appropriate to making inferences from statistical data and those appropriate to the study of an idiosyncratic combination of elements or events which constitute a 'case'" (p.188).

This confusion arises from a failure to distinguish between surface relationships (correlations) and logical connections between features of a situation. While the validity of extrapolating correlations from a sample to the whole population does depend on the representativeness of the sample, the validity of inferences concerning the processes which link features does not. In the latter case, and regardless of whether the data are

1 In the early stages of the research, an interview with the Senior Water Quality Officer of Anglia Water Services pinpointed the catchment as one in which serious levels of pesticide pollution had been detected.

quantitative or qualitative, validity depends on the cogency of the reasoning. Describing a relationship does not involve the same sorts of procedures as explaining it.

Questions about typicality usually betray more than just confusion over analytical practice. They also rest on the assumption that the pursuit of 'the typical' is a meaningful quest. In the case of agricultural pollution this assumption is highly dubious. Pollution problems are heterogeneously constituted, locally composed and locally specific (Ward *et al.*, 1994). The research presented here could have sought to identify some combination of the typical arable farm and typical geography, but even if this was possible it would not be able to identify 'typical' pollution problems. A particular type of farming may be typical of a particular area, but there is no such thing as an area or farm that typifies pollution. In these circumstances, it was decided to focus on a single geographical area which was an archetypical rather than a typical locality in the pesticide pollution issue - the Bedford Ouse catchment.

4.2 The Bedford Ouse Catchment Study Area

The catchment of the Great Ouse is one of the largest river catchments in England. It is usually divided into four sections; the Bedford Ouse (Figure 4.1 and Table 4.1), which includes the headwaters from the source to Earith and has an area of 3,030 sq km, the Ely Ouse, with an area of 3,285 sq km, the Middle Level, with an area of 815 sq km, and the Tidal Ouse, which extends to the mouth of the river at King's Lynn in Norfolk and whose area, including the North Norfolk rivers, is 1,455 sq km. The Great Ouse rises at Teatworth near Brackley to the west of Buckingham, and is joined by Padbury Brook at Foxcote, just to the east of Buckingham, the River Tove at Cosgrove, the River Ouzel at Newport Pagnell and the River Ivel between Bedford and St Neots. A number of smaller rivers also feed the Bedford Ouse throughout its length. Most of these rise in impermeable clay covered catchments, their flow dominated by surface water run-off which responds rapidly to rainfall. Groundwater from the Chalk, the Greensand and the Great Oolite aquifers also contribute to the base flow of the river. The total length of all rivers which make up the Bedford Ouse catchment is 775km, the length of the Bedford Ouse itself being 108km.

Approximately one million people live in the Bedford Ouse catchment, almost two-thirds of the population for the whole catchment of the Great Ouse in just over one-third of the whole catchment area, a population density of over 330 people per km^2. The area has gained population rapidly in recent years, particularly as a result of the growth of Milton Keynes and other local towns (Table 4.2).

Figure 4.1 - A Map of the Bedford Ouse Catchment

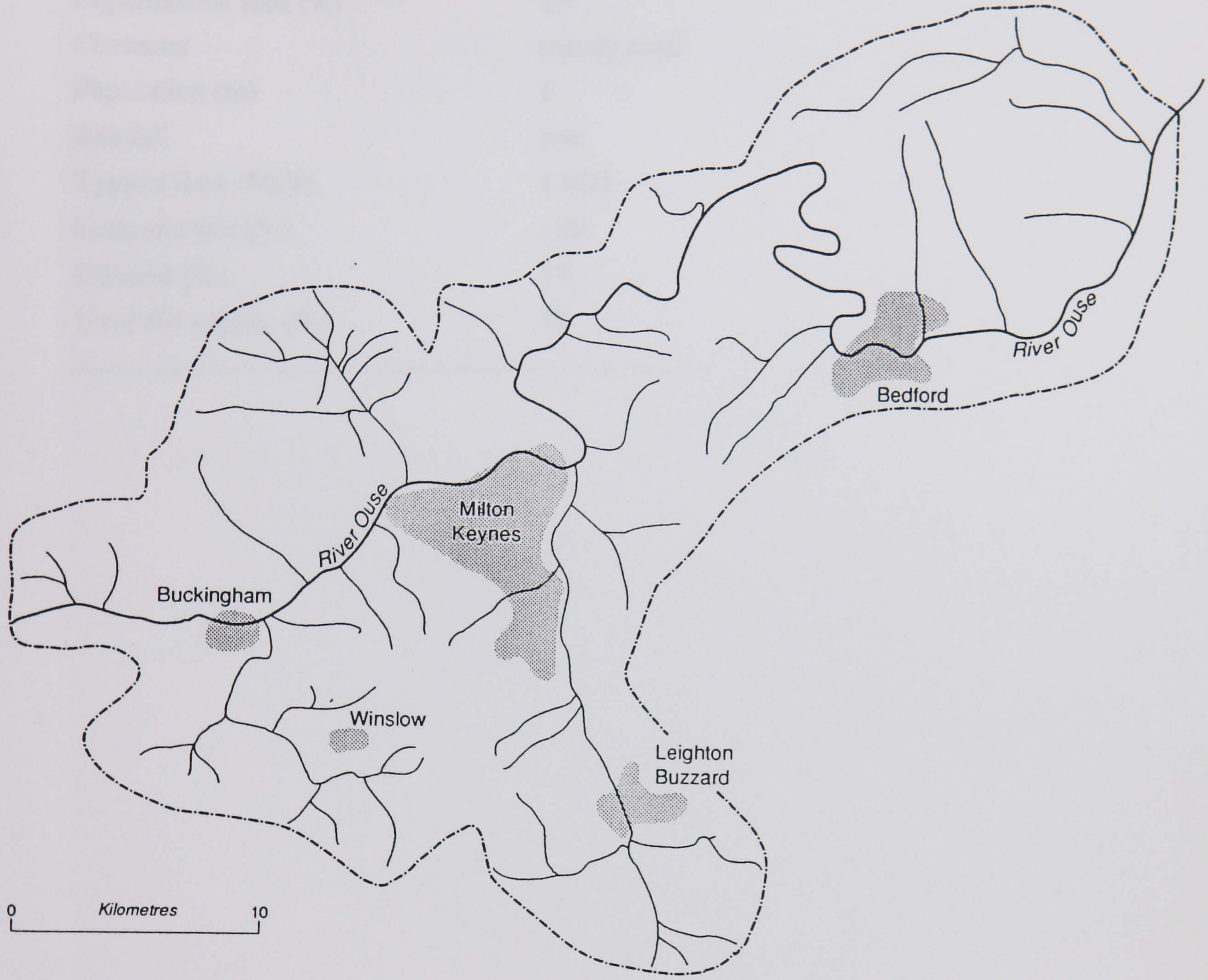

Table 4.1 - The Main Features of the Bedford Ouse

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Source: RCEP, 1992, p.208.

Table 4.2 - Population Growth of the Main Towns in the Catchment

Town	Population 1981	Population 1991	% Growth 1981-91
Milton Keynes	123,296	171,676	+39.2
Bedford	74,300	71,635	- 3.6
Biggleswade	10,900	12,961	+18.9
Buckingham	5,948	9,141	+53.7

Source: 1991 Census of Population.

Population change, coupled with rapid economic development during the 1970s and 1980s, has meant that the local economic context within which farmers run their businesses has been transformed (Murdoch and Marsden, 1994). The Ouse catchment forms part of a particular spatial pattern of population growth in the South East region. This pattern has been summarised by Hall (1984, p.15) as a

> "ring of strongest population growth [which] has moved steadily further out from London...[I]n the 1951-61 decade it was on average...15 to 35 miles from London. By 1961-71 it was...30 to 60 miles away and by 1971-81 more than 60 miles distant".

This pattern of population change is also reflected in rapid economic growth which has 'leapfrogged' the Metropolitan Green Belt, leading to expansion in a series of major towns surrounding London (including Bedford and Milton Keynes). There has also been a parallel shift from manufacturing to service employment, and the area of greatest growth, the so called 'Golden Crescent', lies around the north western part of the outer south east region. The Ouse catchment is situated on the eastern edge of this crescent. Throughout the 1970s, Buckinghamshire's population was the fastest growing in the UK, increasing by nearly 20% between 1971 and 1981. Rapid growth continued during the 1980s, with the county's population increasing by a further 10% (Murdoch and Marsden, 1994). The Green Belt and the Chilterns Area of Outstanding Natural Beauty in the south of the county have meant that much of the 1980s' growth has been channelled northwards towards Aylesbury, Milton Keynes and the Ouse catchment. For example, between 1981 and 1991, the population of Milton Keynes grew by 40%.

Farming in the Ouse catchment area has traditionally been of a mixed character, based mainly upon dairying, sheep and arable enterprises. The proportion of the catchment's agricultural land in the top quality grade (Grade 1) is slightly lower than the national average, whilst almost a third of the land is Grade 2, a proportion more than twice the national average (Table 4.3). Almost 60% of the area is Grade 3 land and 10% is Grade 4. During the post-war period change can be broadly characterised as a gradual 'arable-isation'. Statistics at county level are shown in Table 4.4. For Bedfordshire and Buckinghamshire, the proportion of the total cropped area under wheat and barley more than doubled between 1959 and 1989 from 25.1% to 50.5%. The shift to cereal production began in the 1960s and 1970s and was more marked in Bedfordshire than Buckinghamshire. By 1979, 63% of Bedfordshire's total cropped area was under wheat and barley compared to 42% in Buckinghamshire. These trends are reflected in the agricultural geography of the Ouse catchment. The eastern part of the catchment (in Bedfordshire) is dominated by cereal production, whereas to the west of Milton Keynes (in Buckinghamshire), the catchment has more mixed farms. Here, the spread of cereal

Table 4.3 - The Quality of Agricultural Land

	% of agricultural land area			
	England	Buckinghamshire	Bedfordshire	Ouse catchment*
Grade 1	2.8	0.7	3.6	2.0
Grade 2	14.6	8.3	40.3	30.0
Grade 3	48.9	67.0	53.7	58.0
Grade 4	19.8	23.9	2.4	10.0
Grade 5	13.9	0.1	0.0	0.0

* - estimated figures from map measurements.

Source: MAFF, County Agricultural Statistics.

Table 4.4 - The Changing Proportion of the Area of Crops and Grass Under Wheat and Barley, 1959-89

	1959	1969	1979	1989
Bedfordshire	35.5	53.5	63.4	63.0
Buckinghamshire	18.3	34.3	41.5	41.6
Bedfordshire and Buckinghamshire combined	25.1	41.9	50.4	50.5

Source: MAFF county agricultural statistics.

cropping has also been more recent (see Table 4.4).

Differences in land quality between Bedfordshire and Buckinghamshire have meant that historically cereal yields have been higher in Bedfordshire than in Buckinghamshire. The graphs shown in Figures 4.2 and 4.3 show the changing yields for wheat and barley in Bedfordshire and Buckinghamshire against the average for England. Both wheat and barley yields in Buckinghamshire were lower than the national average for most of the period 1939-1970, while those in Bedfordshire tended to be higher. Since the early 1970s, however, yields have been subject to greater fluctuations and the pattern is less clear[2].

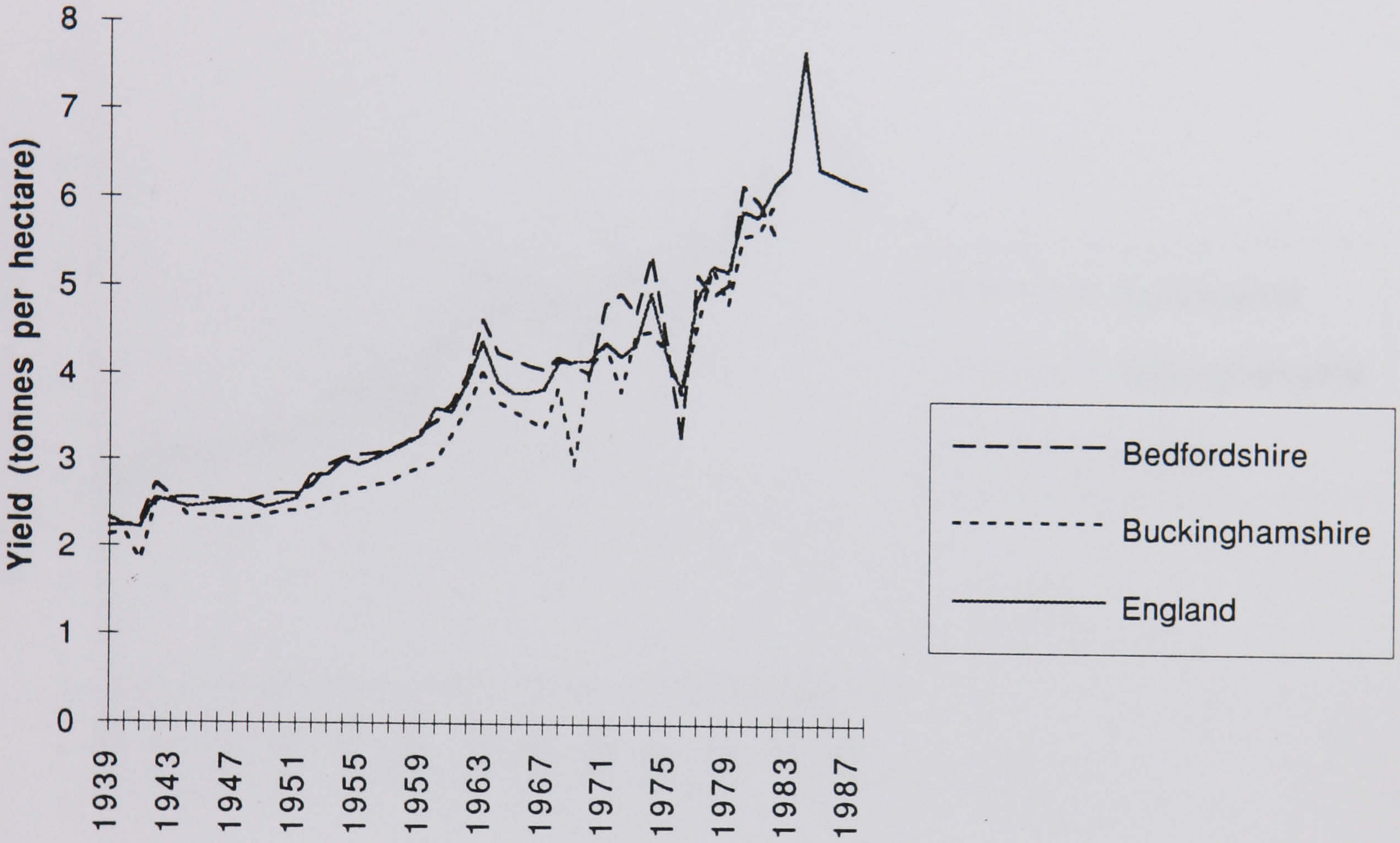
Cereal production in the study area is affected by two main arable weeds - black grass (*alopecurus myosuroides*) and wild oats (*avena fatua*). It is through the relatively successful control of these weeds using pre-emergent cereal herbicides that the growing of cereals has been able to flourish since the 1960s (Wilson, 1992). Surveys have emphasised the durability of grass weeds, despite detailed attention to husbandry (Froud-Williams and Chancellor, 1982; Hollies, 1982), and so herbicide efficacy is usually a significant factor in determining cereal yields (Gwynne and Murray, 1985; Hutson and Roberts, 1987). Research by Hollies (1982) found that over 50% of wild oat and over 40% of black grass treatments gave better than 90% control, but 20% gave less than 80% control, and clear relationships were found between crop yields and weed prevalence. Average yields suffered by 17% from weed competition, and the difference in gross margins between infested and 'clean' crops was calculated to be about 25%.

Black grass is found throughout Britain (Hubbard, 1954) but it tends to be most concentrated in the arable areas of southern England (Figure 4.4) where it now rivals wild oats "as the number one arable weed" (Gwynne and Murray, 1985, 1985, p.113). A 1977 survey recorded black grass present on over 50% of cereal growing farms in England (Elliott *et al.*, 1979) with 40% of the infested acreage being chemically treated, most commonly with Chlortoluron and Isoproturon which "have fairly consistently given the best control of black grass" (Gwynne and Murray, 1985, p.118).

The same chemicals are used to control wild oats which only emerged as a major weed problem following the expansion of cereal production during the Second World War. Concern grew during the 1960s and 1970s to such an extent that a national Wild Oat Advisory Committee was set up to increase awareness of the wild oat 'explosion' and

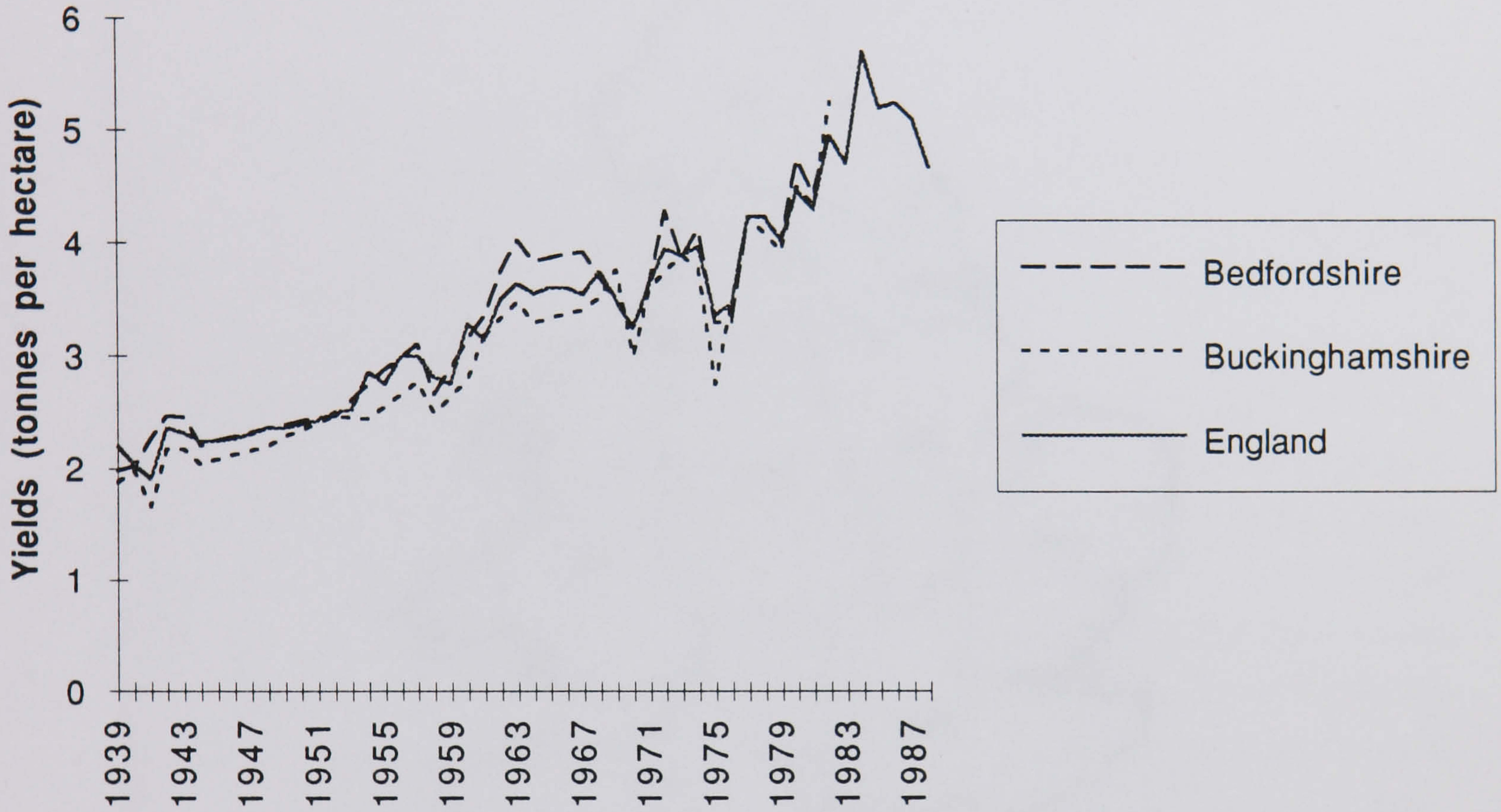
2 Unfortunately, MAFF ceased publishing comparable yield data at the county level in 1982.

Figure 4.2 - Estimated Wheat Yields (in tonnes per hectare) for Bedfordshire, Buckinghamshire and England, 1939-1980s



Source: MAFF Census Statistics.

Figure 4.3 - Estimated Barley Yields (in tonnes per hectare) for Bedfordshire, Buckinghamshire and England, 1939-1980s



Source: MAFF Census Statistics.

Figure 4.4 - The Percentage of Winter Cereal Acreage Infested With Black Grass in ADAS Regions in England and Wales, 1977

Image removed for copyright reasons

Source: Elliott *et al.*, 1979, in Gwynne and Murray, 1985, p.114.

its impacts (Gwynne and Murray, 1985, pp.101-102). The distribution of wild oat infestation during the mid-1970s is shown in Figure 4.5. Since then, wild oats have become more effectively contained in some areas, although the South Midlands and East Anglia remain the most affected areas (Evans and Yates, 1985).

Since the 1970s, the Bedford Ouse catchment has continued to be one of the most heavily infested areas of black grass and wild oats in cereals because of its heavy soils. In addition, the move towards continual cereal cropping had left a reservoir of buried black grass and wild oat seeds, both of which can lie dormant for years in the soil only to germinate after being disturbed by cultivations (Gwynne and Murray, 1985).

Data on the responses by farmers to weed problems in cereals are not collated at local or county levels, although there is some information at the regional level. Two points are clear. First, as might be expected, the regional breakdown of the usage of herbicides corresponds to the geography of cereal production and weed infestation. Thus, as Table 4.5 shows, more than twice as much Isoproturon is used in MAFF's eastern region (1131 tonnes in 1988) than in any other region. Second, data from the annual Farm Business Survey suggest that since the early 1970s, the costs of spraying have become an increasingly important element of total variable costs across a range of cereal crops in the eastern region (Murphy, 1989; 1992). For example, between 1971 and 1991, the proportion of total variable costs taken up by spray costs almost trebled from 15.7% to 46.0% for winter wheat, and more than doubled from 16.0% to 34.3% for spring barley. Similarly, between 1974 and 1991, spray costs as a proportion of total variable costs more than doubled from 20.3% to 43.5% for winter barley (Figure 4.6).

4.3 Water Pollution in the Ouse Catchment

The headwaters of the Ouse catchment lie in gently rolling countryside, but the land soon becomes flat and low-lying. The rain that falls on permeable chalk recharges aquifers rather than running off the surface, and groundwater from the chalk makes up about 50% of the flow of the river at Bedford. This means that seasonal variations in flow are less in the Ouse than in those rivers which receive a greater part of their flow from run-off. Smaller differentials between maximum and minimum flow also make the Ouse a more reliable source of water throughout the year. Thus, according to Warren,

> "the Bedford Ouse is probably better thought of less as a stream of water in an isolated channel than as only the visible part of a much larger body of water moving not only through the river channel but also through the adjacent gravels" (1992, p.224).

Figure 4.5 - Wild Oat Levels and Distribution in 1976

Image removed for copyright reasons

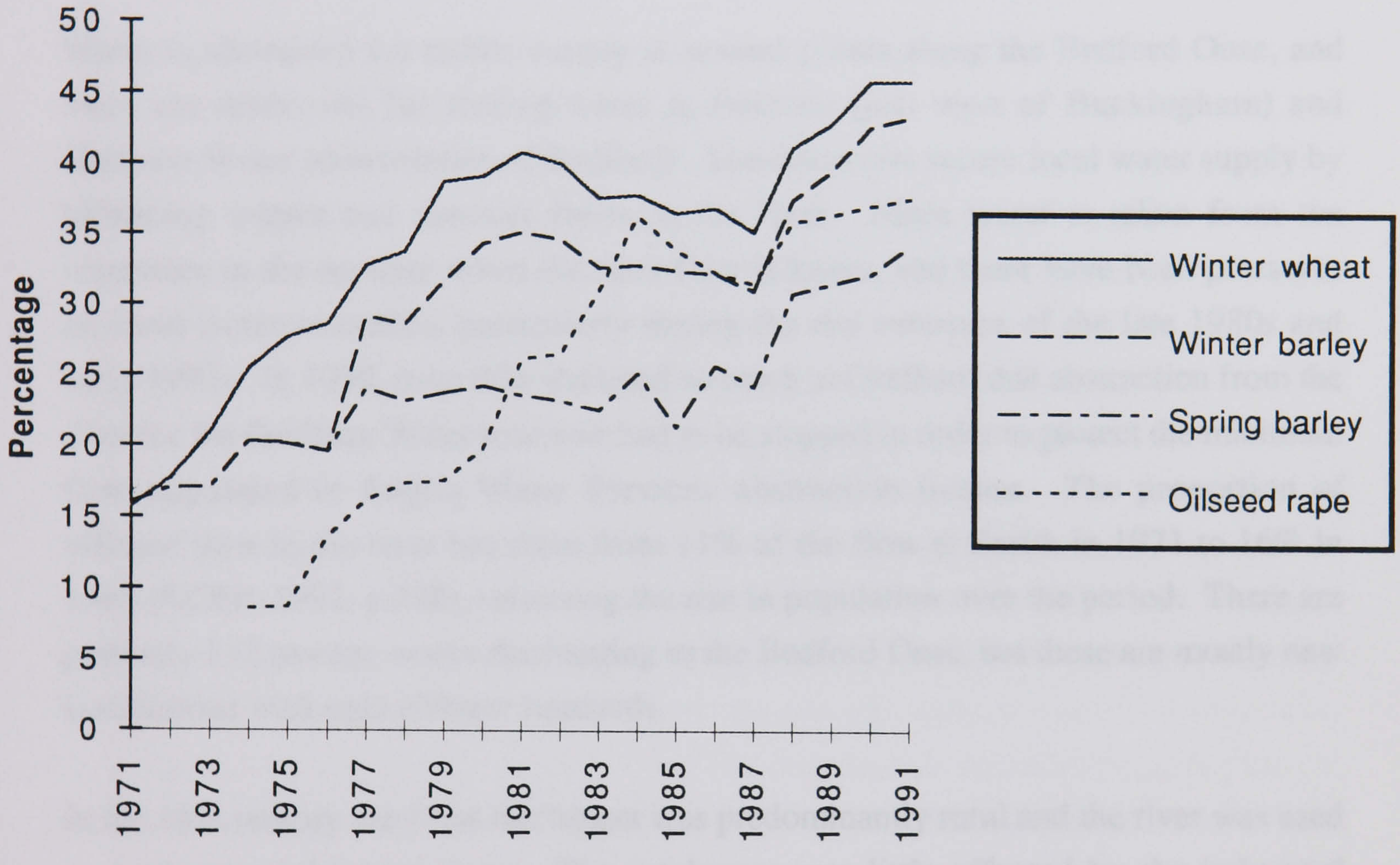
Source: Gwynne and Murray, 1985, p.101.

Table 4.5 - The Regional Use of Isoproturon (IPU)

Image removed for copyright reasons

Source: Drinking Water Inspectorate, 1992b, p.59, using MAFF's 1988 Pesticide Usage Survey data.

Figure 4.6 - Spray Costs as a Percentage of Total Variable Costs for Cereal Crops in the Eastern Counties, 1971-91



Source: Murphy, 1989, pp.34-39; 1992, pp.41-53.

The waters of the Ouse catchment are an important resource for public supply and irrigation. The water used for public supply is returned to the river system as sewage effluent. The effluent makes up an important part of the flow of the river and helps even out flow throughout the year. Moreover, water is exported out of the catchment to supply Luton and Dunstable to the south, with the sewage effluent returned to the Ouse catchment in the headwaters of the Rivers Ouzel and Flit. Water is also extracted all year round at Clapham to supply Bedford. Because effluent is received from a series of sources upstream of Clapham and Grafham, there is "a substantial degree of re-use of the river water" (Warren, 1992, p.226).

Water is abstracted for public supply at several points along the Bedford Ouse, and there are reservoirs for storing water at Foxcote (just west of Buckingham) and Grafham Water (downstream of Bedford). The reservoirs secure local water supply by balancing winter and summer flows in the river. More water is taken from the reservoirs in the summer when the river flow is lower, and there have been pressures on local water resources, particularly during the dry summers of the late 1980s and early 1990s. In 1990, river flow declined so much at Grafham that abstraction from the river for the Grafham Water reservoir had to be stopped in order to protect the minimum flow stipulated in Anglia Water Services' abstraction license. The proportion of effluent flow in the river has risen from 11% of the flow at Earith in 1971 to 16% in 1986 (RCEP, 1992, p.228), reflecting the rise in population over the period. There are currently 112 sewage works discharging to the Bedford Ouse, but these are mostly new installations with tight effluent standards.

In the 18th century the Ouse catchment was predominantly rural and the river was used as a source of drinking water. The catchment was little affected by the industrial revolution of the 19th century. However, water quality began to deteriorate in the second half of this century because of the intensification of agriculture and population growth (RCEP, 1992, p.208). According to the DoE's system of classifying river quality, the Bedford Ouse is class 1B or 2 (lower good and fair) throughout its length, with the exception of a short reach downstream of Brackley which is class 3 (poor). Agricultural pollutants are an important contributory factor to poor river quality, and nitrate levels have been rising since 1965 (Warren, 1992, p.230). By the late 1960s it was estimated that agriculture contributed about 90% of the nitrate in the river (Owens, 1970), and during the 1980s levels have regularly exceeded the 50 mg/l limit of the EC's Drinking Water Directive. As a result, water for Bedford has to be blended with supplies with lower nitrate levels (Whitehead *et al.*, 1981), and it is feared that "additional treatment of water may be needed in future to deal with contamination with pesticides" (RCEP, 1992, p.208). Algae proliferate in local reservoirs at Foxcote and Grafham, both of which are filled from the Ouse, because of high phosphate levels caused by sewage. According to a study conducted for the Royal Commission in 1992,

> "Significant improvements in the Bedford Ouse will ... be difficult in view of increasing demands for supply from a river with an already high degree of re-use. Nevertheless, pollution from pesticides and nitrate is likely to decline slowly as a result of constraints on their use in agriculture" (RCEP, 1992, p.208).

In 1970, chlorinated pesticide levels in the Bedford Ouse were found to be around 0.02μg/l (Billington, 1970), but since then a greater variety of products have been used and in much greater quantities. Surveys in the Anglian Water region have established a range of pesticides in water at concentrations greater than the EC's MAC for drinking water (see Croll, 1986; 1991), and several pesticides have been detected in the Bedford Ouse in recent years. The Department of the Environment has set Advisory Values (AVs) for pesticides in drinking water based on toxicological information, and these AVs tend to be higher than the EC's 0.1μg/l MAC (see pp.101-102). In the Ouse, between 1987 and 1990, recorded levels of Atrazine at Clapham ranged from 0.14 to 1.68μg/l (AV=2); Simazine ranged from 0.02 to 1.89μg/l (AV=10); Mecoprop ranged from 0.1 to 2.7μg/l (AV=10); Isoproturon ranged from 0.2 to 5.13μg/l (AV=4) and Dimethoate from 0.02 to 0.94μg/l (AV=3) (RCEP, 1992, p.231). Isoproturon (IPU) is the only pesticide in the Ouse catchment to have been detected at levels exceeding not only the EC MAC (where it was found at over fift times the drinking water standard) but also the higher AVs set by the DoE. Monitoring has found that concentrations vary considerably from month to month, which suggests that surface run-off of pesticides from farmland is significant (Croll, 1991). Once again, this variation suggests that the timing of the monitoring is crucial to determining the levels of pesticide pollution.

IPU, along with Atrazine and Simazine, is now seen as one of the most problematic pesticide polluting the Ouse catchment. Because Atrazine and Simazine are heavily used by local authorities and British Rail for non-specific weed control, IPU is left as the most serious pollutant solely attributable to farming. The Secretary of State for the Environment was given powers to designate water protection zones within which the use of polluting pesticides could be controlled under the 1974 Control of Pollution Act, and these powers remain under the 1991 Water Resources Act. Under current conditions, IPU and the Bedford Ouse catchment could be seen as leading contenders for regulatory action (ENDS, 1990a, p.7), but so far no such action has been taken in response to agricultural pollution in the Ouse catchment nor elsewhere.

4.4 Methodology and Empirical Schedule

In the spring of 1991 a farm survey was carried out in the Bedford Ouse catchment in Buckinghamshire and Bedfordshire (Figure 4.1). All the farms surveyed either had a cereal enterprise, or had recently stopped growing cereals, and all were located within the catchment. In total, 63 farmers were interviewed, drawn from two other samples. The first of these - the 'Arkleton sample' - contained 300 farms in Buckinghamshire which had been surveyed in 1987/8 and again in 1991 as part of a European-wide, EC-funded research programme examining pluri-activity and co-ordinated by the Arkleton Trust (Arkleton Research, 1990; Shucksmith *et al.*, 1989; MacKinnon *et al.*, 1991). The 'Arkleton sample' was provided by the Ministry of Agriculture's Census Branch from its list of registered agricultural holdings. A list of 300 names and addresses was supplied according to a standard sampling frame used in each of the 24 European study areas. This sample, stratified according to farm size in terms of land area, was designed to allow comparison between similar sized holdings throughout Europe. Given Britain's relatively small number of small farms in European terms, this sampling frame made for an over-representation of smaller farms in the Buckinghamshire sample (see Table 4.6). However, bias was reduced through the drawing of a sub-sample based in the Ouse catchment which only contained cereal producers because these tended to be the larger farms. Moreover, any drawbacks arising from bias in the original Arkleton sample were considered to be outweighed by the advantages of interviewing farmers who were already part of a longitudinal study and for whom background information on farming change was already available.

The 'Arkleton sample' was analysed and it was found that of the 300 farms, 65 were growing some cereals in 1988 *and* fell within the Bedford Ouse catchment area. Arrangements were made such that at the end of each interview in 1991, the Arkleton researcher asked these selected farmers if they would mind being visited again during the following few weeks by an associate to talk about the environmental issues they faced. Interviews were then arranged by telephone with those who agreed, making for a relatively high response rate (14 refusals from 63 farmers contacted). In each case, the household member who identified himself or, occasionally, herself, as being in charge of the farm business was interviewed.

This sample of 49 Buckinghamshire farmers was 'topped up' with a further 14 interviews with farmers from another sample in order to increase the number of farms to be studied. The second sample of 79 farmers in north Bedfordshire covered an area which overlapped with the Ouse catchment. The farmers had been interviewed in 1985 as part of a large study of farm occupancy and landscape change in five different

Table 4.6 - The Size of Farm Holdings in Buckinghamshire

Size category	MAFF Census statistics		Arkleton Sample		Ouse catchment Sub-sample	
	No.	%	No.	%	No.	%
Under 20ha	841	41.4	178	59.9	1	1.6
20-99.9ha	765	37.6	109	36.7	18	28.6
100-299.9ha	374	18.4	8	2.7	30	47.6
300ha+	52	2.6	2	0.7	14	22.2
Total	2032	100%	297	100%	63	100%

Note: The MAFF census data relates to 1989 and the Arkleton data is from the first baseline survey in 1987. Both these data sets contain all types of farm, whereas the Ouse catchment sub-sample used for the research for this thesis contains only cereal producers.

English study areas (see Munton *et al.*, 1987a; Ward *et al.*, 1990). The sample was re-analysed and it was found that 20 of the farms fell within the Ouse catchment *and* grew some cereals when last interviewed. It was possible to contact 17 of these farms, and 14 agreed to be interviewed. This number, combined with the farms drawn from the 'Arkleton sample', yielded a sample for the survey of 63 farmers in the Ouse catchment. The additional Bedfordshire farms, which were on average much larger farms, also provided a means by which the farm size bias in the original 'Arkleton sample' could be further reduced. As Table 4.6 illustrates, the Ouse catchment sub-sample contains a greater proportion of larger farms and a smaller proportion of smaller farms than MAFF's census returns indicate for the whole population of holdings in Buckinghamshire[3]. Cereals tend to be found on larger farms in the region, and both the MAFF Agricultural Census data and the original 'Arkleton sample' contained smallholdings characterised by part-time sheep enterprises and the letting of grass keep. Thus, there is no reason to suspect that the derived sample is not broadly representative of *cereal producers* in the Ouse catchment.

The main objectives of the survey were to reveal farmers' perceptions of pollution problems and how they might be solved, to identify the economic and technological choices they face, and to understand how they have adjusted their practices to changing economic and regulatory circumstances. In addressing these objectives, and in the light of the conceptual approach described in Chapter 1, three main methodological issues were addressed.

First, there was a concern to go beyond the enumeration of attitudes and to avoid imposing definitions upon the interviewees. It was intended to capture farmers' own representations of pollution problems and to understand how their interests and actions are constituted. These matters raised issues of question type and design. In general, researchers of agricultural issues tend to use highly structured surveys, but it was felt that this survey should include open-ended questions. Second, some quantitative data were needed, primarily relating to the farm, its enterprises and farming practices, in order to set other responses in context. A balance had to be struck between quantitative and qualitative questions, bearing in mind the need to avoid too lengthy an interview. Third, the topic of study was a contentious issue for the farming community. In the main, farmers feel defensive about environmental issues, and feelings have been running high in the aftermath of a whole series of food safety and environmental scares in which the finger had been pointed at the farmer. Any farmer who had been

[3] It must be made clear, however, that this comparison is between a sample of farms in the Ouse catchment which straddle Buckinghamshire and Bedfordshire, although more than three-quarters of the farms fall within Buckinghamshire, and MAFF returns for just Buckinghamshire.

prosecuted in the courts for a pollution offence would be likely to be particularly sensitive to ill-considered questioning.

Following standard practice (Fowler, 1988) a pilot study was organised to test the first draft of the questionnaire. Particular emphasis was placed on checking the clarity of the questions, the consistency of farmers' understanding of the terms used, the quality of their responses, as well as their sensitivity to the emotive issues to be probed. The pilot study also enabled the identification of additional questions and the removal redundant ones. Ten farmers were interviewed in June 1990 for the pilot study. The sample was drawn from earlier studies (Munton *et al.*, 1987a) and consisted of farmers who had been noted as 'good respondents' in field notebooks. The interviews were tape-recorded and subsequently transcribed, and the results used to develop the final survey questionnaire. Farmers included in the pilot survey were excluded from the main survey.

The pilot survey identified a number of important issues in the development of the questionnaire. Firstly, the ordering of the questions was critical. The quality of responses and the general tone of the interviews improved if more general questions about farm characteristics were asked first and the more specific and detailed questions about pesticides and pollution problems were left until later. Farmers were much more willing to explain how they felt about pesticides and pollution issues once they were confident that the research was intended to *study farmers' problems* and its findings were not to be used as further criticism of farming practices *per se*. Secondly, the breadth of some of the issues, combined with the level of detail required, meant that there were pressures on time. It was, therefore, important that any overlap amongst open-ended questions be minimised. Any questions requiring a simple 'yes' or 'no' answer, or straight-forward factual responses, were put into a 'tick-box' form. Where possible, farmers were passed a card with optional responses listed on it. Thirdly, problems with differing interpretations of some terms were highlighted. For example, it became evident that the farmers in the pilot survey had a narrower definition of technology than expected. They seemed to see technology as primarily computers, electronics and big, complicated machines. Hence the term 'products and practices' replaced technology in the final questionnaire. Finally, it became clear that farmers were more prepared to talk about the environmental consequences of agriculture in general and about 'other farmers'' practices than to consider the impact of their own farming procedures. It therefore became necessary to address this issue in a more subtle and indirect way.

In consequence, the questionnaire was redesigned so that the interviews would take the form of 'structured' or 'mapped' conversations rather than simply lists of questions 'fired' at the farmers. As well as redesigning particular questions, removing some and including new ones, the questionnaire was ordered such that sections logically followed on from one another. (A transcription of a pilot interview is included in Appendix A and the full questionnaire for the farm survey is included in Appendix B).

The first section of the final questionnaire was designed to elicit straight-forward factual information on the general characteristics of the farm business and household, with particular emphasis on how, and why, circumstances had changed during the period 1981-1991. As the survey involved returning to farms which had already been studied, much of this section was a matter of checking on the accuracy of existing data which had been transposed from earlier questionnaires, and filling-in gaps and bringing material up to date.

In the second section, the style of the questions differed. Here the aim was to gather material on farmers' motives, ethos and aspirations, on their perceptions of the choices and constraints which they face, and on their expectations of the future, including succession to the business. The concept of the family's farming 'strategy' was of particular interest. It was also hoped to tease out the role of environmental perceptions in the construction of the farmer's business tactics and self-image. Responses were intended to shed light on what drives change on farms, in order to help understand the different approaches to pollution control adopted by farmers which were addressed later in the questionnaire. The third section examined farmers' understanding of the role of technology. It probed, *inter alia*, who, in their view, gained from technological change and where they believed technological change was heading.

By this stage, about half way through the interview, responses elicited a strong sense of the characteristics of the farm household and business, how and why these had changed during the 1980s, how the philosophy or style of farming was perceived and justified, and in which direction it was hoped the farm business would develop in the future. Pollution had not been raised explicitly by the interviewer and if the environment had cropped up in discussion, it would have been at the farmer's instigation. The next section of the questionnaire tackled environmental issues. These were introduced by a question about environmental damage with the words "*some people say that...*". By these means it was hoped that the interviewer could remain disassociated from criticism of the farming community. The following questions then invited farmers to discuss how environmental concerns had affected their farming and to outline any experiences they had had of direct pressure to alter their ways from neighbours or officials.

The more contentious pollution issues were then introduced into the conversation indirectly by means of a question on sources of advice concerning various farming activities, including drainage, crop nutrition and pesticide use. This question provided the critical link with the next section which elicited specific technical details on farming practice in relation to potentially polluting activities. The key questions covered how and why herbicide use had changed, and what determines when and how agrochemicals were applied. A series of questions followed which related to farmers' perceptions of the scale of agricultural pollution in relation to that from other industries and the nature and effectiveness of pollution regulations. Scenarios were used to establish farmers' preferred policy options for the regulation of pollution, and their perceptions of the impact of different regulatory regimes on their own businesses. Finally, farmers were asked about any contact they had had with the NRA and HSE, and how they personally viewed NRA and HSE staff and their styles of regulation.

The main farm survey took place between April and June 1991. Most interviews lasted between one and one and a half hours, although several lasted over two hours, and the longest took over three. The material collected via the questionnaire was supplemented by a field notebook in which additional details were recorded immediately after the interview. The main points covered in this less formal way were the tone of the interview, the quality of the farmer as a respondent, the appearance of the farm, and any particularly instructive or revealing responses. This material proved useful in assisting with the post-coding of data and the interpretation of the questionnaire responses.

The farm survey work was supplemented by semi-structured interviews with officials and representatives from farming and environmental groups and other actors in the science and policy world. Here, besides eliciting views and perceptions of the pesticide pollution problem and how it might be solved, information was also sought on how interviewees had participated in certain key developments, such as the drawing up of the revised Code of Good Agricultural Practice and the implementation of regulatory policy. In effect, the interviews in many cases were part oral history (see Thompson, 1978).

For this reason the structure of the interviews was necessarily quite loose. The actors interviewed were located at different places in the network and their roles were generally particular to the individual, so it would not have been sensible to ask each of them exactly the same set of questions. Rather, each interview was approached through a number of issues and themes which it was hoped that the interviewee would be prepared to discuss. This stimulated particular lines of thinking, and various devices were used to keep the conversation open. These included letting the interviewee speak in his or her own terms, avoiding interruptions except for purposes of clarification or when time was short and important issues remained to be covered, and asking, once the prepared themes had been covered, whether there was anything else that the interviewee wanted to discuss. Each interviewee's position and role in the network was always established, along with the nature and extent of his or her participation in the pollution issue. Frequently, it was found that on reflection points needed clarifying or new questions arose. These were pursued by letter or telephone.

A 'snowball method' was used to identify prospective interviewees in the science and policy arenas. Information obtained from official publications identified a number of key witnesses. They in turn suggested other people who had played key roles or who might otherwise assist, and so on. Most of the interviews were attended by at least two members of the PATCH research team (see Footnote 3 on p.16) and notes taken during each interview were fleshed out in more detail immediately afterwards. Interviews were then typed up as soon as possible. Not all interviews were carried out by the author, although all interview transcripts from the PATCH Programme have been made available for the research informing this thesis[4].

This type of interview provided rich data. The methods were sufficiently detailed for the results to be taken as accurate and believable accounts of individuals' views and experiences. In some cases, however, especially those of policy actors, they are unlikely to be complete accounts, either because particular questions were not asked or because the person concerned preferred not to comment. Nonetheless, the results are regarded as sufficient for the purpose of attempting to analyse the phenomenon of pesticide pollution and the construction of solutions to it.

4.5 General Characteristics of the Ouse Catchment Farm Sample

The 63 farms in the Ouse catchment sample could not be said to form a group of traditional 'family farms' as described elsewhere in the literature (see Symes and Appleton, 1986; Marsden *et al.*, 1989). They compare more directly with the kinds of unit in Buckinghamshire described by Marsden *et al.* (1991) and those in Bedfordshire described by Munton *et al.* (1987a). Farm business ownership, for example, is complex and differentiated. While almost two-thirds of the farms (40 farms, 63.5%) were owned as family partnerships, only a fifth (13 farms, 20.6%) were owned by 'sole operator' individuals and about a sixth (10 farms, 15.9%) were limited companies

[4] A list of those actors interviewed is included as Appendix C, and the list differentiates between those interviews that were carried out by the author and those conducted and transcribed by colleagues.

owned and usually managed by company directors. The trend during the 1980s was a gradual move towards more complex forms of business ownership. Twenty-four proprietors (38.1%) altered the structure of their businesses, although the vast majority concerned personnel changes within family partnerships. Eighteen of the changes involved either a new partner entering the business or an older partner retiring, or both. The remaining changes involved the establishment of limited companies and family partnerships. Traditional, local farming families appeared less dominant than in other areas of Britain (Marsden *et al.*, 1987; 1989; 1992b) and over 60% of the farmers surveyed said that they had no other close relatives involved in farming in the local area (north Buckinghamshire and north Bedfordshire).

A variety of agricultural enterprises were found among the sample. A third were arable farms with no other agricultural enterprises. Just over a quarter (17 farms, 27%) were mixed arable and livestock farms where the farmer considered the arable enterprise to be the most important in economic terms. Fourteen farms (22%) were mixed enterprises but chiefly dairy farms, and 9 farms (14%) were mainly sheep, beef or pig farms. On three farms, all arable land had been entered into set-aside schemes since 1988[5]. The mix of farm enterprises varies with the geography of the study area, with mixed arable and livestock farms being more numerous in the western part of the catchment while larger, wholly arable farms dominated the area to the east of Milton Keynes.

The mean farm size for the sample was 217 hectares (541 acres) and the median was 158 hectares (390 acres). Average farm size varied considerably according to the mix of farm enterprises. As Table 4.7 shows, those farms that were wholly arable had by far the largest average size. The average size of the 14 farms in the sample where dairying was the most important enterprise was less than half that of the specialist arable farms. Not surprisingly, the average area of land under cereals in 1991 was greatest for the wholly arable farms, and least for the dairy farms.

Farm size is also linked to business organisation. The limited companies tended to be much larger businesses and averaged 484 hectares in size. This compared with an average of 182 ha for the family partnerships and 121 ha for the sole operator businesses. During the period 1981-1991, 22 of the farms (34.9%) grew in size, 28 farms (44.4%) stayed the same, while 13 (20.6%) experienced a net loss of land. It was, on average, the larger farms that were more likely to grow and smaller farms that were more likely to shed land. The average size of the 'expanders' was 313 ha compared with 137 ha for those that experienced a net reduction, and 180 ha for those

[5] Those farmers who had ceased growing cereals were asked about pesticide use, advice and cropping arrangements at the time when they last grew cereals, which would have been at least as recent as 1988.

Table 4.7 - Farm Enterprises, Average Size and Area of Cereals

Farm Type	No. of farms	Mean Farm Size (ha)	Mean Area under cereals in 1991 (ha)
Arable	20 (32%)	310.2	173.0
Mixed (mainly arable)	17 (27%)	225.4	117.6
Mixed (mainly dairy)	14 (22%)	131.4	44.4
Mixed (mainly sheep, pigs or beef)	9 (14%)	167.2	64.3
Other (*e.g.* set aside)	3 (5%)	106.7	0.0

Source: Farm survey.

that did not change. The 'expanders' grew in size by an average of 71 ha (22.7%) between 1981 and 1991, while those that got rid of land shrank in size by an average of 27 ha (19.7%).

Tenure and land rights were also subject to restructuring during the 1980s. In 1991, almost two-fifths of the sample (24 farms, 38.1%) were wholly owner-occupied farms, 27 farms (42.8%) were mixed owner-occupied and rented, and under two-fifths (12 farms, 19.0%) were wholly rented. Taking the farmed area of the sample as a whole, the farms covered 13,702 ha (33,855 acres) of the catchment area, 9,792 ha (71.5%) of which was owner-occupied land, 3426 ha (25.0%) was securely rented as defined under the Agricultural Holdings legislation, and just 484 ha (3.5%) was rented under insecure leases. As Table 4.8 shows, the total area farmed by the 63 farms increased by 1217 ha (9.7%) between 1981 and 1991, with land under insecure leases expanding by over 20%, land under owner-occupation increasing by 17% and land rented under secure leases falling by 17%.

There is no reason to suppose that the 63 farms do not comprise a broadly representative sample of cereal producers in the Ouse catchment in terms of the range of sizes present, the types of enterprise and the various ownership arrangements. Indeed, the farm characteristics and types of changes outlined above broadly parallel those of other studies and so, in the context of the recent literature, can be said to be fairly typical of recent trends more generally (Carr, 1988; Munton *et al.*, 1987a;b; Whatmore *et al.*, 1987b).

In Part III of the thesis, some of the material obtained from the farm survey will be presented to illustrate the current context for farmers' pesticide practices. In Part I a particular conceptualisation of pesticide use and pollution was developed in which emphasis was placed on farmers' actions in the context of the historical evolution of a technological system. In Part II the historical evolution of pesticide use in association with British agricultural policy was examined, along with the onset of the crisis of productivism in the 1980s and the emergence of pesticide pollution as an issue of public and political concern. Part III goes on to use the empirical material to explore the contemporary conditions surrounding pesticide use and pollution in a particular locality.

In the empirical analysis, the sample size is not large enough to support detailed statistical analysis of sub-groups of the sample. No attempt will be made to use statistical analysis to identify causal relationships between farm or farmer type and pesticide practices. Instead, the main analytical task is to identify key characteristsics among the sample in relation to families' farming strategies, farmers' understandings of

Table 4.8 - Net Change in the Area Occupied - 1981-91 (ha)

Date	Owner Occupied	Secure Leased	Insecure Leased	Total
1981	8382	3701	402	12484
Gains	+1509	+ 190	+121	+1820
Losses	- 98	- 465	- 40	- 603
Net	+1410	- 275	+ 81	+1217
1991	9792	3426	484	13702
% change 1981-91	+16.8%	-7.4%	+20.2%	+9.7%
% of 1991 total farmed area	71.5%	25.0%	3.5%	100%

Source: Farm survey.

environmental problems and pollution, pesticide practices and attitudes to advice, and to explore the spread of different traits through the sample.

In the next chapter the experiences of the sampled farmers during the agricultural crisis of the 1980s are examined, along with their strategies for coping with their rapidly changing contexts, their understandings of environmental change and their pesticide practices. Chapter 6 then examines in detail the role of technical advisors in farmers' decisions about which pesticides to use and how to use them.

In Chapter 7, farmers' understandings of the nature of the farm pollution problem in the Ouse catchment are explored and their views are compared with those of a sample of dairy farmers interviewed in Devon in 1991 as part of the PATCH research programme (see Footnore 3, p.16), before going on to examine farmers' relations with the regulatory authorities and their possible responses to restrictions on herbicide use.

CHAPTER 5: AGRICULTURAL RESTRUCTURING AND CHANGING PESTICIDE PRACTICES

5.1 Introduction

In this chapter empirical evidence is presented to describe and account for change during the 1980s on the sampled farms in the study area. The varying strategies employed by farm households are examined, and particular attention is paid to the reorganisation of farm enterprises and farming practices and the search for new forms of income through diversification and land development. Farmers' philosophies, their representations of farm 'improvement' and 'nature' and their responses to increasing environmental concern are explored, before discussing how pesticides are used and understood.

The analysis will seek to demonstrate how pesticide practices, and the ways these change over time, are subject to different sets of sociological and economic processes. Pesticide practices need to be set within an understanding of farm business and household development trajectories and, in particular, the changing economic importance of arable production. A farm household almost totally dependent on cereal production provides a quite different context for pesticide use to one where, for what ever reason, the goal for farm production is simply to break even. Moreover, pesticide usage is closely bound up with farmers' 'ways of thinking' about what constitutes good farming, healthy farms and improving the land.

5.2 Heterogeneity and Agricultural Change

A recurring theme in Part I was the marked shift in the 1980s in the structural conditions within which farmers operate. As the economic fortunes of British agriculture entered a period of steady decline unprecedented in the post-war period, certainty became replaced by uncertainty. Farm households sought to ensure survival by means of a range of different strategies. For example, land and business ownership arrangements have been restructured and labour has been shed, while some farm enterprises have been rationalised or closed down, and others have sought new sources of non-agricultural income. As it has become more difficult for farm families to make a living from farm-based production, so the variation in survival strategies has increased. Indeed, differentiation has become an important feature of the 'post productivist' period for British agriculture. At first glance, the 63 farms surveyed in the Ouse catchment provide a relatively coherent sample. All the farms fall within the same river catchment, and all grew some cereals (wheat, barley or oats) in the 1987/88 season. Yet, despite these commonalities, the sample is highly differentiated in terms of what farm families are doing and for what reasons.

Falling profitability has been a key feature of the 1980s for farm businesses in Britain (see pp. 87-89). Farms in the Ouse catchment have been no exception, with declining financial returns from agricultural production a common experience. Farmers were asked if their *farm* businesses had made a profit, a loss or broken even, taking the results from the three most recent financial years together (*i.e.* April 1988-March 1991). Just under half the farmers (31 farms, 49.2%) claimed to have made a profit, five of whom emphasised that the profit was 'only slight'. Twenty businesses made a loss and 12 had broken even. When asked how viability had changed during the 1980s, 50 farmers (79.4%) said that their economic returns had declined, and nine said that they had increased, with no change on four farms. Static or falling real prices and rising costs of production were the main reasons cited for falling profits.

Producer prices for agricultural products have been declining in real terms since the 1950s, except for a five year period in the mid-1970s following Britain's entry into the EC and the world economic crisis of 1973. Since the 1970s, the downward trend has resumed and at a faster rate. Producers' real prices have been falling at an annual rate of 1.9% since 1974, but the decline since 1976 has been at an annual rate of 4.4% (Britton, 1990, p.10). There has been additional downward pressure on cereal prices since the mid-1980s as the EC has sought to tackle the budgetary problems caused by over-production. In 1986 the Commission introduced a 'co-responsibility levy' to penalise producers for over-production, followed in 1987 by a stabilizer package which set a production threshold for the EC of 160 million tonnes. By limiting intervention buying, farmers suffered because of the price penalties attached to the production threshold (Neville-Rolfe, 1990).

As well as financial pressures on cereal production, EC steps to control over-production in other commodities have also affected agriculture in the Ouse catchment. For example, 14 farms in the sample were mainly dairy units and a further eight had gone out of dairying during the 1980s. For these farmers, the 1980s had proved to be a tumultuous time with the introduction of milk quotas in 1984. The move caused surprise and consternation among dairy farmers who found their milk production was suddenly restricted to an amount 9% less than their 1983 output. However, once dairy farmers had recovered from the initial shock, it became accepted that the quota system did at least provide some stability for their sector. In addition, milk quotas helped, at least temporarily, to avoid the sharp price reductions that soon were to be visited on other sectors and through the late 1980s dairying was the most profitable farming sector (MAFF, 1992). However, since their introduction, milk quotas have been cut periodically in order to bring output more into balance with consumption within the EC, and the quota for 1991-92 was only 81% of the 1983 production level. Moreover, in 1990-91 the net price received for milk in the UK fell in absolute terms for the first time since 1984 (Federation of United Kingdom Milk Marketing Boards, 1991, p.104).

Not surprisingly then, 55 of the 63 farmers (87.3%) cited financial pressures as the most important difficulty they faced. Not only were prices for farm produce static or falling in real terms, while the costs of labour, machinery and other inputs continued to rise, but at the time of the survey (April-June 1991) interest rates were at historically high real levels, causing extra difficulties for those with mortgages or overdrafts. The sense of despair was widespread and deeply felt. One farmer explained;

> *"This last three years, the whole business feels like it's ground to a halt. You don't know what to do or where to go...There is a lack of profit to reinvest and you don't feel the farm is going forward. It's very difficult to accept after a period of expansion and improvement "* [Farmer interview no.29].

The second most prevalent difficulty cited by the farmers, and exaggerated by the first, was uncertainty (mentioned by 20 farmers, or 31.7%). It derived from a variety of specific concerns. Firstly, two sets of international negotiations were underway at the time of the survey and their implications for British agriculture were the source of much speculation in the farming press. The Common Agricultural Policy (CAP) was to be reformed with the aim of cutting subsidies, while negotiations under the Uraguay Round of the General Agreement on Tariffs and Trade were also seeking to move farm prices closer to world market levels. The two sets of negotiations left farmers feeling insecure about future farm prices and contemplating the prospect of compulsory set-aside for cereal land under a reformed CAP. In addition, the day to day uncertainty of the markets, particularly for beef and sheep, was unsettling those farmers with livestock, as were fears over the future of milk quotas. Concern centred on the regulation of markets by politicians and bureaucrats, and especially those in Brussels.

Nineteen farmers (30.2%) also pointed to increased regulations. Regulations relating to the Control of Substances Hazardous to Health (COSHH) had been introduced in 1988 and were a major source of complaint (see also Blake, 1991). They required, *inter alia*, that farmers assess the risks to workers and the environment posed by pesticide use and record these on paper as a 'COSHH assessment'. One farmer complained that "*you are required to be a walking encyclopedia*". In addition, a straw burning ban was about to be introduced. Other types of environmental regulation were also cited as posing 'major problems'. Nine of the 19 farmers who complained about greater regulation specifically mentioned the control of water pollution. Most of these had significant livestock enterprises. As one farmer with a large beef herd explained

> "*Complying with all the regulations [is a major difficulty]. It's impossible to keep up with them all. The National Rivers Authority will cost farmers more than ever and will drive a lot out of dairying*" [Farmer interview no.35].

Only three mentioned controls on agrochemical use. There was a feeling that COSHH, in particular, was far too detailed in its application to agriculture. One farmer, running a 170 ha beef and arable farm, exclaimed that

> "*Increasing water pollution legislation [is a major difficulty]. I can cope at the moment but if more agrochemical restrictions are introduced, or new legislation on nitrogen....Quite a lot of these things keep coming along. Often you can comply with the spirit of them but not the letter...and there's always a cost involved*" [Farmer interview no.40].

Related to increased regulatory interference was concern at the changing public perception of agriculture. Seventeen farmers (27%) cited this as a major difficulty. Most farmers viewed their falling public standing as closely bound up with increasing environmental controls over farming practices (see also Ward *et al.*, 1994). Difficulties often manifested themselves in conflicts between farmers and non-farming people in rural communities, and access had become a point of conflict for four farmers. But most complaints were less specific and were aimed at the media's representation of farmers and environmental problems. One particularly bitter farmer in his 50s complained;

> "*The bloody public have become anti-farming and want to take over the countryside. They want to mind their own business. They think they own the place. It gets my back up*" [Farmer interview no.44].

Ask any profession to list the major difficulties they face, and lack of money is sure to rank high on the list. However, amongst the farmers interviewed there was a very strong sense that they were experiencing financial pressures the like of which they had not known before. This was combined with a sense of frustration and helplessness arising from a lack of control over their destinies. A frequent comment was that even by working harder and harder, the situation could be little improved. For some, the sense of despair was forcing a rethink about continuing in farming. One farmer who had been required to lay off his farm-hand through financial pressures, and was also considering seeking work off the farm, candidly explained, *"The job has become very insular. You are stuck on the farm and you can go 3 days without seeing anyone else apart from the family. You can get a bit fed up with your own company. I miss my man. You know, I find it harder to motivate myself"* [Farmer interview no.39].

It was not surprising then, that when the farmers were asked if they felt that things were more difficult for them in 1991 than they had been 10 years earlier, the response was emphatic. Only two farmers felt that things had improved. One had been establishing himself in business in the early 1980s and felt that he was in a more secure position now. The other was an elderly farmer in his 60s who was running down his business before retirement and was enjoying new vocations. The important point is the strong sense that things were getting worse. Many felt they had to work harder and yet they were losing public and political support.

A particular source of pressure was the level of borrowing. Eighteen farmers (28.6%) had mortgages for the purchase of land, most of which were taken out with banks, although 7 were with the Agricultural Mortgage Corporation. Forty-three farmers (68.3%) had loans for other purposes, 29 for machinery, and 36 had overdrafts. Table 5.1 shows the level of indebtedness among the sample. Although data on change in the level of indebtedness was not systematically collected, many farmers commented that their debts had increased in recent years at a time of low incomes. Whilst a quarter of the sample had no borrowings, on 18 farms (28.6%) over a quarter of annual farm income was taken up by loan repayments and interest.

Tighter financial conditions were forcing a range of responses. 'Family farming' is less dominant in Bedfordshire and Buckinghamshire than might be found in other parts of Britain (Whatmore *et al.*, 1987b), and this was reflected in the sample. At one extreme was a group of large farming companies, whose origins may have been as large family farms, sometimes employing managers to oversee the day-to-day running of the farming operations. At the other extreme, was a group of smaller farms where the operators had significant business interests outside agriculture and could, therefore, be described as part-time or hobby farms. Between them were family farms where the interests and aspirations of family members were more closely linked with the fortunes of the farm business. The strength of the family's ties to the farm is often derived from a combination of the historical pattern of land ownership and future plans for the business, and it is notable that over a third of the farmers interviewed (22 or 34.9%) had not taken over the farm business from another family member, and only 34 farmers (53.9%) were planning to pass on the farm to the next generation in the family. A study in Buckinghamshire in the late 1960s found the proportion of farms being managed with a succession to the next generation planned for to be 75% (Harrison,

Table 5.1 - Level of Indebtedness Among the Sampled Farm Businesses

Proportion of annual farm income taken up by loan repayments and interest.	No. of Farms	%
None	16	25.4
Less than 1/4	25	39.7
1/4 - 1/2	11	17.5
1/2 - 3/4	3	4.7
Over 3/4	4	6.3
Don't Know	3	4.7

Source: Farm survey.

1975). Although the sample was drawn in a different way to the Ouse catchment sample, leaving a question mark over the direct comparability of the two, the gap between Harrison's finding and the more recent figure would seem to suggest a decline in the commitment of farm families to continuity in agriculture. This may be a result of the poor financial returns in farming at present and the current sense of despondency among the farming community. The relative unattractiveness of agriculture as a career would be accentuated in a rural area like the Ouse catchment with its rapidly growing economy (see Chapter 4).

One of the first lines of defence when facing lower margins is to re-examine the farm's labour requirements. On almost half the farms in the sample (31 farms, or 49.2%) hired labour had been shed during the 1980s by either not replacing retiring farm-workers or making farm-workers redundant. Many farms, therefore, became far more dependent on the work of family members. By 1991, at least three-quarters of the total labour requirements on 31 of the farms were met by family labour, usually with agricultural contractors being hired to carry out the few additional specialist tasks.

Another adjustment farmers make is to alter the balance of crops and other enterprises. The 1980s were a period of significant adjustment. One trend was the decline in the importance of cereal production following major expansion during the 1970s. Since the mid-1980s wheat, barley and oats had become less profitable in relation to other crops and enterprises and the proportion of the farmed area under cereals declined on 37 of the farms in the survey (58.7%) and increased on only 12 farms (19.0%). By 1991, only 50% of the farmed land was under wheat, barley and oats. It was the smaller sized farms with more significant livestock enterprises who most commonly cut back their cereal acreage. Eight farms had stopped growing cereals since 1988, with three of these entering all their arable land into voluntary set aside schemes. Non-agricultural income was much more important to these farm households, contributing, on average, more than 60% of total household income in 1991. Those opting for set-aside were also a group of small farms with a mean size of only 85.4 ha, well under half that for the whole sample (217.5 ha). Those mixed farms with dairy enterprises tended to build up dairy herds at the expense of cereal production, reflecting the recent relative profitability of dairying. Additional milk quota would be bought, usually from dairy farmers that had closed down. Of the 14 farms in the sample which were 'mainly dairying', 10 had expanded their milking herds by an average of 36% in terms of cow numbers since 1981. (The remaining four had stayed the same). Because of increasing yields per cow[1], their output will have expanded by an even greater amount. The

[1] During the 1980s, the average annual milk yield per dairy cow in England and Wales increased by 8.5% from 4715 litres per cow in 1979-80 to 5115 litres in 1990-91 (Federation of United Kingdom

smaller, mixed farms that maintained some cereal production tended to simplify cereal cropping arrangements, concentrating on a smaller range of crops most commonly by cutting out oats and barley.

For those farms where cereal production continued to be of central importance, major changes in cropping patterns often took place. Break crops such as oilseed rape, beans and linseed became much more important, mainly because of an increase in their relative profitability. Almost half the farms grew oilseed rape in 1991, a new crop for many. Over 1260 ha were sown that year, making up almost 20% of the total area of arable crops. Falling margins for wheat production, combined with favourable EC subsidies for oilseed rape and linseed in particular, were prompting a widespread shift away from continuous wheat cropping. This shift was also partly a result of the high cost of growing wheat on heavy soils. Where it has been common practice among local farmers to grow wheat on the same land for perhaps four years running in the early 1980s, many farmers were adopting more complex arable systems in order to increase the number of 'first wheats' in the rotation.

Despite modern farming techniques, after the first year of wheat, yields decline in the second and particularly the third and fourth years. Blackgrass and other weeds can become a particular problem. On 23 of the farms (mainly the larger, specialist arable farms), rotations of, for example, four wheats followed by a break crop, had been replaced by rotations of wheat-beans-wheat-oilseed-wheat-linseed. A greater number of 'first wheats' in the rotation resulted in lower expenditure on sprays (especially herbicides and fungicides) and manufactured nitrogen fertilizer. The advantages are two-fold: lower input costs for wheat crops, and more favourable prices for oilseed rape and linseed.

For many farms in the sample, however, economic pressures had become so severe that more fundamental change was required based upon the search for new sources of non-agricultural income. While some farmers have seen diversification as a survival strategy designed to maintain family occupancy of the farm, others have discovered that non-agricultural enterprises can be lucrative, choosing to run down their agricultural enterprises and concentrate on new activities. Differing degrees of household pluriactivity accentuated the local differentiation already resulting from recent rounds of restructuring. By 1991, less than a third of households relied entirely on farming for their income, and for over a third agriculture contributed less than 75% of total household income. Since 1981 the balance between agricultural and non-agricultural

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Milk Marketing Boards, 1991, p.40).

income had altered on 36 farms, with 31 of these (49.2% of the sample) deriving a larger proportion of household income from non-agricultural sources. Half the sampled farm households received income from either off-farm employment or from non-agricultural enterprises on the farm (Table 5.2). The most common source of non-agricultural income was off-farm employment. While in most cases it was the farmer's wife who sought off-farm work, in four cases financial pressures had forced the farmer to seek off-farm employment too. In addition, four farmers in the sample carried out contracting work for other local farmers. These changes were typical of those recorded in a larger survey of Buckinghamshire farm households (see Marsden *et al.*, 1991).

Among the 63 farmers in the sample, 19 had significant non-agricultural enterprises based on the farm, almost all of which had been established during the 1980s. The most common initiative involved converting redundant farm buildings for light industrial use (Table 5.2). A study of the development of small industrial units in Buckinghamshire had found that three sets of processes underly this increasing number (Marsden *et al.*, 1991). These were the decline of agricultural productivism leading to a search for new on-farm income sources, the restructuring of the local economy resulting in new market demands for small-scale (under 1500 sq ft), flexibly leased workplaces, and a liberalisation of the rural planning system in 1987 and 1988. There has been no comparable research at a national level which would allow a proper contextualisation of this trend, but it is plausible to assume that in the Ouse catchment, part of a prosperous rural region close to London, these trends are generally more pronounced. For the farmers, once planning permission had been granted and investment made in converting buildings and providing infrastructure, their role becomes one of landlord, disengagement from agricultural production being linked to new rentier roles. Of all the different types of on-farm diversification, industrial units represented the most successful means of sustaining accumulation according to many local farmers.

Farm-based tourism or recreation enterprises had been established on four farms during the 1980s[2], although qualitative evidence derived from discussions with farmers suggested that coarse fishing, bed and breakfast and farm open days were not sufficiently profitable to allow disengagement from farming altogether, providing little more than what Ilbery (1991, p.207) calls 'pin money'. Such activities represented a means of *supplementing* household income in the struggle for survival. In addition, four farmers derived income from horse enthusiasts. One farmer simply let grazing land to local horse owners, although three others had established liveries on their farms.

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[2] One household, in addition, had a long established bed and breakfast business.

Table 5.2 - Non-Agricultural Income Sources

Income Source	Number of farms	% of sample
Off-farm work (farmer & spouse)	22	34.9
Agricultural contracting	4	6.3
Farm tourism/ recreation	5	7.9
Industrial units and haulage.	7	11.1
Food processing and marketing	4	6.3
Horses	4	6.3
Benefit payments	5	7.9
Investments	8	12.7

Source: Farm survey.

The close proximity to Milton Keynes ensured a steady supply of visitors to ride. Again, liveries provided a means merely of supplementing income from agriculture.

For five farm households, state benefit payments such as income support, pensions and child benefit had become significant sources of household income. For two households, the situation had not become critical. They had obtained planning permission on parts of their farm and were waiting for the housing market to improve before selling off the land for development. These farmers hoped to join the eight others in the sample who had sold or developed land in recent years and by this means were supplementing their farming incomes with the proceeds.

In summary, diversification of income sources among farm households in the Ouse catchment broadly takes three forms. Firstly, there is the search for off-farm employment, most commonly by the farm wife, as a strategy for survival of occupancy. Secondly, there is the establishment of farm-based recreation enterprises, which is usually also part of a survival strategy to supplement farm income rather than to replace it. Thirdly, there is the conversion of capital assets through the development of land and buildings[3]. These changes slot, sometimes uncomfortably, into long-standing patterns of adjustment such as the shedding of labour and changing the balance of farm enterprises. It is problematic to talk of this multiplicity of adjustments as 'strategies' because many actions have been forced rather than strategic or planned (see Chapter 1, pp.45-46). Rather, these farm businesses and households could be said to be on different types of development trajectory.

During the survey farmers were not only asked about recent changes to their businesses but also about their future plans. They were questioned about what sorts of things their future plans depended upon and what they thought might spoil them. From the responses, farms were grouped according to their *development trajectory*. The groupings were based on current changes in combination with future plans[4]. For some

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[3] These diversification strategies identified in the Ouse catchment are broadly comparable with the results of other recent studies elsewhere in Britain (see, for example, Ilbery, 1991; MacKinnon *et al.*, 1991; Shucksmith *et al.*, 1989) although the number of industrial unit developments appears particular to the local and regional context.

[4] In categorising farm businesses into the different development trajectories, the responses to questions 85-90 on the questionnaire were used (see Appendix B). These related to the farmers' aims and objectives for the next two years and then over a longer period, and any specific plans they had to achieve these aims. From responses to these questions, the disengagers, developers, diversifiers and expanders were easily grouped. The remaining group of 23 farmers fell into two categories, and this in part arose from the differential abilities among the farmers to articulate their future plans during the interviews. Three of these farmers said they intended to 'carry on as we are and hope for the best'. They had no specific plans to make changes but would alter enterprises and practices as the need arose. The remaining 20 farmers had no plans to develop or take on additional land, diversify or disengage. They were, however, committed to making adjustments where necessary, mainly as part of a continual search

a clear and considered strategy could be discerned. For others, changes in the farm business were a response to changing external conditions. For example, some farmers who rented their farms found they were unable to develop land and buildings to realise assets because of the conditions in their tenancies. Five broad development trajectories could be identified, and farmers were classed as either developers, diversifiers, expanders, adjusters and disengagers (see Table 5.3). The nature of each trajectory is outlined below.

Adjusters: Over a third of farm businesses were classed as adjusters. They were seeking to remain in agriculture and maintain or improve profitability through improvements in efficiency. Particular emphasis was placed on keeping down the costs of production, either by altering crop rotations, increasing self-sufficiency in feeds, or improving the quality of livestock carcasses.

Expanders: Almost one-fifth of the sample (12 farms) were expanders. They were also seeking to remain in agriculture but planned to maintain or increase profitability through increasing either the scale or the intensity of production. Most commonly they were planning to take on additional land or increase livestock numbers.

Diversifiers: Seven farm busnesses (11.1%) were diversifiers. The intention again was to remain in agriculture, although for these businesses survival could only be ensured through diversification to supplement income from farming.

Developers: Ten farm businesses (15.9%) were classed as developers. Farmers were planning to continue with agricultural production but business survival was underpinned by land development. Thus, six farmers were hoping to sell land with planning permission for houses, two were developing industrial units, one a golf course and one a mineral extraction site.

Disengagers: Eleven farm businesses (17.5%) were disengagers charcterised, in effect, by gradual withdrawel from agriculture, although all 11 wished to maintain occupancy of the farm house. They had either decided to put land into set-aside or to let it to neighbouring farmers. Several of these farmers had employment off the farm, or had diversified in the past and were now concentrating much more on the non-agricultural aspects of their businesses.

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for efficiency gains.

Table 5.3 shows some of the characteristics of the farms in each development trajectory group. For example, agricultural income was most important to the expanders who derived, on average, 93.0% of household income from farming. Adjusters also derived more than three quarters of their household income from farming, but developers and diversifiers obtained around two-thirds of total household income. For the disengagers, only a half of total household income was derived from farming. Developers were the youngest farmers, with an average age of 45.1 years, and disengagers the oldest with an average age of 52 years. Disengagers were also the least likely to be planning for succession. Only 3 of the 11 intended to pass on the farm, and in each case, the successor would, in effect, be taking over a non-agricultural business.

Eight of the 10 developers were owner-occupiers, with two renting most of their land. Clearly, the land development strategy is one more open to farm families with land of their own. Diversification was also a strategy dominated by owned farms (5 out of 7), and two-thirds of the expanders were owner occupiers too. Almost half of the disengagers and the adjusters were rented farms.

The farm family's strategy can also depend on the types of enterprises present on the farm. For example, only one of the diversifiers was a dairy farm. The twice-daily milking routine on dairy farms makes it much more difficult for farm families to find the time to develop and run non-agricultural enterprises. Indeed, dairy farms were much more likely to be expanders or adjusters following more 'agricultural' strategies. In turn, nine of the eleven disengagers were arable or mainly arable farms.

A pattern also emerges when economic viability is assessed against these development trajectories. For example, over 80% of expanders (10 out of 12 farms) had made a profit when the financial returns of the last three years were combined, and only one had made a loss. Of the 7 diversifiers, 5 were in profit (71%) as were almost half of the adjusters (11 farms or 48%). The farms where viability was suffering most were the developers and disengagers. Under a third of the developers and only 2 disengagers (18%) made a profit, while half these farms had made a loss.

The overall picture is, therefore, one of increasing differentiation. Among a group of farm businesses, all in the same river catchment and all having recently grown cereals, we find not only a wide range of business and household characteristics, but also a variety of development trajectories. Some are involved in a marked retreat from agricultural production and an economic dependence on it. Others are struggling on, seeking agricultural solutions to the problems of falling margins. All seem to be keen to maintain occupancy of their farmhouses, even if this means selling off or setting aside

Table 5.3 - Farm Characteristics by Farm Development Trajectory

	Average size (ha)	Average % under cereals	Average farmer age	Average % agricultural income	% planning succession
Adjusters (23 farms)	204.7 (141.7)	68.9 (22.8)	49.6 (11.5)	77.3 (26.9)	56.5
Expanders (12 farms)	296.2 (289.5)	43.9 (18.5)	46.3 (11.4)	93.3 (13.5)	66.6
Diversifiers (7 farms)	211.6 (154.8)	51.0 (42.3)	47.3 (10.1)	65.9 (30.4)	71.4
Developers (10 farms)	284.6 (245.9)	49.6 (27.2)	45.1 (12.3)	68.4 (36.8)	50.0
Disengagers (11 farms)	98.3 (66.0)	47.3 (28.5)	51.8 (9.3)	50.7 (27.6)	27.3
Whole sample	217.5	48.6	48.4	73.0	54.0

Note: Averages are means and the standard deviations around the means are in brackets.

Source: Farm survey.

land and retreating from an essentially agricultural life-style.

Crucially, however, these shifting economic and social conditions provide the backdrop for processes of technological change, day to day farming practices and the ways in which these alter over time. An understanding of why a farmer uses particular crop protection systems cannot be separated from an understanding of the development trajectory of the farm business and the aspirations of the farm family. It is, after all, the meeting of the farm family's needs and wants that is often the ultimate reason for using pesticides in the first place. The ways in which pesticides are used and understood will be examined later in the chapter. First, farmers' philosophies and values are explored, particularly concerning farm improvement and 'nature'. These underpin farm development trajectories and the way farming practices are carried out.

5.3 Farmers' Philosophies, Nature and the Logic of Farm Improvement

Because of the land-based nature of agricultural production, farmers are at one and the same time both food producers and managers of the rural environment. Notions of resource management and resource conservation are not new to farming. Traditional, mixed farming systems, in particular, have had resource conservation at their heart. A central and analogous idea in the ethos of 'family farming' has been to do more than make a living out of the family's asset (the farm). It must also be passed on to the next generation in sound working order. Thus, notions of resource conservation (in a utilitarian sense) are often strongly linked to norms of family continuity in farming.

Even in an era of technological 'sophistication', farmers still express the need to conserve their farms' productive base. The single-minded pursuit of short-term improvements to that productive base may undermine the long-term sustainability of farming itself because of the continued dependency of farming on the integrity of the natural environment (Body, 1991; Royal Commission on Environmental Pollution, 1979; Conway & Pretty, 1991). But what constitutes the productive base of the farm has changed. Farmers who are considering passing on their businesses to their children will be keen to ensure that their farms are in 'good condition'. By this they frequently mean that the tractors, field machinery and the farm buildings are all in good working order, and that farm roads and field drainage make the farm *easier* to manage. Conservation of the farm's resources is a crucial element in the farmers' understandings of their farms' 'condition'.

Farmers also express some of these notions in terms of their soil, or land being *'in good heart'*. This concern has two strands. First, field boundaries have to be properly managed and kept in good repair, especially on farms carrying livestock. This ensures not only that hedges, ditches and fences are adequately stock-proof (a utilitarian notion) but also that the farm *looks* tidy and well-kept (both a utilitarian and aesthetic notion). More importantly, the second element of land being in good heart is rooted in utilitarian ideals, and involves the maintenance of soil fertility. Thus, in the eyes of farmers, a 'good farmer' is one who typically will keep the land in good heart and so be in a position to pass on the farm in a better condition.

To explore such sentiments further, the Ouse catchment farmers were asked about this notion of 'improving' their farms. The question was worded "farmers often say that they would like to pass on their farm to the next generation in a better condition than when they took it on themselves. What does the phrase 'in a better condition' mean to you ?"

The idea meant quite different things to different farmers. To seven of the 63 (11%), it meant that the farm should be tidy and well-maintained. This technical definition of 'better condition' involved the tidiness of hedges, the good maintenance of yards and buildings and an element of making the farm easier to run. Over half the farmers (34 or 54%), however, talked about the farm being more productive and 18 (28.6%) thought better condition meant that the farm should be more economically viable. Under the 'more productive' category, farmers tended to talk about the land being 'in good heart'. Any farmer who used this term was further questioned about what it meant to them. For most farmers, the notion implied that the soil be fertile and productive. It should be capable of sustaining high yields. But the term also implied a *responsibility* to the land. There was broad agreement that a good farmer "should not take more out of the soil than gets put back in". The soil should not be 'robbed' of its nutrients. As one farm manager running a 100 ha arable business explained,

> "*[Better condition means] land in better heart, with a better soil structure, and capable of growing better crops. If the soil structure is correct and the land is clean and free from weeds then you'll get better yields*" [Farmer interview no.13: Adjuster].

It is within this context of a 'logic of farm improvement' that farmers' attitudes to environmental change in the countryside must be set. The dual objectives are to have a farm that has the capacity to provide a viable income for both the current and the next generation of the farm family, *and* for it not to have been 'robbed' of its productive capacity.

The survey evidence also suggests that farmers have, in the main, become sensitised to environmental issues. Almost two-thirds of the farmers interviewed acknowledged that modern agricultural practices can have an adverse effect on the environment. However, the types of environmental problem that they went on to talk about varied. Fourteen mentioned problems with "the overuse of sprays". However, when questioned further, most were more specifically concerned about the effects of insecticides on friendly predator species like ladybirds. Only four farmers specifically mentioned problems of the persistence of agrochemicals in the environment, and only three of these specifically mentioned the threat to water quality from leaching and run off. Other environmental issues cited by farmers were landscape change (mentioned by 11), nitrate leaching (9), pollution from livestock effluents (8) and the loss of wildlife (6). It is clear that while there is some general unease about heavy usage of pesticides, pesticide persistence and the threat to water quality is not an issue that looms large in their thinking.

Farmers talked extensively about agriculture's environmental problems and their causes. Some talked about "a small number of bad farmers" who caused problems, echoing the rhetoric of farming organisations in the 1970s who talked of 'maverick' or 'rogue' farmers responsible for habitat loss and removal of landscape features (see Chapter 3, p.91). Others blamed 'the system'. They complained that farmers had only done what they had been encouraged to do by Government policy. Furthermore, two thirds of farmers acknowledged that environmental concerns had begun to influence the way they farmed. Eighteen cited the management of environmental features on their farms. They had planted trees, were choosing to keep hedges rather than pull them out, and were building ponds and maintaining footpaths. For these farmers, responding to wider environmental concerns meant 'managing' or even 'creating' pockets of nature on their farms. This zoning of the farm environment in the minds of the farmers was well illustrated by one farmer in his late 40s running a 140 ha arable and sheep farm. When asked how environmental concerns had affected his farming practices, he said

> "*Yes, I have a two and a half acre conservation area. If we see something nice we transplant it. We see our fields as our factory floor and our little conservation area as our haven*" [Farmer interview no.32: Developer].

Moreover, the art of managing nature is itself the subject of social construction and there is no consensus among the farmers about what a good farming environment actually consists of. For example, one elderly farmer on a 120 ha mixed dairy and arable farm said

> "*I don't like to see the countryside as an extension of suburbia, with clinically trimmed hedges. I like to see nature's shagginess, with blooms at different times, and bushes and young trees in the hedgerows*" [Farmer interview no.26: Adjuster].

On the other hand, a young part-time farmer on a small mixed holding, when asked if environmental concerns had impacted upon farming practices, expressed a noticeably different view. He said

> "*Yes, we keep it neat and tidy. We don't let it go back to nature. We spray out weeds and make it look nice*" [Farmer interview no.26: Adjuster].

Other responses to increasing environmental concern among the farmers involved the greater care in the use of sprays (cited by 13), investment in effluent control systems (7) and ceasing straw burning (5). Some went on to explain that they were more careful when deciding which insecticides to use, and tended now to choose those that would not harm ladybirds. Conversely, one third of the farmers said that wider environmental concerns had not at all affected what they do. The majority of these did not consider themselves to be doing any damage in the first place.

Notions of efficient and productive farming practice and farms in 'good condition' were further explored by asking the farmers if they made comparisons between themselves and their neighbours, and if so, on what basis. Almost four out of five farmers (50 or 79%) said that they did look at what their neighbours did. The basis upon which they drew these comparisons fell into three main categories. The first group (20%) made comparisons mainly based on notions of good farming, the health of stock and tidiness of fields. For example, one part-time farmer running a 40 ha arable farm explained, [I look at] "*how their farm and crops look...if they look as good and healthy as mine. It has to be clean. I don't like to see weeds*" [Farmer interview no.34: Adjuster]. A second group (20%) made comparisons based on the timing and methods employed on the farm, such as, for example, who was out spraying and when, and what types of machinery were used. The third and largest group (60%) made comparisons in terms of yields. A typical response in this group came from a farmer in his mid-50s running a 500 ha arable farm who said "*Man is a competitive beast. I like to feel I'm doing the job at least as well and hopefully better than the competition*" [Farmer interview no.5: Adjuster].

The responses suggest that production-maximising values still have strong currency amongst farmers, although notions of 'good husbandry' are also important in the sense that farmers feel some responsibility to what they see as the 'health' of their land.

However, more important than the preoccupation with yields, and of central interest to this study, was the widespread concern with weeds. Whether farmers were drawing comparisons on the basis of productivity or tidiness, weeds seemed to provide a useful gauge of how they were doing. Half of the farmers in the sample said that they looked over the hedge to see whether neighbours were winning the battle against weeds, and many expressed strong aesthetic concerns about 'clean', weed-free fields.

The aesthetics of neatness and weed control as a form of care has been studied by Nassauer (1988), whose research highlighted how the expression of care is an important motive for people involved in managing landscapes. While the notion of 'care' includes a sense of solicitude, protection and nurturance, it at the same time can involve the domination or subordination of nature. The control of weeds is undoubtedly an act of dominance in this sense, although it has a scientific rationale insofar as weeds compete with crops for light, water and nutrients. But because people see beauty in neat, well-kept landscapes, weed control also has a strong aesthetic motive which involves demonstrating care of the land. The responses from the survey suggest that it is the utilitarian notions of clean (weed-free), tidy (rationalised) farm environments which are dominant in their farming culture (or way of thinking). The farmer who appreciated "nature's shagginess" in hedgerows held a minority view. The majority saw their contributions to rural environmental management as planting trees in field corners or on unproductive parcels of land, digging ponds, maintaining styles and managing footpaths, thus helping to create 'pockets' of nature and facilitate access for walkers to enjoy them. These activities could be kept separate from the *farmed* environment which should be kept clean and tidy.

Weeds pose a threat to the viability of cereal production. On the heavy soils of the Ouse catchment, where forty years ago profitable cereal cropping would not have been possible, it has been the control of black-grass and wild oats in particular that has enabled cereal growing. Uniformly coloured fields with as few weeds as possible and with the crop drilled in straight lines symbolise the farmers' success in the battle against nature's constraints on production. It is easy to see how farmers take pride in eliminating weeds. One farmer, typical of many, explained

> *"When I came here the farm was undrained, wet and weedy. It was just ticking over. Now it's clean, it's drained and the crops look well"* [Farmer interview no.7: Adjuster].

Moreover, these deeply felt convictions and the clear understanding about the role of weeds compares with doubts about the significance of the environmental impacts of agrochemical use. Because environmental impacts might be unobservable in the short and medium term, farmers find it difficult to accept that their efforts against weeds are problematic. In addition, they argue that they would surely not be allowed to use any chemicals that pose a threat to the environment. Their faith in the need to combat weeds is mirrored by a faith in the inherent safety of the chemical weapons they use. As one farmer in his late 40s running a 300 ha mixed farm said

> *"You're using strong chemicals, but if they're used properly and professionally, they're advantageous to mankind. We are guided very much by the chemical companies. We hope and believe that everything's been properly tested. We buy them in good faith. If you buy a car, you don't question the research and manufacturing process, you buy it in good faith"* [Farmer interview no.2: Adjuster].

In the trade off between the profitable production of cereal crops and the threats posed to surface and groundwaters, the interests of agronomy transcend those of the water environment. This is crucially because of the relative strengths of the two convictions within farmers' ways of thinking. Weeds are an easily identifiable economic threat, whose presence goes against the farmers' strong convictions in favour of rationalised, clean fields. There are no such strong convictions about the environmental impacts of pesticides. Provided they are used as directed on product labels, the ways in which they pose pollution threats seem doubtful, long term, distant and unproven. When coupled with a relatively strong faith in the registration and approval of chemicals that have been properly and 'scientifically' tested, the assessment of pollution risk need not be taken further.

Furthermore, risk assessment remains locked within a dominant productivist logic. Some farmers admitted that a 'more careful' use of pesticides or nitrogen arose from the need to cut costs rather than any moral sense of protecting environmental resources. Specifically, the analysis of the farmers' representations of 'nature' and 'improvement' suggest that concerns about weed control and clean fields are more important to farmers in the Ouse catchment than concerns about the pollution of surface and groundwaters by pesticides. It is in the context of this trade-off that actual and potential changes to pesticide use need to be assessed.

5.4 Reducing Herbicide Use in the Ouse Catchment

In a series of semi-structured questions, methods for cutting herbicide use were suggested. Farmers were asked if they employed various techniques, if they might consider others and if not, what they saw as the main drawbacks. The results are shown in Table 5.4. Almost 70% of farmers would not consider cultural methods of weed control (nil cultivation, scratch cultivation or direct drilling) as means of reducing

Table 5.4 - Measures to Cut Herbicide Use

Method	Number of farmers (%)		
	Already Use	Would Consider	Would Not Consider
Cultural Methods	4 (7%)	14 (25%)	39 (68%)
Undercut Label Dose Rate	50 (89%)	4 (7%)	2 (4%)
Undercut Advisor's Dose Rate	22 (39%)	4 (7%)	30 (54%)
Mechanical Weeding	2 (4%)	9 (16%)	46 (81%)
Organic Farming	0 *	19 (33%)	38 (67%)

* - No organic farmers but two 'Conservation Grade' producers.

Source: Farm survey.

herbicide use, and over 80% would not consider mechanical weeding. Both options, it was argued, would be more costly than applying chemical herbicides, and they were much less thorough and would lead to a build up of weed problems in the future. As one farmer on a 500 ha arable farm explained,

> "*Cultural methods lead to a build up and a backlog of certain pernicious weeds and then you require more herbicides later. You just scratch the surface really*" [Farmer interview no.5: Adjuster].

Similar views were expressed by several farmers, highlighting the extent to which the chemical control of weeds has become an acceptable and unproblematic practice among farmers. Moreover, the straw burning ban (introduced under the 1990 Environmental Protection Act to take effect from the end of 1993) will make chemical herbicides even more attractive because burning straw and stubble are usually an essential component of cultural weed control (ENDS, 1992b).

Organic farming, defined as applying no agrochemicals and seeking a premium on the price of the crop, was rejected by two thirds of farmers. The remainder said that they would be happy to consider organic farming but felt that the economics were currently unfavourable. One of the central tenets of the ethos of good arable husbandry would also be undermined by organic farming systems. As one farmer running a 115 ha diversified arable farm said,

> "*It would drive me crazy, the rubbish and muck [weeds], I'd probably get complaints from my neighbours too*" [Farmer interview no.16: Disengager].

Some, however, were sympathetic to the philosophy behind organic farming but the current costings ruled it out as an option. One of these farmers suggested that

> "*Unfortunately, organic farming wouldn't be viable. It would be a major relief to get off that treadmill if only we could afford to do it*" [Farmer interview no.34: Adjuster].

One practice already widely in use was to apply the chemicals at dose rates lower than those recommended by the manufacturers on the product label. Almost 90% of the farmers said that they already undercut herbicide dose rates advised on product labels, but this tended to be only on the advice of their spray advisor. When asked if they ever undercut the dose rates advised by their advisor, under 40% of farmers said they did so. Over half the farmers said they would never consider applying herbicides at dose rates lower than those recommended by their advisor, making the negotiative process between farmers and advisors as crucial to practice.

5.5 Conclusions

From the analysis of the empirical evidence on agricultural restructuring and changing pesticide practices in the Ouse catchment, a number of points become clear. First, patterns of farm business development, which crucially set the parameters for changing pesticide practices, have fragmented during the 1980s among the farms surveyed in the catchment, chiefly as a result of the decline in economic fortunes. A range of development trajectories can be identified which involve differing levels of dependence on, and commitment to, agricultural production. While most farm families wish to maintain occupancy of the farmhouse and the essence of an agricultural lifestyle, a significant proportion of households are making changes to reduce their financial dependence on agricultural production in general, and on growing cereals in particular. At its most extreme, some farmers are becoming landords of small rural industrial estates or managers of countryside recreation centres, and the requirement of cereal production for them often becomes simply not to make a loss. These changing patterns of restructuring will provide a different context within which pesticides are used in individual farm businesses within the catchment.

A second important element affecting pesticide usage is the way that farmers represent nature and understand environmental damage, and how these notions interplay with their values of good farming and farm improvement. The dominant mode of thinking is that weeds are 'dirty', 'rubbish' and representative of bad farming. This conviction is markedly stronger than the environmental threat that can arise from pesticides, which seems to farmers to be unclear, unseen and not proven. Moreover, there is strong belief that pesticides have been thoroughly tested before being approved for use and so must be safe.

It is, therefore, not surprising that for most farmers dependence on the cheapest, most effective and easiest to use herbicides has increased during the 1980s. IPU and other residual herbicides used as blanket sprays in the autumn, have become of greater importance to cereal production in the Ouse catchment during the 1980s. They were often referred to in the survey as being "straight-forward" and "reliable". Blanket (or prophalactic) spraying in the autumn thus becomes a straight-forward, routine way of dealing with weed problems with the minimum risk of failure. Indeed, a greater emphasis on autumn residual spraying had been encouraged locally by ADAS and merchants' advisors as the 'safest' weed control strategy for preventing problems in the spring. This advice has still remained compatible with the strategy of cost cutting as margins have been squeezed. Only very recently (since 1990), and with a very limited scope (3 farmers in the survey), has the possibility of a viable alternative to chemicals like IPU, which are less persistent but regarded as more expensive, even begun to attract attention.

Given the widespread dismissal of cultural methods of weed control and organic farming, both of which would seem to contradict the 'chemically-cleaned', weed-free field philosophy of the farmers, the only remaining option left for those wishing to cut back on their herbicide usage has been to cut the dose rates to below those recommended by manufacturers. Here the role of technical advisors becomes crucial to the decision making process. In Chapter 6, the relations between farmers and advisors are considered in more detail.

CHAPTER 6:
THE ROLE OF ADVISORS

6.1 Introduction: Restructuring of the Advisory System

In understanding technological change in British agriculture and the conditions shaping farming practice, research directed at the role of technical advisors has been limited (but see Eldon, 1988; Fearne and Ritson, 1989; Hawkins, 1991). It has become increasingly apparent, however, that farmers have become much more dependent upon technical advice from off the farm in order to meet the production objectives implicit in public policy. The role of technology transfer is crucial and in Britain the dominant feature of the 1980s has been the growth of private sector sources of information, promoted in part by the curtailment of what was previously a largely free state advisory service (Munton *et al.*, 1990). Most non-environmental advice from ADAS now has to be paid for by the farmer in one way or another, and this has helped to open up the 'market' for advice on farming practice to competition from other sources.

Private sector sources of advice for farmers include accountants, bank managers, vets and feed, seed and chemical salespeople and independent consultants. These sources have always been present, and often important in their own right, but Eldon (1988) has documented how some of these private sector sources have 'taken over from ADAS', particularly with regards to animal and crop husbandry advice, by offering farm walks, soil tests, new varieties and computerised farm planning assistance as 'free' features accompanying their agrochemicals or other inputs. He also cited evidence of a 'hard sell' approach of some private companies where representatives would walk farms before approaching the farmer in an effort to encourage a sale.

The accusation from many commentators is that the commercial interests of the manufacturers and distributors of industrial inputs to agriculture cannot be separated from their advisory role (Clunies-Ross and Hildyard, 1992; Hawkins, 1991). Private sector advisory services are seen as a mechanism employed by companies to encourage farmers to buy their inputs. If this is the case, then we can expect that advice from companies will be of a form designed to increase the sales of their inputs.

Eldon suggests from his survey, however, that many farmers considered private sector advice to be superior to that received from ADAS. The 1980s have been more generally characterised by a growing belief in the quality and efficiency of specialist and technical advice from the private sector, in comparison to what has been seen as a bureaucratic and outmoded public sector. The belief that those in business must be efficient because they can function in the marketplace, and are customer-oriented and up to date as well, has been promoted by Government. A similar view is reflected in Government attitudes towards the orientation of agricultural research and development (Munton *et al.*, 1990). At the same time, farming's greater reliance on those companies which manufacture and sell inputs for technical advice has also been cited as illustrative of the growing subsumption of the farm production process by industrial capitals and the increasing control they are able to wield over farming practice (Whatmore *et al.*, 1987a;b; Clunies-Ross and Hildyard, 1992)[1].

The question of farmers' loss of autonomy through subsumption has been addressed by Hawkins (1991) in her research into technological change in milk and potato production in Cheshire. She found that uncertainty in agricultural markets and low returns on farms were increasing the financial pressures on the manufacturers and distributors of agricultural technologies. Three sets of responses could be identified. First, manufacturers were developing exclusive agency policies whereby the number of merchant outlets was limited through exclusive franchises. While this practice has had a longer history in relation to farm machinery, pesticide manufacturers have also been rationalising their distribution networks and concentrating their sales through chosen distributors (Hawkins, 1991, p.134). Second, input suppliers have developed credit packages to tie farmers to individual companies. Again, this has been a longer-standing feature of the agricultural machinery sector where leasing deals are now common (Marsden *et al.*, 1990b), but agrochemical merchants have also developed shorter-term credit deals as part of their pesticide sales strategies. Third, Hawkins identified the development of technical advice by companies as a strategy to maintain sales. As a fertilizer manufacturer explained to her

> "We have to keep farmer contacts to develop the market. This is done through a technical route to sell a higher volume" (Hawkins, 1991, p.137).

According to Hawkins the representatives of private sector companies can be seen as 'agents of the technological treadmill' in these respects (see also Long *et al.*, 1986; van der Ploeg, 1989). In the UK, the little empirical work that has been conducted emphasises the roles of technical advice and credit packages as examples of the subsumption of production relations. According to Munton *et al.*, the offers of soft loans by some input suppliers, guaranteed by special deals made between them and the clearing banks, can help hard pressed farmers in the short run, but in the long run they

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[1] In much of the European literature this process has been termed 'externalisation' (van der Ploeg, 1990, pp.18-21).

> "only increase their dependence upon off-farm assistance and reduce their share of the value-added in the food chain. These links also reinforce the process of differentiation between farm businesses as those clients deemed worthy of such advantageous treatment are increasingly singled out from the remainder on the basis of strict cost-accounting and forward budgeting criteria" (1990, p.110).

The sales strategies of input suppliers are not necessarily designed to maximise the sales of their products in the short term, but to maintain market share. This is the argument employed by companies' representatives when questioned, in response to the charge that their commercial interests influence the nature of the advice they give. If they were to give advice to farmers that was not the most cost-effective, they say, farmers would transfer their custom to other companies. Instead, technical advice is used to foster customer loyalty through strengthening the links between company and farmer. As the director of a regional agrochemicals firm explained to Hawkins

> "In the main our reps. have a gang of loyal farmers and their business is to seek these farmers out at the beginning of the season. After that it's a bit routine and a bit emergency...It's done to keep the loyalty of our customers. It's better than if it depended on a market deal, discounts, salesmanship and that sort of thing" (Hawkins, 1991, p.137).

Links between farmer and company are becoming stronger for other reasons too. Concentration in the manufacturing sector has meant that a small number of large multi-national manufacturers dominate the markets for most inputs to agriculture, including agrochemicals. At the same time, the decline in the number of local merchants has tended to strengthen the links between the manufacturers and the merchants that remain, through franchising and exclusive agency policies, in particular. This has, in turn, led to more intense contact between the farmer and input suppliers, which

> "although still framed in technical terms, has extended for many farms from a purely 'trouble-shooting' technical level to a regular managerial one" (Hawkins, 1991, p.139).

The use of technology on farms becomes important, not only at the product level, but also by means of the advisory process. It is what Benvenuti *et al.* (1982) have called technology's 'techno-administrative' role which can also become important in eroding the farmer's control over commodity production on the farm.

Hawkins also found that despite the fact that the underlying faith in technology remains strong among the potato and milk producers she studied, farmers were adopting a range of strategies to resist agribusiness pressures. In particular, some would develop a diversity of links with input suppliers to prevent the constraining power of agribusiness. While this might prove effective for fertilizers, animal feed and milking machinery (the technologies Hawkins studied) it may not be so applicable in the case of pesticides, given the greater dependence upon technical expertise for chemical crop protection, and the more routinised nature of pesticide use.

In this chapter, these issues will be examined in terms of the ways that farmers select and use pesticide advice. The variety of sources for such advice will be discussed, before going on to present evidence from the farm survey in the Ouse catchment.

6.2 Advising British Farmers on Pesticide Use

In Britain one of the most detailed studies of farmers' advisory sources has been carried out by Fearne and Ritson (1989). The study, which consisted of a survey of over 900 farmers coupled with a series of group discussions, supports the view that

> "Decision making on the farm is an iterative process, with information and advice from various sources being cross-referenced and verified, to varying degrees and often sub-consciously, before, during and after the adoption of a new idea" (Fearne and Ritson, 1989, p.6).

The survey found that the extent to which farmers paid for advice from ADAS or other independent consultants varied significantly according to age, farm size and education. Over half the surveyed farmers had never hired a consultant, and it was the younger and more educated farmers operating larger units, that were found to be most likely to seek external advice. It was also established that free newspapers and commercial representatives had an important role to play in influencing changes in farming practice. The sources of advice that farmers favoured depended upon the type of farm enterprise and the nature of the advice required. Freely available advice from newspapers, journals and other media was, inevitably, general in nature, whilst farmers were more prepared to pay consultants for specific advice and 'problem-solving'. Here, accountancy services were most heavily used by dairy farmers (45%), and advice on grants and subsidy applications were sought by over half the beef and sheep farmers surveyed.

The study concluded that while farmers found it relatively easy to identify the most important sources of advice for different aspects of their work, two things remained much less clear. First, it was extremely difficult to discover how farmers valued the quality of the advice they receive, and second, it was unclear how advice and information were translated into action (Fearne and Ritson, 1989, p.58). (These issues will be examined below in relation to pesticide advice). Besides the general advice and information that are available through the farming press, there are five main sources of advice for British farmers when using pesticides. These are the agrochemical manufacturer, the agrochemical merchant, ADAS, crop consultants and arable farming research centres. Changes in each of these since the 1970s are now briefly reviewed.

a) The agrochemical manufacturer: The 'engine' for innovation in pesticides was the large research bases of the major agrochemical companies. However, as many of the more established and economically successful pesticide products came off patent during the late 1970s and early 1980s, so manufacturers without the burden of large research and development programmes were able to produce off-patent pesticides. Increased competition in the manufacture of pesticides has led to a gradual withdrawal from advising farmers. According to Walker (1987), a representative of BASF United Kingdom Ltd,

> "Pressures on profit are resulting in the need to cut costs, which will mean it will be more difficult to justify and maintain advisory services to the farmer" (Walker, 1987, p.322).

Today most manufacturers' advice comes in the form of recommendations for applying agrochemicals on the product labels.

b) The agrochemical merchant: One consequence of increasing competition amongst manufacturers has been the emerging role of merchants in providing specialist advice on pesticide use. Traditionally, corn merchants distributed agrochemicals as they became available, but since the late 1960s merchants have developed specialist expertise in crop protection. By the 1980s, agrochemical distribution was conducted either as a separate business or as a specialist division of the main merchant business. The more progressive merchants even carried out their own field trials to compare products and to develop crop husbandry recommendations which integrated fertilizer and pesticide applications (Walker, 1987). Today, merchants' salespeople usually offer pesticides for sale at two price rates, a lower and a higher rate. The higher rate will include technical advice from the merchant's own specialist spray advisor who regularly visits the farm and walks the fields to assess crop protection requirements and then advise on product choices and dose rates.

c) ADAS: Responsibility for delivering 'official' advice to farmers on pesticide use lies with ADAS. ADAS is able to support field officers with information from a network of experimental farms and regional centres, but since 1987 ADAS has been obliged to charge farmers for all non-environmental advice, and this has had the effect of making advice from merchants' specialists more attractive to many farmers. Findings from in depth discussion groups conducted by Fearne and Ritson (1989) revealed how ADAS advisors still tend to be regarded by farmers as 'the man from the Ministry', despite their new found commercial role.

Farmers can obtain ADAS advice on a personal or group basis. Personal advice covers the calling out of an ADAS consultant to advise on any of a range of farm management issues. The farmer is then charged on a consultancy basis. In addition, farmers can subscribe to ADAS groups, and obtain more general advice which can be tailored to local or regional conditions. For example, weather reports and pest infestations are circulated and farmers are advised about the timing of spraying and so on.

ADAS's new commercial role was the subject of a study by the National Audit Office in 1991. The study focused on how ADAS combines its new role with the remnants of its statutory duties which involve providing free 'public good' advice covering conservation and pollution control. The report was critical of some ADAS regions where the provision of public good advice, including that covering pollution risks from farming practices, was found to be poorly structured (National Audit Office, 1991).

d) Independent consultants: According to a study by the agrochemical company BASF, independent consultants gave advice on pesticide use affecting about half a million hectares of cereal production in 1982, and their influence is likely to have increased since then (Walker, 1987). By the late 1980s, there were over 200 practising consultants registered with the British Institute of Agricultural Consultants or the Association of Independent Crop Consultants, over half of which had specialist expertise in crop husbandry (Fearne and Ritson, 1989). They are independent of product sales and their livelihood thus depends directly on the farmers' perception of the quality of their advice in relation to business profitability. Whilst independent consultants can capitalise on specialist technical expertise in combination with detailed experience of the requirements of individual farms and fields (Read, 1985), one of their limitations, Walker argues, is their lack of research facilities and inability to keep up with new developments (1987, p.324).

e) Farming research groups: In 1991, as part of the state's gradual withdrawal from underwriting the productivist policy model, the Government stopped funding 'near market' research, research intended to provide farmers with a commercial benefit within five years, leaving farmers having to fund this area of R&D themselves. Commodity based R&D levies still remain, however. For example, the Home Grown Cereals Authority levy deducts 22.3p/tonne from cereal growers for cereal R&D and this was expected to raise £34.8 million in 1992/93 (Skinner, 1992, p.63).

Farmers who tend to value up to date but general crop husbandry advice are now more prepared to pay for advice by joining together to fund arable crop research centres, where the emphasis is on providing local advice to farmer members. The number of centres has risen to more than 60 in England in recent years, and their strategy has been to encourage the most progressive and innovative farmers to join. According to Skinner (1992), more than 10% of farmers with more than 20 ha of cereals are now members of research centres. Walker (1987, p.324) identifies three common facets of these organisations - they carry out extensive experimental programmes; they employ permanent scientific staff; and they are financed mainly by controlling farmers. Centres run on the philosophy of exclusivity, with access to research results and advice limited to members, and the notion of independent R&D and advice, free from the influence of commercial interests, is also very important to their functioning. Their growth is, in part, a response to the mistrust of advice from representatives of merchants and manufacturers among more progressive and innovative farmers[2].

These different sources of advice on pesticide practices do not provide farmers with clear choices between independent and commercial, or paid for and free, advice. Indeed, the distinctions are often quite blurred. While advice from commercial specialists, like those attached to merchants, is often cited as 'free' advice, (see, for example, Fearne and Ritson, 1989, pp.48-49), the widespread use of commercial sources of advice cannot be explained solely on the basis of price advantage. Advice from merchants is not, in fact, free because those farmers who avail themselves of it usually have to buy their pesticides at higher prices.

As part of Fearne and Ritson's study, farmers were asked what would be the most likely source of advice they would approach for crop husbandry problems. It was found that ADAS was more widely used for crop husbandry (30.4%) than for animal husbandry (15%), but that the most popular source was the commercial representative (64.9%). In addition, over a fifth of arable farmers also cited private consultants as a source of crop husbandry advice (Fearne and Ritson, 1989, p.48). It is, therefore, surprising that past studies of farmers' pesticide decision making have not paid much attention to the role of external advice (such as those by Mumford, 1982; Tait, 1982).

Pesticide use is an aspect of farming practice where farmers are particularly dependent upon external advice. This is, in part, because the chemistry of crop protection has become increasingly complex and beyond the level of knowledge that many farmers either have or feel comfortable with acquiring (Lever, 1990). A large survey by a

[2] Following this, farmers' perceptions and understandings of the differences between 'independent' and 'commercial' advice will be examined in this chapter.

market research group found that over 50% of British farmers routinely turned to outside advisors for guidance on pesticide use, and 22% admitted to feeling out of touch with technical developments in agrochemicals, product suitability and choice (Produce Studies Group, 1990; Agricultural Supply Industry, 1990b). The complexity of the science is compounded by the large and increasing number of pesticide products from which farmers must choose. For example, in the period 1970 to 1981, the number of different active ingredients officially approved for use on wheat alone rose from 97 to 301 (Walker, 1987, p.316). Moreover, while the 1960s and 1970s were years of innovation in the pesticide industry, the 1980s were the decade when many patents ran out. This led to the greater availability of mixtures of active ingredients and distributors' 'own label' products on the market (Metcalfe, 1982).

In addition to the greater complexity and wider range of pesticides available, another factor explaining the greater use of external pesticide advice has been the rising cost of pest control. In the case of winter wheat, for example, the proportion of total variable costs attributable to pesticides almost trebled from 15.7% to 46.0% between 1971 and 1991 (Murphy, 1989; 1992). This rising relative importance of pesticide costs has come at a time when the regulation of agriculture has increased and the number of farm-workers has steadily declined. Therefore, the demand for help with pesticide decisions from off the farm has correspondingly increased (Walker, 1987).

While merchants' and manufacturers' advice may be driven by the need to maintain sales (and, according to some commentators, a desire to increase control over the production process), from the farmer's point of view, advice from merchants' representatives will often be easier to obtain. Merchants' representatives visit the farm as a matter of routine to discuss sales and crop husbandry problems. ADAS or independent consultants, on the other hand, have to be called out .

6.3 Farmers and Pesticide Advice in the Ouse Catchment

During the farm survey, farmers were asked about sources of advice, their understandings of bias in commercial advice, and the ways that advice and information were translated into action. First, they were asked what sources they used relating to fertilizers and land drainage (Table 6.1), two aspects of farming practice with an important bearing on water pollution risks, and then to rank their importance. The first column in Table 6.1 shows the sources that farmers have consulted at any time. All had consulted private sector sources, such as representatives of merchants and manufacturers, whilst four fifths of the farmers had at some time consulted ADAS. Sixty percent had used an independent consultant and almost fifty per cent had acquired

Table 6.1 - Sources of Advice for Fertilizers and Drainage

	Farmers that used this source for any advice (%)	Most important sources of advice (% of farmers)					
		Fertilizer use (63 farms)			Drainage (54 farms)		
		1st	2nd	3rd	1st	2nd	3rd
Own expertise	100	51	13	6	24	7	2
Merchant's representative	100	25	24	5	2	-	-
Manufacturers representative	100	3	16	3	-	-	-
Independent consultant	60	3	-	6	2	-	-
Contractor	97	-	-	-	44	26	2
Employee's expertise	97	-	-	2	-	2	-
Neighbour	90	2	5	6	-	2	-
Family	92	2	5	6	-	-	-
NRA	57	-	-	-	-	-	2
HSE	94	-	-	-	-	-	-
ADAS (personal)	78	13	11	8	24	13	2
ADAS (group)	52	3	8	3	-	-	-
Farming research group	49	-	-	5	-	-	-
Farming press	97	-	3	5	-	-	2
Farming events & conferences	94	-	-	2	-	-	-
Other		3	5	-	4	-	-

1st = most important source of source of advice; 2nd = second most important source of advice; 3rd = third most important source of advice. Vertical columns do not total 100% because some farmers gave joint first choice of advice and some farmers did not give a second or third preference.

Source: Farm survey.

information from a farming research group. Over a third of the farmers surveyed also belonged to local farmer-funded arable research groups.

The findings support those of Fearne and Ritson (1989) in suggesting that sources of advice differ according to the different aspects of farming practice. For example, when deciding what fertilizer products to buy and how to use them, over half the farmers relied mostly on their own expertise, with only a quarter of farmers citing the merchant's representative as the most important source of advice. Most commonly, farmers would perhaps consult the merchant's advisor but would be confident in taking the final decision themselves.

When it came to decisions about land drainage, a different pattern emerged. While the vast majority of farmers said that it had been several years since they last carried out any drainage work, primarily because of the withdrawal of grants for such work, those that did answer affirmatively said that the drainage contractor would be the most important source (44%). A quarter relied mostly on their own expertise, but would probably consult the contractor, and another quarter felt that ADAS would be the most important source.

These findings can be compared to those for pesticide use (Table 6.2). Farmers were asked about sources of advice relating to two aspects of pesticide use - the decision about what type of product to use, and the decision about how best to apply the pesticide. The results underline the importance of private sector sources, especially the merchant's representative. Over 50% of farmers claimed that the merchant's representative was their most important source of advice, both when deciding what type of pesticide to use and how best to use it, and no farmers said that they never took advice from this source. Only 19% insisted that it was on the basis of their own expertise that they decided which product to use, but all these consulted other advisors (either merchants' representatives or ADAS) at some stage, and then made up their own minds.

Whilst 57% of farmers had received some advice from the National Rivers Authority (NRA), the Government agency responsible for protecting the water environment, no farmer found the NRA an important source of advice for selecting and using pesticides. This may be partly explained by the recent establishment (in 1989) of the NRA as a regulatory body responsible for *enforcing* environmental policies, with the result that it is viewed with caution or even suspicion by farmers. Also, their primary remit does not concern agricultural production or even (directly) pesticide use. In addition, although the vast majority of farmers had had some contact with the Health and Safety

Table 6.2 - Sources of Advice for Pesticide Use (63 farms)

	Farmers that used this source for any advice (%)	Most important sources of advice (% of farmers)					
		Which product to use.			How best to use it.		
		1st	2nd	3rd	1st	2nd	3rd
Own expertise	100	19	16	6	16	10	2
Merchant's representative	100	57	22	6	56	10	5
Manufacturers representative	100	2	3	3	8	6	-
Independent consultant	60	6	2	-	5	-	2
Contractor	97	-	2	-	5	5	-
Employee's expertise	97	-	-	-	-	2	-
Neighbour	90	-	2	6	-	-	-
Family	92	-	-	2	-	-	-
NRA	57	-	-	-	-	-	-
HSE	94	-	-	-	-	-	-
ADAS (personal)	78	14	8	-	13	8	2
ADAS (group)	52	5	11	2	5	2	1
Farming research group	49	2	-	2	-	-	-
Farming press	97	-	5	5	-	2	2
Farming events & conferences	94	-	2	3	-	-	-
Other		2	2	-	3	2	-

1st = most important source of source of advice; 2nd = second most important source of advice; 3rd = third most important source of advice. Vertical columns do not total 100% because some farmers gave joint first choice of advice and some farmers did not give a second or third preference.

Source: Farm survey.

Executive's (HSE) Agricultural Inspectorate, no farmer found them an important source of advice on pesticides, despite the fact that the HSE, as a body, has the main statutory responsibility for regulating and advising farmers on safety in pesticide use.

In their survey of over 900 farmers, Fearne and Ritson found that almost half their respondents were undecided over whether advice which is paid for is more important than free advice[3]. Amongst the remainder, the majority (32.8%) agreed that advice which is paid for is more important than free advice, and only a fifth disagreed. Farmers seemed similarly undecided about whether advice that is paid for is more reliable than free advice, and almost half the farmers, especially the more experienced, felt that farmers would tend to pay for advice only as a last resort.

The survey sheds some extra light on this issue in the context of pesticide practices. When farmers were asked if they felt there were differences in the nature of the information between the various sources, 65% acknowledged that commercial advice could be biased (Table 6.3). In the words of one of these farmers, "*Commercial sales people usually recommend the product they get most profit from*". As one farmer who chose to pay an independent advisor for his pesticide advice put it,

> "*Independent advice is independent. There's no financial incentive or benefit to the man to advise you to use more. You've already paid for what he's selling. He's selling his expertise*" [Farmer interview no.28].

Another farmer explained in more detail what he saw as the main reason for bias. He said

> "*Of course there is bias. An independent consultant has nothing to sell except his reputation. A commercial rep. has a product to sell. This must put them under pressure at times. There are some excellent chaps in the business but there must be pressure to sell sometimes*" [Farmer interview no.5].

The view that there are some 'excellent chaps' in the business of advising farmers on pesticide usage was shared by many of the farmers interviewed. This seemed to make it difficult for some farmers to even acknowledge the possibility of bias, when they had in their minds the experience of their personal relationships with their own advisors. Many respondents who acknowledged the risk of bias then qualified their answers by

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[3] A note of caution must be sounded here because it is unclear from Fearne and Ritson's report exactly what is meant by 'free' advice. It is most likely that they are referring to the advisory services linked to the commercial sales of products. With pesticides, the farmer usually pays for these services through higher prices. It is also unclear what exactly is meant by the relative 'importance' of advice. This confusion may help to explain the level of indecision amongst the farmers Fearne and Ritson surveyed.

Table 6.3 - Farmers' Responses to the Question 'Do you think there is any difference between independent and commercial advice ?' (57 responses)

Response	No of farmers	% of sample
Yes, commercial advice can be biased	37	65%
No, no difference	15	26%
Yes, different quality but not bias	5	9%

Source: Farm survey.

arguing that the information they received from their *own* merchant's representative was not biased. As one farmer explained

> "*There can be bias but you have to choose your advisor. The general opinion on [my commercial advisor] is if he leaves, how on earth could we carry on. He's very well respected and works very hard. It's not the same with all of them. Some are set terrible [sales] targets by their firms*" [Farmer interview no.7].

One farmer running a 70 ha mixed beef and arable farm quantified what he saw as the difference between commercial and independent advice. In 1988 he had become suspicious about the amount of agrochemicals he was being advised to apply by the merchant's representative, and their high cost. After changing merchants several times, he decided to switch to ADAS and by consulting their specialist found that he was able to cut his total agrochemicals bill by two-thirds and yet maintain the same level of pest control. He has stayed with ADAS ever since and remarked "*merchants' reps are not welcome here*". There was also a feeling that economic pressures in the agricultural supply industries were placing greater pressures on commercial advisors to maximise sales. One young farmer in his 30s running a 240 ha arable farm put it like this

> "*As there's less and less money in the job of selling chemicals, I think you can trust [commercial advisors] less and less. There's more pressure on them to sell*" [Farmer interview no.58].

A quarter of the farmers surveyed felt that there was no difference between independent and commercial advice. Most were familiar with the accusations of bias in advice, however. A closer examination of some of their responses sheds further light on the issue. For example, one farmer on a 150 ha mixed sheep and arable farm felt that while accusations of bias might have once held some truth, this was now less so. He explained

> "*I think there has been bias in the past but the merchant's reps are very aware of it now. For example, a merchant did advise my neighbour that he didn't need to spray. It's because independent consultants have set up in competition. Merchants are more aware of this*" [Farmer interview no.32].

It is worth noting that this farmer, like almost all the group who dismissed the idea of bias in commercial advice, relied on the merchant's representative as his most important advisor. It is, therefore, perhaps less likely that he would acknowledge the potential bias in the advice he was receiving, especially if he had a good working relationship with his advisor. Several farmers seemed to suggest that their own advisor was quite exceptional and was even giving them special treatment. For example, one farmer running a 120 ha mixed sheep and arable farm said

> *"I can see the argument that commercial advice is biased, but I know my chap very well and trust him. He advises lower dose rates and I give him a turkey for Xmas"* [Farmer interview no.54].

The trust displayed by these farmers could also be interpreted as a measure of the success of companies' strategies for developing farmer loyalty (see pp. 169-170). Hawkins (1991) found that a great deal of effort was spent by technical advisors trying to convince farmers of the coincidence of interests between farmer and company. Many farmers see their spray advisor as someone who is 'on their side' in the fight against pests.

Other farmers who felt that there was no difference between independent and commercial advice did acknowledge the *potential* for bias in commercial advice. One farmer who felt that on the whole there was little risk of bias, did go on to say that

> *"Providing the merchant has a range of manufacturers to draw on, then there's no problem. There are problems when certain merchants can't obtain certain products... Then they will recommend the product they can supply, while another product might be more suitable"* [Farmer interview no.39].

One farmer argued that there were discernable differences in the quality of independent and commercial advice, although it was not necessarily true to say that commercial advice was more biased. The farmer, who ran a relatively large 300 ha mixed beef and arable farm, explained that

> *"Since ADAS have gone commercial, they are just as biased as commercial reps. It's just that the bias will be different. Some commercial reps. will be influenced by commercial factors such as higher margins or bonuses on certain chemicals. But ADAS have to justify their cost so they have to bias their advice to show that they're worth their salt. It would be difficult for them to visit a farm, charge for advice and then advise to do nothing. Most farmers are aware of the bias. It's like sailing a boat. You tend to steer to compensate for the bias"* [Farmer interview no.2].

The 'sailing a boat' metaphor is a powerful one, and reveals how even those farmers who suggested that commercial advice was not biased also often acknowledged the *potential* for bias. Moreover, the farmers' responses to these questions suggested implicitly that for each pest problem there was an optimal solution which needed to be identified and recommended. However, every occasion that a pesticide is applied is, in a sense, an experiment and a farmer can never know for sure whether an optimal solution has been found or not. The farmer will be able to see whether the weeds have been effectively controlled, but will have no way of knowing whether such control could have been achieved had the pesticide been applied at a lower dose rate. In these circumstances, the importance of the social relationships surrounding pesticide decisions become even more important. Crucially, and following Hawkins (1991), the responses from the Ouse catchment farmers about 'compensating' for bias show how, in some cases, pesticide practices can be seen as a *negotiated* outcome of the advisory process, with more confident and experienced farmers 'steering to compensate' when it comes to deciding what to do. This ability to assess critically the advice received was variable. At one extreme, some farmers simply chose the advisor that they found most amenable. For example, one respondent running a 110 ha County Council smallholding said

> "*I favour the merchant's advice rather than ADAS, but I couldn't really say why. I just get on with the bloke really*" [Farmer interview no.30].

At the other extreme, a manager employed by a large agribusiness company to farm 420 ha of arable land had developed a strategy to strengthen his position in relation to pesticide advisors. He explained,

> "*If you rely on purely one company, they have their own product to sell. We use more than one company to minimise the risk of bias. Merchants are getting very conscious of this criticism though, and if you use a reputable firm you get much less risk of bias now*" [Farmer interview no.30].

The translation of advice into action was one of the issues highlighted by Fearne and Ritson's study (1989, p.58) as an area worthy of more research, and was also examined here. Given the farmers' acknowledgement of the *potential* for commercial advisors to give advice on pesticide use which suited their economic interests, the survey examined the extent to which farmers might consider applying pesticides at dose rates lower than those recommended by advisors. The responses to the question were detailed in Table 5.4 in Chapter 5 (p.165).

Almost 90% of farmers said that they already undercut dose rates recommended on the product labels, but usually did so *only on the advice of their advisor*. When asked if they ever undercut the dose rates recommended by their advisor, less than 40% of farmers said they did so. They acknowledged that merchants had an interest in selling as much pesticide as possible, or as much of the most profitable pesticides in their portfolios as possible, but felt that their own advisor, with whom they had often struck up a close working relationship, was not biased. Farmers also justified their reluctance to over-ride the advice of their advisors by arguing that they did not have the necessary technical expertise themselves to take such risks. They suggested that if the pesticide failed, their negotiating position with the merchant would be undermined and their opportunity to claim compensation for failure would be jeopardised. However, one farmer explained,

> "*Labels encourage you to put on enough to make sure that it does the job, but in good conditions I think there is scope for cutting dose rates*" [Farmer interview no.45].

Such a strategy would involve farmers taking an economic risk. They would be trading off the savings on the amount of pesticide applied against the risk of the chemical not giving sufficient pest control. The minority of farmers who were prepared to apply pesticides at dose rates lower than those recommended by their advisors stressed the preconditions for such action. It was not something that they would do as a matter of course, but 'occasionally', or after 'some convincing', or 'under ideal weather conditions', they may decide to take a chance. As one put it

> "*If you pick and choose the conditions carefully you can cut dose rates. I would only undercut my advisor if weather conditions are ideal. They give their advice to make sure you're covered, but with practice and experience, you can identify the weather conditions whereby you can go lower than they say*" [Farmer interview no.35].

This farmer acknowledged that there was 'room for manoeuvre' but 'going it alone' was seen as a risky experiment. One farmer explained

> "*I don't like experimenting myself. It's very difficult to get the advisor to stand by a recommendation to cut the dose rate. He might say "I know people who get away with half rate", but he wouldn't put himself on the line. You then cut it at your own risk*" [Farmer interview no.30].

Much stronger convictions were expressed about why the dose rates recommended by advisors should not be undercut. Five typical responses are illustrated below:

> "*I would never go lower than the advisor says. If I think he's going too high, I'd get another advisor*" [Farmer interview no.14];
>
> "*I trust his judgement and [if I undercut] I wouldn't be able to complain if the spray didn't work*" [Farmer interview no.17];
>
> "*I don't agree with cutting dose rates really because if a weed recovers from a lower dose, its more likely to become resistant to the chemical*" [Farmer interview no.43];
>
> "*I usually put on what he says. It's good then for compensation if anything goes wrong*" [Farmer interview no.50];
>
> "*Nobody gets rich doing half a job. I'd cut dose rates if my advisor recommends it but I'd never go lower than that. I wouldn't have any comeback on the firm if it failed*" [Farmer interview no.52].

The risk of taking action independent of the advisor was too great for most farmers. If the treatment failed, then they would not be able to make a claim against the company. In issuing advice on dose rates, merchants and manufacturers share some of the responsibility for chemical crop protection. This sharing of responsibility is reassuring for many farmers who do not feel confident about their own expertise. One farmer, for example, said, *"I figure the advisor knows his job and I know mine"* [Farmer interview no.54]. Such deference to the specialist expertise of advisors was widespread among the farmers interviewed, and appeared to differ little between farmers who favoured commercial or independent advice. For example, one young farm manager, running a 300 ha arable farm, cited the merchant's representative as the most important source of advice on pesticides. When asked if he would consider using lower dose rates than those advised, he said

> *"My advisor gives good advice. He's a trained agronomist. How can you argue with him ?"* [Farmer interview no.57].

The evidence from the survey demonstrates how the role of external advisors in pesticide decision-making is crucial in determining how much pesticide is used. Not only is the merchant's representative by far the most important source of advice, but the extent to which farmers in general are prepared to modify advice from external advisors is limited. In particular, farmers constantly assess the risk of pesticide failure, and the prospect of compensation from the manufacturers or merchants, against the possible savings from applying pesticides at lower dose rates. Most farmers (89%) feel there is scope to make savings on pesticide costs in spite of the risk, and feel that dose rates on product labels are set too high. Recommended dose rates on product labels are set within statutory limits yet 'high enough' to be sure of killing pests under a range of weather conditions. Just how high these rates are set is unclear because the information is deemed commercially sensitive and is not supplied by manufacturers. The willingness of farmers to exploit this potential area of savings depends on their confidence, knowledge and ability to withstand financial losses. Those in the survey most confident about experimenting with dose rates tended to be younger and more highly educated and were often the larger specialist cereal producers who employed a wider range of sources of advice. The more conservative farmers, on average, were older, farmed smaller units and had mixed farms where cereal production formed only a part of the business.

The analysis also highlights the dominance of economic risk assessment over environmental risk. The greatest risk in cutting dose rates, as perceived by the farmer, is that of the pesticide failing and the supplier not being liable to pay compensation for crop failure or yield reductions. Environmental risk seems not to bear directly on the farmers' decisions or the advisor's advice. This can be explained by two factors. First, as was shown in Chapter 3, the pollution of surface and groundwaters by pesticides is a new issue. During the survey farmers were asked what they thought were agriculture's main detrimental effects on the environment, before specific issues about pesticide usage were raised. Water pollution by pesticides was hardly mentioned. Second, there is an assumption among both farmers and advisors alike that once a pesticide has been scientifically tested and approved by the authorities it must be safe to use, provided they keep to the instructions on the product label or from the manufacturers' advisors.

6.4 Conclusions: Externalisation and Negotiated Action

It has been argued elsewhere that a new perspective on agrarian change in advanced economies is required which incorporates the reduced concern for production, the greater commitment to environmental protection, and the greater economic uncertainties farmers now face (Ward and Munton, 1992). Together, these changes demand models which pay more attention to farm-level considerations and the abilities of individual farmers and their households to negotiate their own futures than are allowed for in most political economy perspectives or neo-classical economic models. Thus, aspects of a 'knowledge systems' approach to individual farmer decision-making need to be incorporated. Particular attention has been drawn to the concepts of negotiation and strategy which, when combined, emphasise the local construction of action which can be either constrained or liberated in particular cases by structural tendencies.

The analysis here shows that it is the personal relations between farmers and their advisors that are often crucial in determining pesticide use. This is equally so whether advisors are independent, from ADAS, or linked to a commercial firm (Ward *et al.*, 1993). It is in the process of negotiation between farmers and their advisors that the fate of the local water environment is often sealed, although the environmental risks of herbicide use seem to have little impact on the outcomes of their negotiations. Indeed, the assumption that only 'safe' pesticides are permitted for use prevails and as a result, water pollution risks rarely enter the equation when decisions about which pesticides are to be used and in what quantities are taken.

The importance of advice to decisions that farmers take has major implications for the regulation of agricultural production and underlines the need for research into the strategies of the agrochemical manufacturers and their merchants as well as farmers. There is a need to investigate the constraints the advisors themselves are under, and thus to 'trace the origins of action' back up the system. It is not at all clear whether farmers, in general, can develop the necessary expertise in crop protection to enable them to modify to their advantage the pesticide advice they receive. In any case, the concern with protecting themselves in the event of a chemical failing suggests that many farmers would not modify the advice they receive even if they had the wherewithal. It seems more likely that with the rapidity of technological change and product development farmers are becoming *more* rather than less dependent on the technical expertise of external sources of advice.

It is ironic that farmers are finding themselves increasingly reliant on advice from representatives with commercial interests in selling pesticides at a time when there are increasing economic and environmental pressures to increase the efficiency with which pesticides are used. During the early 1990s, articles have begun to appear in the farming press advising on how best to cut back on pesticide use (Proven, 1991; McKirdy, 1991; Abel. 1992). Abel, in discussing the new economics' of arable crop protection, has argued that

> "a totally new philosophy could develop whereby weed control is concentrated, at least in part, on traditional methods of overwinter cultivation. That could result in some spring crops replacing winter ones... *The traditional cost: benefit values for agrochemicals and other inputs are in the melting pot"* (Abel, 1992, p.3, emphasis added).

Two strategies espoused by Proven (1991) are the threshold system and the low rate route. Thresholds operate under the principle of 'don't spray if you don't need to' which tolerates a level of weed infestation in the crop up to an economic threshold before spraying is required. In order to be adopted, however, farmers' intolerance of any weeds will have to become overcome (Chapter 5). Proven's second strategy is to cut dose rates. Using the two strategies in combination, average improvements in margins at five ADAS experimental farms have been up to £23 per hectare. However, the evidence presented in this chapter suggests that the widespread dependence on commercially linked pesticide advice, and a strong reluctance to contradict the recommendations of external advisors will provide a major barrier to the adoption of such measures.

CHAPTER 7: FARM STRATEGIES, PESTICIDE POLLUTION AND REGULATION

7.1 Introduction

From the empirical evidence from the Ouse catchment, a number of points are clear. First, agricultural restructuring during the 1980s has prompted a wide range of farm responses placing farming practices like pesticide usage in markedly different production contexts. Second, farmers still find their increasing dependence on chemical technologies unproblematic in environmental terms, and are confident that all pesticides will have been thoroughly tested before being approved for use. Third, herbicides, in particular, have been crucial in enabling cereal production to take place in the area, and the farmers' strong convictions about the threat to their crops from weeds stands in contrast to their perception of water pollution risks from pesticides as being long term, unclear and unproven. Fourth, in determining which pesticides get used, and how, the role of technical advisors is usually critical, with the majority of farmers unwilling or incapable of modifying the advice they receive.

In this chapter, these themes are examined in more detail, drawing some links between farmers' practices, types of farm enterprises, and farm development trajectories. The chapter will go on to further explore how farmers understand the seriousness of pollution problems and their roles in creating them, how they perceive the nature of the pollution problem from pesticides, and their relations with the regulatory authorities. The Ouse catchment farmers' attitudes and experiences will then be contrasted with findings from the PATCH Programme's study of dairy farmers in Devon.

Finally, farmers' possible responses to a series of regulatory measures aimed at tackling water pollution from agricultural pesticides are analysed. Given that the greatest threats to water quality from agriculture in the Ouse catchment come from the use of cereal herbicides, and the autumn use of Isoproturon (IPU) in particular, the impact of three different regulatory scenarios are assessed. These scenarios are: a ban on the use of IPU in the catchment during the autumn months; a total ban on the use of IPU; and a ban on the use of all herbicides in the autumn.

7.2 Farm Types and Pesticide Practices

Over half the farmers said that they would not consider applying herbicides at dose rates lower than those recommended by technical advisors, while under 40% said they sometimes went lower (Table 5.4, p.165). Those who admitted to undercutting the rates recommended by advisors usually went on to say that they did so only when conditions were strictly suitable (when weather conditions were ideal) and not as a matter of course. Specialist arable producers were more likely to undercut dose rates than their counterparts with significant livestock enterprises. Seventeen of the 37 arable and mainly arable producers (45.9%) said that they already undercut the dose rates recommended by their advisors or would consider doing so, compared to 7 of the 23 mainly livestock farmers (30.4%). There was also a relationship between a belief in the potential for bias in commercial advice and the propensity to modify advice. The vast majority of farmers (19 out of 22) who were prepared to undercut dose rates believed that commercial advice could be biased.

Those that did undercut dose rates recommended by advisors were, on average, a group of larger farms with a greater proportion of household income derived from agriculture. The mean farm size of the 'undercutters' was 293 ha compared with just 205 ha for those not prepared to modify advice (and 218 ha for the whole sample)[1]. Also, on average, the 'undercutters' derived 85% of total household income from agriculture compared to only 72% for those unwilling to modify advice (and 73% for the whole sample). There was, however, very little difference between the mean ages of the two groups of farmers.

Those farmers seeking to survive through diversification or land development were more likely to undercut dose rates than the disengagers, in particular (see Table 7.1). Indeed, only one of the 11 disengagers ever applied cereal herbicides at dose rates lower than those recommended, compared with two-thirds of the developers and diversifiers. Those following the most 'agricultural' strategies - the adjusters and expanders - fell between these two extremes, although half the expanders said they did sometimes undercut advised dose rates. Often those farmers who had sought new sources of income did so because of severe financial pressures and squeezed margins for cereal production. Attempts to reduce the herbicide bill by as much as possible could, therefore, be seen as compatible with such a strategy. However, willingness to undercut advised dose rates is not strongly associated with profitability, although those who were making a profit were, on average, more willing to undercut than those making a loss or breaking even (see Table 7.2) .

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[1] However, a difference of means test revealed that the differences in mean farm size were not statistically significant at the 90% confidence level.

Table 7.1 - Willingness to Undercut Dose Rates Recommended by Advisors and Farm Development Trajectories (Number of farmers)

	Already undercut	Would consider	Would not consider	Don't know
Adjusters (23 farms)	8	0	12	3
Expanders (12 farms)	5	1	5	1
Diversifiers (7 farms)	4	1	1	1
Developers (10 farms)	4	2	3	1
Disengagers (11 farms)	1	0	9	1
Whole sample	22	4	30	7

Source: Farm survey.

Table 7.2 - Willingness to Undercut Dose Rates Recommended by Advisors and Farm Business Profitability (Number of farmers)

	Already undercut	Would consider	Would not consider	Don't know
Made a profit (31 farms)	11	2	15	3
Made a loss (20 farms)	5	2	9	4
Broke even (12 farms)	6	0	6	0
Whole sample	22	4	30	7

Source: Farm survey.

In summary, the analysis here suggests that there are noticeable differences between the ways farmers in different social and economic circumstances use herbicides and modify the advice they receive. Certainly, all are not acting in the same way simply in response to price differentials and market conditions. The type of farm business, the mix of enterprises and the direction of its development all help to form the context within which decisions about what types of herbicides to use and how to use them are taken.

7.3 Farmers' Understandings of Pollution and Regulation

Because agricultural pollution is a relatively recent issue of public and political concern, little is known about how farmers' understand the nature of the pollution problem. This section addresses this gap in our knowledge with particular reference to pesticide pollution. In doing so, it is possible for the analysis to parallel other work carried out under the PATCH research programme[3]. As part of the programme, sixty dairy farms in Devon were surveyed by the author in 1991 using a similar questionnaire to that for the Ouse catchment survey, but the Devon survey concentrated on the pollution of rivers by livestock effluents (see Lowe *et al.*, 1992a; Ward and Lowe, 1994; Ward *et al.*, 1994). During the survey in the Ouse catchment, farmers were asked the same types of question about agricultural pollution. It must also be stressed that in their immediate responses to questions about agricultural pollution and its regulation, the farmers mostly talked about pollution from livestock effluents and occasionally about nitrates. Over two thirds of the sample carried some livestock on their farms, and it tended to be the associated effluents that most farmers first thought of when discussing pollution risks. Moreover, those specialist arable producers who had no livestock often had some difficulty in thinking about pollution risks from their own farming practices at all, and were much more likely to consider water pollution and its regulation as, in the main, a problem for 'other' types of farmer. Water pollution from pesticides was not something which the Ouse catchment farmers had a clear understanding of, or detailed views about, in contrast to Devon's dairy farmers where the issue of pollution from livestock effluents had a much higher profile.

From the responses to the questions about pollution two divergent views were apparent, as had been the case in Devon. In both surveys there were farmers at each extreme arguing that pollution regulations were either an unfair attack on an already beleaguered industry or that pollution regulations were a necessary step towards putting agriculture's house in order. For example, farmers were asked what they thought

[3] Footnote No. 3 on p.16 explained how the research for this thesis was conducted alongside other contract research work. Most closely related was the PATCH (Pollution, Agriculture and Technology Change) Programme's study of water pollution from livestock effluents on Devon dairy farms.

would be the effects of a strict prosecution policy for pollution incidents. Of the 63 farmers, 37 (or 59%) felt that it would help to reduce pollution. However, 14 farmers (22%) argued that a strict prosecution policy would be detrimental to the industry and would drive some farmers out of business (see Table 7.3).

There was a similar split between positive and negative views when farmers were asked their opinion about current incentives to prevent pollution. Half of them thought that these were adequate (Table 7.4). Amongst this group there was generally praise for the high level of grant for pollution control equipment (to store effluents and pesticides, for example), although there was also an undercurrent of concern that, while farmers might have done all that was expected of them in improving their facilities, accidents could still happen and they would still be liable. Twenty-five farmers (40%) felt that the incentives were not adequate. There was a sense that it was unfair for farmers to contribute much at all in a situation where they were being obliged to comply with policy and where the money spent would bring them no financial return, especially at a time of recession in the farming industry.

Farmers were also asked how they felt about agricultural pollution compared to pollution from industry, and how its regulation was affecting agriculture in general, and their own farms in particular (Tables 7.5 - 7.7). Around two thirds of farmers interviewed felt that pollution from agriculture was not as significant as that from industry, a similar proportion to that in Devon. Under a fifth of the farmers in the Ouse catchment felt that agricultural pollution was significant in comparison, and this proportion is noticeably lower than that found in Devon. Farm pollution of rivers has been an issue of great public concern locally in Devon, and farmers have become more sensitized to the issue, and to pollution risks, through regulatory, advisory and media campaigns (see Ward *et al.*, 1994). This could explain the greater willingness to accept farm pollution as a significant issue there. The higher profile regulatory stance adopted in Devon involving Britain's first advisory campaign aimed specifically at farm pollution was also reflected in the fact that only a third of Ouse catchment farmers felt that agricultural pollution was being more strictly dealt with than industry, compared with almost a half of the Devon dairy farmers interviewed (Table 7.6). The farmers of the Ouse catchment were much more confident that industry and agriculture were being treated the same, perhaps reflecting the fact that they were, in effect, being subjected to less forceful regulation than the dairy farmers in Devon.

Evidence supporting this view can be found in the farmers' perceptions of the impact of pollution regulation (Table 7.7). A quarter of the Ouse farmers felt that pollution regulation was something that only really affected livestock farmers, and seven farmers

Table 7.3 - Farmers' Responses to the Question 'What do you think would be the effects on farmers of a strict prosecution policy for pollution incidents ?'

	Devon (60)		Ouse (63)	
	No*	%	No	%
It would reduce pollution	34	57%	37	59%
It would drive some farmers out of business	21	35%	14	22%
It would cause resentment in the farming community	6	10%	8	13%
Don't Know	3	5%	4	6%

Note: Some Devon farmers gave responses to this question that fell into more than one category.

Source: Farm survey and PATCH Programme farm survey in Devon.

Table 7.4 - Farmers' Responses to the Question 'Do you think that there are adequate incentives to prevent pollution on farms generally ?'

	Devon (60)		Ouse (63)	
	No	%	No	%
Yes	35	58%	31	49%
No	24	40%	25	40%
Don't Know	1	2%	7	11%

Source: Farm survey and PATCH Programme farm survey in Devon.

Table 7.5 - Farmers' Responses to the Question 'Do you think that pollution from agriculture is significant compared to pollution from industry ?'

	Devon (60) No	%	Ouse (63) No	%
Yes	16	27%	12	19%
No	39	65%	43	68%
Don't Know	5	8%	8	13%

Source: Farm survey and PATCH Programme farm survey in Devon.

Table 7.6 - Farmers' Responses to the Question 'Do you think that pollution by agriculture is being dealt with in the same way as pollution by industry ?'

	Devon (60)		Ouse (63)	
	No	%	No	%
Industry and agriculture treated the same	15	25%	29	46%
Tougher on agriculture	29	48%	20	32%
Tougher on industry	1	2%	1	2%
Don't Know	5	8%	12	19%

Source: Farm survey and PATCH Programme farm survey in Devon.

Table 7.7 - Farmers' Responses to the Question 'What impact do you think pollution regulations have had on farming practices generally ?'

	Devon (60)		Ouse (63)	
	No	%	No	%
Pollution has been reduced	19	32%	-	-
Costs/ difficulties have increased	25	42%	7	11%
Farmers are much more aware	16	27%	25	40%
No effect	1	2%	5	8%
Improved handling of agrochemicals	-	-	4	6%
Regulations have only affected livestock farmers	-	-	15	24%
Don't Know	-	-	7	11%

Source: Farm survey and PATCH Programme farm survey in Devon.

felt unable to respond at all. While 40% of the Ouse farmers felt that farmers had been made more aware of pollution risks, none claimed that pollution had been reduced. This compares with a third of Devon dairy farmers who could see (and had paid for) widespread investment in pollution control equipment and were confident that river quality was improving as a result.

When it came to pollution risks from pesticides, farmers in the Ouse catchment saw storage and handling as the main areas where improvements had been made and pollution risks had been reduced (Tables 7.7 and 7.8). This is where most regulation, technical innovation and inspection by the HSE, had been concentrated, leaving the timing and rates of application as the least regulated aspects of pesticide use.

From the responses to this series of open-ended questions about pollution from farming, it became clear that the problem of agricultural pollution is viewed by different farmers in different ways, but with some consistent patterns. Like the analysis of the 60 Devon dairy farms for the PATCH Programme, (see Ward, 1994; Ward and Lowe, 1994; Ward *et al.*, 1994) three categories were established for the Ouse catchment farmers, including two contrasting positions and a large, middle-ground group[4].

a) The Sceptical Farmers: A group of 8 farmers in the Ouse sample (13%) was inclined to adopt the stance of "what pollution problem ?" . Farmers in this (minority) group felt that the pollution issue had been "blown up out of all proportion" and that regulation had "gone too far" in restricting what farmers could do. They were most likely to feel embattled by pollution regulation and tended to be the most vocal complainants of the farmers' treatment. All in the group felt that agricultural pollution was far less of a problem than industrial pollution, and suspected that farmers were being more strictly regulated because they were "easy targets". Some farmers in the group also questioned whether agricultural pollutants, such as livestock effluents, were 'serious' pollutants at all.

b) The Ambivalent Farmers: A larger group of 33 farmers (52% of the sample) tended to see causing pollution as what might be characterised as a form of rule breaking. They readily acknowledged that farm pollution was a problem and that measures had to be taken to solve it. Critically, however, they saw pollution as a problem *for* farming, rather than as a problem *of* farming[5]. The sense, among this majority group of

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[4] Responses to questions no. 126, 127, 128, 129, 133 and 134 were the main source of information used to place farmers in one of the three categories (see Appendix B).

[5] A similar distinction has been identified by Susan Carr's research on farmers' attitudes to conservation (see Carr, 1988; Carr and Tait, 1990).

Table 7.8 - Farmers' Responses to the Question 'What impact do you think pollution regulations have had on this farm in particular ?'

	Devon (60)		Ouse (63)	
	No	%	No	%
No effect	22	37%	25	40%
Pollution control equipment has been installed	34	57%	14	22%
More care taken generally	16	27%	6	10%
Stopped dairying	1	2%	3	5%
Improved handling of agrochemicals	-	-	13	21%
Cut nitrogen use	-	-	1	2%
Reduced straw burning	-	-	1	2%

Source: Farm survey and PATCH Programme farm survey in Devon.

farmers, was one of pollution regulations coming from changes in policy that were beyond their control, but had to be adhered to if only because it was unacceptable to break laws and regulations. In other words, pollution is a problem chiefly in the sense that it "can get you into trouble". The main difficulty, as perceived by this group of farmers, was how to meet new regulations and the restrictions they implied. These farmers tended not to question the *need* for action to curb pollution and generally accepted that livestock effluents, in particular, caused pollution problems. However, there was a feeling of ambivalence. For example, whilst the farmers acknowledged the environmental threat, they found the notion of water pollution being caused by 'normal' pesticide practices particularly problematic, and generally treated the issue as an administrative one. Their actions appear to be motivated by a need to 'keep the authorities happy' rather than by their own moral imperative. However, several farmers in this group argued that much pollution, particularly that from farm effluents, is "accidental" in that it often results from heavy rain causing yard run-off, or from the failure of effluent storage facilities. They felt, on the whole, that farmers who had been the "victims" of such "accidents" should be treated leniently and *encouraged* to make improvements to pollution control facilities. They were keen to distinguish between these "accidents" and the "much more serious" pollution incidents which involved the deliberate disposal of effluents or pesticides into watercourses, where, they stressed, the full force of the law should be brought to bear.

c) The Radical Farmers: A third group of 22 farmers (35% of the sample) tended to see pollution as something reprehensible. Farmers in this (minority) group accepted the need for regulation to address farm pollution problems. They expressed approval of the regulations, describing them, for example, as "a good thing" that would help to "put agriculture's house in order". Most were quite emphatic that regulations must be adhered to and that the adoption of improved environmental practices was for the good of the industry as a whole. It is, these farmers tended to agree, the responsibility of the individual farmer to ensure that pollution is adequately prevented. One of the defining characteristics of this group was their unwillingness to differentiate between accidental and deliberate pollution incidents.

These findings from the Ouse catchment can be compared with those from the survey of dairy farmers in Devon (Table 7.9). In the Ouse sample, a smaller proportion of farmers were classed as 'sceptics' and a larger proportion as 'radicals'. This would seem to support conclusions from the PATCH Programme research in Devon which suggested that it has been social change in the countryside which has helped begin to transform values in agriculture (Ward *et al.*, 1994). It is those farmers who remain most strongly committed to the notion of agriculture as a special case for public support

Table 7.9 - Pollution Perception Groups

	Devon (60) No	Devon (60) %	Ouse (63) No	Ouse (63) %
Sceptical farmers	10	17%	8	13%
Ambivalent farmers	37%	62%	33	52%
Radical farmers	13	22%	22	35%

Source: Farm survey and PATCH Programme farm survey in Devon.

who find it most difficult to accept the seriousness of farm pollution problems or to incorporate measures to reduce pollution risk into their routine farming practices. However, as farm families become more closely linked to non-agricultural social networks in the countryside, so their view of agriculture as a special case weakens. Increasing social and economic contacts with new, middle-class ruralites provides a route by which new environmental values can flow into the farm household.

In this case, it might be expected that there would be a greater proportion of radicals and fewer sceptics in the Ouse catchment compared to Devon for several reasons. Firstly, agriculture is more closely integrated with the wider rural economy and society in the Ouse catchment. In Devon a larger proportion of people work in agriculture and related industries and strong family farming values can still be found[6]. In conducting the two farm surveys, there was a greater feeling that the Devon sample comprised a farming 'community', with farm families knowing each other within a district. Farmers also had regular opportunities to meet with each other at local livestock markets. This sense of a community was much less apparent in the Ouse catchment. Sampled farms in Devon also tended to be more geographically isolated, and were often clustered in small farming hamlets and villages. In the Ouse catchment, agriculture's retreat from its dominant position in the rural economy and rural land use has had a longer history. The catchment serves as a commuter zone for London, and experienced a land development boom in the 1980s. Moreover, the Devon farmers were all dairy farmers, and the incessant, day to day demands of running a dairy unit are a major barrier to farm diversification for dairy farm families, even in a tourist area like Devon. By comparison, farmers in the Ouse catchment were much more likely to have diversified, and as a result, were welcoming people from the nearby towns of Bedford and Milton Keynes regularly onto their farms. (For example, two-thirds of the Devon farm households studied relied entirely upon agriculture for their income compared with less than one third of those in the Ouse catchment).

The characteristics of the farmers in each of the three groups provides more support for the findings from the Devon analysis (Table 7.10). The average age of the farmers falls as 'sensitivity' to pollution increases. The average age of the sceptics was 51.5 years,

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[6] According to figures from the Agricultural and Population Censuses, 1.2% of the economically active population in Buckinghamshire worked in agriculture in 1991 compared to 4.2% in Devon. Data from earlier studies have also documented the distribution of farms from a 'pure' family farm type to 'corporate farming businesses' in different farming regions in Britain (Whatmore *et al.*, 1987a;b; Marsden *et al.*, 1992b; see also Gasson and Errington, 1993, pp.73-77). Although similar analyses have not been conducted for the Devon and Ouse catchment samples, immediately neighbouring districts in Dorset and Bedfordshire have been studied. It was found that 81.8% of Dorset farms fell into the least subsumed, more 'pure' family farm type compared to only 55.7% in Bedfordshire (Marsden *et al.*, 1992b).

Table 7.10 - Farm Characteristics by Pollution Perception Groups

Category	Average size (ha)	Average % under cereals	Average farmer age	Average % farming income	% planning for succession
Sceptics (8 farms)	358.3	50.0	51.5	79.0	50.0
Ambivalent farmers (33 farms)	194.0	47.6	49.0	79.2	57.6
radicals (22 farms)	201.5	49.1	46.3	61.6	50.0
Whole sample	217.5	48.6	48.4	73.0	54.0

Source: Farm survey.

compared to 49 years for the ambivalent farmers and 46.3 for the radicals. Also, agricultural income was relatively less important for the radicals. Only 62% of total household income, on average, was derived from agricultural production among the radicals, compared to 79% among the sceptics and the ambivalent farmers[7].

However, evidence that would link commitment to succession with perceptions of pollution is not as strong as in the Devon dairying sample. In Devon, commitment to succession declined as farmers' 'sensitivity' to the pollution issue increased. In the Ouse catchment, half of the radicals and half of the sceptics were planning for succession, while the proportion among the ambivalent farmers was 57%. This compares with 80% of Devon sceptics, under two-thirds of ambivalent farmers and under half the radicals (see Ward and Lowe, 1994). In the Ouse catchment, there are no strong patterns in tenure, enterprise type or farm strategy that can be linked to the pollution perception categories, although it is notable that there are no dairy farmers among the sceptics, suggesting perhaps that they have become more sensitized to farm pollution issues than their arable counterparts because of the specific risks arising from dairy farm effluents.

7.4 Farmers and the Regulatory Authorities

Farmers were also asked about their relations with the two main regulatory bodies responsible for pesticide use and protection of the water environment. Fifty-five farmers (87.3% of the sample) had been visited by the Health and Safety Executive (HSE) in recent years. Of these, 8 had received visits that were other than routine (*i.e.* in relation to specific safety issues or incidents), and four of these had been visited specifically in relation to the new COSHH (Control of Substances Hazardous to Health) Regulations[8]. When asked 'what sort of things do the HSE pick up on when visiting your farm ?' 38 farmers mentioned machinery and fixed equipment, 14 pesticide storage facilities, and only 8 safety precautions for spraying practices. Three farmers had had spot checks in relation to spraying practice.

The findings reveal the relative weakness of the relations between farmers and the regulatory agency responsible for pesticide spraying practices. Most contact was through routine visits and it was machinery and fixed equipment that was inspected most often. This would seem to support the concerns of the Institution of Professional

[7] However, two sample difference of means tests revealed that these differences in mean farmer age and agricultural income were not statistically significant at the 90% confidence level.

[8] COSHH regulations had been introduced in 1988 and required that farmers assess the risks to workers and the environment posed by the use of chemicals on their farms and record these on paper as a 'COSHH assessment'.

Civil Servants who estimated that, nationally, the average farm is visited only once in every 9.8 years, and a self-employed farmer might not see an inspector for 29 years (see British Medical Association, 1992, p.66). While most farmers had had some contact with HSE agricultural inspectors, their role in regulating how pesticides are applied seems, from the survey evidence, limited and aimed more at worker safety than protection of the water environment. Moreover, the majority of farmers were not particularly favourably disposed towards the HSE (Table 7.11). For example, one farmer, categorised as 'ambivalent' about pollution who ran a 150 ha dairy and arable farm saw HSE's role as interference. He explained

> *"They're a pain in the neck and have the wrong approach and are arrogant. They pick up on little safety bits and pieces. It's not like pollution where other people get affected. It's just your own safety that's at risk. It should be my choice, like whether to wear a seatbelt"* [Farmer interview no.4].

Other farmers saw HSE's role as indicative of a bureaucratic onslaught on agriculture, and were suspicious of the motives of regulators. One such farmer with a 100 ha dairy and arable farm complained that

> *"They are too pernickety. There is a whole new bureaucratic world building up there, another strata of people riding on our backs, finding problems just to justify their jobs"* [Farmer interview no.62].

The majority of farmers remained indifferent towards the HSE. As one farmer explained, *"I can't say I'm pleased to see them but they're few and far between"* [Farmer interview no.49].

Only nine farmers described their dealings with the HSE in a positive light. One such farmer on a large 500 ha arable farm was concerned, however, that agricultural specialists within the HSE would be replaced by people more used to dealing with other types of industry. Of those HSE officials who had visited his farm, he said

> *"So far so good. They've always had an agricultural specialist and so have understood agriculture. They are very helpful and gently point out if something's amiss. They haven't come in with guns firing. The're very constructive. But my fear is that the next HSE chap spends most of his time in factories and doesn't understand agriculture. You used to feel you were talking to a colleague. I'm not so sure about the new breed who seem to be more geared to industry's experiences"* [Farmer interview no.5].

Farmers were also asked about their views on the new National Rivers Authority (NRA). In this case, questions differentiated between the farmers' views about the organisation as a whole, and their dealings with its officials in the field. Although the

Table 7.11 - Farmers' Responses to the Question 'How do you find HSE officials ?'

Response	No. of Farmers	%
Favourable	9	16
Indifferent	36	65
Unfavourable	10	18

Source: Farm survey.

NRA are the main regulatory body responsible for protecting the water environment, they have little to do with pesticide spraying practices (NRA, 1992; RCEP, 1992). Instead, their contact with farmers usually involves inspections of effluent and storage facilities. It was, therefore, the livestock farmers in the sample that had had more contact with the NRA. Farmers' overall impressions of the NRA as an organisation are shown in Table 7.12. Nineteen farmers (30%) expressed unfavourable views about the NRA (compared with 14 (23%) from the PATCH survey in Devon). Many of the Ouse farmers, especially the specialist arable producers, had had no contact at all. Of those who were unfavourably disposed, a common complaint was that the NRA had begun charging for abstraction and discharge consents. As one farmer on a 140 ha arable and sheep farm explained

> "*I don't think they are in touch with the farmer in the field. There's a lot of ground between us and them. The way they raise their money is unfair and gets the farmers' backs up*" [Farmer interview no.32].

Other complaints were that the NRA were too 'bureaucratic', 'confrontational' and 'officious'. It was often argued that the NRA did not understand farming, resulting in an 'us and them' feeling amongst farmers. One farmer running a 315 ha mixed farm was more specific, saying that

> "*They are an appointed body and are out to be dictatory. They are not representative enough. They are a new body with new powers and are flexing their muscles a bit. The big stick approach would be better if there was more liaison first*" [Farmer interview no.35].

Farmers were asked what experience they had had of the new NRA and how this compared with the old water authorities before privatisation. The results are shown in Tables 7.13 and 7.14. Over half the farmers had not had any personal contact with the NRA. Of those who had, most were indifferent. The most common complaint was the lack of detailed knowledge of farming practices amongst NRA fieldstaff.

More farmers could recall having been in contact with the old regional water authorities before water privatisation, and a third of the sample had noticed differences in regulatory style between the old authorities and the new NRA, with the NRA pursuing stricter enforcement strategies which did not bode well for farming. One farmer explained "*The old water authorities' policy favoured agriculture more*", and another complained that the regulators "*have gone from being practically-oriented to bureaucratic and bungling.*" However, one farmer who ran a 200 ha mixed dairy and arable farm had a more specific complaint about the change of regime. He explained

Table 7.12 - Farmers' Responses to the Question 'What is your impression of the National Rivers Authority ?'

	Devon (60)		Ouse (63)	
	No	%	No	%
Indifferent	27	45%	15	24%
Favourable	9	15%	10	16%
Don't know	10	17%	19	30%
Unfavourable	14	23%	19	30%

Source: Farm survey and PATCH Programme farm survey in Devon.

Table 7.13 - Farmers' Responses to the Question 'How did you find the new NRA/ old water authority officials ?'

Response	National Rivers Authority	Old Water Authority
No contact	38 (60.3%)	25 (39.7%)
Favourable	5 (7.9%)	6 (9.5%)
Indifferent	14 (22.2%)	25 (39.7%)
Unfavourable	6 (9.5%)	7 (11.1%)

Source: Farm survey.

Table 7.14 - Farmers' Responses to the Question 'Have you noticed any differences between the old water authority and the new NRA ?'

Response	No of Farmers	%
No Difference	40	63.5
Higher fees now	7	11.1
Stricter enforcement	12	19.0
Other	4	6.3

Source: Farm survey.

"The old pollution people were more attached to the river while the NRA are expected by the public to go and get results. We used to feel we belonged to our catchment. It's like local government rather than national. You are concerned about what happens in your own backyard. But now the NRA is a national body and it's less personal" [Farmer interview no.18].

7.5 Regulating Farmers and Protecting Water

The specific nature of the pollution risk in the Ouse catchment was outlined in Chapter 5, but two further developments demand comment. First, because of the increasing recognition of Isoproturon as a problematic pesticide pollutant of water (Harvey, 1990; Fielding, 1992; NRA, 1992, p.138; RCEP, 1992, p.231), its use has come under closer scrutiny. In 1990, MAFF announced that, in line with commitments given in the DoE's White Paper, *'This Common Inheritance'*, 38 active pesticide ingredients including Isoproturon would be reviewed by the Advisory Committee on Pesticides (MAFF, 1990). Results of the review are not yet available, although one possibility is the introduction of restrictions on the use of Isoproturon, or even its complete ban from the market.

At the same time, the NRA has been emphasising the value of catchment management planning as a strategy for controlling pollution (NRA, 1990; 1991; 1992, p.79; RCEP, 1992, pp.164-165). This would allow the identification of vulnerable surface and groundwaters leading to the designation of water protection zones under the 1991 Water Resources Act. Restrictions on farming practices, including the use of particular pesticides, could then be imposed in specified catchments. Similar schemes, common in continental Europe, are already being piloted under MAFF's Nitrate Sensitive Areas schemes, although restrictions on farming practice have so far been voluntary, accompanied by compensation payments and, crucially, administered by MAFF rather than the NRA (Seymour *et al.*, 1992).

In the light of these two developments, three possible regulatory scenarios and their possible impacts on agriculture in the Ouse catchment are considered here. The scenarios are: a ban on the autumn use of IPU in the catchment; a total ban on the use of IPU; and a ban on the use of all herbicides in the autumn.

7.5.1 Responses to an Autumn Ban on IPU Use

Farmers were asked what they might do if Isoproturon (IPU) was banned from autumn use[9]. Responses are shown in Table 7.15. The most common response to an autumn ban would be to switch to another chemical such as Chlortoluron (Dicurane) or Fenoxapropethyl (Cheetah). The former is also a pre-emergent herbicide whilst the latter is a contact herbicide[10]. Twenty-six farmers (44%) said that this would be their most likely response. It was clear that IPU plays a very important role in their arable cropping, and a ban on its use in the autumn would cause major problems for most of the farmers because of the increased threat to cereal crops from blackgrass weeds in particular that would result. As one elderly farmer on a small 30 ha holding explained

> "*I'd have to seriously think about not growing wheat. You can't grow wheat and blackgrass. The blackgrass will kill the wheat. You could try killing it in the spring using Cheetah. It's one of the new ones...but it's much dearer*" [Farmer interview no.21].

Another farmer in his 30s running a large 600 ha arable farm explained;

> "*We wouldn't have a crop. IPU is very important. The blackgrass is unbelievable. It's very serious. Once after oilseed rape we didn't spray for blackgrass, but the next year it cost us twice as much to spray. We couldn't really farm without IPU*" [Farmer interview no.41].

The idea of leaving blackgrass weeds in the crop until the spring and dealing with them then did not seem a viable option, particularly for those farmers who placed great value on 'clean', weed-free fields. One farmer with about a third of his 140 ha sown with winter cereals said

> "*It would look bloody dirty. You'd get weed infestation and it would affect yields....maybe by up to 60%. I don't know what I'd do. I'd have to see what other alternative chemicals were available*" [Farmer interview no.32].

The most commonly cited alternative to using IPU in the autumn was to use the new contact herbicide, Cheetah. However, the main problem, as the farmers saw it, was the relatively higher cost of contact herbicides in general, and Cheetah in particular. This is because Cheetah is a new product which is still under patent. The company, Hoescht, have a monopoly on its production. Its cost is about £22 per acre (£54 per hectare), compared with £10-£14 per acre (£25-£35 per hectare) for IPU. One farmer, growing

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[9] All the farmers surveyed in the Ouse catchment used IPU at some stage for weed control in cereals. (For further details about IPU and its herbicidal action see pp.107-110).

[10] Contact herbicides kill weed foilage on contact, and so are less likely to need to be persistent in the environment (see Hassan, 1990).

Table 7.15 - Farmers' Responses to an Autumn Ban on IPU Use

Response	No. of farmers	%
Don't know (I would have to ask my advisor)	6	10.2
Use IPU in the spring and drill later	14	23.7
Switch to another chemical (Cheetah or Chlortoluron)	26	44.1
Spring cropping	5	8.5
Change cropping pattern / rotation	2	3.4
Use cultural methods of weed control	2	3.4
No effect	8	13.6
Consider stopping cereal production or set aside	4	6.8
Total	59	100%

Source: Farm survey.

110 ha of winter cereals in 1991, estimated that using a contact herbicide in the spring would increase herbicide costs by about 50%. He explained,

> "*It would increase the cost of the chemical bill as we'd have to use a more expensive contact herbicide in the spring. Cheetah would work out 50% dearer to get the same level of weed control. It would put a strain on viability and would make my blood boil. The chemical companies are ripping us off. IPU is competitively priced, but we'd have to use patent chemicals*" [Farmer interview no.36].

The option of switching to Dicurane rather than Cheetah seemed to be the least disruptive. However, Dicurane's main active ingredient, Chlortoluron, is persistent and has also been detected in surface and groundwaters at levels above the EC's MAC (Croll, 1991; RCEP, 1992) and so future restrictions on IPU could also be applied to Chlortoluron. The chemical can only be used in conjunction with particular cereal varieties, and so a switch from IPU to Dicurane could also mean a change of varieties grown. As one farm manager responsible for 356 ha of arable land owned by a large farming company explained

> "*I'd use a different chemical. We use Dicurane where we can and then IPU on the non-Dicurane varieties .... We could switch to more Dicurane varieties but a chemical switch is easier than a cropping switch. Anyway, non-Dicurane varieties tend to be the best yielding....Last year was the first year that Cheetah was available. People are still sussing out dose rates*" [Farmer interview no.60].

Cheetah would involve a chemical switch rather than a cropping switch but, as the farmer above pointed out, farmers are still not clear how best to maximise the efficiency of Cheetah whilst not compromising its efficacy. Some farmers considered how Cheetah might prove economic to use if IPU were banned from autumn use. One young farmer in his early 30s thought that a combination of chemical and cultural methods of weed control might be workable on his large, 700 ha farm. He said

> "*Firstly we'd pick the next best chemical, and secondly we'd culturally attempt to alleviate the problem. We could use either Cheetah or Hoegrass sequentially, but they're at least double the cost of IPU. Cheetah would require two doses. That's maybe £75 a hectare, against £25 for IPU. You might be able to get Cheetah down to £50*"[Farmer interview no.55][11].

In the economics of crop husbandry the ability to cut dose rates by half can become critical. The costs of IPU vary from farmer to farmer according to the suppliers used,

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[11] Different farmers cite different prices for agrochemicals. This is because while prices tend to be set by the agrochemical companies at the highest rate that the market can bear, there is scope for renegotiating lower prices if chemicals are bought in bulk. Usually, larger farmers can buy their sprays at lower prices. In addition, the costs of sprays vary according to whether the farmer chooses the accompanying advisory services or not.

but its markedly lower cost and its widely recognised reliability mean that a switch to Cheetah without an increase in costs is unlikely for most farmers. Moreover, switching to using fewer residual herbicides like IPU in the autumn would go against the strategy that many farmers in the sample were following, which was to concentrate more on pre-emergent weed control in the autumn. One farmer told how ADAS had been recommending that he use more IPU in the autumn as the most cost-effective method of weed control in cereals. This was also the current advice from the local merchants' representatives. Some farmers, however, had been cutting down on pre-emergent herbicides, although an autumn ban on IPU would still cause problems for them. One farmer running a 550 ha mixed farm over half of which was down to cereals explained

> "*It would have a drastic effect. We rely quite a lot on IPU. We'd have a lot of blackgrass. I'm probably using less IPU. It's getting to the stage now where we can hit the weeds at a later stage and it's more effective*" [Farmer interview no.48].

Leaving weeds until a later stage in their growth can be a risky strategy, particularly given the competitiveness of blackgrass. The size of the weed is important, because with older plants the flesh has a chance to harden and consolidate. Fresh, newly emergent weeds are easier to kill with Cheetah, although higher dose rates will be required if weeds are left to strengthen.

The second most common response to an autumn ban on IPU was to drill cereals later and then use IPU in the spring. Just under a quarter of the farmers said this would be their response. Again, this option seemed to be much less attractive than carrying on with IPU in the autumn. As one farmer in his late 50s on a 400 ha arable and sheep farm explained

> "*No IPU in the autumn would be disastrous because of the blackgrass. Maybe not in the first year but in the second and third it would be dramatic. We tried it three years ago, using no IPU, and the [yield] loss was 30% by the second year. It's taken us three years to get back to where we were*" [Farmer interview no.43].

Spraying in the spring would involve greater dose rates because weeds would be that much more established. Moreover, crop yields would suffer because of the competition from the weeds for water and nutrients. By drilling later, these risks would be reduced, but also the spring workload would be increased at a time of year when weather conditions are variable and heavy land is often still too wet to cultivate with farm machinery. There could also be problems in finding suitable times to spray. But even given good weather conditions and appropriate soil conditions, the perception was that spring spraying would be less effective in controlling blackgrass. One farmer on a 180 ha arable farm growing 130 ha of cereals attempted to quantify the difference. He claimed that

> "*Blackgrass has to be controlled. I'd have to go in the spring. You get 90% odd control in autumn but only 70% in spring*" [Farmer interview no.63].

7.5.2 Farm Responses to a Total Ban on IPU Use

The second scenario put to the farmers was a total withdrawal of IPU (Table 7.16). This would eliminate the option of continuing to use IPU outside the autumn restriction period. The responses shed more light on the nature of the farmers' dependence on IPU. Thirty-three farmers said that they would switch to Dicurane (Chlortoluron) or Cheetah. Again, the greater costs of adequately controlling the threat from blackgrass posed the biggest problem under this scenario. One farmer running a 500 ha arable business explained

> "*We use large quantities of IPU to control blackgrass. It's pernicious, particularly here. If we couldn't control blackgrass we couldn't farm. There's only one good non-IPU product that can control blackgrass and that's Cheetah. It can only be used on wheat but is very safe with no restrictions. If IPU was banned it would have very significant effects. We would probably have to stop growing winter barley and of course Cheetah is much more expensive*" [Farmer interview no.5].

The farmers were more willing to consider changing chemicals than altering their cropping practices. As one farmers put it, "*Given the market conditions at the moment, a change of chemicals would be the solution*". One solution that was considered but rejected by most farmers as uneconomic was a return to spring cropping. Only two farmers thought this might be feasible. One suggested the 'old methods' of rotations and cultivations but feared their high relative cost. He said

> "*We'd be going back to the old traditional method. Wait for the weeds to grow then harrow then drill. That would break the farm. We couldn't grow corn in those conditions. It would be completely unviable. Cereals rely on [IPU] to control the blackgrass*" [Farmer interview no.31].

Cropping changes could follow under this scenario. It would be likely that there would be less emphasis on cereal production and a greater emphasis on arable break crops such as oilseed rape, beans and linseed, a continuation of a trend already apparent in the catchment (see p.151). As one farmer explained

Table 7.16 - Farmers' Responses to a Total Ban on IPU Use

Response	No. of farmers	%
Don't know (I would have to ask my advisor)	14	24.1
Use IPU in the spring and drill later	-	0.0
Switch to another chemical (Cheetah or Chlortoluron)	33	56.9
Spring cropping	2	3.4
Change cropping pattern / rotation	2	3.4
Use cultural methods of weed control	3	5.2
No effect	2	3.4
Consider stopping cereal production or set aside	8	13.8
Total	58	100%

Source: Farm survey.

"If IPU were withdrawn it would lead to problems. I'd have to move to all first wheats or spring cropping, but even in first wheats you can get blackgrass. I don't know what I'd do. I wouldn't spring crop cereals, but linseed and spring rapes maybe. Half the farm would have to go to break crops" [Farmer interview no.63].

The responses clearly show what problems such a restriction would cause the farmers. Their eventual action following an IPU ban would most probably be taken after consultation with their advisors. Indeed, almost a quarter of the farmers were unsure what to do. One in his late 30s running a 75 ha fairy and arable farm said

"It would be catastrophic if we couldn't use them at all. I don't think there would be any other products. I don't really know, I'd have to ask my spray man. I rely on him" [Farmer interview no.19].

For some farmers, the current economic margins for to cereal production were so tight that any further restrictions would lead to a re-evaluation of the whole farm strategy. One such farmer, when asked how a total ban on IPU would affect him, responded, *"I don't know. It would be a headache. We would be bordering on having to go into set aside"*. Eight farmers said that a total ban on IPU would force them to consider stopping cereal production, possibly by entering into set-aside. This is double the number of farmers who gave such a response to the autumn ban.

7.5.3 Responses to a Total Ban on Autumn Herbicide Spraying

The final scenario put to the farmers was an autumn ban on the application of all herbicides. Responses were more evenly spread (Table 7.17), and again underline the fundamental importance of pre-emergent herbicides to cereal production in the catchment. The most common response (15 farmers) would be to switch to Cheetah, followed by the spring use of IPU in combination with later drilling (14 farmers). Eleven farmers said they might have to revert to spring cropping and withstand lower yields.

A number of interesting issues emerged in the discussions with farmers. First, the central importance to cereal production of the autumn use of pre-emergent herbicides in the Ouse catchment. As one farmer who grew cereals on a third of his 140 ha explained,

"It would make growing grain in North Bucks very difficult. It was mainly grass here and the grass weeds and seeds are deep seated. Marginal grain land would go out...I'd have to think again about grain" [Farmer intervew no.32].

Table 7.17 - Farmers' Responses to an Autumn Ban on All Herbicides

Response	No. of farmers	%
Don't know (I would have to ask my advisor)	10	16.9
Use IPU in the spring and drill later	14	23.4
Switch to another chemical	15	25.4
Spring cropping	11	18.6
Change cropping pattern / rotation	6	10.2
Use cultural methods of weed control	8	13.6
No effect	6	10.2
Consider stopping cereal production or set aside	9	15.3
Total	59	100%

Source: Farm survey.

Moreover, spraying in the spring would increase the pressures on the spring workload, and there were fears about weather conditions making spraying difficult in the spring months. One farmer who was interviewed in mid-April highlighted the problems of being forced to concentrate spraying in the spring. He said

> "*It would make it very difficult....Weather conditions would make it just about impossible. There have only been 2 decent spraying days in the last 6 weeks due to the wind and frost*" [Farmer interview no.19].

Some farmers wondered about what steps could be taken to minimise the threat to the crops from weeds. Four broad strategies were identified, although much of the discussions were tentative and theoretical. Rotational fallows may be one option. By leaving fields fallow, the build up of weed pests could be reduced. However, this would mean a proportion of each farm would lie unproductive each year. Since the survey was conducted, a rotational set-aside scheme has been agreed under the Common Agricultural Policy reforms, and it is possible that rotational set aside could contribute to weed control under future autumn herbicide spraying restrictions. A second strategy could be to drill crops later in the autumn so that weeds do not become a problem until the spring. However, the later the drilling, the greater the risks to the crop and to future spraying programmes from the weather. Smaller crop plants are less able to withstand harsh winters, and there is also a potential for poorer yields. Switching to spring-sown crops could be another option, but yields tend to be lower. Most farmers thought that wheat and barley yields would fall by about 30%. One final option could be to rely more on cultural and mechanical methods of weed control like direct drilling, scratch cultivation and mechanical weeding. Farmers were suspicious of these methods (see Chapter 5). One farmer running a 300 ha mixed farm highlighted the problem, when asked what the effect of restrictions would be. He claimed that

> "*[They would have] a massive effect. But for residual herbicides we couldn't continue to farm in the same way. We could maybe carry on for 3 years but than have to go back to spring cropping and change the rotation. We could use cultural methods of weed control but the yield penalty would be £100 per acre. Chemicals cost £10 per acre, so you can see why we use chemicals*" [Farmer interview no.2].

Again, the scenario prompted farmers to consider set-aside as an alternative. Nine farmers thought that an autumn ban on herbicide spraying would leave them unable to carry on producing cereals. However, a small minority of farmers felt that, although costs would inevitably increase, they would still be able to continue. It depended on their current spraying systems and the amount of cereal land they had. One farmer said

"As long as we could use the same stuff in the spring it wouldn't make too much difference. It's just that it eases the workload if you do it in the autumn. Also, with pre-emergents, you want it to rain afterwards to wash it in. When we used to spray just in the spring, it was hard to find the time with the right conditions" [Farmer interview no.31].

Another who managed a large, 650 ha arable business suggested that a total ban on autumn spraying would not be as bad as the total withdrawal of IPU from the market. He said

"IPU could be put on in the spring. You would get satisfactory control but would have to put on higher doses in the spring to get the same control. You'd need a 50% increase in dose rate to get a result with blackgrass in spring compared to autumn" [Farmer interview no.56].

Thus, such regulatory measures aimed at reducing pollution risks in the autumn could result in greater risks at other times of the year.

7.6 Conclusions

The survey findings presented in the first part of this chapter highlight the variability of pesticide practices at the farm level, particularly concerning farmers' willingness and ability to modify the advice received from technical specialists by undercutting dose rates. This is, in part, explained by the different contexts within which individual farm businesses are managed. For example, larger, specialist cereal producers are more likely to develop the technical expertise and wherewithal to be able to cut pesticide dose rates below those recommended. On the other hand, mixed farmers who have to acquire technical skills across a broader range of farming practices including livestock husbandry perhaps do not have the time to develop specialist expertise in pesticides and so find themselves more dependent on the recommendations of their advisors.

Secondly, the survey evidence underlines the marginality of the pesticide threat to watercourses in the minds of the Ouse farmers. Although the majority of farmers were concerned that water pollution from farming practices should be tackled, either because it was morally reprehensible or was breaking environmental regulations, most saw pollution as primarily a problem of the mishandling of livestock effluents. Farmers were generaaly not aware of the pollution risks from the 'normal' and routine use of cereal herbicides, for example. This led to a feeling that water pollution from farming was a problem going on somewhere else' (such as in Devon, for example) and perhaps explains the greater level of moral opprobrium attached to pollution amongst the Ouse farmers, who were not currently in the forefront of pollution regulation compared to those interviewed in Devon (Table 7.9).

The low profile of the pesticides in water issue among the Ouse farmers may also be explained by the relatively low exposure to the regulatory authorities (compared, for example, with Devon farmers). The NRA has been more concerned nationally and locally with pollution from livestock effluents. This is easier and cheaper to detect in the field, first requiring only a visual examination of streams, followed by a simple test for biochemical oxygen demand. Pesticide pollution, on the other hand, is more likely to be diffuse rather than point source, and so is more difficult to attribute to the activities of any one farmer. Detecting pesticides in water also requires more complex (and expensive) chemical testing of water samples. Furthermore, the NRA have been more vigorously pursuing livestock effluent pollution *incidents* as a means of demonstrating the need for a strong, prosectution-oriented regulatory agency (Lowe and Ward, 1993).

Finally, the discussions about the impacts of possible future restrictions on the use of IPU, the most frequently detected agricultural pesticide in breach of the EC MACs, illustrates the continued dominance of the chemical paradigm in tackling pest problems. The most widespread response amongst the farmers to the three regulatory scenarios was to look to alternative chemicals rather than consider non-chemical weed control strategies.

CHAPTER 8:

CONCLUSIONS AND DISCUSSION

8.1 Introduction

The thesis has sought to address a set of four questions which surround the issue of pesticides in water. These are: i) why since the Second World War have pesticides become such an important element of farming practice in Britain ? ii) how has pesticide pollution of water emerged as a 'problem' ? iii) how do farmers decide which chemicals to use and precisely how to use them ? and iv) what are the implications for farming practices of regulations to tackle pesticide pollution ? The methodological approach employed can be characterised as 'action in context'. It treats the fundamental object of analysis as action in its social context, rather than analysing either isolated, individual actors or 'macro-processes'. As a 'sensitizing device', the approach enables the reciprocity of action and context to be established. Each is shaped by and co-evolves with the other.

In this final chapter the conclusions of the study are presented and discussed. First, the evolving context for the use of pesticides in Britain is explained. Particular attention is paid to the early post-war period, the growing importance of pesticides for crop protection and the subsequent emergence of a pollution 'problem'. Second, the empirical findings from the research into farmers' roles within the pesticide 'pollution production process' (Figure II, p.19) are summarised and conclusions drawn. Third, action and context are drawn together to produce a new conception of pesticide use and pesticide pollution, and finally, some of the implications of the study's findings for future policy are discussed.

8.2 The Evolving Context for Pesticide Use

Part II of the thesis explains the causes of, and influences upon, the emergence of a pesticides in water 'problem' in Britain from the perspective of the changing political, economic and social context within which technologies (including pesticides) are produced and used in agriculture. Concepts from the regulationist school are used as an ordering device to highlight the ways in which agricultural development, the role of state policy, and the diffusion of new technologies in agriculture since the 1940s can be linked to the context of capitalist development. Farming change has not occurred in a socio-political vacuum. The concerns of the British state to sustain capitalist accumulation through the pursuit of a mass production-mass consumption development model required the provision of cheap food to the urban working class and this, combined with the concerns for national food security evoked during the war and a balance of payments crisis, prompted the expansion of British agriculture by means of what Goodman and Redclift (1991) call a 'technology/policy model'. This model was characterised by guaranteed prices and markets and incentives to adopt new agricultural technologies that saved labour and raised yields.

The institutional networks and arrangements required to foster this model were largely in place by the end of the 1940s and coincided with important developments in pesticide science. Synthetic herbicides were first marketed in Britain during 1945 and the system of public research institutes and a free state advisory service facilitated the flow of new chemical innovations from the laboratory to the farm. At the same time, price support provided farmers with the prospect of stability and even greater economic returns through adopting new chemical practices. The notion of pest (including weed) control as intrinsic to good farming practice was not only embodied in the 1947 Agriculture Act, but was also shared throughout agricultural science and among the agricultural supply industries. Thus the 'problem' of weed control was constructed. It required a solution and a network of actors was able to join in an alliance to promote a chemical solution. Each actor had different interests, but in representing chemical use as the optimal technical solution to farming's pest problems, each was able to pursue its own strategy to the greater good of the whole. Through such means, agricultural scientists and advisors saw their roles in society become more highly valued; for advisors, success was achieved through increasing the adoption of the new techniques; for scientists, the task became to increase the agricultural efficacy of new chemical innovations. Farmers saw their yields and productivity rise and were able to shed labour and increase profitability. The state had successfully implemented its policy of increasing food production, and the instigation of a cost-price squeeze during the 1950s helped to control the rising costs to the Exchequer of agricultural support, while at the same time making any cost-reducing technologies that did not require major capital outlays even more attractive.

Chemical crop protection can be viewed as a technological paradigm, an "entire constellation of beliefs, values, techniques and so on shared by the members of a given community" (Kuhn, 1970, p.175). From this perspective, once the problem had been defined and the optimal technical solutions to it agreed, then development became channelled along a particular technological trajectory (*i.e.* the chemical route). This is not to say that the technological trajectory is indicative of 'natural' technological progress created by 'objective' scientists who produced 'improved' technologies. Scientists do not work only in the realm of the technical and the natural, outside of society and social influences. Rather, the notion of a trajectory points to how past technological arrangements set the preconditions under which new products and practices may be introduced. Once pesticides had been invented and the systems for manufacturing, distributing and applying them were in place, it became impossible to 'uninvent' them, more costly to switch to other methods, and easier to introduce more of the same. Within technological trajectories, socio-technical network become self-reinforcing. In this case, to advance new pesticide technologies it was important to put in place an advisory service that would continually promote successive technological developments, and farmers' links with technical advisors continue to be of great importance to this day in maintaining the trajectory.

The account presented in Chapters 2 and 3 negates any notion of technological determinism. Instead, it highlights how a set of socially-determined objectives were pursued. The account also shows how the environmental problems associated with pesticide use, like all environmental problems, are more than technical issues requiring technical solutions. The underlying causes of problems, as Newby puts it, "lie in *human* societies and their systems of economic development" (1991, p.2, original emphasis). It is thus through the interplay between the social and the technical that systems evolve, problems arise and solutions are promoted.

It was to meet social and political objectives that pesticide use was encouraged and the development of new pesticides was stimulated. In particular, pre-emergent herbicides helped revolutionise cereal production and made the switch to winter cereals and continuous cropping technically feasible and economically viable. At the same time, their use meant that persistent chemicals were lingering in the soil at the time of year when bare ground is most susceptible to erosion and run-off (Evans, 1990).

In Part II of the thesis it is shown how increasing pesticide use is best explained in terms which combine the technical *and* the social. The section also accounts for the way in which the issue of pesticides in water emerged as a source of public and political concern and how this concern has been subject to social shaping. Here too, the technological and the social are combined in a 'seamless web' (Hughes, 1988).

By the mid-1980s, the context within which British farmers manage their land and make decisions about pesticide use was dramatically different from that prevalent in the late 1940s. The success in bringing science and technology to bear on agricultural production processes had led to major improvements in productivity for four decades over much of the Western world. This 'success' contributed to the breakdown of the post-war system of regulating world agricultural trade under US hegemony. It was integral to the market instability of the 1970s and spawned the international farm crisis of the 1980s. It exaggerated concerns in Britain and across Western Europe about the rising budgetary costs of agricultural support, the costs of storing and disposing of surplus produce and a succession of environmental problems. Indeed, the role of technology in economic development more generally had become subject to greater critical questioning by the public. For example, we can contrast Dunlap's description of the immediate post-war period when "technical marvels were part of daily life" (1981, p.3) with Norgaard's description of the 'fall of progress', characterised by the notion "that the products of new technologies do not necessarily increase happiness" (1988, p.610).

The economic implications of the farm crisis, and the promotion of a deregulatory, free-market philosophy by successive British governments in the 1980s led to important shifts in the relations surrounding pesticide use in agriculture. First, the state gradually withdrew from financing agricultural R&D, leaving an increased role for private capitals. Second, farmers were required to pay for all non-environmental advice from ADAS. Third, an economic squeeze meant greater levels of financial risk, increased uncertainty over future developments and higher levels of borrowing. More generally, by the late 1980s, the economic pressures upon agriculture in Britain had prompted a search for new sources of income for farming households. Finally, greater commitment to consumption concerns in the countryside among policy-makers, pressure groups and the public led to the closer scrutiny of environmental practices on farms. This 'horizontal' squeeze on farmers' actions in rural spaces occurred alongside farming's diminishing economic influence within the food system. However, despite this shifting context, the goals of production in all but the dairy sector remained much the same in the late 1980s as those of the 1950s - to maximise margins through the achievement of as high yields as possible at minimum cost. While the productivist philosophy was experiencing a crisis of legitimacy in the public and political spheres, the medium term objectives of many farmers remained little altered.

It was in these circumstances that environmental policy began to have a much greater bearing on the way that the use of pesticides in Britain was viewed. The mid-1980s saw the EC Drinking Water Directive become law and the passing of the Food and Environment Protection Act 1985 which placed the pesticide approval system on a statutory basis for the first time. As was shown in Chapter 3, the monitoring requirements laid down in the Drinking Water Directive have been critical in bringing the spread and levels of pesticide contamination of water supplies to light. The requirement that suppliers monitor water from consumers' taps enabled Friends of the Earth to produce compilations of data on pesticide pollution whose legitimacy was difficult to question (FoE, 1988). Moreover, FoE could point to each individual breach of the EC's standard as a breach of European and thus British law.

Pesticide pollution came to public attention not because pesticides suddenly began to enter watercourses, but because standardised, numerical information on the spread and levels of contamination became available for the first time. It remains impossible to be sure of the extent of pesticide pollution or the length of time over which contamination has been occurring. Any pollution that does enter the public and political arena must first be detected. Therefore, the extent of pesticide pollution cannot be divorced from the extent of monitoring for it, and decisions about how and where to monitor remain in the realm of public policy actors.

The EC standard (or MAC) of 0.1μg/l has become the very definition of what counts as pollution, a definition whose origins lie in political decisions rather than 'objective' science or 'natural' laws. This standard has not only been instrumental in bringing the pesticides in water issue to light, but it has also helped shape the nature of the subsequent debate. Because the Directive addresses the quality of the water that passes through consumers' taps, the debate has been framed in public health terms focusing on the health risks to humans. There is no equivalent requirement that 'raw water' in rivers and groundwaters should be monitored at the point of abstraction and prior to treatment at waterworks. Monitoring raw water remains at the discretion of individual water companies and NRA regions. With only very limited information in the public domain on 'raw water' quality it is not surprising that very little public and political attention has been focused on the spread and levels of contamination in the wider water environment. As yet, very little is known about the impacts of pesticide pollution on aquatic ecosystems, for example.

The emphasis on drinking water has also meant that the debate in Britain and in Europe has polarised around the question of whether the EC standards are set at the most appropriate level to protect public health given current scientific knowledge. The British government, agrochemical manufacturers and the British water companies all argue that EC standards for most pesticides in water could be relaxed at no greater risk to public health. Environmental groups, other EC Member States and the Commission, on the other hand, argue that pesticides have no place in water at all and the very low standards are an example of the precautionary principle in environmental protection.

There is no question that regular and widespread breaches of the EC's legal standard in Britain have brought embarrassment to the Government and have resulted in increasing pressure to tackle pesticide contamination of water. The withdrawal of two polluting herbicides - Atrazine and Simazine - from non-agricultural uses and the instigation of a review of older pesticides are two steps which have already been taken. Since 1990, current policy is to reduce the use of pesticides to a minimum consistent with efficient food production, the protection of human health *and the environment.* This subtle yet important shift in policy has come at a time when other countries have already translated similar general objectives into quantified, achievable targets for the reduction of pesticide use. Denmark, Sweden, Norway and the Netherlands are pursuing pesticide reduction policies with targets and objectives clearly laid down, and are progressing towards meeting them (Wossink *et al.*, 1992; Høyer, 1993). In addition, the Clinton administration has recently announced its intention to establish goals for the reduction of pesticide use in the US by year 2000 (Griffith, 1993), and there have been calls for the adoption of similar policies in Britain (Pesticides Trust, 1992; Beaumont, 1993). This shifting policy context leaves British farmers facing the possibility of future measures either to reduce or to more effectively control the use of pesticides.

The network of actors involved in the early post-war period (including the state, agricultural scientists, advisors and farmers) sought to put agriculture on a new footing within a technological paradigm based on chemical crop protection. In the 1990s it is a different group of actors (involving the National Rivers Authority, the European Commission, the Royal Commission on Environmental Pollution, the British Medical Association and environmental pressure groups such as Friends of the Earth and the Pesticides Trust) that is seeking to promote a new approach to pesticide use and regulation. It was the publication of the FoE report that allowed other actors to point to the scale of the pollution problem and to call for a British policy which actively encourages a reduction in pesticide use (FoE, 1988; British Medical Association, 1992; NRA, 1992; Pesticides Trust, 1992; RCEP, 1992). However, these actors have not been able to undermine or replace the network which helped establish the chemical paradigm in the 1940s. As the next section will argue, strong farmer-pesticide advisor relations highlight the resilience of elements of the 'old' network and its impermeability to these new groups.

8.3 Farmers' Use of Pesticides

Part III of the thesis examined farmers' understandings of pesticides in water, the influence of technical advisors upon their decisions as to how pesticides should be used, and the continued dominance of the chemical paradigm in crop protection. The farm survey revealed that even within one river catchment, among a group of farmers who were either growing or had recently stopped growing cereal crops, a diversity of actions and understandings could be identified. Not only did characteristics such as farm size and the mix of enterprises vary (Chapter 4), but also quite different development *trajectories* were being pursued (Chapter 5). While some businesses were taking on more land, other farmers were seeking to maintain incomes by increasing productivity, either through the adoption of new technologies, changes to cropping patterns, the search for cost reductions, or the acquisition of new sources of farm household income. A significant group of families were seeking to disengage from agricultural production altogether.

The degree of differentiation of farm circumstances has important implications for how the adoption of agricultural technologies and the relationships between technological change and environmental change are understood. For those farm households where food production had been replaced by the management of industrial units as the main income generating activity, for example, the strategy for managing arable crops became one of minimising financial losses and seeking simply to break even. This provides a quite different context from those farms where cereal production remained the main source of household income. The diversity of goals within which businesses are currently managed also calls into question some of the assumptions of the models often used to explain the spread of new technologies in agriculture, such as the classical diffusion model and the theory of the treadmill, which usually assume farmers to be rational actors managing a full-time, wholly agricultural business.

Among the farmers interviewed there was little understanding of the nature of the pollution threat to ground and surface waters posed by pesticides. This has its roots in a number of factors. *First*, the pollution of watercourses with pesticides had not attracted public attention locally. Levels of contamination had only been publicised nationally for the first time in November 1988, following the publication of the FoE's report (FoE, 1988). In the two years between the report and the survey of Ouse catchment farmers in early 1991, this 'national scandal' had not been translated into local public and political concern. When asked to specify what types of harmful effects farming practices could have on the environment, the contamination of water by pesticides was hardly mentioned by farmers. Pollution from farm livestock effluents attracted much more attention. This can be explained, in part, by the greater emphasis placed on farm 'waste' pollution by the NRA. Pollution from cattle slurry, silage effluent and dirty water from yards is easier and cheaper to detect than pesticide pollution, because such pollution often takes the form of point source 'incidents'.

The NRA, in its regulation of agricultural pollution and its publicity campaigns aimed at raising awareness on farms of pollution risks, had effectively represented the 'farm pollution problem' as being one of pollution from farm livestock effluents. Moreover, while the NRA's concerns centred on farm wastes, the HSE - the other regulatory authority with responsibilities for pesticide use - is only infrequently seen on farms and, in any case, tends to concentrate its efforts on protecting the health and safety of farmworkers rather than addressing potential risks to the environment. This leaves farmers with only occasional and weak links with regulators regarding pesticide use and pollution risk, especially by comparison with the regulation of farm wastes. At the same time, as Chapter 7 revealed, farmers in the Ouse catchment tend to view the regulatory authorities with suspicion and are sceptical not only about their regulatory capabilities, but also their understanding of the day to day practicalities of farming.

Second, the lack of understanding of pesticide pollution among farmers can, in part, be explained by their faith in the prior approval system for screening pesticides before they are licensed for sale on the market. There was a widespread and deeply-felt belief amongst the farmers that pesticides were well-tested before being officially approved and so, therefore, must be safe to use. The approval system was seen as the point at which any detrimental effects from pesticides were dealt with, removing any responsibility from the farmer for environmental problems associated with pesticide use. If problems arose, it was a failure of the approval system and not the fault of the farmers, who buy pesticides 'in good faith'.

Under one-fifth of the farmers interviewed considered pollution from farms to be at all significant by comparison with that from industry[1]. This 'context of complacency' meant that risks to the environment, and particularly risks to the water environment, did not enter into their decisions about what types of pesticide to use or how best to use them. These concerns, it was felt, had been addressed at the approval stage and with the setting of statutory maximum dose rates. This having been said, however, a level of moral opprobrium attached to pollution was discernible among the Ouse catchment farmers, a proportion of whom saw pollution as morally reprehensible.

The farmer interviews also revealed the central importance of the technical advisors from off the farm in influencing how pesticides were used. All farmers sought advice about pesticide use from technical advisors at some stage and for most farmers the spray advisor was routinely the most important influence in deciding exactly what to do. The most frequently consulted sources of advice were the representatives from the merchants who sold the pesticides. Despite these advisors having an interest in selling pesticides, farmers were extremely reluctant to do other than what they were told

[1] This complacency existed despite the recognition amongst many farmers that the use of insecticides, in particular, could pose problems because of their harmful effects on friendly predator species such as ladybirds.

(Chapter 6). A minority were prepared to apply chemicals at lower dose rates than those recommended by advisors, but these tended to be specialist cereal producers running larger farm businesses and with higher levels of technical expertise themselves. Even among these farmers, however, there was a general reluctance to undercut advised dose rates except in 'ideal' conditions when the risk of pesticide failure was deemed to be lower.

The crucial importance of technical advisors has implications for how we understand the pollution issue. Traditionally, increasing pesticide use has been explained either in terms of diffusion-adoption models or the theory of the treadmill. However, there is a need to go beyond the question of whether technologies are adopted or not. Although the simple distinction between adoption or non-adoption makes for easier questionnaire survey research, the nature of the environmental risks associated with the use of some agricultural technologies requires an understanding of *adaption* as well as adoption. It is more a question of how pesticides are used, what types are applied and in what quantities that influence environmental risk.

It is in the interaction and negotiation between two groups of actors - farmers and advisors - that decisions about which pesticides to use and how to use them are taken. The process of negotiation is uneven, and this is reflected in the differential willingness and ability to modify the advice that is given. The ability to cut dose rates beyond those recommended by advisors depends on the skills and wherewithal of individual farmers. More generally, the influence of advisors has been crucial, not only in establishing the chemical paradigm for crop protection, but also in maintaining it. Whether spray advisors are employed by merchants or ADAS, once they are called onto a farm non-chemical pest control options are, in effect, closed off. Crop protection decisions are informed primarily by agronomic concerns, environmental risk hardly enters the equation.

The chemical paradigm (and, as a result, the 'momentum' of the corresponding chemical 'technological system') is also reinforced through the ways that environmental management, and especially weed control, are represented within farming culture. The 'environment' or 'nature' is generally seen by farmers as something that can be managed (or even 'created') on unproductive corners of their farms. Nature equates primarily with wildlife and its habitats and so being an 'environmentally-friendly' farmer consists of allowing shrubs and trees to grow in specified places, while the business of producing food is allowed to proceed unhindered on what one farmer called 'our factory floor'. This notion of nature is poorly adapted to more holistic views of agriculture's environmental impacts which see nature and ecology as a complex system of energy flows, flows of pollutants and so on. The notion of 'creatable, zoned nature' is, however, a recognisable trait in those agro-environmental policies which either encourage the planting of woodland and the maintenance of landscape features, or designate sensitive zones in which intensification is tempered and farmers are encouraged to enter environmentally sensitive schemes voluntarily. These all help to maintain the idea that environmental concerns are best accommodated in particular zones but should not be allowed to interfere generally with agricultural practices.

Crucial, insofar as the use of pesticides is concerned, are farmers' ways of seeing weeds. Because herbicides are the most widespread and problematic pollutant of water, an understanding of the philosophy behind weed control is essential to any discussion of herbicide use and the causes of pollution. Farmers clearly understand the short-term economic risks that weeds pose to profitable cereal cropping. This understanding can be contrasted, however, with their perception of the environmental risks that herbicide usage poses. These risks are considered vague, long term and unproven. Moreover, the control of weeds is a key element in what constitutes 'good' arable farming practice, to the point that farmers are reluctant to tolerate *any* weeds in their crops. They compare their performance as farmers with those of their neighbours on this basis. Chemical control continues to be viewed as the 'common sense' method of eliminating of weeds, and so good farming is equated with optimal chemical use. Even so, an important distinction can be made between 'optimal' use in economic terms and in terms of weed control. The former involves the use of herbicides to maximise economic margins; the latter is based on the elimination of as many weeds as possible and reflects the ethic of 'clean', weed-free fields. The interviews reveal how the latter perspective prevails, adding to the momentum of the chemical paradigm in crop protection.

The continued dominance of the chemical paradigm is also highlighted by the farmers' responses to the alternative regulatory scenarios put to them. Under each scenario, most farmers indicated they would use the nearest alternative chemical for weed control, rather than switching to alternative technological systems, such as mechanical weeding or new rotations. Many also felt unable to say how they might respond to herbicide restrictions without first consulting their advisors, further underlining the extent to which farmers are dependent upon their advisors.

8.4 A New Conception of Pesticide Use and Pollution

There has been a tendency in the literature on the environmental problems of contemporary capitalist agriculture to see farmers in one of two ways. One is as rational actors, responding to price signals and market conditions in order to maximise the profitability of their operations. The other is as 'policy dopes' operating in highly regulated economic conditions, 'forced' to adopt ever more intensive practices in order to stay in business. In these terms, responsibility for the environmental effects brought about by technological change in agriculture lay with either agricultural policy or the capitalist system, which has enabled the penetration of farm production by industrial capitals through, *inter alia*, the promotion of manufactured agricultural inputs.

In both cases the dynamics of technological change are usually regarded as exogenous. New technologies are treated as emerging from what Clark and Lowe call the "autonomous and alien realm of science" (1992, p.15), and are mechanistically 'taken up' by farmers. The analysis in this thesis has sought to bring the issue of agriculture's environmental impacts onto a new plain by opening the black box of science and technology and placing technology in a more central position. In the context of the pesticide pollution of water supplies, this has required, first, that pesticide practices on farms be seen in the wider context of the network of relations surrounding the farmer, and, second, that science and technology be seen not as autonomous and separate from society, but as continually combing technical and social elements.

The historical analysis in Part II and the local work in Part III both demonstrate that the causes of pesticide pollution of water are best understood in terms of the workings of a socio-technical system, labelled here as the pesticide 'pollution production process' (Figure II, p.19). This process involves a range of actors beyond the farmer, extending to the agricultural R&D sectors, the crop protection advisory system and the system of regulating pollution. These relations not only provide the context within which farmers make choices about pesticide use, but also have an historical dimension with a dynamic of its own.

Conceptualising pesticide pollution as the outcome of a 'pollution production process' allows the role of pesticides in agriculture to be problematised. Rather than see their widespread diffusion and adoption as a given, resulting from the outputs of the black box of science and prevailing market conditions, pesticide use can be examined as an outcome of social and political choices. The technological paradigm in agriculture centred on the chemical control of pests was well established by the 1950s and showed every sign of conforming to Freeman's definition of a technological paradigm; "a new set of guiding principles which become the managerial and engineering 'common sense' for each major phase of development" (1984, p.499). This thesis has demonstrated how forty years from the construction of the technological system and its development along a trajectory, 'momentum' is a key feature of the system.

The 'action in context' perspective has helped illustrate how technological momentum is maintained. The explanation derives from the reciprocity of action and context. The chemical paradigm has, for over four decades, meant that the 'common sense' solution to crop pest problems involves the application of pesticides. A range of actors in the network attempt to tie individual farmers into the technological system so that farmers find their pest problems 'translated' in such a way that they can be best solved by pesticides. The role of advisors is as carriers of the paradigmatic view. Farmers become enrolled by their advisors. They take on a set of attitudes promoted by pesticide protagonists which are also advanced in farming journals, agricultural colleges, agricultural shows and so on. If farmers in the Ouse catchment are to come to see pesticides in a different light, they must be enrolled by different networks carrying different representations; pesticides as pollutants threatening the health of the nation and the water environment, for example.

In these terms, what is often called 'structure' becomes an outcome rather than a cause of action. The context for current pesticide use has emerged out of past rounds of actions and technological choices, some of which took place fifty years ago. Current rounds of action are shaped by and yet also help shape this context. Thus, for example, the policy, economic and technical conditions of the 1940s and 1950s provided a 'technological frame' (Bijker and Law, 1992) which facilitated the use of chemicals while constraining non-chemical crop protection strategies. It was through the use of pesticides that the context became reshaped. The politics surrounding pesticides have been redefined, in part, by the technologies themselves. Again the social and the technical combine in a seamless web. Pesticides achieved the productivity increases promised by their protagonists, and in doing so helped, ultimately, to undermine the stability of the productivist framework of which they were a central part. However, by entering watercourses they helped bring about increased pressures for greater controls over their use. In such an analysis, it is not only that the social and technical overlap or interplay, but that they can never be wholly separated. Momentum in technological systems is derived from both.

The use of concepts such as technological systems, paradigms and momentum leaves us with an explanation of pesticide use and pollution that is neither socially nor technologically reductionist. The use of pesticides becomes an outcome of the interactions between sets of heterogeneous actors (farmers and advisors) but also an input to the next round of decisions. Farmers are neither wholly free agents nor impotent in the face of capitalist (or policy) processes. Instead, change and action are negotiated between actors. The thesis helps push forward our empirical understanding by demonstrating how it is through these negotiations that the technological (chemical) system acquires momentum, and how these negotiations can vary from farmer to farmer, depending upon the skills, resources, experience, values and objectives of the farm family.

8.5 Implications for Future Policy

In adopting an action in context perspective, and by examining pesticide pollution as a 'pollution production process' the study has identified some of the dynamics of pesticide use and the consequences for the pollution of water. Pesticide pollution is more than a simple technical problem. It is indicative of a complex set of processes with important historical dimensions. This has implications for future policy, as well as for the questions that future research might address. The tendency in much of the policy debate has been to see the issue as a simple technical problem and take without question current technical arrangements as a pre-given. This has resulted in the promotion of technical fix solutions including, for example, the search for less persistent and mobile pesticide compounds. For several years now the trend in Europe and North America has been towards greater control over the use of pesticides (Pimentel and Lehman, 1993) and an increasing number of countries (especially in the most developed world) have introduced specific policies to reduce the quantity of pesticides used in agriculture. For any such proposals to be effective in Britain would require a greater sensitivity to the processes by which pesticide use has been encouraged in the past including the structure of the agricultural R&D system and the current reductionist paradigm in science.

Despite public opposition in Britain to the relaxation of standards[2], the British Government has persuaded the European Commission to review its MACs for pesticides in water. Even if the standards were to be relaxed, and this outcome is currently being strongly contested by other powerful actors, it would take several years for any changes to the Drinking Water Directive to come into effect (ENDS, 1993b). The government, therefore, will continue to be compelled by EC law to work towards meeting the pesticide standards.

The current strategy of treating drinking water supplies to remove pesticides also contradicts the stated objectives of UK pollution control policy (DoE, 1990) by overturning the polluter pays principle. Water consumers, rather than farmers or pesticide manufacturers, are left to pay the clean up costs through higher water bills. At

[2] A Gallup opinion poll in September 1993 asked members of the public if they would accept more pesticides in their drinking water if told that the levels were not dangerous and water bills would be lower as a result. Seventy-seven per cent of respondents said 'No' (Clover, 1993).

the same time the current strategy neglects the causes of pollution (pesticide use) by merely addressing its symptoms (the contamination of drinking water supplies).

Public pressure groups currently demand of farmers that they not only produce food, but that they also act with responsibility in three different respects: as producers of wholesome food, as environmental managers, and as responsible rural business-people. The model of farmer as environmental manager requires, over and above which technologies are adopted, the responsible *adaption* of agricultural technologies. This means that whatever technologies are employed, they should be adjusted to meet local environmental circumstances. The productivist period saw standardised agricultural technologies diffused across the countryside over-riding local environmental conditions. The result in the Ouse catchment, for example, where once mainly grass was grown, is large-scale cereal production only made viable through the routine use of pre-emergent herbicides.

A concern for how technologies are adapted rather than just adopted does not necessarily mean that technological change has to be brought to a halt or that the clock has to be turned back. Instead it requires a recognition that agriculture-environment relations are not aspatial. Local uniqueness is of especial environmental importance and value, and the use of industrial technologies in agriculture should respect it. A recontextualisation of agriculture is therefore called for as people demand from farming a responsiveness to local conditions. This change in emphasis does not imply 'all power to the farmer', although this romanticised view has been espoused elsewhere (Kloppenburg, 1991), but is also a question of responsibilities among farmers to local environments.

Several recent environmental policy documents either contain statements about reducing pesticide use or have implications for the ways that pesticides are to be used in the future (DoE, 1990; UK Government, 1994). There is, however, little strategic direction in British policy or the British interpretation of European policy. The EC's Fifth Environmental Programme, announced in 1992, aims to reduce 'significantly' pesticide use per unit of land under production, but did not make clear how this was to be achieved. Also, the CAP reform package agreed in 1992 seeks to reduce over-production and to reflect a greater concern for the environment through a series of agri-environmental measures. It is too soon to predict the impact of CAP reform on pesticide pollution in Britain, although it is clear that the accompanying agri-environment measures to promote 'environmentally-friendly' farming only make up a tiny proportion of the entire agricultural budget. The requirement that 15% of arable land be entered into a rotational set-aside system will mean that a smaller land area is sprayed on each farm each year. Moreover, the implications of the recent GATT agreement may require that the proportion of land in set-aside increases to 25-30%.

However, leaving part of arable farmland fallow on a rotational basis could require that more herbicides be used in the following years to combat the build up of weeds. The planting of a cover crop, it is suggested, could help reduce the risk of post-set aside weed problems (Lechner *et al.*, 1992), but it will take several years for the full implications of these new agreements on pesticide use to become apparent. Of more immediate effect is the implementation of a straw burning ban which took effect at the end of 1993 under the 1990 Environmental Protection Act. Studies have demonstrated how most cereal farmers plan to cope with the ban by mechanically incorporating straw into the soil and then increasing their applications of Isoproturon and Chlortoluron to combat weed growth. Thus, in addressing an air pollution nuisance, one consequence may be a greater risk of water pollution (ENDS, 1992b).

Recent policy statements repeatedly make the commitment to 'minimise' pesticide use, the most recent being the Government's strategy for sustainable development (UK Government, 1994, pp. 9, 12 & 100-111), but biotechnological R&D is geared to improving the efficacy with which pesticides are applied *within the chemical paradigm.* Currently 27 companies are conducting genetic engineering research to produce crop varieties tolerant or resistant to increased doses of herbicide (Beaumont, 1993, p.185), and this is likely to reinforce the chemical crop protection trajectory[3]. There is also a concern that herbicide resistant volunteer plants could be carried over to the next crop rotation, and so become problematic weeds themselves.

In this rapidly changing context, it is difficult to point to a single policy which would 'solve' the water pollution problems associated with pesticides. Because throughout the thesis the focus of analysis has been the issue of pesticides in water, there is a danger of offering solutions which alter the way pesticides are used just in the light of this particular pollution problem. However, although it is the use of pesticides that, in the first instance, is the cause of pollution, any strategy for tackling pollution is likely to be confused or hampered by the vague and often conflicting objectives of wider agricultural and rural policy in Britain (and, for that matter, Europe). The agricultural productivism of the decades following the Second World War provided an overall strategy for rural policy in general. Its recent breakdown and the onset of contradictory

[3] Recent evidence is also provided by Beck and Ulrich (1993) who have analysed the awarding of environmental release permits for genetically modified crop varieties and found that herbicide tolerance is by far the most commonly researched trait. Of 794 permits approved up to November 1992, 462 (58%) were for trials to develop herbicide tolerance in crop varieties.

tendencies in policies which at the same time promote continued agricultural efficiency, environmental protection, farm diversification and land development, have created a policy vacuum at the strategic level. Current policy objectives for agriculture and the countryside remain ambiguous, and it is still not clear what the primary objectives of British agriculture are to be in the 'post-productivist' era. Until the objectives of an agricultural (and a rural) strategic policy are made more explicit, the practical questions about how changes to agricultural practices can best be brought about are more difficult to address. It is, perhaps, only once this is achieved that any policy addressing the role of pesticides in agriculture and the reduction of pollution can be effectively devised.

Until such time, arable farmers in Britain will continue to make decisions about pest control within a dominant chemical paradigm that has been the long-term cause of the pesticide pollution problem. With differing degrees of freedom of action, they remain not so much trapped on the pesticide treadmill as caught up in the momentum of the chemical, technological system.

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APPENDIX A:

An interview transcript from the pilot survey

PATCH Programme: Exploratory Interviews with Farmers

Farmer K, Bedfordshire. Early 60s. Massive farmhouse, almost a mansion. Nephew arrived during the interview. He's a partner in the business, studied agronomy at Nottingham University, and was very aware/articulate. The were both staunch in their opinions. In 1985 the farm was 1600a. Since then, two neighbouring farms have been added, making the total size now almost 2000a, farmed in 6 units which are farmed as one unit as far as management, machinery and livestock are concerned. The main enterprises are cereals, sheep, beans and oil seed rape. Vegetables are declining. [R-respondent, N-nephew]

The Farmer's Philosophy and Outlook

1. "In general terms how would you describe the way you farm ? And why?"

[Objective: to see if farmer has an overall approach to farming (ie farm "philosophy"), how he/she characterises it. To identify attitudes towards farming as a business, way of life, family continuity, sustainability, stewardship, etc.]

We farm it as a business. We wouldn't be in it if we didn't consider it also slightly as a way of life, but it wouln't be a way of life on our land (mostly grade 3) if we didn't consider it in business terms and use normal commercial methods.

2. "Has your approach changed in the last ten years ?"

The same objectives. We got elm disease a few years ago and it made us realise that perhaps we hadn't given the trees enough attention and because of that they were vulnerable. Clearing up and replanting are more difficult with the greater financial pressures on farmers. We get a little bit irritated by the general public blaming us for the environment when we have planted thousands of trees [I cut him off at the beginnings of a full scale rant with the next question..]

3. "What are the major problems that farmers like you face today. Are there any more ?"

[Objective: to find out farmers' perceptions of the key pressures on them.]

Maintaining profitability really. In order to maintain one's labour force, equipment and so on. If this can be done then you can maintain good husbandry practices and in that one includes the environmentalist. We always have political pressures. We're not in beef at the moment, but one can only quote whats happening to the beef industry which is all political. It's been blown out of all proportion. It's quite categorical that there's no threat to humans. Our foreign prtners have jumped on it to make a bob or 2 for themselves. I think the Ministry and the vets were well aware of the problem and the cause was banned 2 years ago. It's just that the effects are still coming through.

4. "What is your response to these problems ?"

[Objective: to explore farmers' personal outlook and strategies.]

Increase farm size in order to make the maximum use of modern machinary and keep our unit costs down to the minimum. We have been able to maintain a reasonable level of profitability doing that. With the political pressures, we've always been aware of the need to keep the public aware of the problems we face. Some of the pressures we face come from a fair degree of ignorance from the general public and its the media as well of course. We see part of our job as educating people by entertaining as many people on the farm. We have schools round at lambing time. The teachers also find it interesting.

Sources of Advice and Information

1. "Which sources of advice do you use for what categories of information"

[Objective: to find out how farmer categorises technical advice and to obtain as full as possible specification of sources (down to names and addresses) in order to get a preliminary idea of actors in local technology transfer systems.]

Prompts by type of advice:

crop nutrition/fertlisers
varieties/seeds/crops
grassland management
livestock health
waste management/slurry containment/silage
nature conservation
crop protection/agrochemicals/pesticides

We do use ADAS but my nephew will give you more information on that. He's a sort of agronomist and goes to seminars and so on. The specialist agronomist comes about once a week. We belong to a cereal group connected to Chattleworth College and the agronomist is linked to this. Its the same for seed varieties and everything.
With grassland, it comes under the sheep enterprise. Again theres a sort of league in Beds of which there are 12 members and the MLC act as adjudicators in going through our methods and financial results. Last year our herd came top of the league in terms of gross margins per ewe. For nature conservation, we belong to FWAG in Beds.

2. "Do you find it easy to follow the advice to the letter or do you tend to adapt it?"

Prompts; why or why not?
which type of advice?
how do you adapt it?

We use our own experience, particularly the younger partners. We do consider advice but we're not driven by it.

Attitudes towards Technology

1. "Over the next decade or so, how do you expect farming practices to change, and what new types of products do you expect to see on the market?"

[Objective: to discover expectations of future technological trends and what farmers believe will influence those trends.]

So much is dependent on the political scene and consumer attitudes. It could be worrying if the trend towards vegetarianism continues. Young people dont seem to like the idea of killing animals.

2. "What benefits has technological change brought to your farming operations?"

Reduced labour costs. The hours haven't shortened but there are fewer people employed.

3. "What problems has technological change created for your farming operations?"

It's making it more difficult for young people with limited capital to get into farming. Bigger units all the time. They have to be bigger to keep viable. We've kept viable through specialisation and a larger area enabling bigger machines.

4. "Who are the main beneficiaries of technological change in agriculture?"

[Objective: to explore farmer's understanding of the distributional consequences of technological change.]

It's been possible for the consumer to continue to buy cheap food. [NEPHEW ARRIVES and I sum up where we've got to]

N - *I don't think the agrochemical companies have suffered much either. Agricultural merchants aren't making any money out of technological change at the moment, but the chemical manufacturers seem to be returning good profits. It's worrying that the chemical companies are now in charge of a very large part of the breeding programs for new varieties, so although they might be producing new varieties with high potential, it is linked in with their own chemicals to realise that potential.*

6. "Are current research efforts relevant to your farming practices?"

N - *We are turning to independent resaerch organisations. The arable resaerch centres at Cambridge, which does gear its research to our needs at the near farm level. The problem is that there are other aspects of research that we cant possibly get engaged in such as safety. That has to be done by an independent Govt source. When it comes to research into getting over problems with the straw burning ban and changes in rotation, we look more towards independently financed organisations rather than ADAS.*

Attitudes towards Environmental Problems

1. "Are there any major environmental consequences of modern agriculture?"

[Objective: to explore farmer's perception and evaluation of types of problem; types of risk - occupational, public health, ecological, conservationist.]

N - *I think when you ask a direct question, are we damaging the environment, I would say to anybody who doubts the farmer, that I have to sit in a sprayer regularly. I wouldn't do that if I thought there was too great a risk. These products are tested independently by Govt. I'm handling them in massive cencentrates compared to what might be found in a river in a years time. That concentration is minute. To query our interest in the environment.. [beginning to rant]..People spread chemicals in their gardens. Our land is like our garden. We want it to be beautiful. We want it to be productive but we care for it more passionately that anybody else.*

2. "What do you see as the main environmental consequences of your own farming activities?"

Pause...N - *Difficult to say really. I think there must be environmental consequences. A percentage of our nitrogen must reach the water. An absolute minute % of pesticides must get from the soil to the water in the long term. So there is an environmental consequence. What needs to be evaluated is the cost in relation to producing food for the country.*

R - I think with wildlife we are tree-planting, rather than replanting hedges because there's a necessity for larger fields with the bigger machines. The planting is a positive environmental consequence. Planting trees depends on profits though.

3. "Have environmental concerns affected the way you farm? If so, how?"

[Objective to guage the salience of environmental concerns/ restrictions for the farmer.]

N - *Yes, definitely. As the public's attitude changes, our awareness is increasing. We are taking more precautions. We are now probably taking more visible precautions to allay the public's fears but which aren't necessarily changing anything.*

4. "Do you think that there is a water pollution problem from farming in this area? If so, what is it and what are its causes ?"

R - *Farmers are more aware of things like silage effluent. Every effort is made to do it.*
N - *Leaching on these heavy soils is minimal. It's the most superb filter system. It holds nitrogen.*

5. "What should be done to solve farming's environmental problems?"

N - *I think there are problems. With nitrates, purley telling farmers to reduce inputs won't solve the problem. It needs direct aid to the water boards to put in water pyrifying units. With livestock farmers, they must receive grants to help them treat the problem.*
R - *A lot of nitrogen has been traced back to the ploughing up of grassland 40 years ago.*
N - *If the Govt requires direct action, it must encourage people to do it.*

6. "Do you think new technology (eg safer pesticides, improved spraying technology, new crop varieties) will be developed to cope with these problems ? Or will farming practices have to change (or both)?"

N - *Hoescht launched a new herbicide [Cheetah] which is a contact spray and breaks down in the soil after about 4 weeks. In the past chemicals have layed on the soil and acted residually over a long period. I'm convinced that its no good bankrupting farmers to get there. It's technology and the way we're treated and the way we're encouraged. Also there are more organically based nitrogen compaounds available. Again it's making these things economically viable that will encourage us to use them. it must be remembered that farming isn't a very productive time.*

Q - What about farming practices ?

N - *Where there are high nitrate levels in water courses, I assume that cropping patterns will have to change. I don't see it as a problem here. And yes, where sprayers are filled will have to change. They should be filled carefully. I think farmers should have to fill sprayers out of the public eye, so as not to worry the public.*

R - *The govt is cutting back on R & D. While there was some waste a few years ago. It's important to keep the EHFs. They can really carry out independent research into these practices.*

N - *Up until fairly recently, there's been advice to put the first nitrogen applications on to the oilseed rape very early. They have tempered that off a bit now but it needs to be constantly practiced and researched. Before we were following govt advice but in doing so, were increasing the environmental risk.*

Farmer's Behaviour

1. "How do you decide what herbicides to use, at what stages, and how much?"

[Objectives: to discover factors influencing choice of product, choice of dose rate, and choice between insurance or firebrigade use and farmer's perception of what choice he/she has regarding herbicide use and rate of application.]

N - *Experience, advice, history of the fields. We know where we have problems and where to put on a lot of black grass spray before the problem arises. We know it will come because of previous experience. One new herbicide I've mentioned is probably leading us now to tend to wait to see the weeds and then spray, which is a helpful development. The chemical is more expensive but it probably does a more thorough job. We've experimented quite a lot this year with it and I think in the long run it might be a big benefit to us. Historically we have had to use residual chemicals. With heavy soils, you have a particularly long dormancy period with grass weeds and black grass seeds. So once you've got a black grass problem it tends to remain.*

4. "In what form do you apply nitrogen, and how do you decide how much to apply and when to apply it?"

[Objectives: to discover factors influencing level and timing of application and farmer's perception of what choice he/she has regarding level/timing.]

N - Predominantly liquid nitrogen and we follow advice from the arable research centres which will be by dissecting the plant to tell when its at its most demanding stage for nitrogen. We'll also consider the weather, temperature, the calender.

5. "Do you keep records of the nutrients and crop protection chemicals which you put on your crops ? In what form do you keep them ? How far back do they go ? May I see an example ?"

Yes. Very closely indeed. It's absloutely essential.

Attitudes to Pollution Regulation

1. "Do you think pollution by agriculture is significant compared to industrial pollution ?"

R - *The answer is no*
N - *Insignificant I would suggest.*

2. "Do you think that pollution by agriculture is being dealt with in the same way as pollution by industry ?"

N - *The public is being led to belive that its agriculture-led where I think the local companies, coupled with the sewage companies are probably enormously more responsible. I wouldn't like to compare agriculture with industry because I don't know the pressure that industry's under. My perception from the way the media reports it is that we are getting a rough deal.*

3. "What do you think are the best ways of tackling agricultural pollution?"

Prompt: legal with advice but under ultimate threat of prosecution?
Pollution guidelines with advice.
Change of government support to de intensify agriculture?
Higher prices for potentially polluting substances
(pesticides and nitrogen) ?

N - *The first one would be my favourite as long as its based on sound research, a correct measurement of pollution, and to make sure that its not someone else's pollution. I think if a farmer spills chemicals into the river, he ought to be caught. If he is slopping nitrogen about carelessly in large volumes, he should be responsible for his actions. To make the cost of nitrogen higher through a tax when somebody is using it responsibly and is using their inputs carefully is damaging the efficient and the dilligent. With de-intensification, I'm wondering if the nation could afford it.*

R - *We've got a big balance of payments problem.. I don't know that the govt or the country can afford it.*

N - *I think organic farming is for people who are middle class and affluent. Expensive food to the working man is very distressing. I think the person who has spent what has decreased from 18% to 13% of his income is very appreciative of cheap food. You tell him that because some chap is worried about a bit of nitrate in a river that his food prices are going up. [This all sounded like a well-rehearsed argument] To say that organic farming cuts output by 30% is ridiculous. You can only grow an organic crop of wheat every third or fourth year, so it would significantly cut production. We would have to import large volumes of food.*

4. "What impact do you think pollution regulations have had on farming practices generally ?"

N - *It's definitely sharpened peoples recording of inputs. It's upgraded peoples storage and handling of chemicals. There's more awareness and understanding.*

5. "What about on this farm in particular ?"

N - *All of those things I've just said*

6. "Have you noticed any changes in pollution regulation since water privatization and the establishment of the NRA ? Do you think it will ?"

R - *It's still early days. There hasn't been time for any changes*
I can't see how changes are going to affect agriculture. If it's necessary to get the water up to a certain standard, then privatisation means that funds will be available, more so that the govt who restrict expenditure each year.

7. "Have you had any contact with NRA officials?

"How do you find NRA officials?"

R - *Yes I've had contact because I'm on the local river board. I don't see any change. I think staff appear to be more enthusiastic now on being able to cope with the problems which they know are there than they were before. But that's just an opinion.*

N - *I think we'll see that through the use of contractors, we'll see a more efficient service on maintaining rivers and through the staff they used to employ in very large numbers and have a complex management structure*

8. "What do you think would be the effects on farmers of a strict prosecution policy for pollution incidents?"

R grunts "*We've already answered that*"

N - *As long as its done on the basis of sound information and people knowing the facts. Its important that if someone is doing something thats completely negligent, and they're aware of the problems thay are causing, then I agree whole-heartedly that prosecution is by far the best way of dealing with it. With the nitrogen 50mg/l limit, its a nonsense. Where is the research to prove it ?*

R - *It's been set in France where they have problems with organic matter in water. We are having to suffer on a regulation that is not important here.*

N - *One of the weaknesses of the EC is trying to set rules for differnt areas.*

9. "Do you think that there are adequate incentives to prevent pollution on farms generally" (What is your own experience)

[Objective: to reveal knowledge and reactions to current grants for pollution control. Do they cover the measures necessary to reduce the pollution risk.]

N - *I think that as the govt demands higher levels of storage for chemicals and filling points, then grants should be made available for putting in new installations etc. They should be aid assisted. We want to comply with evrything. We're getting there slowly. We're putting in a new tank filling point this year. You can't do everything. We're getting there slowly. It takes time. If there were grants available, the industry as a whole would get there quicker. While I like to think that we're a progressive farm in that we still are fortunate enough to be making profits, a lot of farms aren't making money at all and to tell them to spend £2000 to put in new installations is impossible*

General Discussion

Q - "What did you think of the questions ?".

R - *There's some repetition*

N - *OK.*

APPENDIX B:

The farm survey questionnaire

FARM ADJUSTMENT, TECHNOLOGICAL CHANGE AND ENVIRONMENTAL REGULATION

BUCKS QUESTIONNAIRE

STRICTLY CONFIDENTIAL

Interviewer:

Interview Number (PATCH):

Interview Number (Arkleton):

Date and Time of Interview:

Thank you very much for agreeing to talk to me today. The objectives of the survey are to find out how farmers are responding to the economic and environmental pressures they face. Before we start, I would like to stress that anything you tell me will be treated as strictly confidential. No individual farmers can be identified from any of our written work. If you feel unhappy about answering any of the questions, please say so and we'll move on to the next one.

SECTION A : CHANGE ON THE FARM

1. [*] Are you the principal manager/ decision-maker of the business (Y / N)

2. [*] Who else is involved ?

3. [*] When did you take on this farm ?

4. [*] What were you doing before taking on this farm ?

5. [*] Was your family, or your spouse's family, involved with this farm before you started running it ? (Y / N)

6. How are the business assets of this farm owned ?

a - Sole Operator
b - Family Partnership
c - Non-family Partnership
d - Limited Company
e - Other (please specify)

7. Have you made any major changes to the structure of the farm business since 1980 ? (eg setting up partnership or limited company) (Y / N)

8. IF 'YES', what are the details ?

Change in structure of farm business	Date of change

9. What were the main reasons for these changes ?

10. [*] What is the total acreage of this farm today...... Acres

11. [*] How was this land acquired ? (We have a number of possible ways recorded on this questionnaire, would you please read them through before answering)

Acres

(a) purchased freehold on the open market
(b) purchase from former landlord
(c) purchase from another farmer/landowner
(d) succeeded to freehold from parents
(e) inherited freehold from other relative (specify)
(f) open tender tenancy agreement
(g) succeeded to tenancy from parents
(h) inherited tenancy from other relative
(i) marriage
(j) other (specify)

TOTAL

12. [*] Has the total acreage of this farm changed since 1981 (Y / N)

	ACRES [*]	DATE [*]	REASON FOR CHANGE
Bought land			
Sold land			
Renting land			
Stopped Renting			
Other (specify)			

13. Could we just check the tenure of this farm using the table which is shown on CARD A ?

	Owner-occupied		Tenanted		Total acres
Sole Ownership	Joint Family Ow'ship	Other	Secure Lease	Insecure Lease	

14. If we take land which has been within the holding since 1981, has there been any change in tenure ? For example, buying land that was previously rented, or changing from secure to insecure leasing arrangements) (Y / N)

15. If YES, what were the changes and when did they occur ?

16. Why were the changes made ?

17. Do any other relatives of your family or your spouse's family farm in this area ? (Y / N)

18. How many ?

19. Where ?

20. Please could you look at this list of farming and non-farming organisations and tell me which ones you or your spouse belong to (or have belonged to) and in what capacity (CARD B) ?

	M'ship	Position	Dates
NFU			
CLA			
Young Farmers Club			
FWAG			
Small Farmers' Association			
Other Farming Organisation (Specify)			
Game Conservancy			
RSPB			
National Trust			
Beds & Hunts Wildlife Trust			
Berks, Bucks & Oxon Naturalists' Trust			
Friends of the Earth			
Ramblers' Association			
CPRE			
B. Ass for Shooting and Conservation			
British Field Sports Society			
Local Fishing Club			
Local Shooting Club			
Other 'Rural' Groups (Specify)			
Farm Business Survey			
Arable Research Institutes Association (formally Long Ashton Members Association & Friends of Rothamstead)			
Breed Group			
Local Arable Farming Group			
Soil Association			
Other Farming/Research Groups (Specify)			
Parish Council			
District Council			
County Council			

21. Do you pursue any country sports such as fishing or shooting Y / N
(Specify)

22. Are there any commercial rights to such sports on your farm
Y / N (Specify)

23. [*] What are your agricultural enterprises on this farm ?

24. [*] Which is the most important ?

25. [*] Since 1981 have you set up or closed down any enterprises ?

Details:

SHEEP

26. [*] How many sheep do you have ?

27. [*] Has the size of your flock changed since 1981 ? Y / N

Change	By how much
Increased	
Decreased	

28. What were the main reasons for these changes ?

BEEF CATTLE

29. [*] How many beef cattle do you have ?

30. [*] Has the size of your herd changed since 1981 ? Y / N

Change	By how much
Increased	
Decreased	

31. What were the main reasons for these changes ?

DAIRY CATTLE

32. [*] How many dairy cattle do you have ?

33. [*] Has the size of your herd changed since 1981 ? Y / N

Change	By how much
Increased	
Decreased	

34. What were the main reasons for these changes

ARABLE

B35. [*] What arable crops do you grow ?

B36. [*] What is the approximate acreage of each crop ?

CROP

ACREAGE

B37. How has this general pattern changed since 1981 ?

B38. What were the main reasons for these changes ?

40. [*] How many family members live on this farm ?

41. [*] How much labour do members of your family put into the farm business, and what sort of work do they do, starting with yourself ?

Family Member	Hours/week	Type of agricultural work
Respondent		

42. [*] In broad terms, how much of the total labour requirements are met by your family's work on the farm (including your own) would you think ?

Less than a quarter
Quarter to a half
Half to three-quarters
More than three quarters
All of it

43. [*] How many hired workers do you employ ?

(a) on a full-time basis	Hrs/week
(b) on a part-time basis	Hrs/week
(c) on a casual/seasonal basis	Weeks/yr
(d) on a contracting basis	Weeks/yr

44. Since 1981, what have been the broad changes on the farm in your use of:

family labour ?

hired labour ?

contractors ?

45. What were the dates and the reasons for these changes ?

46. [*] Do members of your family undertake work on the farm, other than strictly agricultural labour ? (Eg farm shop, farm tourism, B & B etc)

Family Member	Non-agricultural Work Undertaken
Respondent	

47. [*] How has this changed since 1981 ?

48. [*] Do you rely entirely on farming for your income ?

Y / N

49. [*] If not, in broad terms what proportion of your total HOUSEHOLD income is derived from the following sources:

	Proportion	Type of work
On-farm		
Off-farm		
"Unearned" (Shares, pensions, etc)		
TOTAL	100%	

50. [*] Has the balance between these sources of income changed since 1981 ?

Y / N

51. [*] IF 'YES', how has it changed ?

52. Referring to CARD C, please could you indicate what is the approximate size of your annual farm business turnover (by which I mean your agricultural enterprises only), say for the last financial year?

Less than £10 000
£11 000 to £30 000
£31 000 to £60 000
£61 000 to £100 000
£101 000 to £200 000
£200 000 to £500 000
£500 000 to £1 000 000
Over £1 000 000

53. Has the viability of the farm business changed since 1981? Y / N

54. If so, how ?

55. Why do you think these changes have occurred ?

56. Now if we concentrate on just the last three years, has your farm business on its own,

(a) made a profit
(b) made a loss
(c) broken even

57. Do you have any specific plans to improve the viability of the farm business ?

58. If so, what are they ?

59. [*] Have you any plans to diversify the farm business at all? Y / N

60. [*] IF 'YES', what do you plan to do, and why ?

61. [*] Are you presently repaying any loans or mortgages for the purchase of land on this farm holding ?

Y / N

62. [*] Who was the lender ?

a - Bank
b - Agricultural Mortgage Corporation (AMC)
c - Family member
d - Private individual
e - Other (specify)

63. [*] Is the farm business currently servicing any loans for working capital or fixed assets other than land ? (Y / N)

64. [*] What are they for ?

65. [*] Who is the lender ?

66. [*] How long does the loan run ?

The Ministry of Agriculture and the Farm Income Report from Exeter University have both suggested that one of the main problems facing farmers in recent years has been their level of borrowing. If you don't mind, I would like to ask you a couple of general questions relating to this.

67. Referring to CARD D, could you tell me in very broad terms, what proportion of your annual farm income do mortgage, loan repayments and interest represent, say for the last financial year ?

None
Less than a quarter
Quarter to a half
Half to three quarters
More than three-quarters
Dont Know

68. What are the effects of this on your farming operations ?

SECTION B : FARMERS' PHILOSOPHY AND FUTURE EXPECTATIONS

69. In general terms how would you describe the way you farm ? And why ?

[Prompt (if necessary): I mean, for example, what is your overall approach to farming, your philosophy]

70. How important are the following beliefs to your approach to farming ? (CARD E)

	Not Important	Fairly Important	Very Important
Making a reasonable living			
Maximising profitability			
Carrying on the family tradition			
Enjoying the farming way of life			
Looking after the countryside			
Being a progressive, up-to-date farmer			
Keeping the land in 'good heart'			

71. Has your general approach to the way you farm changed in the last ten years ? (How ?)

72. How would you describe good farming ?

73. Do you ever find that you draw comparisons between yourself and surrounding farmers ?

Y / N

74. If yes, on what basis ?

75. Farmers often say that they would like to pass on their farm to the next generation in a better condition than when they took it on themselves. What does the phrase "in a better condition" mean to you ?

76. What are the major difficulties that farmers like you face today ?

77. Are there any others ?

78. How would you sum up your response to these difficulties ?
(briefly recap on the difficulties)

79. Do you feel that things are more difficult now than 10 years ago?

80. [*] Do you plan to stay in farming until you retire ? Y / N

81. IF 'NO', Why not ?

82. Do you hope for another member of your family to succeed to this farm business ?

Y / N

83. If yes, who ?

Comments:

84. What do you think are the chances of this happening ?

Unlikely / Fairly likely / Likely / Very Likely

85. Can we now talk briefly about your aims and objectives in the near future, and then in the longer term.

First, lets take the next two years.

How would you sum up your aims for the farm business ?

86. What plans do you have to achieve these aims ?

87. Now taking a longer perspective, how would you sum up your aims for the longer term, say over the next 5 to 10 years?

88. Have you made any plans yet ? Y / N

89. If so what are they ?

90. What sorts of things do you think could spoil your future plans ?

SECTION C: New Products and Practices on the Farm

I now want to turn to a set of questions about new products and practices on the farm.

91. What benefits have changes in technology brought to your farming operations ?

92. What difficulties have changes in technology created for your farming operations ?

93. Who are the main beneficiaries of technological change in agriculture ?

94. Over the next decade or so, how do you expect farming practices to change, and what new types of products do you expect to see on the market ?

95. How do you hear about new agricultural products and practices ?

96. Some people say that modern agricultural practices have an adverse effect on the environment. Do you agree ?

Y / N

Comments:

97. If YES, could you expand. What sorts of adverse effects do you think modern agricultural practices have on the environment ?

98. Have these environmental concerns affected the way that you farm at all, and if so, how ?

99. Have you experienced any direct pressure to alter your farming practices, for example from neighbours, local people or officials ?

100. Modern farming uses powerful machinery and chemicals and inevitably certain risks are involved in their use. Referring to CARD F, could you tell me how great or small you feel the following types of risk to be from modern farming ? (CARD F)

	Negligible	Small	Moderate	Large
Risk to wildlife, plant life and river life				
Risk to public health through water contamination				
Risk to public health through food contamination				
Risk to farmers and their workers from using chemicals				
Risk to farmers and their workers from using machinery				

101. Now could you go through the same list and tell me if you think the levels of risk are increasing, decreasing or are staying the same ?

	Increasing	Decreasing	Staying the Same
Risk to wildlife, plant life and river life			
Risk to public health through water contamination			
Risk to public health through food contamination			
Risk to farmers and their workers from using chemicals			
Risk to farmers and their workers from using machinery			

Advice and Information

102. On CARD G is a list of possible sources of advice available to farmers. Looking down the list, could you read out if there are any from which you have never had advice ? (MARK WITH AN 'N')
Now could you tell me which are your main sources of advice regarding each of the following aspects of your farming operations ?

	Crop nutrition/ fertlisers	Drainage	Agrochemicals What product to use	How to apply it
	B103	B104	B105	B106
Merchant's representative				
Manufacturer's representative				
Independent Consultant				
Contractor				
Own expertise				
Employee's expertise				
Neigbours				
Family				
NRA				
HSE				
ADAS (Personal)				
ADAS (Group)				
Farming Research group				
Farming press/ freebies/media				
Farming events, meetings, conferences				
FWAG				
Other-specify				

Could you say which are the 1st, 2nd and 3rd most important sources of advice for each activity ?

Do you think that there is any difference between 'independent' and 'commercial' advice ?

B107. Over the last 10 years, in what ways, if any, would you say that your usage of cereal herbicides has changed ?

(Prompt: frequency of application; switch to new products)

B108. In the case of products which you have tended to use year in year out, has your usage increased, decreased or stayed the same ?

B109. What were the main reasons for these changes ?

B110. In deciding when precisely to apply cereal herbicides, what sorts of things do you bear in mind

B111. What changes, if any, would you like to see in the marketing or labelling of herbicides ?

B112. Do you already use, or would you consider using any of the following ?

	Already Use	Would Consider	Would Not Consider
a) Cultural methods of weed control *			
b) Using herbicide dose rates lower than those on the product label or given in off-label approvals (specify)			
c) Mechanical weeding			
d) "Organic farming"			

(* eg. nil cultivation, scratch cultivation, direct drilling)

B113. Could you explain your reasons ?

a)

b)

c)

d)

B114. Has your use of nitrogen changed since 1981 ?

	Increase	Decrease	No Change	Don't Use
Quantity (manufactured) applied per hectare on average				
Quantity of bulky organices applied per hectare on average				

Timing of application	Same	Changed
Manufactured		
Organic		

Attitudes to Pollution Regulation

125. There has been a great deal of discussion in the media about the issue of pollution. What does the term pollution mean to you ?

126. Do you think pollution by agriculture is significant compared to industrial pollution ?

127. Do you think that pollution by agriculture is being dealt with in the same way as pollution by industry ?

128. What do you think would be the effects on farmers of a strict prosecution policy for pollution incidents ?

129. Do you think that there are adequate incentives to prevent pollution on farms generally.

B130. Here is a list of measures that have been suggested to tackle agricultural pollution (CARD H).

a) Voluntary changes in farming practice based on Government advice

b) Statutory controls on the use of any chemicals causing a problem

c) Change in Government support to deintensify agriculture

d) A tax on chemical inputs

e) Across-the-board statutory restrictions on the volume of chemicals that farmers could use

f) Encouragement to the chemical companies to develop 'greener' technologies

g) Other (Please specify)

Firstly, are there any that you would oppose in principle ?

131. Would you suggest any other possible measures ?

132. Now could you rank those which you do not oppose in order of your own preference (ie. Which would be your first, second, third preference etc) ?

133. What impact do you think pollution regulations have had on farming practices generally ?

134. What about on this farm in particular ?

B135. Looking at CARD I, do you use any of the products on the list ?

ARELON WDG	ARELON	ASSASSIN
ASTIXFARMON CMPP	ASTROL	ATLAS CMPP
AUTUMN KITE	BANLENE PLUS	CAMPBELL'S MPP
CAMPBELL'S FIELD-MARSHALL,	BELLCLO	HERRIFEX DS
CAMPBELL'S CAMPPEX	CHAFER CMPP SUPER	CHILTERN IPU
CLEANACRES CMPP 60	CLEAVAL	CLENECORN
CLIFTON CMPP AMINE 60	COMPITOX EXTRA	DI-FARMON
DUPLOSAN CMPP	FANFARE 496 FW	FOXSTAR
HEADLAND CHARGE	HERRISOL	HYMEC
HYPRONE	HYTANE 500 FW	INVICTA
IPSO	ISO-CORNEX 57	JAGUAR
JAVELIN	METHOXONE	MSS MIRCAM
MSS MIRCAM	MSS CMPP	MSS CMPP AMINE
MUSKETEER	ORACLE	OXYCORN EXTRA
PADDOX	PANTHER	PINNACLE
PORTMAN ISOTOP	POST-KITE	POWER SWING
POWER ISOPROTURON	QUAD CMPP 60	QUADBAN
QUIVER	SABRE	SELEXONE
SPRINGCORN EXTRA	STAR CMPP	SWIPE 500 EC
TERSET	TETRALEX PLUS	TOLKAN 500
TOLKAN LIQUID	TRUMP	

The sprays contain chemicals which have been found in surface and groundwater. If they were to be banned from use, how would your farming activities be affected ?

Autumn ban:

Total ban:

B136. Let us say that legislation was introduced which banned autumn applications of all herbicides. How do you think this would affect your farming activities?

137. Let us say that new legislation was introduced to cut nitrogen inputs by 20% (in terms of active ingredient). How do you think this would affect your farming activities ?

Water Privatisation

138. What is your impression of the NRA ?

139. Have you had any contact with NRA officials ? (Prompt: attended talks, farm visits, shows) Y / N

140. If 'Yes' How do you personally find NRA officials ?

141. Did you have any contact with the old water authority officials ? Y / N

142. If 'Yes' How did you find them ?

143. Have you noticed any differences between the old water authority and the NRA?

B146. Have you had any contact with Health and Safety Executive Agricultural Inspectors ?

Y / N

B147. If 'Yes', for what reason ?

B148. How do you personally find HSE officials ?

144. Thank you again for your help. Would you like to be sent any summary findings from our research sometime in the next few months ?

Y / N

145. This survey has been of about 80 farmers in this area. We hope to revisit a few farmers again to discuss some of these issues in greater detail. If we should need to, would you mind if we contacted you again in the future ? Y / N

APPENDIX C:

Interviews with Scientific and Policy Actors

List of names has been removed to protect privacy

Errata

p. 5	"4.5 General Characertistsics" should read "4.5 General Characteristics"
p. 13	Footnote no. 2, line 1, " pesticide' " should read " 'pesticide' "
p. 17	Third paragraph, line 7 " accidental' " should read " accidental"
p. 21	First paragraph, line 2, "have" should read "has"
p. 21	First paragraph, line 4, "(ADAS)" should read "(ADAS, which is now sometimes known as ADAS - Food, Farming, Land and Leisure)"
p. 26	Fourth paragraph, line 2, "is explored" should read "are explored"
p. 31	Second paragraph, line 5, "benefit" should read "benefits"
p. 32	Fourth paragraph, line 5, "prevent" should read "prevents"
p. 34	Last paragraph, "they argue" should read "Clunies-Ross and Hildyard argue"
p. 35	Second paragraph, line 8, "yields, and" should read "yields and"
p. 39	Fourth paragraph, line 6, "Europe, that" should read "Europe that"
p. 43	First paragraph, line 5, "1930s, and" should read "1930s and"
p. 43	Last paragraph, line 3, "structures, to" should read "structures, and to"
p. 47	First paragraph, line 5 "configurations, all" should read "configurations all"
p. 48	Last paragraph, "present and future actions" should read "present and future actions (1993, p. 152)"
p. 55	Title, "BRITIAN" should read "BRITAIN"
p. 55	First paragraph, "social control processes" should read "social processes"
p. 55	Fourth paragraph, line 4, "schools' " should read "school's"
p. 57	First paragraph, line 4, "war, and" should read "war and"
p. 79	First quotation, "Kloppenburg]" should read "Kloppenburg])"
p. 86	Second paragraph, line 9, "producers, were" should read "producers were"
p. 94	First paragraph, line 2, "has grwon" should read "have grown"
p. 101	Second paragraph, line 2, "is now" should read "are now"
p. 115	Title, "STUDY ARE" should read "STUDY AREA"
p. 116	Third paragraph, line 13, "contribute" should read "contributes"

p. 131	Third paragraph, line 11, "levels have regularly" should read "levels regularly"
p. 132	Third paragraph, line 14, "over fift times" should read "over fifty times"
p. 135	Foot note no.3, "which straddle" should read "which straddles"
p. 136	Second paragraph, line 5, "removal redundant" should read "removal of redundant"
p. 142	Second paragraph, line 6, "was owner-occupied" and "was securely rented" should read "were owner-occupied" and "were securely rented"
p. 142	Second paragraph, line 7, "was rented" should read "were rented"
p. 147	Third paragraph, line 6, "Uraguay" should read "Uruguay"
p. 147	Fourth paragraph, line 6, "encyclopedia" should read "encyclopaedia"
p. 156	Fourth paragraph, line 1, "busnesses" should read "businesses"
p. 156	Sixth paragraph, line 1, "charcterised" should read "characterised"
p. 156	Sixth paragraph, line 2, "withdrawel" should read "withdrawal"
p. 166	Last sentence, "making the negotiative process...as crucial to practice" should read "showing the negotiative process...to be crucial to practice"
p. 167	First paragraph, line 11, "landords" should read "landlords"
p. 168	Fourth paragraph, line 2, "have been" should read "were"
p. 172	Third paragraph, "recommendations for applying agrochemicals on product labels" should read "recommendations on product labels for applying agrochemicals"
p. 176	Footnote to Table 6.1, "most important source of source of advice" should read "most important source of advice"
p. 178	Footnote to Table 6.2, "most important source of source of advice" should read "most important source of advice"
p. 182	Third paragraph, line 1, "descernable" should read "discernible"
p. 219	First paragraph, line 4, "fairy and arable" should read "dairy and arable"
p. 219	Second paragraph, line 1, "for to cereal" should read "for cereal"
p.222	Last paragraph, line 6, "were generaaly" should read "were generally"
p.222	Last paragraph, line 8, " somewhere else' " should read " 'somewhere else' "
p. 223	Second paragraph, line 3, "illustrates" should read "illustrate"
p.226	First paragraph, "socio-technical network" should read "socio-technical networks"

Bibliography Errata

p. 251	Kjolholt (1990), "distribution" should read "Distribution"
p. 252	Kneale et al. (1992) "Univerity" should read "University"
p. 252	Knorr-Cetina (1981), "Towrads" should read "Towards"
p. 254	Marco et al. (1991) "in Their Regulation" should read "in Their Evolution"
p. 307	Bottom note, "attented" should read "attended"