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Agriculture — reconciling ancient tensions

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ABSTRACT: Decision-making in agriculture has tended to be driven by factors other than environmental concerns. This may be changing, and perhaps the emphases of the 2 creation accounts in Genesis (responsible management or 'dominion', and active care) may become more important. The paper examines a number of current developments in agriculture (synthetic fertilizers and pesticides, genetic manipulation, and organic versus industrial methodologies) and discusses the issues they raise for agricultural productivity and the human communities dependent on farming. The questions raised are complex; we are faced with establishing a new paradigm for agricultural practice.

The history of environmental decision making in agriculture over the last quarter century, tends to confirm a view of the environment as being something which is only considered vital when a list of other criteria are met and it is deemed that environmental criteria can be afforded. It has certainly only been a primary driver when priorities such food supply, rural employment etc were no longer considered critical to the national interest. Relative priorities are a major element in decision making. The history of agriculture shows that this is neither a new nor a recent phenomenon.

The Bible affords us 2 accounts of the creation that can be read as being significantly different. They seem to establish 2 different models for our interaction with the environment.

In Genesis 1 v. 28 we read 'Be fruitful and increase, fill the earth and subdue it, rule over the fish in the sea, the birds of heaven and every living thing that moves upon the earth'.

In contrast in Genesis 2 v. 15 we read 'The Lord God took the man and put him in the Garden of Eden to tend and care for it'. The selection of the words, subdue/rule in Genesis 1 as compared to tend/care in Genesis 2 suggest 2 alternative models for how we perceive the environment. The first model, the dominance model has, in the past, had a significant resonance. The following very selective examples illustrate developments from this view of non-human organisms and the environment:

> The end for which all things were created (was) that none of the conveniences and necessaries of life might be wanting to men. John Calvin.

> The world exists for our sakes and not for its own,
> John Dickie, Moderator of the General Assembly of Church of Scotland 1930

> 'We may use them (animals), we may destroy them at our pleasure … for our own ends, for our own benefit or satisfaction. John Henry Newman

The second model, the partnership model, is radically different. In parts of Christendom non-human life forms and 'nature' have been seen by some as a backdrop against which more important events have occurred. Several broad ranging texts have explored the environmental debate within the churches in detail (Bradley 1990, Elsdon 1992). These arguments are not repeated here, but illustrate that the existence of very different views of the importance of the environment and of the criteria for environment decision making are of considerable antiquity and ultimately may relate to the prevailing balance between 'rule' and 'care'.

CONTEXT

An important starter question is why the environment affecting agriculture should be of interest to anyone other than those directly concerned with agricultural management or regulation? The answer is that in the UK agriculture uses around $^3/_4$ of the land area and consequently it has a major effect on air and water

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quality and, because agricultural land is the home of most wildlife, on biodiversity. Agricultural decisions influence the wider environment in which we exist. This is exemplified by the discussion in the recently published Curry Report (Anon 2002). A similar situation exists for much of Europe.

The summary of current issues in the Report of the Curry Commission indicates that the complexities of land use in relation to agriculture preclude even complex legislative solutions and require societal agreement to a series of trade-offs. The antiquity of these problems within the agricultural sector suggests that analysis of issues and their history might provide some guidance to other sectors. The purpose of this paper is thus to examine, through a series of case histories, how society and the agricultural industry have reacted to environmental challenges and what we can learn about successful environmental stewardship from past and current examples.

CASE STUDIES

A perspective on the series of case studies presented here can be exemplified through the following extracts taken from the 2001 Bawden Memorial Lecture (Lever 2001) which encapsulates the issues and the long standing tensions. Lever (2001) commented:

> At the beginning of this century, the world's population was estimated to be 6 billion. Seventy-five percent of the 1000-fold increase in human numbers since agriculture emerged 10 000 years ago occurred during the last century ... The ability to increase agricultural output to keep pace with population growth was due to a revolution in farming based on modern plant breeding, the extensive application of fertilisers and crop protection chemicals ... The challenge for the next 50 years will be to improve the food security of the 6 billion and to feed an additional 3 billion people.

The prevailing message from this is that nothing matches the importance of feeding the world and perhaps that this is the only significant requirement for life. This position clearly leads to many subsidiary consequences and actions. The case studies introduced here and which are intended to illustrate the duration of tensions of this type, are based on (1) the introduction and use of chemically manufactured fertilisers (synthetics); (2) the introduction of pesticidal chemicals (insecticides, herbicides, fungicides, etc); (3) issues raised by genetically modified crops (GM crops).

SYNTHETIC FERTILISERS

The use of synthetic fertilisers in agriculture is a relatively recent innovation. In 1840 the German chemist Justus von Liebig argued that inorganic fertilisers could replace manure because neither manure nor humus were needed for plant growth. This theory gave agriculture and chemical technologies power over the soil and control of crop production leading to the concept of 'maximum' productivity. In 1843 Rothamsted Experimental Station and its famous Broadbalk Field experiment were established. This demonstrated that arable crops could be grown for long periods without organic manures. However, reliance on the use of synthetic fertilisers for food production was relatively low until 1940.

Over the period from 1940 to 1990 the application of synthetic fertilisers in UK increased from around 200 t yr^{-1} to over 2000 yr^{-1} while the use of fertiliser nitrogen went up from around 100 t yr^{-1} to around 1500 t yr^{-1} (Greenland 2000). This change in fertiliser use was clearly accompanied by a paradigm shift in thinking about nutrient additions and use, and views moved from a concept of the supply of the nutrients for crop growth and yield through the recycling of materials on an agricultural unit and the management of crop rotations to a concept where the nutrients needed for growth were supplied directly. A typical mixed rotation is shown is Fig. 1 (Atkinson & Watson 2000). The 'conventional' arable agricultural system, which uses synthetic fertilisers, minimises its reliance on the range of soil biological and microbiological processes that are critical to other systems of agriculture, e.g. organic farming systems, which depend absolutely on these processes. The application of soluble synthetic fertilisers results in losses through leaching and denitrification. The effect of the leaching of nitrogen and phosphorus fertilisers on water quality has been known for some time. Information on the effects of gaseous nitrogen losses are more recent. The use of synthetic fertilisers accounts for around 90 % of N_2O emissions from Scotland. As N_2O has a global warming potential 310 times higher than CO_2, current levels of synthetic fertiliser use raise questions about the environmental sustainability of current levels of use. It should be noted however, that organic farming methods also release N_2O.

The use of synthetic fertilisers challenged the traditional 'Rule of Return', which accepted limits to production and decreed that soil health and fertility must be maintained by the presence of humus. Soil as a living entity is a key element in the traditional view of agriculture production. The wisdom of developments related to synthetic fertilisers consequently was a major issue for the Organic Farming Movement before and immediately following the 1945 war (Conford 2001). The critical nature of a living healthy soil remains one of the principles which underpins organic agriculture. This puts it firmly within the Genesis 2 tradition.

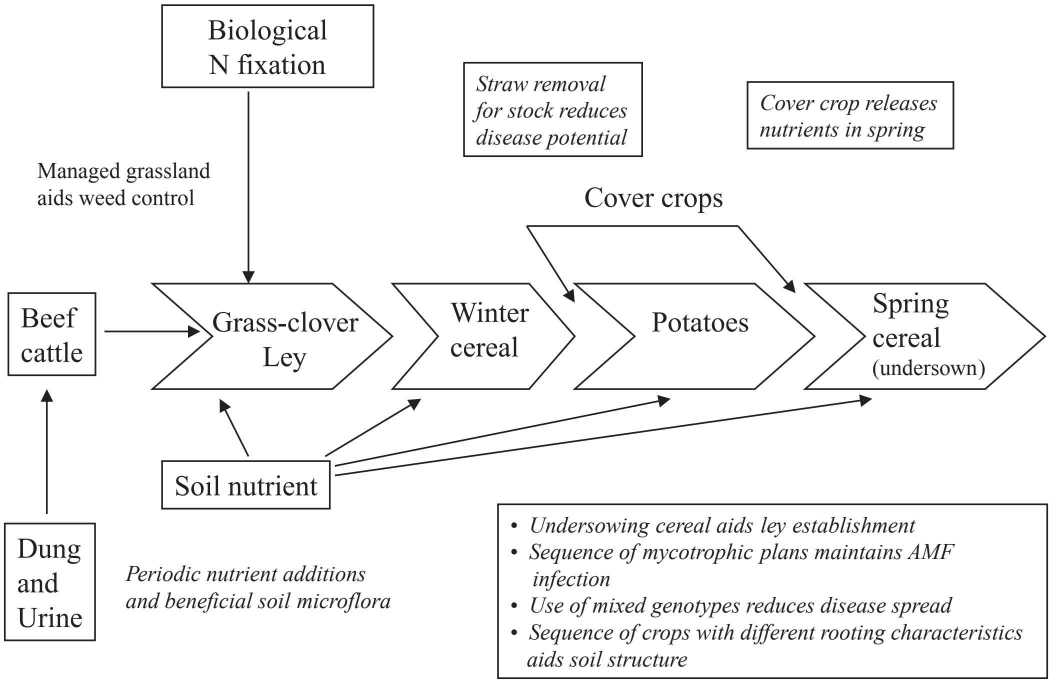

Fig. 1. A typical mixed stock/crop rotation and some of its influences on crop health

PESTICIDES

Synthetic pesticides were introduced following the 1945 war and led to the development of a major world wide industry which grew at a rate of around 15% per annum in the 1960s falling to a slower rate of around 5% per annum in the 1980s. The industry has been dominated by herbicides, 42% of sales, and insecticides, 35% of sales (Braunholz 1998). High proportions of some crops, e.g. 94% for soya, are treated with herbicides (Finney 1998). The use of pesticides to control or eliminate unwanted biological organisms in crop production have had direct effects on the environment and have allowed the development of systems which through their associated characteristics can significantly affect the environment. For example the use of fungicides permits the use of higher applications of nitrogen which then directly and indirectly influence the environment. The potential of pesticides to influence the environment has long been recognised by both the agricultural and agrochemical industries. Graham-Bryce (1998) noted that while herbicides have contributed to substantial increases in yield their properties allow them to affect unintended recipients and beyond the intended area. He recognised that 'there is an absolute obligation to ensure that amounts applied do not exceed levels which the environment can accept without harm' Pesticides production in the USA increased from 28 000 t yr^{-1} in 1945 to 643 000 t yr^{-1} in 1974 (Green et al. 1987). Use has continued to increase and much of current agriculture in the developmed world is a product of the ability to control unwanted organisms through chemical technologies.

Fertilisers and pesticides influence both the environment directly and the types of agriculture that can be practised. They permit intensive agriculture both by increasing the amount of crop that can be produced from a unit area of land, and, by simplifying management practices that employed much labour allowed agriculture to be dominated by an industrial model. The introduction of fertiliser and pesticides have allowed agriculture to become dominated by the products of the chemical industry and so have moved this type of agriculture to a status similar to that of a conventional industry. This clearly has significant implications for an activity which is so dependent on public financial support.

GM CROPS

Biotechnologically developed crops (GM crops), like fertilisers and pesticides, can potentially influence the environment both through specific direct effects on biodiversity and via effects consequent on the further intensification of current conventional agricultural systems. GM crops, in addition, raise a whole series of ethical questions such as is it acceptable to transfer the innate features of one organism to another, perhaps unrelated, organism. These are beyond the scope of this paper. They do however raise questions in respect of our interpretation of Genesis and introduce a further series of 'slippery slope' arguments. GM crops have the potential to influence biodiversity in ways that are more substantial and less reversible than previous technological interventions into agriculture. Environmental decision making in this area is thus a current high priority and the subject of much public interest.

The areas planted with GM crops have risen at a rapid rate. In 1996 the estimated world area of GM crops was 2.8 million ha. By 2000 the area of herbicide tolerant crops alone was 35.9 million ha (Sykes 1998, Glick 2001). This type of crop is now being justified on just the same basis as was previously used for the introduction and use of fertilisers and pesticides. Sykes (1998) wrote: 'In the next 30 years the greatest demand on global agriculture will be to produce the amount of food that the increasing population of the world will require'.

In the developed world consumers are now questioning whether GM technology is necessary and whether its impact on the environment is acceptable in the absence of problems with food supply. For the late developing world the potential for GM technology to contribute a solution to current problems seems more obvious although current consequences of major reliance on pesticides for crop protection in the production of crops for export are causing questions to be asked about the long term sustainability of GM technologies. Issues for both sectors of the world return us to questions about ruling or tending for the earth.

FARMING SYSTEMS

Farming systems can usefully be classified on the basis of their intensity. An intensity classification picks up and links to a range of inherent values, including the importance given to the use of labour, the structures and viability of rural communities and the environment. The classification of farming systems developed by Atkinson & Watson (2000) is shown as Table 1.

Although systems of agriculture become more intensive with a move from intensive arable to mixed organic it is suggested that the real paradigm shift is between integrated crop management (ICM) or mixed farming systems on the one hand and organic farming systems on the other. Organic production (Conford, 2001) links to a distinctive philosophy and is a clear unequivocal example of ecological agriculture. Organic farming aims to be a closed recycling system with a crop health strategy which is wholly dependent on the practical management of a range of ecological processes. Its crop rotation is designed to provide nutrient supply and to be the basis of its pest and disease protection strategy (Fig. 1). As a consequence, an organic system is not merely one which just functions without fertilisers and pesticides but one which under normal conditions does not need these inputs. In addition, the values inherent in this type of system of production will result in it asking difficult questions about biotechnological inputs.

Organic farming systems are explicitly designed to minimise environmental impact and to have a positive impact on biodiversity, both at the site of production and further afield. They eliminate the energy costs and CO_2 release inherent in the manufacture of fertilisers and pesticides. In the purest state of an organic system, volume output of crop or animal is sacrificed to give rise to a system which delivers environmental goods such as biodiversity. Systems of this type internalise a number of costs that are externalised by agricultural systems based on the industrial model.

Conventional industrial agricultural systems are not so much the opposite of organic systems as a means of production based on totally different values. These values are now the subject of debate. When the object of an industrial production system is in demand then the indirect costs of its production, even if adverse, may be acceptable to society as part of the price of the production of that commodity. Limits to food supply in the post-war period after 1945 meant that the public initially accepted the adverse impact of fertilisers and

Table 1. Suggested gradation of farming systems based on external resource use (development type) and their most important development needs

	Development Type		
Intensive arable →	Environmentally aware cropping (IPM/ICM) →	Mixed farming →	Organic farming
	Development Needs		
Cost reduction	Optimisation of element use and biological control	Additionality between enterprises	Management of biological cycles
Externalisation of costs	Cost reduction	Rotations	Ecology of production systems
Simplification of management	Optimisation of yields	Scale/links	Use of biodiversity
Maximisation of yields	Product quality	Flexible management	Product health and quality

pesticides as elements of the programme needed to feed a world recovering from a major conflict. Cheap food, releasing financial resources for other priorities, was also important. Now, however, with food comprising less than 10% of the average household budget, and with agriculture no longer identified as a key industrial area for countries such as the UK, although one which through the European Union's Common Agricultural Policy (EU CAP) represents a significant drain on resources, the adverse impacts of agriculture on the environment are being questioned in new ways. This has most recently been seen in the public debate over GM crops. Here the questions most inherent to the debate are: Is this a technology we need? How do we retain public control over rapidly developing methods? And how can the balance of public risk to industrial gain for any new technology be made acceptable to the public? The restrictions associated with the 2001 outbreak of foot and mouth disease in the UK, fell heavily on non-agricultural rural industries such as tourism and so raised further questions about how agriculture impacts upon the environment and how this impact should be regulated in situations where the environmental and biosecurity consequences are particularly felt on other industries.

Environmental decision making requires the environmental benefits and dis-benefits of various types of agriculture to be evaluated. A SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis is used in many decision making processes as a means of identifying key issues. Its application to a biotechnologically enhanced intensive system compared with an organic agricultural system draws out some of the key differences between these systems (Table 2). The intensive high-tech system is assumed to use optimum rates of fertiliser, appropriate pesticides and modern crop varieties, including GMO varieties, where appropriate. The organic system is based on one that would meet the requirement of Soil Association Certification. The SWOT analysis shows that the strengths of the 2 methods of production are very different. Some of the areas of key strengths are also areas of weaknesses and for some important attributes the strength of one system is the weakness of the other. This aids in the identification of areas where there is need for society as a whole to make choices. Many of these same choices are highlighted in the report of the post-FMD Curry Commission (Anon 2002).

KEY ISSUES

In this paper it has been the intention to document the impact of agricultural inputs on the environment as a means of identifying the types of decisions which need to be made. Most of the decisions relate to the priorities given to different values and especially to the non-human biological entities within the environment. Specific proposals in relation to new systems for resolving conflicts are beyond the scope of this paper and clearly it has not been the intention to suggest a need for new legislation or to review existing legislation within the sector. Legislation is seen as society's means of putting its collective will into effect. The issues that relate to defining the will of society, in respect of agriculture are the focus of this paper.

The analysis, of the environmental problems of agriculture identified above is intended to provide a framework which can act as the basis for a discussion of how environmental decision making within the agriculture sector might be addressed. The key current issues for environmental decision making include the following.

(*1*) *All types of agriculture, including organic farming involve a significant disturbance of the 'natural' environment.* Compared to the environmental changes induced by almost any type of agriculture the differences between the most intensive system and the most organic system can be small, particularly for arable systems. This highlights the importance of identifying the minimum level of agriculture needed within a country. It matters that this position is consistent with not simply exporting the problems of agricultural production to late-developing countries. This gives rise to the key question of how does any country decide how much and what types of agriculture it needs?

(*2*) *The level of employment in rural areas influences the structure and vitality of rural communities.* Agriculture remains a major employer in the rural sector. How we balance environmental and related needs with employment matters to rural communities. Recent discussions in the UK related to hunting with dogs illustrate the complexity of these issues and the strong emotions they can arouse. Should agriculture be treated, in terms of finance and legislation, like any other industry? At the current time this is a significant issue in WTO discussions

(*3*) *How agriculture is practised will influence its environmental impact.* The balance of exploitation and stewardship is important but not simple. There is need for workable guidelines to answer, 'Against what environmental criteria should new innovations, such as GM crops, be evaluated'?

(*4*) *In rapidly developing areas such as biotechnology, practice is likely to run ahead of regulation and legislation.* The precautionary principal can act as a brake on development in countries where it is applied. It may, however, just cause activities to move to other countries. This can represent a new form of colonisation. The precautionary principal can thus become a device which avoids the need to take decisions on fun-

Table 2. Environmental SWOT Analysis for an Intensive Arable System and a Mixed Organic System. The analysis of each system has been limited to 5 elements

a) Intensive Arable

Strengths
- Produces high yields of crops
- Yields are relatively predictable between years
- Externalises many environmental costs
- Minimises the amount of land needed for a unit of crop production
- Allows the rapid introduction of new technologies

Weaknesses
- Externalises many environmental costs
- Results in significant losses of inputs to ground water
- Capital intensive so requires high yields
- Does not prioritise environmental impact
- Expects payment for avoiding environmental harms

Opportunities
- Willing to introduce new innovations such as biotech crops
- Able to produce bulk commodities at a decreasing relative price
- Can demand payment for environment goods
- Food quality, beyond limits, not a major issue
- Introduction of new crops/varieties relatively easy

Threats
- If new technologies are not rapidly introduced may be out completed by those who do
- Improved 'analytical' technologies can lead to new legislation
- Public may decide that cost benefit of food produced in this way is too 'costly'
- May not deliver the required quality of food
- Public may reject the industrial values and payment needs

b) Mixed Organic

Strengths
- Harmony with the environment a major objective
- Reducing losses of nutrients to the environment is a production imperative
- System design reduces potential impact
- Systems are designed to enhance biodiversity
- Internalises most environment costs

Weaknesses
- Management system complex and labour intensive
- Subject to limitations of soil and climate in a major way
- Internalises most environmental costs this is expensive
- Opportunities for introducing innovations restricted
- Needs greater areas of land for a unit of production than other systems

Opportunities
- Can build on public valuation of environmental goods
- Potentially able to contribute usefully to the CO_2 balance
- Delivers food which is wanted by the public
- Can be a base for associated green industries, e.g. eco-tourism
- Aids a local food ethic

Threats
- Potentially high in needs for skilled labour
- Requires complex environmental management to be done well
- Cost of food and environmental benefits may price it out of market
- Environmental grants for other system may make it un-competitive
- Risks of 'genetic pollution' may make system impossible

damental issues. Whether the facilitated movement of functionally active genes across large genetic distances is acceptable, wise or safe is an important question and illustrates the importance of mechanisms which will allow a balance to be set between issues where the basis of the issue is very different e.g. finance or inherent values. In the practical world 'slippery slope' arguments need to be accepted and limits defined. These limits are often arbitrary or set by available technologies. How society decides is problematic. However it is clear that if the precautionary principal is simply an alternative to making a clear decision it will in the long term be unhelpful to environmental planning.

(*5*) *In the controversial area of animal welfare the 3 principles developed by the Banner Committee* (*Anon, 1995*) *provide a framework for making difficult decisions:*
- some wrongs are never acceptable.
- benefits must always be substantially greater than costs
- any costs must be minimised.

In the context of the environment impact of agriculture key questions would be: What environmental impacts are unacceptable? How do you estimate benefits and costs? What is an acceptable ratio between these? For GM crops all of these issues are difficult, but the first is perhaps the one which reflects the greatest divide in society.

(*6*) *The philosophy which underpins organic agriculture values both soil and the agricultural production system as a 'living entity' which requires to be care-*

fully maintained (Conford 2001). Until the advent of current chemical and biological technologies not following this approach to agriculture was impossible. Technology has provided alternative solutions to food production and has therefore provided new options. We now have choices within the framework set out in (e) above, with some within society would arguing that some of these technologies, e.g. pesticides and GM Crops, are wrongs which cannot be accepted.

(*7*) *Advances in information technology* (*IT*) *have allowed a range of quantitative models to be developed and compared.* Complex calculations in relation to issues such as climate change can however be counterintuitive. This makes them hard to explain to a sceptical public. Even more difficult: how can public acceptability be obtained for this type of solution to high level issues such as climate change mitigation proposals? Environment issues tend to involve both financial and non-financial elements e.g. the values inherent in an organic system. How can they be combined in ways which gains both public and industry acceptability? This is perhaps the key challenge for the management of that part of the environment which is covered by agricultural land.

THE WAY AHEAD

Developments in the technologies available for use in agriculture are posing questions about how they should be used in situations where agriculture uses a high proportion of available land and thus provides most wildlife habitat. This is the situation in much of Europe. Resolution can only come from the identification of key issues and the subsequent development of a mechanism for establishing consensus between different approaches e.g. biotechnological agriculture and organic agriculture. The positioning of the consensus needs to be based upon societal decisions on the relative importance to be given to food production and to the complex of issues embraced by both environmental and rural stewardship. This is likely to involve the development of an alternative paradigm to the present assumptions used in valuing agriculture and the environment. There is need to move beyond the blunt tools of legislation and regulation which have been of limited use in the land use sector. Decision as to how the UK and other countries in Europe can permit GM agriculture in a countryside where organic agriculture is a significant presence represents a 'slippery slope' argument. Society in Europe is faced with establishing a new paradigm for the agricultural sector.

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