Agricultural Futures and Implications for the Environment

Defra Project IS0209
Technical Report

Institute of Water and Environment,
Cranfield University.
Silsoe Research Institute.
Macaulay Institute.

November 2005
www.cranfield.ac.uk

Project IS0209 entitled Agricultural Futures and Implications for the Environment is reported by means of the following documents:

- An Abstract (half page)
- An Executive Summary (4 pages)
- A Main Report (30 pages)
- A Technical Report (100 pages: this report)
- A Set of Supporting Appendices (A, B and C)

For referencing the work should be referred to as:

Morris, J., Audsley, E., Wright, I.A., McLeod, J., Pearn, K., Angus, A. and Rickard, S. (2005) *Agricultural Futures and Implications for the Environment.* Defra Research Project IS0209. Bedford: Cranfield University. Available on hppt//www.silsoe.cranfield.ac.uk

The lead authors acknowledge contributions from:

Alison Bailey (Reading University, on agricultural sector review material), Paul Burgess (Cranfield University, on farming systems and bio-energy), Charles Neame (Cranfield University, on policy review), Roger Sylvester-Bradley (ADAS, on crop yields), Pete Berry (ADAS, on crop yields), Julian Wiseman (Nottingham University, on livestock yields).

The contributions of participants at the stakeholder workshop are gratefully acknowledged.

The support provided by Defra for this project is gratefully acknowledged, together with the assistance provided by Dr Phil Goodliffe as Project Officer for Defra.

List of Contents

List of Tables

List of Figures

Supporting Appendices*

A - Past Trends and Current Status of Agriculture in UK, England and Wales
B - Demand Estimates for Agricultural Commodities, including bio-fuels. Appraisal of Alternative Farming Systems
C - Proceedings of Workshop on Future Agricultural Scenarios, Silsoe., 23rd Sept 2003,
D - Report on Dissemination Workshop, Nobel House, London, 24th April, 2006

* available as separate pdf files

Chapter 1: Introduction

Agriculture in the UK and Europe as a whole is experiencing a period of unprecedented change and uncertainty as the drivers which have hitherto shaped the characteristics of the farming sector have realigned. Dependency on high levels of taxpayer support, concerns about the negative environmental impacts of intensive farming, the growing dominance of agri-business and the demise of the family farm have questioned the long term sustainability of farming systems in Britain. Side swipes in the form of BSE and Foot and Mouth Disease have further damaged the performance and reputation of the industry. The sector has beset by a number of external pressures associated with calls for policy reform, namely: increased market orientation, free international trade in agricultural commodities, enlargement of the European Union, and higher standards of environmental protection and animal welfare (PCFF, 2002).

UK Agriculture is shaped by global, European and national influences. At global level the Doha Declaration commits World Trade Organisation members to 'fundamental reform' aimed at reducing or eliminating subsidies and protection for agriculture. At European level, the Commission's mid-term review of the Common Agricultural Policy European Commission accelerated The Agenda 2000 reforms which switch support from agricultural production to rural development and environmental protection. At national level, the UK government is anxious to make farming more market-oriented, while simultaneously producing environmental and social benefits.

Meanwhile, with respect to environmental futures, the commitment to sustainable development has raised the profile of environmental protection as a key policy area. This is evident in international agreements such as the Kyoto protocol on greenhouse gases such as CO_2 and the Gottenburg protocol on sources of acidification such as ammonia. European member states have adopted a range of Directives and Regulations to protect water, land, and air quality, such as the Water Framework Directive, the Habitats Directive, the Nitrates Directive and the Integrated Pollution Prevention and Control Regulation. Many of these interventions have direct implications for agriculture as a land and water using activity. Indeed the link between agriculture and environment in this changing policy context is complex, with increasing emphasis on the multi-functionality of agriculture. The environment is a resource for, as well as constraint on agriculture, and agriculture is increasingly looked on to provide environmental goods and services for the benefit of society (Defra, 2002a, b).. Thus agricultural and environmental futures are inexorably entwined.

As the various drivers that shape agriculture in the UK realign themselves, it seems reasonable to development an understanding of how things could turn out. In this respect, there are two main approaches to scanning possible futures which reflect different motivations, namely

- a positivist approach which describes a future and asks, given that some features might be of concern, what might be done about them to make the future better, and
- a normative approach which describes a desirable future and asks how actions taken now and over time will help achieve it.

The former is the main motivation here, that is identifying what the future could be like with a view to making decisions now in order to help deal with it and make it better than it otherwise might be.

1.1 Aim and Objectives

In this context, the overall aim of project is to explore possible long term futures for agriculture in England and Wales in order to inform decision-making on environmental policy and provide a framework for Defra research on sustainable agriculture, climate change and other environmental issues.

In order to meet the project aim, the following objectives were set:

- to identify and explain the identities and characteristics of possible long term futures for agriculture;
- to identify and explain the possible economic, social and environmental outcomes and impacts of these futures for the farming sector, the countryside and the wider rural sector;
- to determine the implications of these futures for environmental objectives and targets and for possible environmental (and related agricultural sustainability) policy interventions; and,
- to identify the type of research required to address key issues and concerns associated with possible futures, especially as these relate to issues of sustainability.

A further objective was to develop a conceptual framework in which possible agricultural futures could be explored.

1.2 Approach

The study was carried out over the period 2003 to 2005. This concurred with a period of significant agricultural policy reform, including the implementation of the Agenda 2000 CAP Reforms in early 2005. The study did not intend to predict the immediate outputs and consequences of this reform process, the details of which emerged towards the end of the study reported here. Rather the purpose was to look towards the medium and long term, beyond that of the existing EU policy regimes.

The approach to the study is summarised in Figure 1.1 and Table 1.1. Following a review of trends in agriculture and agricultural policy in England and Wales over the last 50 years (Chapter 2), five scenarios were constructed to represent possible alternative futures based on those adopted by the Foresight Programme for long term planning (Dti, 2002). These included a Business as Usual Case and four other futures distinguished in terms social preferences (consumption versus conservation) and political interconnectedness (autonomy versus interdependence). Narratives were drawn up to represent the characteristics of agriculture under these alternative futures (Chapter 3), drawing out differences in terms of key economic, social and environmental parameters

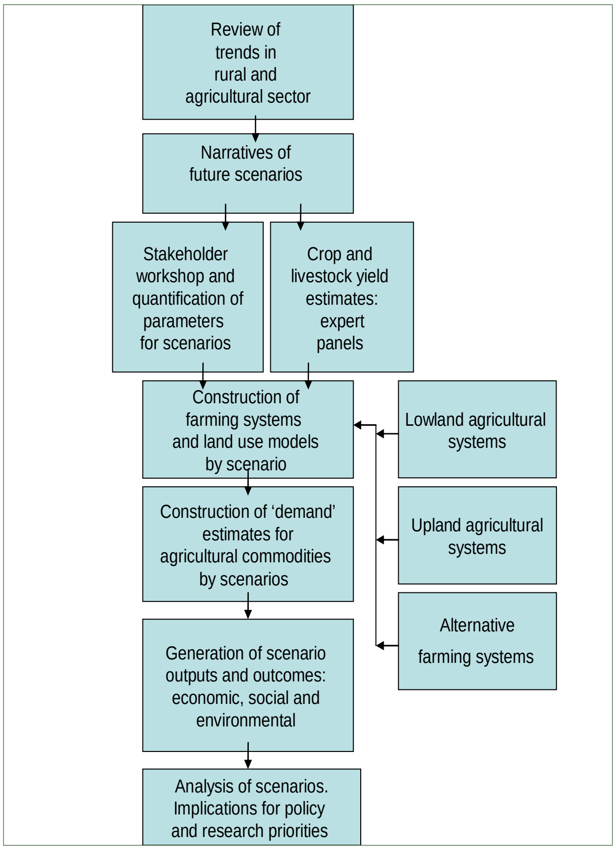


Figure 1.1 Research methodology

A workshop was held with key informants from major stakeholder groups to further develop descriptions of these possible futures, where possible producing quantifiable measures such as crop yields and relative prices for agricultural commodities (Chapter 3). Scenario mapping of production systems and yields was also conducted with crop and livestock researchers working on parallel Defra project ISO210.

The narratives and quantitative estimates of possible futures were used to model regional land use and farming systems for England and Wales using the Silsoe Whole Farm Model (Chapter 4) . Focusing on mainly lowland arable and intensive grassland agriculture, this optimization model was run for each future scenario to produce estimates of production, profitability, employment and selected environmental impacts through to the year 2050. Simultaneously, Hillplan, a non-optimisation grassland model, estimated livestock production from extensive mainly upland systems for each scenario (Chapter 5). These estimates were combined with those generated for lowland livestock to derive production for the grassland sector as a whole.

During initial scenario description and modeling, agricultural commodity prices were treated as predefined input variables for each scenario. This proved problematic, generating inconsistent and unreliable model results. For this reason, a simple model was constructed to predict the likely demand for agricultural commodities to be met by domestic farmers under each scenario. From this, it was possible to estimate commodities prices which generated domestic supplies sufficient to satisfy assumed demand.

Table 1.1 : Research objectives and methods and report structure

Research Objective	**Method**	**Chapter (refers to Main Report and Technical Report)**
1	***Scenario Building***	
Possible futures for agriculture in England and Wales	Review of existing research and other literature concerning agriculture and environmental issues (trends, present status, future possibilities) Preliminary definition of future scenarios based on foresight type scenarios	Chapter 2 Appendix A Technical Report
	Stakeholder workshop to map out possible agricultural futures Quantification of scenarios for modelling purposes: quantitative indicator sets	Chapter 3
2	***Scenario Modelling***	
Outcomes, impacts and sustainability	Application and extension of Silsoe Whole Farm model for analysis of lowland farming systems, land use, and outcomes under possible futures, including effects of alternative yields, input:output prices, resources and constraints. Development of framework for estimating demand for agricultural outputs under alternative scenarios.	Chapter 4 Appendix B Technical Report
	Application of grassland model to simulate stocking regimes for upland livestock systems	Chapter 5
3	***Policy Impact Assessment***	
Implications for environmental objectives and the need for policy interventions	Incorporation of agricultural and environmental policy instruments and objectives in the modelling process, including alternative input regimes, farming practices and pricing policies Policy impact assessment, and exploration of agricultural and environmental policy trade-offs, and policy interactions Interpretation for policy formulation	Chapter 6
4	***Implications for Research***	
Research needs and priorities	Compilation of a typology of research, classified in terms of purpose, focus and /or impact pathways Prioritisation of research needs to maintain or enhance sustainability under possible agricultural futures	Chapter 6

A number of alternative farming systems were also considered in the analysis, including low input farming, minimum cultivation farming, precision farming and GM technology. These systems were initially considered for the BAU case and the extent to which they are likely to be compatible with, and make a difference to the outcomes of other future scenarios was assessed in broad terms.

The main outcomes of each future scenario were determined and judgment made whether these would gain acceptance by policy makers and managers. There is a degree of circularity here: future scenarios contain inherent policy preferences and the outcomes are the product of these. However, some outcomes, once identified, may be considered undesirable and a case might be made for policy interventions to address these concerns. It is apparent, however, that common themes arise across all scenarios and are thus likely to be relevant across a broad range of possible futures. Thus the final stage of the study explored the implications of possible futures for the management of policy and research (Chapter 6).

1.3 Summary

Agriculture in England and Wales is undergoing significant change as the factors which have shaped it over the last 50 years are realigned. This study explores possible futures for agriculture and the implications for the environment with the purpose of informing policy and research priorities accordingly.

The next chapter reviews changes over the last 50 years or so in order to identify some of the drivers and characteristics of agricultural change.

Chapter 2: Dimensions of Change in Agriculture for UK, England and Wales

This chapter provides an overview of the main characteristics of agriculture in the UK, with particular reference to England and Wales and how these have changed over time. The purpose is to look backwards with a view to informing perceptions of the future, although, as discussed later, the future is unlikely to be an extrapolation of the past. The treatment here is necessarily partial and selective: there is a large literature on the topic and this is reviewed in the supporting papers of Appendix A including reference to source material . The period over which data are available varies, as does the classification of data itself. In some cases data refer to UK and in other cases to England and Wales.

After a brief review of farming systems, the chapter briefly reviews trends in the role of agriculture in the national economy, land use, crop and livestock production and productivity, agricultural and agri-environment policy and issues of sustainability. It does this to provide a framework for the subsequent definition and modelling of future scenarios.

2.1 Overview of Agricultural Systems

The agricultural sector in the UK comprises a complex array of processes which transform inputs into outputs (Figure 2.1). The latter include crop and livestock commodities for sale as well as 'non-market' environmental outcomes such as landscapes (positive) and agrochemical pollution of surface waters (negative). Agricultural systems are set in a broad social, economic and political framework that, along with the endowment of natural resources and climate, define the outputs required and the resources available. More recently greater attention has been given to environmental outcomes, as well as agriculture's contribution to sustainable livelihoods (Defra, 2002a, b). An understanding of past trends and future possibilities can be framed in terms of how agriculture, set within an institutional context, employs available resources to generate useful and valued outputs.

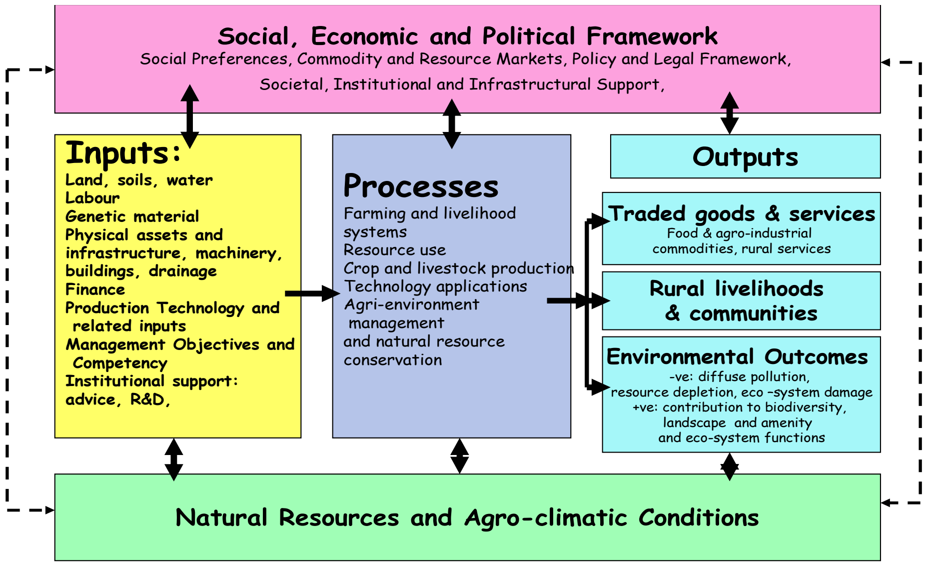


Figure 2.1 : Components of agricultural systems

2.2 Agriculture in the National Economy

In 2004 agriculture accounted for 0.8% of UK GDP (£8.7bn), down from 5% in the 1950s. This is generally lower than the current EU (15) average of 1.6%. The sector currently employs 546,000 persons full or part time, equivalent to 1.8% of the UK workforce, down from about 6%

in 1950. Including the food industry and rural tourism increases the share of GDP and employment to about 8% and 12.5% respectively (Defra, 2005a).

2.3 Agricultural Land Use and Cropping

Although the UK is a highly urbanised country, agriculture occupies 77% of the total land area, a total of 18.4 million ha (Defra, 2005a): 73% and 79% in England and Wales respectively. Its impact on the rural landscape is obvious.

Long term trends in land use and cropping during the 1900s are shown in Figure 2.2. During the period 1900-2000, the area of agricultural land use declined by about 15%. In England, there was an absolute decline in grassland, and an absolute increase in arable, reflecting an expansionary phase of UK agriculture in response to policy support. In the case of Wales, the total extent of arable cropping and rough grassland declined, and that of improved permanent pasture increased.

With respect to arable cropping in England, the area of wheat has doubled since 1950s, although the total area of cereals has declined,. The area of protein and oilseed rape increased from very little to over 20% of the total arable area, while root crops, mainly sugar beet and potatoes have declined in total area. The total arable area appears to have increased, mainly associated with the take up of set-aside, some of it involving land previously down to grass. The horticultural sector is now half the area of that in 1950, mainly due to reduced vegetable and fruit crops. These changes in land use are attributable to a range of policy, market and technological drivers that have shaped the feasibility of alternative land uses as well as the structure of the farming sector itself. The decline in area has however been more than compensated by increases in yields such that for much of the period output increased.

The post 1950 trends apparent in Figure 2.1 for the UK have become more deep-seated in the last twenty years as shown in Table 2.1. The main points are:

- decline in the total area by about 15,800 ha each year, equivalent to about 0.2% per year;
- decline in temporary grass, mainly linked to a decline in dairying;
- stability in the total area of cereals and break crops: within this a decline in cereal cropping, particularly in barley, offset by an increase in oilseed rape and proteins;
- decline by over 20% in the area of root crops, notably sugar beet and potatoes, partly reflecting the effect of increased yields in the face of static markets;
- decline in the horticultural area by over one third;
- growth in maize as a forage crop (from very little about 100,000 ha between 1980 and 2004);
- introduction and growth of ‘set-aside’; and
- doubling of farm woodland.

The pace and direction of change is broadly similar for England and Wales considered separately, although land use in Wales is predominantly grassland. There has been recent a move from temporary to permanent grassland linked to decrease in dairying. There is regional variation in land use change within England: the decline sugar beet, potatoes and horticulture has mainly occurred in central and eastern parts of the country.

In the UK, over two thirds of land use is given to grass for livestock, and a similar proportion of the value of output is linked to livestock production. Welsh agriculture is predominantly livestock based. In England, grassland, mainly occurring in the west and north, accounts for over 60% of land use and about half of output by value.

2.4 Livestock Type and Numbers

Table 2.2 shows livestock numbers for the UK over the period 1980-2004. There has been a 20% reduction in the dairy herd over the last 25 years, off set to a degree by increasing beef sucker cows as farmers moved out of dairying. Sheep and lambs numbers peaked in the 1990s but subsequently fell to give an overall 15% increase over the period. Pig numbers declined partly in response to overseas competition, and poultry production has increased in association with market growth and industry consolidation. Most of these changes can be attributed to policy and market drivers, linked to technology changes.

2.5 Farm Numbers, Types and Sizes

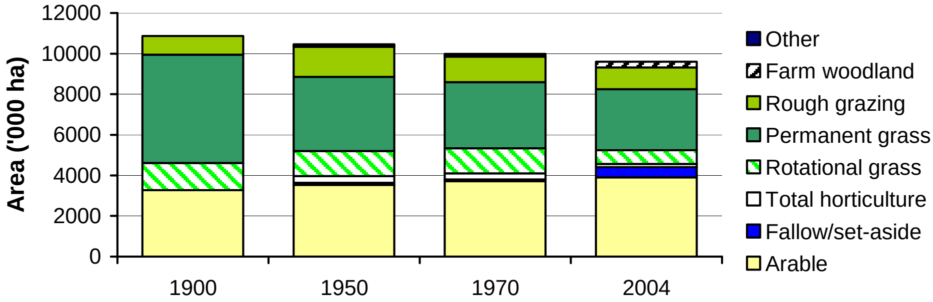
Since 1945 the number of farms in England and Wales has reduced by approximately 50%. Concomitantly, the average area per farm and the average number of livestock per farm has increased by about 40% and 150% respectively. There were 228,700 holdings in England and Wales in 2004, 84% in England and 16% in Wales. By number of holdings, cereal, dairy and lowland cattle and sheep farms account for 42% of all farms in England (Defra, 2005a). In Wales, cattle and farms in Less Favoured Areas account for a third of all farms.

The decline in the number of farms, about 9% since 1990, has mostly occurred amongst general cropping and dairy farms. This has been associated with increased intensification and specialisation of farms, and a move away from mixed arable and livestock and mixed cropping farms. Structural adjustment has been associated with retirement and/or exit of farmers from the industry, pressure on farm incomes, and economies of scale associated with new technology. There has also been a recent trend towards diversification of farm businesses, with 58% of farms now deriving income from other non-farming or off-farm activities. Many farms now operate as ‘partnerships’ or loose amalgamations.

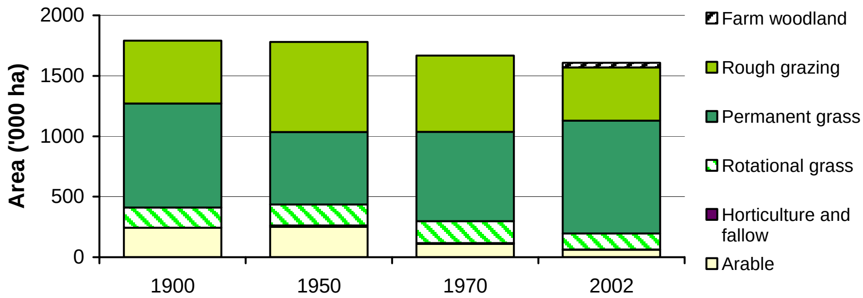
2.6 Arable Sector: Areas and Yields

Although average on-farm yields of arable crops have increased in the last 50 years or so, there is considerable variation amongst crops, partly reflecting improvements in genetic stock, the use of yield enhancing inputs such as fertiliser and standards of farm husbandry. Defra Project IS0210 (Sylvester-Bradley and Wisemann, 2005) showed that:

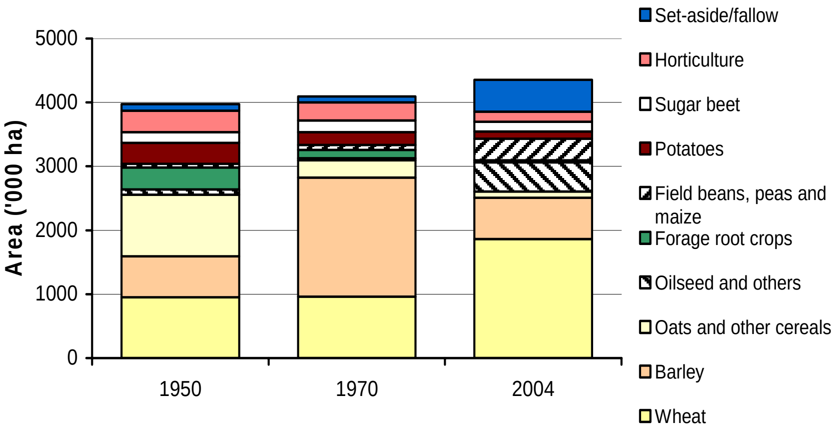
- on-farm yields of wheat averaged across England and Wales have risen steadily over the last 50 years by 0.1 t/ha/year (Figure 2.3);
- although maincrop potato yields increased from an average of 28 t/ha between 1973 and 1978 to over 40 t/ha in 1992, since then they have remained more or less static;
- on-farm yields in oilseed rape and peas have not shown significant increase since the mid 1980s, although trials on new varieties show increases of 0.05 t/ha/year for both species over the same period; and
- national average yield of grass is thought to be about 6 t/ha (dry weight). Potential yields of new varieties of perennial rye grass do not appear to have transferred to increases on-farm.
- The evidence suggests that potential yields have been developed by plant breeders and taken up by farmers where there has been an incentive to do so. Wheat is a prime example.



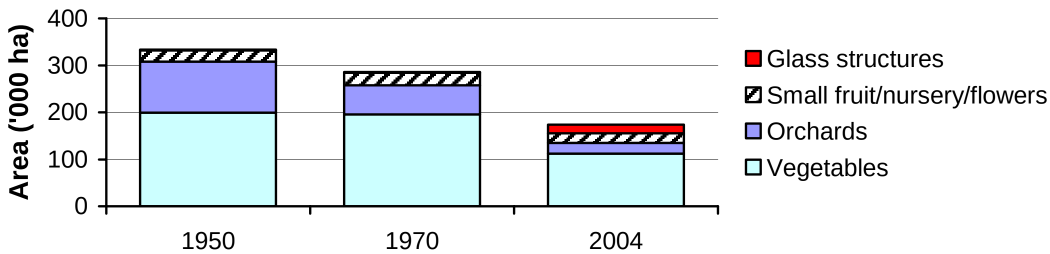
Agricultural area in England (1900 to 2004) (Defra, 2002; Defra, 2005) (Board of Agriculture, 1902).



Agricultural area in Wales (1950 to 2000) (National Assembly for Wales, 2002; Board of Agriculture, 1902).



Area of arable crops in England (1950 to 2000) (Defra, 2004)



Area of Horticultural crops in England (1950 to 2000) (Defra, 2002; Defra 2004).

Figure 2.2 : Dimensions of agricultural change: land use in England and Wales during the 1900s

Table 2.1 : UK land use ('000 hectares)

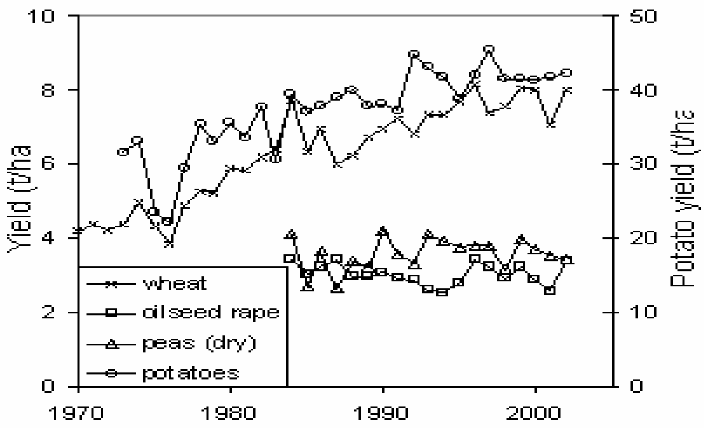
	Average of 1979-1981	1990	2000	2004	% change 79-81 to 2000
Land use					
Total crops	4,960	5,013	4,665	4,593	-7%
Bare fallow	69	64	37	29	-58%
All grasses under 5 years	1,933	1,580	1,226	1,246	-36%
All grasses over 5 years	5,145	5,263	5,363	5,620	9%
Sole right rough grazing	5,093	4,706	4,445	4,326	-15%
Set aside	-	-	567	560	
Other including woodland	486	680	780	825	70%
Total area on agricultural holdings	17,686	17,307	17,083	17,200	-3%
Common rough grazing	1,213	1,236	1,226	1,237	2%
Total agricultural land	18,899	18,542	18,308	18,437	-2%
Crops					
Cereals	3,932	3,657	3,348	3,133	-20%
Oilseed rape	97		332	498	413%
Sugar beet	212		173	154	-27%
Hops	6		2	2	-67%
Peas and field beans	78		208	242	210%
Linseed	-	-	71	30	-
Other crops	198		192	203	3%
Potatoes	200	177	166	149	-26%
Horticulture	270	208	172	175	-35%

Source: MAFF/Defra various

Table 2.2 : Livestock numbers UK ('000 head)

	1979-1981	1990	2000	as of June 2004	% change 79-81 to 2004
Dairy	3,237	2,854	2,336	2,131	-34%
Beef	1,481	1,601	1,842	1,735	17%
Dairy heifers in-calf	689	530	532	461	-33%
Dairy heifers in-calf	164	232	186	228	39%
Other beef	7,812	6,950	6,238	5,994	-23%
Sheep	31,163	44,217	42,264	35,890	15%
Pigs	7,836	7,606	6,482	5,161	-34%
Poultry	125,712	124,763	154,504	165,324 (2003)	32%

Source: Defra (various)



Source: MAFF/Defra (various)

Figure 2.3 : Average crop yields for England and Wales

2.7 Livestock Sector Yields

National average animal yields have been reported since 1973 for milk, 1980 for cattle, and 1984 to 1986 for the other species. (Figure 2.4)

Animal yields have shown continuous increase over the period. Milk yields have increased by 88 l/cow/year and egg yields have increased by 2.12 eggs/bird/year. The annual increases of the carcass weights of cattle, pigs and poultry have been 2.0 kg, 0.5 kg and 0.0053 kg respectively (Figure 2.4);

There has been a increase in progeny over time, such as lambs per ewe, piglets per sow and reduced interval between calving;

Sheep yields show modest improvement in output, limited by low average fecundity, seasonality of breeding and high peri-natal mortality;

Feed conversion efficiencies have improved (i.e. less feed per unit yield) for some species, notably pigs, poultry and sheep but evidence of this in cattle is lacking due to the wide range of types of feed used.

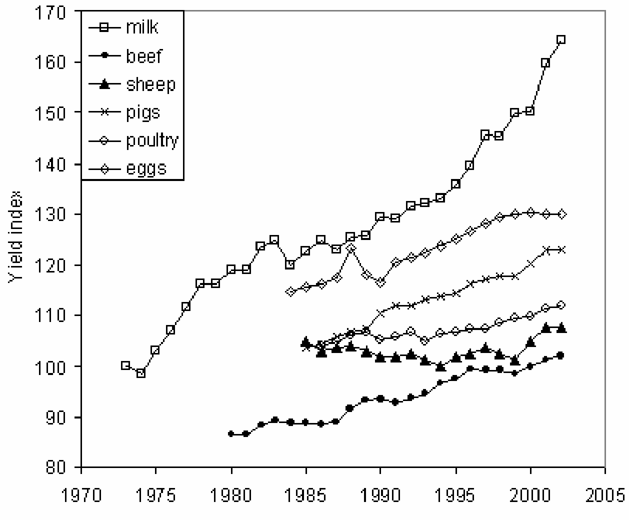


Figure 2.4 : Average animal yields for England and Wales (Sources: MAFF/Defra)

1986 yields: Beef (274 kg/carcass), sheep (17.9 kg/carcass), pigs (61.3 kg/carcass), poultry (1.44 kg/carcass), eggs (259 eggs/bird/year), milk (4970 l/cow/year).

In the case of milk production, and in the face of relatively static market demand, there have been compensating trends in milk yields per cow and the size of the national herd (Figure 2.5). Since the early 1970s, yields have almost doubled and the number of cows has declined by over a third. This change has been associated with a rapid decline in the number of dairy farmers.

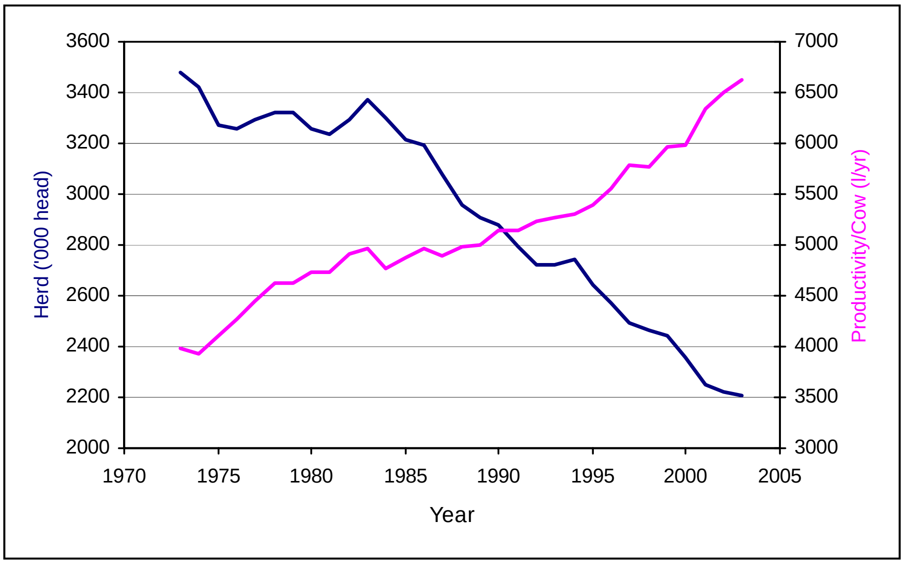


Figure 2.5 : UK dairy herd and yield per cow 1973 – 2002 (Defra)

2.8 Agricultural Markets, Prices and Incomes

The period 1950 to 1985 saw considerable increases in agricultural production in response to government support and market drivers. Self sufficiency of indigenous foods rose from 60% to 90%, more recently declining to about 75%. Household expenditure on food as a percentage of total expenditure has, however, declined, as has the proportion of this going to the farmer compared to other agents in the food supply chain. Increased relative power of the retail sector, increased processing and sophistication of final food products, and the lack of connectedness between consumers and farmers have accompanied this decline in share of final consumer price by farmers.

Since the early 1970s there has been a remorseless long term decline in real farm commodity prices (Figure 2.6), a relative rise in input prices, and in spite of increased yields, a general fall in farm incomes (Figure 2.7). These trends have encouraged the continuing structural adjustment alluded to earlier as farmers seek to maintain incomes through economies of scale and specialisation, or leave the industry altogether. This has undermined the viability of many small, family operated grassland farms, particularly in Wales and upland areas of England.

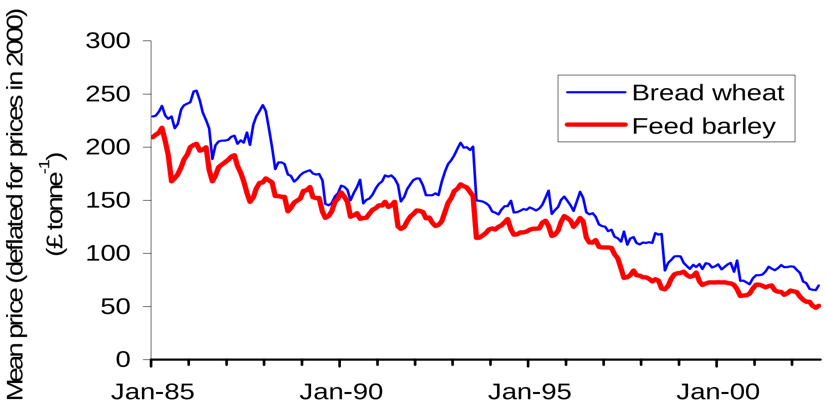


Figure 2.6 : UK real mean value of wheat and barley from 1984 to 2002 (Defra, 2002; HM Treasury, 2003)

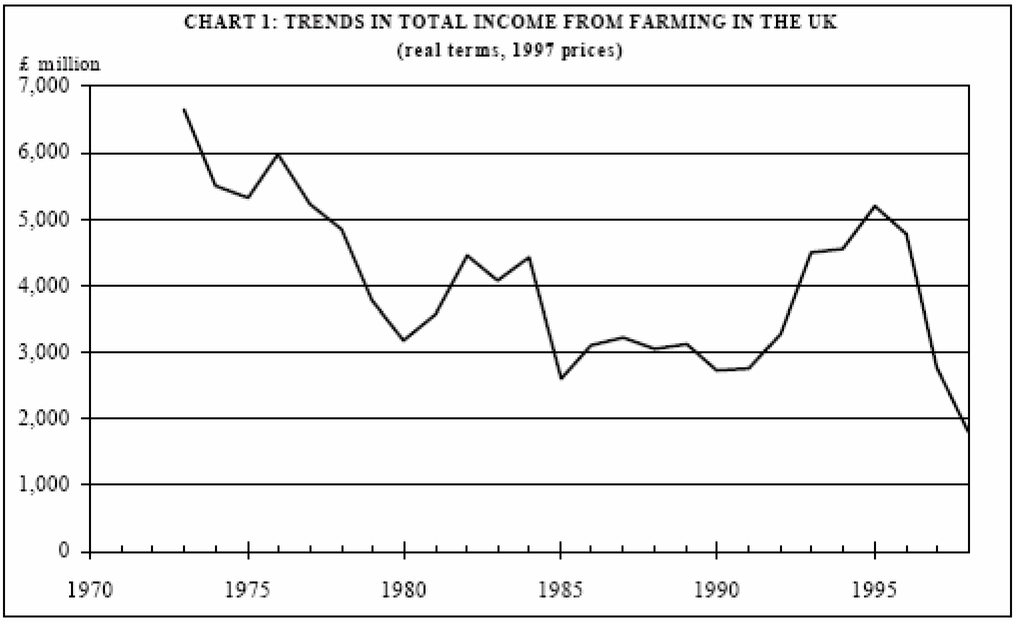


Figure 2.7 : Trends in total income from farming (Source: Defra, 2002b)

2.9 Productivity, Farming Systems and Technology

Regarding overall productivity in UK agriculture, Total Factor Productivity (TFP), the volume of outputs from agriculture per unit of all inputs, has increased by 45% since 1973 Figure 2.8). Up to the mid 1980s, TFP increased sharply as a result of increased volume of output with the volume of inputs remaining reasonably stable, although decreased labour inputs were substituted by other types of input. TFP stagnated during the 1985 to 2000, but has increased more recently mainly because inputs have fallen more sharply than outputs.

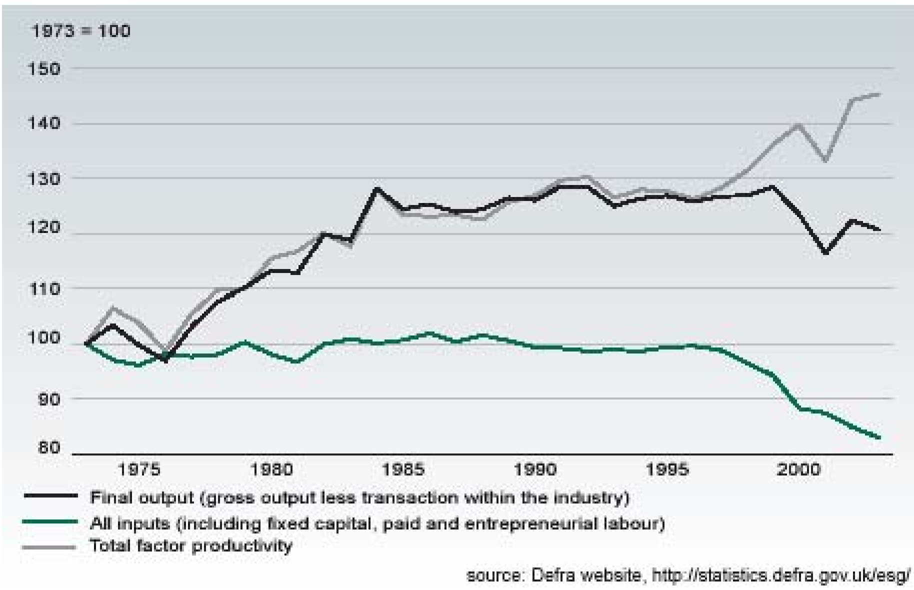


Figure 2.8 : Total factor productivity in UK agriculture (source: Defra. 2003a)

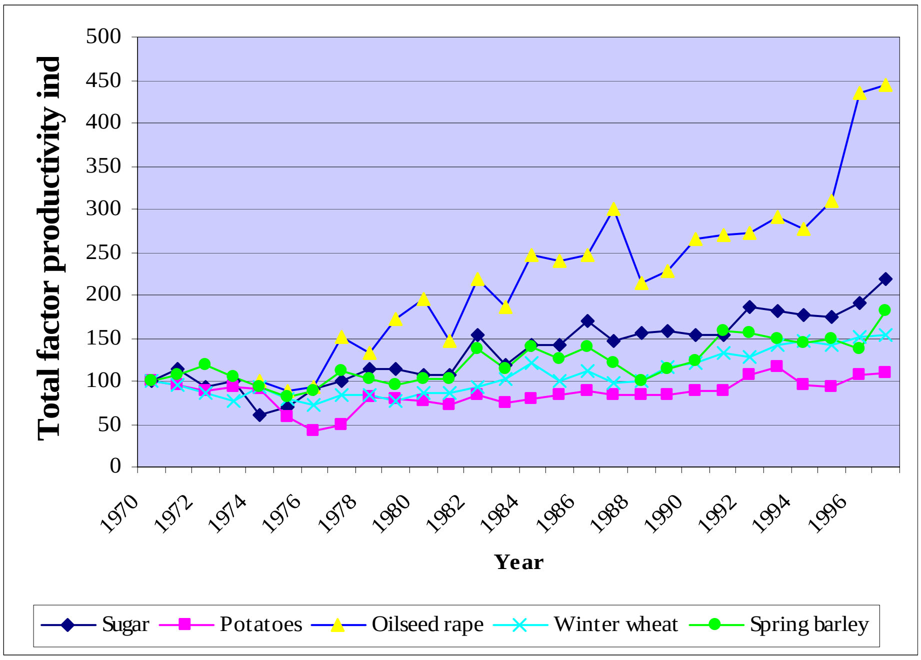
Thirtle and Holding (2003) derived estimates of TFP for selected crop enterprises and for types of farms in the UK using value-based estimates of the ratio between output and labour, land and all inputs respectively over the period 1970 to 1997 (Figure 2.9). They note that:

yields per ha increased by between 150%-200% during the period for most crops, output per worker increased by between 200% and 400% due mainly to increased mechanisation, except for potatoes which remained relatively labour intensive;

land use shifted towards higher productivity crops, into wheat, oilseed rape and sugar beet, and out of potatoes and barley;

23% of the growth in productivity was associated with shift in land use and 77% was due to improved productivity of existing cropping;

crop research and advice had a beneficial effect on productivity in sugar beet.



Source: Thirtle and Holding, 2003

Figure 2.9 : Trends in total factor productivity for selected enterprise in Eastern England, 1970-1997

With regards to farm level productivity over the period 1982 to 1997, Thirtle and Holding suggests that:

- the most efficient farms increased their productivity considerably by about 2.5 % per year for pig and poultry farms, 1.5% for dairy, 0.7% for sheep and 5% for cereal farms;
- overall average efficiency declined as the majority of farms fell further behind the most efficient, suggesting a failure to exploit potential productivity gains;
- the most efficient farms were generally larger, and the least efficient were associated with older farmers, indebtedness and a lower degree of specialisation.

The authors point out that these results require careful interpretation because they are affected by changes in relative prices of commodities and exchange rates over time (although adjustments were made for this) and policy interventions in latter years that encouraged extensification, including set-aside of arable land.

It is noted that the realisation of potential productivity depends on farmer motivation and competency. For example, a positive correlation between efficiency and management characteristics such as information seeking, experience and farm size amongst has been observed wheat farmers in eastern England (Wilson, Hadley and Asby, 2001) and Dutch sugar beet growers (Koeijer, Wossink, Renkema and Struik, 2002).

Comparisons of TFP in agriculture have been made between countries to assess relative efficiency and competitiveness (Gopinath, Arnade, Shane and Roe, 1997; Ball, Bureau, Butault, and Nehring, 2001). After relatively rapid growth, the UK appears to have lagged behind other EU member states since the mid 1980s, with growth in TFP less than 50% of that achieved in France for example (Figure 2.10). TFP is an important determinant of country's international comparative advantage, and in the event of further liberalisation of agricultural trade, a key determinant of whether a country imports or exports. The competitive advantage of USA agriculture has rested on its ability to sustain and increase growth in TFP (Goponath et al., op cit). Of course, this measure of competitive advantage is not independent of government support.

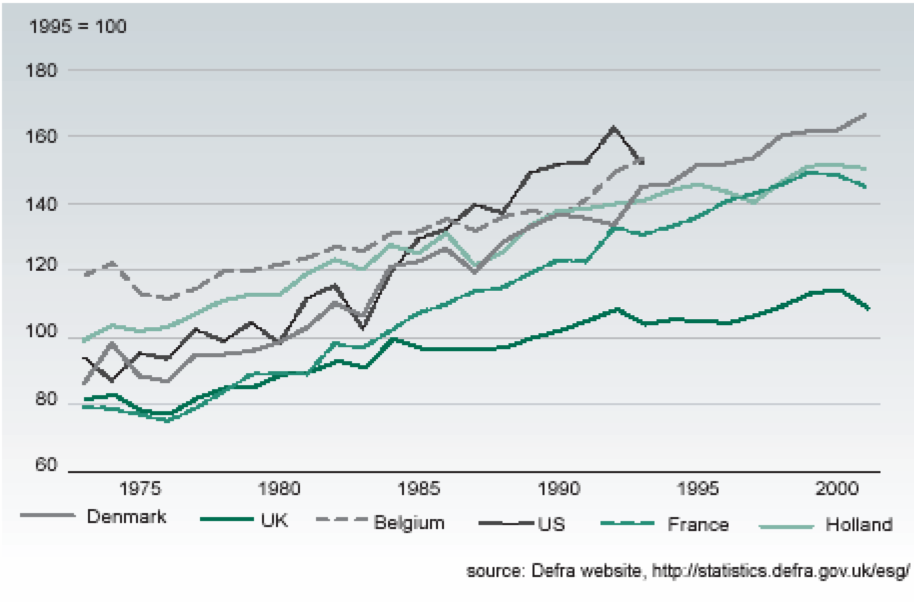


Figure 2.10 : International comparisons of agricultural TFP, 1975-2001

2.10 Environmental Dimensions of Productivity

Given growing concern with the impact of agriculture on environment and society, there has been a call for a more comprehensive definition of productivity (Pretty, 1998; Defra, 2002a, b). Modern farming technologies have impacts beyond the farm which are inadequately accounted for (Environment Agency, 2002). Indeed, agriculture is now seen the major source of uncontrolled discharges of pollutants to water (HCEFRAC, 2003; Defra, 2003b). Allowing for the environmental impacts associated with agrochemical pollution, for example, led Barnes (2002) to reduce estimated annual TFP growth rates by about 20%. This also resulted in reduced rates of return to public expenditure on agricultural research and development.

Recent estimates have put the 'external' costs to the environment of agriculture in the UK at over £1.2 bn per year, equivalent to about £200/ha for arable land (for the UK: Pretty, Brett, Gee, Hine, Mason, Morison, Raven, Rayment, van der Bijl (2000), and Hartridge and Pearce (2001) and for England and Wales: Environment Agency (2002) (Table 2.3). This is offset to a degree by positive environment contributions, equivalent to £0.3 bn per year according to Hartridge and Pearce (op cit), and £0.9bn according to the Environment Agency .

Table 2.3 : External environmental costs of UK agriculture

	Hartridge and Pearce	Pretty et al	Environment Agency
Cost Category	(£ Million)	(£ Million)	(£million)
• Damage to Natural Capital: Water	430	230	203
• Damage to Natural Capital: Air	585	1115	760
• Damage to Natural Capital: Soil	20	95	264
• Damage to Natural Capital: Biodiversity and Landscape	40	125	NA
Total	£1075	£1566	1266

For these and other reasons, sets of indicators have been developed to measure the sustainability of agriculture (MAFF, 2000; CEC, 2000; Defra, 2002a; Pannell and Glenn, 2000) and there is a move to account for the natural resource and environmental impacts of farming in the national accounts for agriculture following guidance by UNSEEA (2003). Reducing waste and pollution can simultaneously provide efficiency gains which, in the face of rising inputs costs, can help secure the financial viability of farming.

2.11 Alternative Farming Systems

Over the last two decades, various alternatives to conventional intensive farming systems have been developed in attempts to improve efficiency and/or reduce the environmental burden of farming. Some have drawn on traditional farming knowledge and methods to reduce reliance on artificial inputs, some have harnessed new developments in modern science and technology, and some have engaged a mixture of the two approaches. Examples include:

- Integrated Crop Management which use rotations to control pests and diseases
- Modified Tillage systems which involve reduced, minimum or zero tillage systems
- Combined mechanisation operations involving single pass systems
- Precision farming which involves spatially variable operations to reduce inputs and reduce pollution risk
- Genetic modification which involves the use of transgenics to confer desirable traits in crops and livestock in order to reduce vulnerability or enhance saleable quality
- Organic farming, without the use of agrochemicals
- Bio energy crops, particularly involving use of conventional crops for bioethanol and biodiesel production

These systems are reviewed in Appendices A (Topic Paper 5) and B (Topic Paper 10). The first three systems have already been adopted to varying degrees, encouraged by potential costs savings and perceptions of good practice. ICM has shown equal or better financial performance compared with conventional methods, even though yields may be reduced by 10 to 20% (Pretty and Howes, 1993). Reduced tillage and combined mechanical operation are now widespread, although heavy cultivations remain the dominant practice. GM technologies have not moved beyond farm trials in the UK and they have met with market resistance in Britain. Should consumers find them acceptable, it is likely that farmers will adopt them where there is financial benefit. Organic farming now accounts for about 300,000 ha in England and Wales, although this has recently declined due to insufficient price incentives: 70% of organics are imported. Bio-fuels have not taken off in Britain to date, but the EU Biofuel Directive and rising fuel prices have increased interest by farmers and fuel producers.

2.12 Agricultural and Rural Policy

Agricultural policy has been an key influence on the direction and pace of agricultural change. In 2004, support to the UK farming sector was about £2.5bn, equivalent to about 45% of the total value-added in agriculture.

It is apparent that agriculture in the UK has changed continuously over the last 50 years associated with three phases of policy:

- Agricultural enhancement period from the 1950s to the early/mid 1980s, characterised by continued production support;
- Agricultural adjustment period from mid 1980s to the early 2000s, characterised by production quotas, headage and area payments and agri-environment schemes;
- Reform period, mid 2000s, evident in the current CAP Agenda 2000 reforms with increased decoupling, environmental and rural regulation, entry and high level environmental stewardship and the move to single farm payments.

The UK 1947 Agricultural Act laid the foundation for agricultural support until accession into the EU in 1973. With purpose of securing food supplies and rewards to those employed in agriculture, this was probably one of the most successful post-war policy regimes. Agricultural markets were regulated through a combination of producer marketing boards, production quotas, some controls on imports and direct ‘deficiency payments’ funded by tax payers which were made to farmers to compensate for relatively low market prices, the latter justified as part of a cheap food policy.

After 1973, the EU Common Agricultural Policy, with similar policy objectives, switched the burden of agricultural support from tax payers to consumers by introducing import restrictions and tariffs which maintained high internal prices. Since the early 1980s, however, concerns about the burgeoning financial costs of CAP, over-production and food mountains, the environmental damage of intensive farming and continued vulnerability of some sections of the farming community, have led to a succession of measures to ‘decouple’ income support to farmers from support to commodity prices. A range of policy instruments have been used at different times, including scrapping of producer marketing boards, introduction of production quotas, guaranteed prices, export refunds, arable area payments, livestock ‘headage’ payments, diversification grants, and agri-environment schemes. In April 2005, the Single Payment Scheme was introduced which pays farmers an annual amount broadly based on previous entitlement to income support.

Table 2.4 : Areas under agri-environment schemes in England (source: Defra)

	1987	1992	1999	2000	2001	2002
			000 ha			
ESA	31.2	129.4	523.5	550.0	579.0	620.0
Countryside Stewardship	..	..	139.9	192.1	263.3	334.0
Organic conversion	..	..	16.1	95.9	134.5	158.3
Woodland		12.8	32.7	36.2	40.9	45.9
Moorland (discontinued)	..	..	15.8	15.8	15.8	2.7

In the last two decades, agri-environment has been a growing component of agricultural and rural policy, initially in England under the Environmentally Sensitive Areas (ESA) Scheme and latterly under the Countryside Stewardship Scheme (CSS) and Organic Farming Scheme (OFS). In Wales, agri-environment schemes comprise Tir Gofal and Tir Cymen,. About one million hectares are now enrolled in environmental schemes in England (Table 2.4) and about 160,000 ha in Wales, of which about 100,000 ha are under Tir Gofal and 60,000 ha under organic conversion. These schemes involve extensification of farming and management practices to enhance landscape and wild life, with consequences for land use. Over 75% of total organic conversion involves grassland.

2.13 DPSIR Framework

The preceding review has shown that agriculture in Britain has changed considerably in the last 50 years, evident in changes in land use, employment, farm size and farming practices. The underlying processes of gradual change have at times been hastened by unforeseen events such as outbreaks of BSE and Foot and Mouth Disease. Evidence of climate change adds an additional dimension.

In the first half of the period, agriculture pursued a predominantly production oriented pathway, whereas in the latter half this has been moderated by policies to protect the environment. Throughout the period, farms have tended to become larger and more specialized, although more recently there has been a rise in the number of lifestyle and hobby farms where farming is not the main source of income. Recent policy reform is reducing the incentives for intensive farming, requiring farmers to comply with codes of good practice and placing more emphasis on environmental stewardship.

High level policy, market and technology drivers have led to economic, social and environmental pressures (Figure 2.11) which in turn have consequences for the state of farming, the latter evident in the production, farm incomes and livelihoods, food supply and the quality of the environment. In turn this state has affected the welfare of those working in farming, food consumers and those affected by quality of the farmed environment.

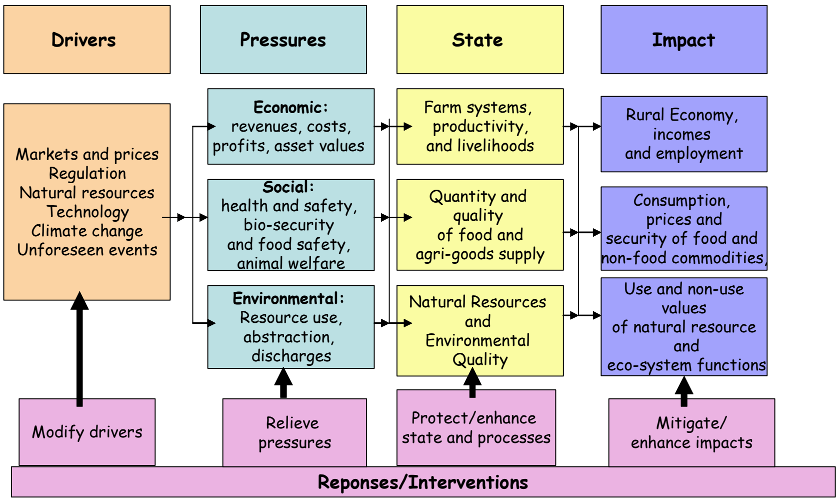


Figure 2.11 : DPSIR Framework Applied to Agricultural Systems

Where there is concern that agricultural systems are not performing well against a range of social, economic and environmental criteria, ‘responses’ may seek to modify drivers, such as reform of agricultural policy through reduced general support for farm commodities or increased support for organic production. Responses to relieve pressures may include promoting codes of good agricultural practice, placing limits on nitrogen use and providing economic incentives for ‘cleaner’ technologies. Actions may be taken to protect the state or condition of agriculture by designating protected area status, setting biodiversity targets, or providing income support for vulnerable farming communities. Responses may also include measures to mitigate undesirable impacts through, for example, river and groundwater recharge during drought periods and compensatory or insurance payments for farmers experiencing loss due to disease or adverse climatic conditions,. Figure 2.3 reinforces the argument that measures of agricultural ‘productivity’ must take a broad perspective, demonstrating that factors that influence productivity are diverse and subject to change. It also helps to frame responses to promote agricultural development in accordance with societal preferences.

The DPSIR framework provides a broad conceptual model within which to explore possible futures. The preceding review confirms the relevance of framework as a means of explaining past changes. Drawing on evidence from the past, the framework can also be used for exploring the future. As explained in the next chapter, narratives were drawn up to express the variations in drivers that could describe possible futures for agriculture. These narratives were subsequently expressed quantitatively in a modelling framework in order to express potential pressures, states and impacts, as well as helping to identify possible policy responses.

2.14 Summary

It is apparent that a range of factors have come together to produce the current set of land uses and farming systems in England and Wales. The importance of agricultural policy, and more recently agric-environment policy, is clear. Policy analysis is thus a critical component of any attempt to scan possible futures for agriculture. As explained in the next chapter, the insights derived from this review were used to help generate narratives for future scenarios which for the most part are distinguished in terms of dominant policy regimes, but within which trends in population, consumer preferences, markets and technology also play a key role.

Chapter 3 : Future Scenarios for Agriculture

It is clear from the previous chapter that there have been major changes in the agricultural sector in England and Wales in the last 50 years. In the face of changes in key policy and market drivers, agriculture currently faces a very uncertain future. In this context, this chapter considers possible future scenarios for agriculture in England and Wales. These scenarios are presented as annotated narratives that are subsequently quantified using selected parameters in preparation for their inclusion in modelling of future agricultural land use.

3.1 Scenario Analysis

The construction of the future agricultural and related environmental scenarios draws on the methodology developed under the UK Foresight programme (OST, 2002; Berkhout and Hertin, 2002) that considers long term futures and possible implications for UK industry and society. Scenarios are not intended to predict the future, but rather to help think about how it might turn out. Scenario analysis assumes that:

- the future is unlike the past and is shaped by human choice and action;
- the future cannot be foreseen but exploring it can inform present decisions;
- there are many possible futures: scenarios map a ‘possibility space’;
- scenarios combine rational analysis and subjective judgement.

Thus, scenarios are statements of what is possible; of prospective rather than predictive futures; propositions of what could be. They are often made up of a qualitative story-line and a set of quantitative indicators which describe a possible future condition. The scenarios arise as a consequence of modelling drivers of economic and social change, new trends and innovation, and of unexpected events.

The Foresight Programme (OST, op cit) constructed four possible futures, distinguished in terms of social values and governance (Figure 3.1). Social values, the horizontal vector in Figure 3.1, are evident in behaviour: ranging from individualistic consumerism to community oriented conservationism: from short term hedonism to long term sustainability. Governance, reflecting distribution of power and decision making , varies from local/regional autonomy through to global interdependence.

These quadrants shown in Figure 3.1 are labelled and described as follows:

- World Markets: emphasis on private consumption and a highly developed and integrated world trading system.
- Global Sustainability/Responsibility: pronounced social and ecological values evident in global institutions and trading systems, with collective action to address social and environmental issues. Growth is slower but more equitably distributed compared with the World Markets scenario.
- National Enterprise: emphasis on private consumption, market values dominate but within protectionist national/regional boundaries.
- Local Stewardship: strong local or regional governments which emphasise social values, encouraging self-reliance, self sufficiency and conservation of natural resources and the environment.

Unforeseen events, such as international conflict or major technological advances or failures, can also shape possible futures. Some of these risks and uncertainties may be associated with particular futures.

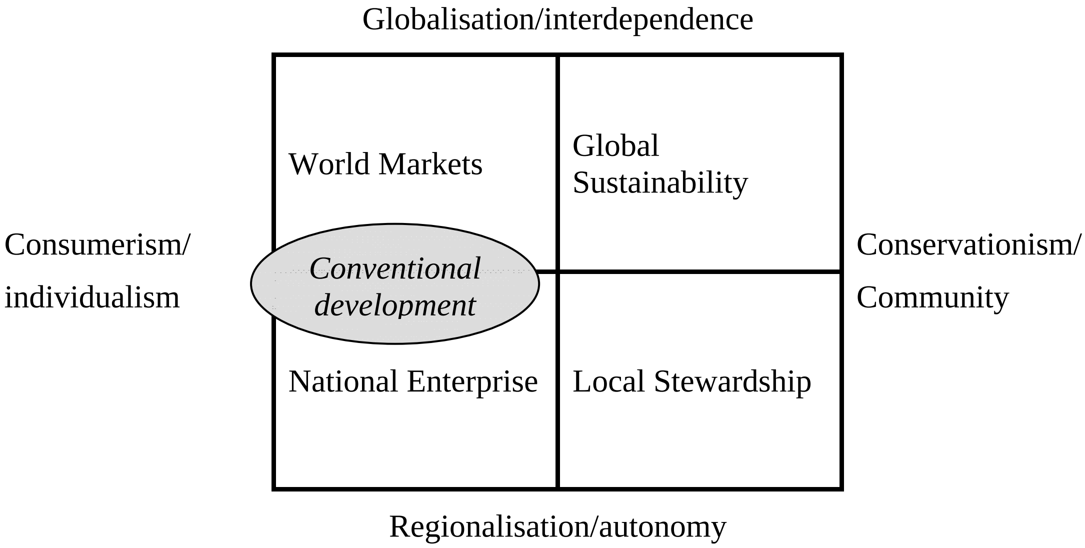


Figure 3.1 : Possible future scenarios, based on foresight (OST, 2002)

3.2 Scenarios for Agriculture in England and Wales

3.2.1 Drivers

The generic scenarios in Figure 3.1 were used to define possible agricultural scenarios for England and Wales. Although these futures are intended to stand alone, they are described relative to the existing ‘baseline’ position, and relative to an expected, most likely extrapolation of this ‘baseline’ assuming that current observed trends continue: a ‘Business as Usual’ future. Agriculture in England and Wales is currently very dependent on the EU CAP framework such that possible futures largely depend on changes in or away from this framework. The historic review in Chapter 2, combined with results from a stakeholder workshop (see below), suggested that the main drivers that shape agriculture in England and Wales are:

Primary drivers (exogenous to agriculture)

Macro-economic factors

Agricultural trade and policy

Consumers and markets

Climate change

Secondary Drivers (partly arising in response to primary drivers)

Agricultural systems and technology

Structure of the farming sector

Farmer motivation

Rural Development Regulation

Environmental and agri-environmental policy

These drivers, many of which are interconnected, combine with the political, economic and social imperatives contained within the scenario types. In turn these generate the input (such as crop prices) and output (such as land use) parameters which give the scenarios their particular distinguishing characteristics.

The links between the Foresight scenarios and the scenarios for agriculture in England and Wales are shown in Table 3.1, together with a brief description of agricultural policy regimes.

The baseline is the agricultural policy regime in place in 2002, as determined by CAP at that time. This baseline provides a reference point for the definition of future scenarios. The baseline can be extrapolated to 2012 based on predictions (rather than possibilities) of agricultural markets and prices derived from EU, OECD and other sources (see Appendix B). This extrapolated baseline shows a tendency, due to predicted reform of CAP and greater influence of WTO, towards Global Sustainable Agriculture. (The CAP reforms introduced in April 2005 have further consolidate this trend).

Provincial Agricultural Markets are characterised by protectionist regimes similar to those under pre-reform CAP. Local Community Agriculture, as the label implies, emphasises self sufficiency and conservation of natural resources at a local level.

Table 3.1 : Links between foresight and agricultural policy scenarios

'Foresight' Scenario	Agricultural Policy Scenario	Intervention Regime
	Baseline	Moderate: Existing price support, export subsidies, with selected agri-environment schemes
World Markets	World Agricultural Markets (without CAP)	Zero: Free trade: no intervention
Global Sustainability	Global Sustainable Agriculture (Reformed CAP)	Low: Market orientation with targeted sustainability 'compliance' requirements and programmes
National Enterprise	National Agricultural Markets (Similar to pre-reform CAP)	Moderate to High: price support and protection to serve national and local priorities for self sufficiency, limited environmental concern.
Local Stewardship	Local Community Agriculture	High: locally defined support schemes reflecting local priorities for food production, incomes and environment

3.3 Future Agricultural Scenarios

Narratives were compiled for each scenario for England and Wales for 25 years hence. These are summarised in Table 3.2 and presented in more detail in Appendix C (Scenario Workshop). A longer time frame would assume a deeper application of the scenarios. The detail of narratives vary amongst regions in England and Wales due to differences in resource endowments and farming systems. The impacts of international trade, for example, vary between regions according to commodity specialisation. Scenarios which give primacy to local decisions reflect history, customs, resources and preferences at the local scale.

Table 3.2 : Annotated narratives of future scenarios for UK agriculture

Drivers	World Markets	Global Sustainability	National Enterprise	Local Stewardship
Agricultural and rural policy	Abandonment of CAP. WTO led free trade in agricultural commodities. Limited interventions for social or environmental purposes. Increased global trade in agricultural commodities Rural diversification opportunities based on market potential.	Reformed CAP. WTO promoted liberalisation. Decoupled agric support. Promotion of sustainable agriculture, including agri-environment and animal welfare regimes Global rules seek ethical rural development. Multi-functional agriculture produces public goods.	Protectionist agricultural policies, involving input and commodity subsidies, deficiency payments and marketing/intervention regimes. Limited environmental and social concerns. Rural economy is based primarily on agriculture and food. Farming is the main agent of development	Support regimes in accordance with local needs and priorities reflecting self reliance, social and environmental objectives as defined at local level. Development defined in terms of conservation and community: a living/working countryside.,
Food markets and prices	Market led, consumer driven, but with increased domination of major food retailers. International procurement and market integration. Producer and consumer food prices fall for global products, with premia for niche products	Food supply chain accepts responsibility for promoting and responding to consumer concerns about safe, healthy and ethical foods. Consumer food prices rise due to quality assurance and compliance costs, providing incentives to producers	Supply driven food chain. Food industry, especially producers and processors define product offering and criteria for food quality Government supported supply side interventions maintain high producer prices, but cheap consumer food prices .	Greater connectivity between consumer and producer. Local area produce and market. Local 'brands' emphasise environmental and social attributes. Farmers join co-operative production and marketing schemes to add value and raise prices.
Environmental policy	Limited restrictions on chemical use, other than market imposed. Limited interest in soil and water conservation unless affecting production. Environmental risk managed through economic instruments	Comprehensive, integrated approach to prevention/minimisation of diffuse pollution from agriculture. Policy mix includes regulation, voluntary measures and economic instruments reflecting a commitment to 'stewardship' and biodiversity	Input intensive farming, limited controls on agro-chemicals and farming practices on environmental grounds. Regulation for controlling high risks which prejudice commercial interests.	Generally lower environmental risk but fragmented and selective regulation and control. Sustainable soil and water management embedded in farming culture, with policies, including regulation, to promote and support.
Farmer attitudes/ motivation	Polarisation into commercial and lifestyle farmers: 'real' and 'hobby' farmers. Biodiversity in farmed areas to suit commercial farming, or a commercial activity in itself.	Production oriented farmers tempered by increasing interest in conservation. Conservationists find expression in agri-environment schemes.	Commercially driven production focus, emphasis on output and production. Environmental motivations mainly commercially based and remedial.	Welfare maximising custodians, embracing commitment to sustainable livelihoods. Strong conservation and community ethic. Varied income sources, on and off-farm.

Agricultural production and farming systems	Competition leads to moderate to highly intensive, high technology, commercially driven large scale production by specialists., industrialised and global in scope, emphasis on efficiency through reduced unit costs for bulk commodity crops, with focused high quality production to gain price advantage where possible. Marginal land abandoned., GMOs widely promoted and adopted. Differentiated organic produce are an important niche market Intensive feedlot livestock systems, but some extensive grazing on abandoned cropland.	Moderate increases in agricultural productivity and production. Agri-environment contributes to global services. Diversification/multi-functionality important. Strong 'compliance' requirements. Large scale farms, but with policy to retain family farms. Areas taken out of production used to support nature conservation Selected adoption of GMOs, driven by environmental benefits. Limits on stocking rates, extensification incentives, strong welfare controls. High quality assurance. Some differentiated organic produce.	Broad based, relatively high input:high output farming to provide self sufficiency. Vegetables and agro-industrial raw materials are growth sectors. Mixed arable and livestock farming systems, intensive lowland dairy and cattle, with beef and sheep maintained in disadvantaged areas Moderate trend towards large farms but family farms remain viable. Patchy adoption of GMOs, given limited economic incentives and little concern about side effects. Limited by investment. Organics limited .	Decreased productivity but total agricultural area increases. Commitment to sustainable rural livelihoods reflecting community priorities Mix of intensive and extensive and greatly diversified systems. Retention of small scale, family based farming units Low input systems an important part of sustainable farming. Widespread adoption of Integrated Farming Systems. GMOs rejected. Relatively extensive livestock systems, part of mixed farming systems. Emphasis on environment and welfare, Undifferentiated organic produce widespread

3.4 Turning Narratives into Numbers

3.4.1 Stakeholder workshop: indicator metrics

Drawing on the descriptions of agricultural scenarios in Table 3.2, a set of indicators was drawn up by the research team to represent each of the major driver types shown. The indicator sets were considered in a participatory one-day workshop attended by 27 representatives of various stakeholder interests in the farming, food and related environmental sectors held at Cranfield University at Silsoe in 2003. The report on workshop proceedings, results and interpretation is contained in Appendix C. The workshop outcomes, and the approach to exploring possible agricultural policy futures in the context of northern Europe, is also reported in Rickard, Morris and Audsley (2005).

Participants used the indicators to map out each scenarios, scoring each indicator as an index relative to the future Business as Usual Case for the year 2025. By way of example, Table 3.3 shows derived values for selected indicators for each scenario, with more details provided in Appendix C.

Table 3.3 : Values of selected indicators by scenario derived in stakeholder workshop

Factor	Narrative/Indicator Value	BAU*	WM	GS	NE	LS
Free Trade, WTO/CAP influence	Degree of protectionism: use of import/export interventions (quota or prices)	100	10	50	90	100
Farm commodity price subsidies	£/t direct support	100	0	0	150	200
Consumer food prices	Food retail price index	100	75	100	125	140
Farm size	Average ha per farm unit	100	210	120	100	70
Yields	t/ha crops	100	130	80	110	60
Conservationist farmers	% of farmers acting to protect enhance environment	100	50	150	90	160
Farm Diversification	Number and range of enterprises per farm	100	80	100	90	150
Biodiversity	Intensity of bio-diversity targets, eg habitats directive, BAPs	100	50	120	70	130
Environmental Regulation	% of land area, number of practices/processes, subject to regulation,	100	50	120	80	140
Economic instruments	Use of ‘green’ taxes, subsidies and permit trading	100	80	120	90	110
Voluntary Measures	% of farmers adopting voluntary measures	100	70	110	80	130

* BAU in 2050. Source Appendix C: Workshop, September 2003

Workshop participants reflected on the use of scenarios for mapping long term futures (Table 3.4). They concluded that although the approach encouraged long term strategic thinking, it ran the risk of being overly prescriptive, especially if too much emphasis is placed on precise metrics rather than broad narratives.

Table 3.4 : Comments by stakeholder workshop participants on the use of scenarios for scanning of agricultural futures:

• The approach can provide a useful framework for considering long term futures: the longer the term, the greater the need to think radically beyond existing knowledge and experience.
• The approach takes time to understand, especially to appreciate that there is a difference between possibility and probability.
• Scenarios are useful for taking action to shape possible futures or to mitigate against them.
• Many factors that shape futures lie beyond the sector or focus of the enquiry, eg in information technology and transport.
• Events!: ‘with the benefit of foresight we might have seen it coming’, implying that some futures might be associated with particular types of events and risks.
• It is important to clearly define a reference point for future scenarios, eg comparison with present situation or a future BAU scenario.
• Choice of indicators and the units used to measure them are critical: some qualitative factors, such as farmer motivation are not easily measurable, hence the need for suitable narratives.
• It is important to understand the reasoning behind the quantification of scenarios. There may be a similar outcomes, eg value of output, but for very different reasons eg combinations of different yields and prices.
• The approach can become too prescriptive with an emphasis on quantification and the presumption of accuracy: futures could be very varied, comprise composites of all of the scenarios and full of uncertainties.
• Scenarios, whether in narrative or numeric form, must be internally consistent: this is a challenge, especially given uncertain or undefined boundary conditions and complex feedback loops, eg between cereal and livestock prices.
• Some scenarios may be favoured on ideological grounds: the Global Sustainability future fits the current dominant ideology and is ‘set up’ as the desirable future.

Source: Appendix C: Stakeholder Workshop held at Silsoe, September 2003

3.4.2 Scenario quantification: indicator values for model inputs

Drawing on the preceding analysis, including a review of price *predictions* made for the Business as usual Case derived from published sources (Appendix B, Topic Paper 9), estimates where derived of input and output prices for farm modelling. Table 3.5 shows some of the values used, expressed as indices of the BAU case. Output commodity prices are lowest under WM and highest under LS as a consequence of policy and market regimes. For similar reasons, input prices are lowest under WM and NE, and highest under GS and LS.

Table 3.5 : Input and output prices by scenario for 2050 expressed as an index of current (100)

	WM	GS	NE	LS	BAU
Fertilizer prices	80	151	136	147	100
Seed prices	134	100	150	56	100
Pesticide prices	89	124	136	74	100
Machinery prices	80	160	111	189	100
Fuel prices(incl fuel tax)	72	156	136	158	100
Labour wage rates	134	147	100	90	111
Area subsidy (a=area, c=crop specific)	0	a87	0	0	c90
Cereal prices	71	90	181	267	90
Sugar beet price	55	80	90	111	100
Oilseeds price	80	100	181	233	100
Roots and tubers prices	71	80	202	303	90
Protein crop price	77	100	122	159	100
Set-aside required	0	100	0	0	80
Milk prices	63	80	202	403	90
Water prices	170	213	140	197	100

3.4.3 Factors influencing future yields

There is a hierarchy of exploitation of potential crop productivity as shown in Figure 3.2 using the example of take-up of potential crop yield potential. The maximum technological potential is set by the bio-physical limits of the crop type such as those defined by photosynthesis. The existing technological boundary of productivity is evident in the trials of 'researchers'. There is often a small but recognisable gap between the yields of research trials and those achieved by the 'best' farm practitioners which can be attributable to a 'research attention' bias. In terms of yield performance, the best farmers represent the technical frontier, fully exploiting available technologies to maximise productivity. They can be regarded as the most technically 'efficient', against which other 'less efficient' farms can be compared. (Technical efficiency here is used in the conventional sense of measured physical output per ha, without reference to economic efficiency or the inclusion of external impacts).

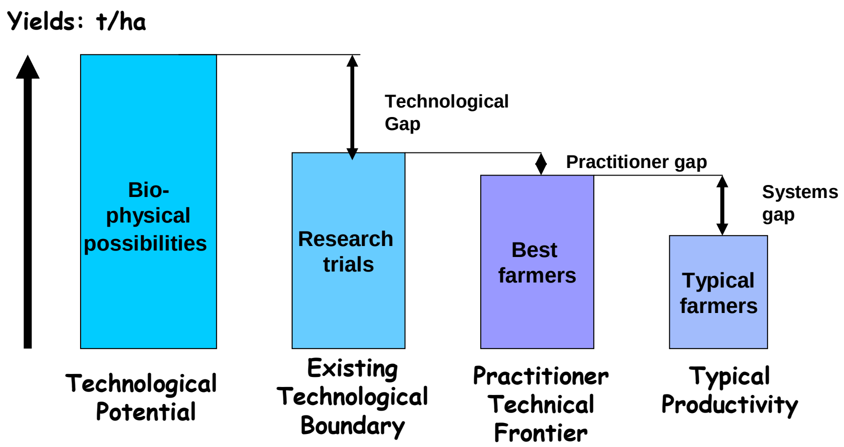


Figure 3.2 : Exploitation of Technological Potential: Yields/ha

For a variety of reasons farmers may not be able or willing to take up the potential yield benefits of well established and new technologies: there is often a considerable 'systems gap' between the productivity of the most efficient farm (or group of farms) and that of the mean or typical farm. This gap may due to a range of economic, social and environmental factors associated for example with farmer knowledge, motivation, resources, and perceptions of the potential advantage and suitability of the technology. For technologies to be adopted, they must be perceived to be relevant by, and therefore suited to the needs of the adopter community. It is often the case that when farmers are under pressure, the systems gap widens, as illustrated later.

Drawing on the review of past trends, factors deemed to be associated with crop and livestock yields were identified and the potential direction and strength of influence assessed. These influencing factors were then mapped out for alternative scenarios to derive estimates of future yields.

Commodity 'farm gate' prices, as determined by market forces and government policy are strongly positively correlated with on-farm crop yields. In some cases, however, markets may offer more rewards for product quality rather than quantity. The use of production inputs is also strongly associated with yields. These include a varied array of physical and knowledge-based inputs and processes, such as crop and livestock genetics, crop nutrition and crop protection, mechanisation, irrigation and general levels of farm husbandry. Other positive drivers include area based payments linked to particular crop types (although single farm payment regimes attempt to break this link), farm size in that larger farms often exhibit greater take-up of technological possibilities, and genetic modification which may be able to enhance yield potential or overcome constraints.

Factors perceived to be negatively correlated with yield include environmental regulation as it constrains the levels of inputs. Organic production techniques are similarly perceived to be associated with lower yields, partly as a result of reduced use of artificial inputs, though higher market prices may offset this effect. Business uncertainty, particularly linked with unpredictable variation in prices and outcomes of farm business decisions is also likely to influence take up of yield benefits negatively. For the most part farmers are risk averse, and business risk tends to reduce willingness to invest in new technology.

Drawing on the narratives of scenarios presented earlier, relative values of factors shown associated with variation with yields were derived for the current situation and future scenarios, including the Business as Usual (BAU) case which extrapolates recent trends (Table 3.6). For example, farmgate output prices are relatively high under the protected National Enterprise (NE) and Local Stewardship (LS) scenarios, and relatively low under the Business As Usual case and World Markets as agriculture is exposed to international competition. Global Sustainability (GS) demonstrates moderate farm gate prices, reflecting consumer willingness to pay for environmental protection.

Table 3.6 : Relative values of factors influencing exploitation of yield potential by future scenario

Characteristics	Future Scenarios						
	Yield Assoc.	Now	Business As Usual (BAU)	World Markets (WM)	Global Sustain-ability (GS)	National Enterprise (PE)	Local Steward-ship (LS)
Commodity prices	+++	L-M	L	L	M	H	H
Area based payments	+	H	H	0	L	0	0
Input prices	--	M	M	L	H	M	M-H
Input prices (animal feed)	--	L-M	L	L	M	M-H	H
Input levels	+++	M	M	M-H	M-L	H	L
Farm sizes	+	M-H	M-H	H	M-H	M	L
Economic uncertainty	--	L-M	L-M	H	M	L	L
Organics*	--	L	L-M	L*	M	L	H*
Acceptance of GMO use	+	0	L	H	L-M	L-M	0
Environ. regulation	---	L-M	L-M	L	H	L	H
Climate change rate	+/-	L	M	H	L	M-H	L-M

Notes to Table 3.6 : Relationship with yields + positive correlation, - negative correlation, weighted by strength of association. Relative value of parameter amongst scenarios: 0 = not applicable or zero, L = low, M = medium, H = high. *Organics: under WM organic farming is low as a % of total crop production but there is an important market in differentiated organic products compared to business as usual, driven by concern about food quality and facilitated by high incomes. Under LS, food production using organic methods is a common feature accounting for a relatively high % of total cropping.

The scenario descriptions in Table 3.6 were presented separately to a panel of crop specialist and a panel of livestock specialists as part of Defra Project IS00210 (Prediction of Yields into the 21st Century). The specialists reviewed the contents of the matrix and suggested modifications to the original set are included in Table 3.7.

3.4.4 Estimates of realisable yield by future scenario

Table 3.6 was used to derive estimates of the relative magnitude of crop yields on farms under each of the scenarios for the years 2012, 2025 and 2050 drawing on the panel of crop and livestock specialists engaged project IS0210. Future yields were expressed as an index of the current (2000-2003) average farm yields, bearing in mind the genetic potential of each species. Panel members were asked to consider the main factors affecting yields under each scenario and the main uncertainties affecting estimation. The estimates derived in collaboration with the IS0210 team (Sylvester-Bradley and Wisemann, 2005) are given in Table 3.7 for crops and Table 3.8 for animals. Two messages emerge: there is a considerable difference amongst scenarios in terms of perceived exploitation of yield potential for a given species, and there are differences in yield take-up amongst species for any one scenario.

Crop species

Under the BAU scenario wheat yields continue to grow at 0.1 t/ha/yr to reach 13 t/ha by 2050 and the yield of other species remain static, or increase very slightly, to give predicted yields of 3.2 t/ha for oilseed rape, 4 t/ha for peas and 42 t/ha for potatoes. For grass, genetic improvements are 0.3 to 0.6% per year for perennial ryegrass. Potential genetic improvements have not been taken up by farmers in recent years in proteins, oilseed rape and grass due to limited financial incentive, and this trend continues. The yield of grass remains at 6 t/ha under BAU.

The greatest yield improvements occur the NE scenario due to high commodity prices together with medium input costs and low environmental regulation which enables a high level of inputs. All of the breeding improvement is transferred to farm yields: estimated at 0.1 t/ha/yr for wheat, 0.05 t/ha/yr for oilseed rape, 0. 05 t/ha for peas and 0.006%/yr for grass. Therefore, yields reach 13 t/ha for wheat, 5.7 t/ha for oilseed rape, 6.1 t/ha for peas and 7.8 t/ha for grass by 2050. A modest increase in potato yields to 50 t/ha is due to the greater focus on quality compared with yield.

The second greatest yield improvements occur under the WM scenario due to lower input prices, less environmental regulation and the abandonment of less productive land. GM technology is exploited in the long term. Commodity prices are lower and more variable which reduces the level of inputs to below NE. Inputs and management are high enough to realise about half of the genetic improvement quantified above. By 2050, yields are 12 t/ha for wheat, 4.5 t/ha for oilseed rape, 46 t/ha for potatoes, 4.7 t/ha for peas and 6.9 t/ha for grass.

The GS scenario has medium inputs, but a high level of environmental regulation restricts inputs and crop options e.g. lower yielding spring wheat and oilseed rape as a break crop. Crop yields are unlikely to rise significantly and may even decline in the medium to long term for crops such as potatoes which rely heavily on inputs.

The LS scenario has the least intensive inputs and farm yields fall in this scenario. Yields of wheat, oilseed rape and potatoes are intermediate of those produced by integrated farming methods (80-90% of conventional) and organic methods (50-60% of conventional). Yield reductions are less for grass because inputs to this crop are already low relative to arable crops. Pea yields increase slightly in this scenario due to strong relative prices (high protein crop), the potential to fix nitrogen and the important contribution to crop rotations. By 2050, yields are 6 t/ha for wheat, 2.4 t/ha for oilseed rape, 34 t/ha for potatoes, 4.3 t/ha for peas and 5.7 t/ha for grass.

Table 3.7 : Indices of estimated crop yields by future scenario (current yields = 100)

Crop Yields by year	Business As Usual	World Markets	Global Sustain-ability	National Enterprise	Local Steward-ship
Wheat (8t/ha)*					
2012	120	115	100	120	95
2025	140	130	105	140	90
2050	160	150	115	160	75
Oilseed Rape (3.2t/ha)					
2012	100	108	100	117	90
2025	100	115	90	130	75
2050	100	140	90	180	75
Potatoes (42t/ha)					
2012	100	100	100	100	95
2025	100	105	90	110	80
2050	100	110	80	120	80
Peas (3.6t/ha)					
2012	100	100	108	115	105
2025	110	115	115	130	115
2050	110	130	125	160	120
Grass (6 t/ha)					
2012	100	105	100	110	100
2025	100	108	100	115	95
2050	100	115	100	130	95

*current average farm yields shown in brackets

Animal species

The yield for livestock enterprise is measured in terms of carcass weight of cattle, pigs, sheep, poultry and the production of milk and eggs per animal per year. Under BAU, the current yield trends continue with yield increases of 20-25% by 2050. Sheep yields rise, despite being static over recent years, due to the uptake of new technologies such as sire referencing schemes. The greatest yield increases occur under WM due to the lack of constraints and the low input costs. Here, there are yield increases of 65% for milk yields and between 30 and 35% for beef, sheep, pig and poultry yields. More constraints and greater input costs meant that the GS and NE scenarios have smaller yield increases than the WM scenario. Yield increases for the GS and NE scenarios by 2050 are 30 to 35% for milk and 20 to 25% for the other species. Under the LS scenario yields of milk and beef decrease by 5%, and yields of sheep, pig and poultry increase by 5-15%.

Table 3.8 : Indices of estimated animal yields by future scenario (current yields = 100)

Crop Yields by year	Business As Usual	World Markets	Global Sustain-ability	National Enterprise	Local Steward-ship
Milk (6531 l/cow/yr)*					
2012	105	115	110	110	100
2025	110	135	120	125	95
2050	125	165	130	135	95
Beef (315 kg/cow)					
2012	105	110	105	105	95
2025	110	120	110	115	100
2050	120	135	120	125	95
Sheep (18 kg/lamb)					
2012	105	110	105	105	100
2025	110	120	110	110	105
2050	125	130	120	125	105
Pig (95 kg/pig)					
2012	105	110	105	105	100
2025	110	120	110	110	105
2050	125	130	120	125	110
Poultry (1.6 kg/bird)					
2012	105	110	105	105	100
2025	110	120	110	110	105
2050	125	130	120	125	115

*current average farm yields shown in brackets

These estimates of yields were used in modelling future scenario as discussed in the next chapter. The relationship between yields and input levels referred to earlier were also incorporated in modelling process.

3.5 Summary

The scenarios developed here attempt to prescribe rather than predict future possibilities for agriculture in England and Wales over the next 50 years in order to model the implications for sustainability. The Foresight Scenarios provided a useful framework for this purpose. The approach involved the construction of narratives supported by quantitative values for key parameters, facilitated by workshops with representatives of key stakeholder groups, including research scientists. These participatory exercises confirmed the view that key drivers which shape possible futures are a composite of agricultural policy, markets for agricultural commodities, environmental policy and the technology of farming systems. Discussions with crop and livestock researchers identified considerable variation in the likely exploitation of potential yields under different scenarios, with implications for land use, productivity and environmental consequences. These aspects were carried forward into the modeling procedures reported in the next chapter.

Chapter 4 : Modelling Future Scenarios

This chapter describes the approach to and results of modelling future scenarios for lowland agriculture in England and Wales. Drawing on the narratives and parameters for each scenario described in the previous chapter, lowland land use and farming systems were modelled at the regional level allowing for variations in soils, hill slope, and climate. Outputs where generated for each scenario, expressed as selected economic, social and environmental parameters. The performance of specific alternative farming systems was also considered using the BAU scenario.

4.1 Approach to Modelling Lowland Agriculture

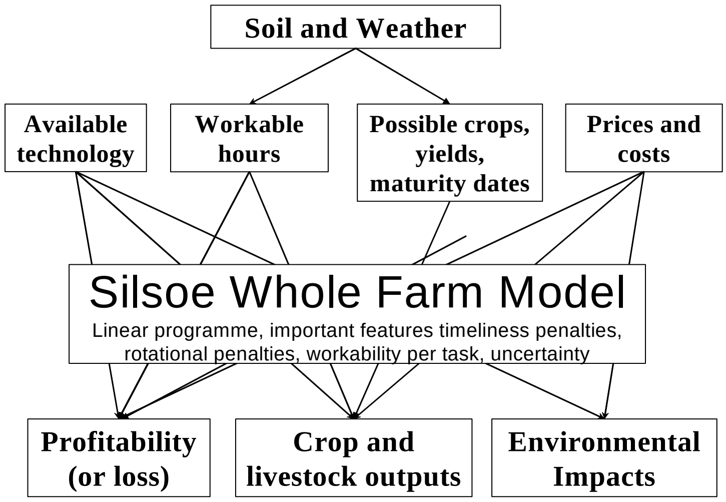


Figure 4.1 : Input, context and output used in modelling

For lowland land use, the Silsoe Whole Farm Model (Annetts and Audsley, 2002; Rounsevell, Annetts, Audsley, Mayr, and Register, 2002) was used to estimate agricultural production for each soil/climate combination and for each scenario for the years 2012, 2025 and 2050. (Figure 4.1) The model uses a linear programming algorithm to determine that combination of crop and livestock production (and hence land use) which maximises profits to land managers operating under the constraints imposed by a range of physical, social, economic and technological factors. The latter include soil and climate, markets and prices, available technologies, yields, and environmental regulation. These factors vary amongst scenarios and therefore give rise to different outcomes. Furthermore, spatial variation in soils and climate result in differences in dominant farming systems and result in spatially variable outcomes for any one future scenario.

The operation of the model is illustrated in Table 4.1. This shows the effect of a few combinations of soil, rainfall and climate on the estimates of cropping. In actual operation many data within the model are modified based on the location but in these examples only the items indicated are changed. For example, on a sandy/sandy clay loam soil with annual rainfall of 600mm, the most profitable cropping is a classic arable and roots crop mix of wheat, sugar beet, potatoes and peas/beans. The second row shows the effect as the rainfall increases; roots are replaced by cereals (note that in this example crop yields are not changed and the effect is purely due to workability of soils). The third row shows the effect of a more northerly location where the timing of harvest is later; if it was 1 month later, the farmer would choose mainly grass cropping. The fourth row shows the effect of soil type, which has an effect on both yields and workability. In this case roots are again no longer profitable and grass is becoming profitable. The following row shows how grass increases further with a delayed more-northerly harvest. Finally as in practice the model would also adjust the yield for rainfall, the grass yield is reduced by 20% to show the effect of low rainfall; the most profitable choice is now all combinable crops.

Table 4.1 : Illustration of some typical cropping outcomes from the Silsoe Whole Farm Model (Changes between successive rows are shown in bold).

Soil	Rain		Wheat	Barley	Beet	Pots	Rape	Peas/Beans	Grass	Cows
Sandy/SCL	600		109	14	23	4	2	62	0	0
Sandy/SCL	**1000**		104	40	0	1	16	63	0	0
Sandy/SCL	1000	**+1mo**	47	7	0	0	12	19	147	227
Clay loam	600		92	15	0	0	32	53	36	64
Clay loam	600	**+1mo**	29	5	0	0	9	15	182	325
Clay loam	600	**-20%gr**	112	14	0	0	43	58	0	0

Scenario input parameter values were given in Chapter 3 above. Using data on soil type, weather and altitude for England and Wales, areas which were not suitable for arable agriculture (slope too high, soil not suitable) were first eliminated. Using soils data from NSRI on a 5km grid square, converted to the soil textural classes used by the SWFM, combined with Land Cover data on arable and managed grassland, the soil areas potentially suitable for arable agriculture in each 5km grid square were estimated. These areas were then clustered into farming groups with similar soil type, temperature and rainfall within NUTS1 regions (EC, 2003) (Figure 4.2). Table 4.2 shows the number of clusters identified in each region which covered 70%, 90% and 100% of the possible area.

The standard database reflects climate conditions around the location of Silsoe, Bedfordshire. Crop and grass yields and harvest dates were modified for the range of climates identified. Crop yields were reduced based on the lack of excess summer evapotranspiraton over rainfall. Harvest date was adjusted based on the time required to accumulate the same day degrees as at Silsoe.

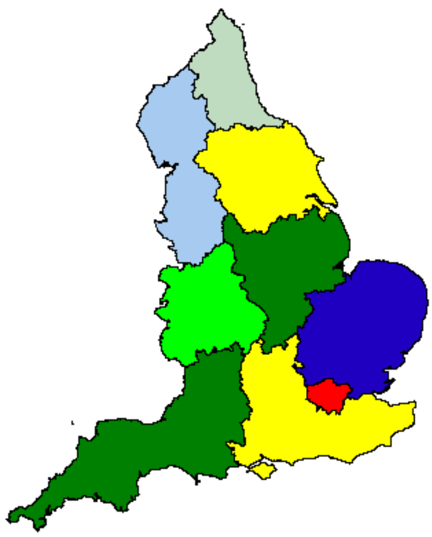


Fig 4.2 : NUTS1 ("Nomenclature of territorial units for statistics") regions of England (Source www.defra.gov.uk)

Using the SWFM, estimates of land use, production and profitability were estimated by farming group. Land is defined as profitable for intensive agriculture if the calculated farm profit (crop gross margin minus labour and machinery costs) is more than a threshold level. Summing over the region gives the overall cropping and environmental impacts from which it is possible to derive economic, social and environmental indicators. The threshold level for future scenarios is modified by the labour cost change, since if it rises the threshold at which farming is a viable profession must also rise, and the labour required per hectare, since this indicates the increasing area which one farmer can work.

Table 4.2 : Number of farming groups which make up 70, 90, 100% of the suitable land in each NUTS1 region

	70%	90%	100%
NORTH EAST	6	13	58
NORTH WEST	16	32	147
YORKSHIRE & THE HUMBER	7	16	79
EAST MIDLANDS	2	7	40
WEST MIDLANDS	7	12	34
EAST OF ENGLAND	2	6	12
SOUTH EAST & LONDON	7	17	34
SOUTH WEST	13	35	114
WALES	26	56	122

The model was calibrated for the present (2004) situation comparing the estimated land use with estimates of actual regional land use based on NUTS1 (Table 4.3). A threshold value of £150/ha was found to give a reasonable fit. Note that there are many more break crops in the census data than are listed whereas the model only contains the major ones. For example in Wales there are over 6000ha of forage crops other than peas and beans. The model correctly estimates the area of cereals though tends to underestimate winter wheat at the expense of winter barley, and estimates the other major crops per region reasonably accurately, with a tendency to spread sugar beet more widely than in practice because no effects of factory locations were included. It was not possible to validate the area of grassland since the model covers lowland agriculture only and defines the areas that would be intensive grass such as for dairy cows. By comparison, census data are for all grassland. However the analysis of upland and rough grazing in Chapter 5 indicates that the areas are properly represented.

4.2 Modelling Alternative Future Scenarios

The model was then used to analyse the five scenarios described previously, namely Business as Usual (BAU), World Markets (WM), Global Sustainability (GS), National Enterprise (NE) and Local Stewardship (LS), and for the years 2012, 2025 and 2050. As described in Chapter 3 above, different sets of input and output prices were used to map alternative scenarios. The rates of increase were converted into a single rate of change which is then used to derive values for any specific year. WM storylines indicate low prices due to globalisation and then strive for high levels of efficiency. An RE world maintains high gross margins which encourage the search for higher yields both in breeding and the use of inputs. GS and BAU look at the different versions of area subsidies – GS being a simple area subsidy and BAU a crop specific subsidy. In a GS world, costs rise and the desire for reduced inputs nullifies any yield gains from breeding. An LS world carries this further with reducing yields due to the pressure for organic and low input farming on small farms with increased costs of inputs. Table 4.4 summarises the input values used in each scenario expressed as values for 2050. Other years are calculated using the same rate of increase as ry, thus the RE fertiliser cost for 2012 is $1.36^{(10/48)}$.

Table: 4.3 Comparison of census data with model results for current situation, 000ha

Region (NUTS1)	Wheat	Winter Barley	Total Cereals	Potatoes	Peas and Beans	Forage Maize	Oilseed Rape	Sugar beet
North East	58	47	110	2	6	0	20	0
North West	21	50	75	9	3	10	4	1
Yorkshire & The Humber	201	135	342	20	38	3	46	23
East Midlands	317	104	433	21	67	9	86	40
West Midlands	129	77	224	19	30	16	28	16
East Of England	440	185	635	40	87	8	78	97
South East & London	213	105	341	6	48	22	70	0
South West	163	145	333	8	31	52	36	1
Wales	13	11	47	3	1	6	2	0
Total (excl Wales)	1540	848	2492	126	311	120	367	177
Model Estimates								
North East	35	29	65	1	10	0	18	0
North West	53	55	115	11	11	9	11	13
Yorkshire & The Humber	128	117	278	16	57	6	44	22
East Midlands	206	163	390	22	67	33	85	31
West Midlands	143	122	279	19	23	20	45	21
East Of England	372	259	649	39	43	60	87	63
South East & London	153	101	255	6	18	54	47	3
South West	137	101	239	6	28	53	39	5
Wales	38	28	68	3	11	6	4	2
Total (excl Wales)	1226	947	2270	121	258	235	376	157

Table 4.4 : Quantification of percentage changes to input data in each scenario expressed as 2050 values.

	WM	NE	GS	LS	BAU
Costs of fertiliser	80	136	151	147	100
Costs of seed	134	150	100	56	100
Costs of pesticides	89	136	124	74	100
Costs of machinery	80	111	160	189	100
Costs of fuel	72	136	156	158	100
Cost of labour	134	100	147	90	111
Area subsidy (a=area, c=crop specific)	0	0	a87	0	c90
Cereal prices	71	181	90	267	90
Sugar beet price	55	90	80	111	100
Oilseeds price	80	181	100	233	100
Roots and tubers price	71	202	80	303	90
Protein crop price	77	122	100	159	100
Set-aside required	0	0	100	0	80
Milk prices	63	202	80	403	90
Water cost	170	140	213	197	100
Irrigation efficiency	122	100	160	147	122
Rotational penalties	62	80	100	122	100
Reduction in labour required	73	94	87	94	87

4.2.1 Predefined prices for scenarios

Table 4.4 shows the area of land used under each scenario when prices are defined as part of the scenario. Under BAU, total land use tended to decrease over time. Agricultural land is totally employed under predefined price regimes for LS and NE. However for WM and GS, which involve reductions in real prices relative to current levels, farming becomes almost universally unprofitable and land is abandoned as far as agriculture is concerned. Clearly, this cataclysmic change in land use is unlikely.

Table 4.3 also shows the impact of predicted price regimes on patterns of production compared to current levels. In BAU, there are increases in cereals and sugar beet and a continuing decline in milk production before its disappearance in 2050. In LS, increased profitability maintains land use but promotes grassland, dairy production and protein crops while reducing cereals and oilseeds. NE, characterised by high gross margins, retains a balanced portfolio of production, with the biggest long term increases in cereals, oilseeds and potatoes.

Table 4.5 : Production of farm commodities under future scenarios expressed as a % of current production assuming prices defined as part of the scenario storyline.

	Cereals	Oilseed	Sugar Beet	Roots	Protein	Milk	Land Used
NE 2015	45	21	123	142	3	171	100
NE 2025	83	43	127	159	6	168	100
NE 2050	404	268	51	191	37	93	100
LS 2015	15	4	60	104	30	196	100
LS 2025	7	3	13	85	114	214	100
LS 2050	0	1	Disappeared	37	486	286	100
GS 2015	1	Disappeared	Disappeared	0	0	19	8
GS 2025	Disappeared	Disappeared	Disappeared	Disappeared	Disappeared	Disappeared	0
GS 2050	Disappeared	Disappeared	Disappeared	Disappeared	Disappeared	Disappeared	0
WM 2015	1	Disappeared	Disappeared	0	Disappeared	19	8
WM 2025	Disappeared	Disappeared	Disappeared	Disappeared	Disappeared	Disappeared	0
WM 2050	Disappeared	Disappeared	Disappeared	Disappeared	Disappeared	Disappeared	0
BAU 2015	148	39	144	106	56	97	98
BAU 2025	212	39	167	107	60	75	96
BAU 2050	344	32	235	103	77	1	72

The results of scenario analysis using predefined prices are difficult to interpret and are not very helpful as a basis for mapping possible futures. They confirm the difficulty of predicting input and output prices (and the relative profitability of crop and livestock options) which are consistent within and between scenarios, especially given the very diverse and uncertain interdependencies amongst demand, supply and prices. It is very likely, for example, that low commodity prices and rapid reduction in domestic supply assumed for WM would encourage a demand-side response in the form of higher prices and/or a supply side response in terms of reduced average costs through efficiency gains. Similarly, for LS, relatively high profitability would encourage a supply side response with a deflationary effect on some prices as well as relative changes in production (although in this scenario land is a constraining factor).

Given the nature of demand for agricultural commodities, there is a tendency within a given scenario for relative prices to converge towards some general equilibrium defined by market conditions, supply capabilities and any regulatory measures. It is difficult to predefine this set of prices before modelling begins, and for this reason this approach to modelling was abandoned.

4.2.2 Estimating ‘equilibrium’ prices of agricultural commodities by scenario

Appendix 4.1 describes the estimating of market demand for commodities consistent with the scenario storylines. These were defined as model inputs and market prices were derived such that model output supply and demand were in balance. Modelling began by using the values for input parameters, including predicted commodity prices, derived from mapping the alternative scenarios. Commodity prices were then adjusted upwards or downwards until a best match ‘equilibrium’ was achieved, that balanced demand and supply. Where surpluses arise, land is taken out of use by low profits. In the case of deficits, some shortfalls are made good by increasing the farmed area, including use of land otherwise used for 'set-aside', but within the total available area. However for some scenarios, supply deficits could not be met.

Table 4.6 Balanced demand and supply and associated equilibrium prices by scenario for 2050

Scenario	Commodity	Future Demand and Supply expressed as a % of current solution		Derived 'equilibrium' prices (% of current 2004 prices)	Original Scenario derived prices
		Demand	Supply		
BAU with energy	Cereal	117	119	59	90
	Oilseed	172	180	159	100
	Sugar beet	80	78	44	100
	Potatoes	98	102	102	90
	Peas/beans	34	37	94	100
	Milk	102	113	90	90
BAU without energy	Cereal	103	118	62	
	Oilseed	126	127	125	
	Sugar beet	77	77	43	
	Potatoes	95	97	102	
	Peas/beans	88	103	126	
	Milk	102	114	90	
WM with energy	Cereal	97	111	99	71
	Oilseed	153	156	136	80
	Sugar beet	67	65	47	55
	Potatoes	82	87	101	71
	Peas/beans	3	5	138	77
	Milk	80	85	87	63
WM without energy	Cereal	88	84	98	
	Oilseed	123	118	138	
	Sugar beet	65	65	47	
	Potatoes	80	90	102	
	Peas/beans	38	35	220	
	Milk	80	80	87	
NE with energy	Cereal	142	136	104	181
	Oilseed	186	185	120	181
	Sugar beet	134	136	75	90
	Potatoes	156	152	110	202
	Peas/beans	123	118	130	122
	Milk	115	103	82	202
NE without energy	Cereal	128	123	99	
	Oilseed	139	150	87	
	Sugar beet	130	130	54	
	Potatoes	153	152	100	
	Peas/beans	176	170	140	
	Milk	115	130	80	
GS with energy (setaside zero)	Cereal	137	124	232	90
	Oilseed	212	86	308	100
	Sugar beet	70	75	100	80
	Potatoes	108	107	213	80
	Peas/beans	17	17	168	100
	Milk	103	113	122	80
GS without energy	Cereal	109	106	219	
	Oilseed	117	91	308	
	Sugar beet	63	67	95	
	Potatoes	102	104	210	
	Peas/beans	128	138	239	
	Milk	103	113	121	
LS with energy	Cereal	129	70	308	267
	Oilseed	184	125	308	233
	Sugar beet	120	126	292	111
	Potatoes	146	143	213	303
	Peas/beans	183	186	198	159
	Milk	140	142	101	403
LS without energy	Cereal	105	66	308	
	Oilseed	150	107	275	
	Sugar beet	114	118	280	
	Potatoes	140	135	211	
	Peas/beans	275	280	226	
	Milk	140	146	101	

In reality, there are different ways of addressing imbalance of demand and supply. For surpluses, as well as abandonment, increased exports or reduced yields through extensification are possible solutions. And conversely for deficits, as well as extending the farmed area, increased imports, and increased yields through intensification are possibilities. However, scenarios prescribe levels of self-sufficiency of supply and yields: changing these would represent a different scenario. Rather than modify assumptions for self-sufficiency, yield and the stock of potential agricultural land, attention is drawn to the concerns that might arise within a particular scenario, and possible responses consistent with the scenario are identified in general terms.

For each scenario, estimated land use, production and other output indicators were obtained assuming with and without the production of energy crops, allowing occupation of otherwise 'set-aside' areas where required. Table 4.6 lists the solutions for each scenario which balanced, within 10% where feasible, the estimated demand for and supply of agricultural commodities and the 'equilibrium' prices associated with that balance. Estimates are for year 2050, with prices expressed as a percentage change on 2004 values.

A number of points are worthy of note.

- Generally, commodity prices are positively correlated with demand: the greater is the increase in demand, the greater is the relative price rise. For minority crops, such as proteins, price rises are apparent even where demand falls because of the effect of competition from dominant, more profitable crops. This might require deficits to be met through imports.
- Commodity prices for cereals, oil seeds and sugar beet are marginally higher where energy crops are included in scenarios, especially for WM and GS. Prices rises for protein crops are moderated downwards as a consequence of competition from oil seed residues in animal feed markets.
- Under BAU, cereal prices fall to 60% of current prices, and sugar beet prices are more than halved. Oil seed prices rise moderately, while other prices remain reasonable stable.
- Under WM, in spite of reduced relative demand for most home grown commodities, there is a modest upward trend in crop prices, with the exception of sugar beet price which halves. Protein prices rise sharply even in the absence of energy crops, which suggests that there will be pressure for an even more increased level of imports, although the same factors are likely to be operating in the rest of Europe. Milk prices fall by a small margin due to reduced demand.
- Under GS, there is a modest increase in demand for cereals and oil seeds relative to the current situation and BAU. Potato demand holds firm, and sugar beet decline is moderated compared to WM.
- As a consequence, prices are strong under GS, more than doubling in the case of cereals, oil seeds and potatoes, and remaining stable for sugar beet. The demand for oil seed rape cannot be met from domestic sources. (It is likely that there would be pressure from increased imports across a range of commodities under this scenario, with a downward influence on prices).
- Under NE, there is strong demand across a broad range of commodities to be met from domestic sources. Prices are similar to current levels, moderately higher than WM and BAU except for oil seeds, but significantly lower than GS and LS. Milk prices are relatively low. Derived prices are much lower than those anticipated in the scenario narratives. NE is likely to require subsidies in the form of deficiency payments in order to protect farm incomes and retain producer incentives;
- Under LS, modest increases in demand for cereals are accompanied by relatively large most other crops, including roots and proteins. Prices are generally high. Supply deficits in cereals and oil seeds, partly attributable to low yields under this scenario, push prices

to three times current levels. (It is likely there would be pressure to increase yields or imports across a range of commodities to alleviate supply deficit and high prices;

- Estimates are sensitive to assumptions regarding the balance of imports and exports.

Much of the change in prices is associated with maintaining similar levels of farm profitability amongst scenarios and a degree of equilibrium between the gross margin of competing crops. In other words, the results effectively achieve similar levels of crop gross margin allowing for changes in unit labour and input costs. In WM for example, as less land is required, the level of profitability falls slightly, thus taking some land out of production, but the 34% increase in unit labour costs, requires a higher gross margin in order to maintain overall profitability, while at the same time the removal of subsidies also requires higher commodity prices if profits are to be maintained at a level to make farming feasible. Thus calculating an appropriate scenario price for each commodity is complex and requires the use of the farm model.

4.2.3 Land use by scenario

Figure 4.3 shows the corresponding proportion of total potentially-arable agricultural land which is needed to meet the demand for agricultural commodities in the 2050 scenarios compared to that used currently (including setaside land). Land requirements vary amongst scenarios due to differences in total demand and supply as determined by cropped areas and future yields per hectare. Those shown in red indicate scenarios where there was insufficient land to meet the demand.

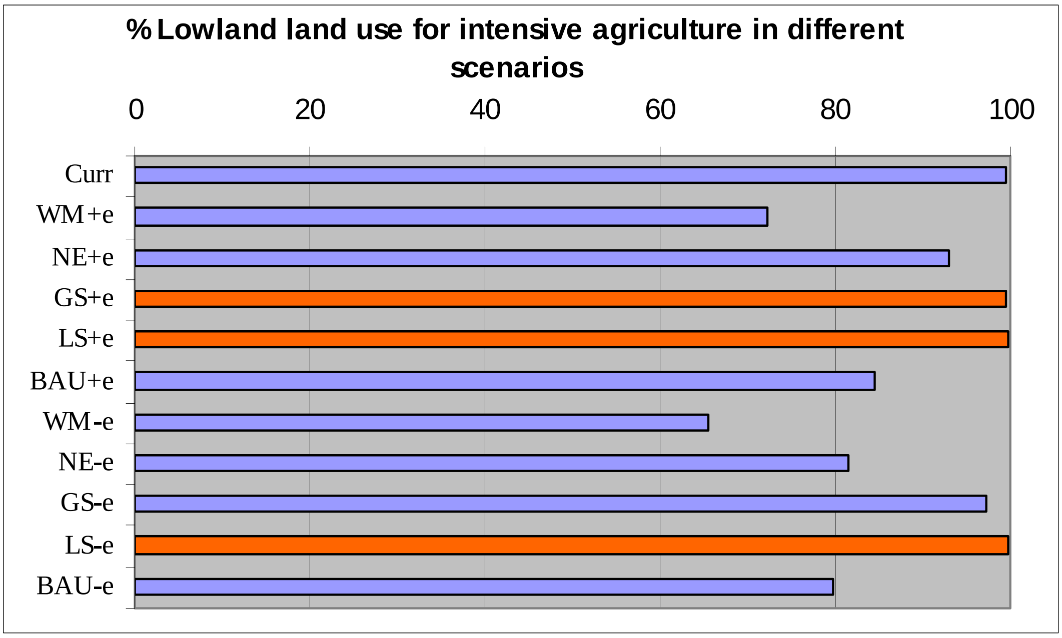


Figure 4.3 : Land Use in Scenarios with Equilibrium Prices **(+e , with energy crops, -e without energy crops)**

Most scenarios show a decline in agricultural land use from the current situation. Under BAU, land use declines to about 90% of current land use, with and without energy crops. Under WM, land use falls to about 70% of current use, reflecting modest increases in demand combined with substantial increases in yields. GS exhibits small reductions in land use to about 97% where energy crops are excluded, but is unable to meet demand where energy crops are included, in part because the scenario ahs the highest demand for energy crops. NE required about 90% of the land and is little affected by energy crops. In LS, reductions in average yields and assumed high rates of self sufficiency result in 100% land utilisation and a supply deficit. There may be pressure to bring new land into agricultural use.

Figure 4.4 shows the regional distribution of total land use for the WM scenario (including energy crops) which demonstrates the greatest degree of 'abandonment' of agricultural land, due to the large increase in yields and the reduction in export possibilities. The East Midlands region shows the largest reductions in land use due the combination of the predominance of cereal cropping, a 50% increase in yields and a slight decline in demand to be met from domestic sources: thus less than two thirds of current cereal land is required, and most of this occurs in the eastern counties. In the case of milk production, declining demand for milk, combined with increased yields per cow and per ha, reduces the demand for grassland, retaining production in areas which have comparative advantage. The combination of surplus land, opportunities for large scale farming, possibly adopting less intensive methods, and scope for increasing exports in a global 'free' market, could mean that more land is taken up. This outcome represents a variation from the originally defined WM scenario, but being no less feasible, suggests that a WM scenario would not survive for 50 years.

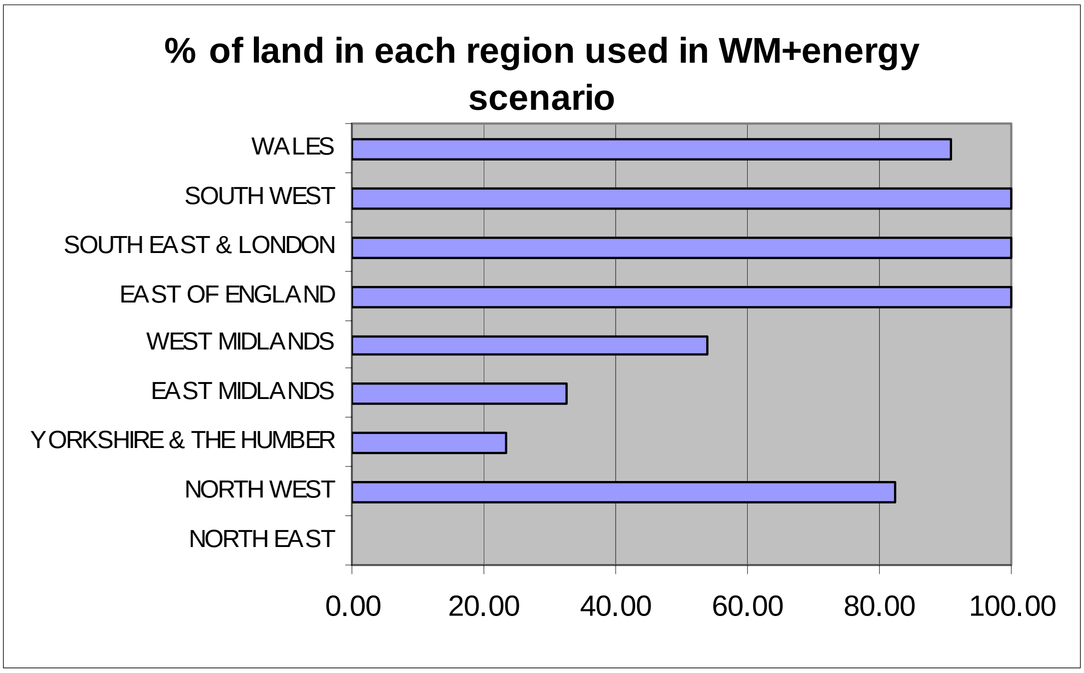


Figure 4.4 : Regional distribution of lowland land used for intensive farming for WM Scenario, 2050

In all other scenarios where land is taken out of production, the first area to be removed is the North East (for example 10% of land used in BAU) , followed by reductions in land use in Yorkshire, then Wales and the West Midlands (82% of land used in BAU). The GS scenarios use almost all available land: production of energy crops displaces areas of set-aside. Unused lowland in these scenarios occurs in the North East as this is the least profitable grass region and required grass production can be achieved by higher yields on a smaller total area.

4.2.4 Economic, social and environment aspects of scenarios

Table 4.7 shows changes in the values of selected indicators for each scenario for the year 2050.

Labour use reduces in most scenarios as they combine increased labour efficiency and in some cases reduced farmed areas. Labour employment falls most in the WM scenario. By comparison, GS and NE retain relatively high levels of employment in farming at about 90-100% of current levels. LS, with lower yields per ha and high rate of land use, shows about 10% increased in labour employment compared to the present situation. Generally, incorporation of energy crops increases employment in each scenario, but notably the NE scenario with its large increase in demand, does not require an increase in labour due to increased efficiencies.

Table 4.7 : Values of selected economic, social and environmental parameters by scenario

	Weighted prodn	Weighted price	Nitrate leaching	B'grass herbicide	Soil erosion	N fertiliser	P fertiliser	K fertiliser	Water	Profit	Labour	Energy
Curr	100	100	100	100	100	100	100	100	100	100	100	100
WM+e	106	69	139	79	60	112	105	106	60	51	52	89
GS+e	134	183	135	126	92	126	119	116	85	124	90	107
NE+e	140	90	205	100	78	152	148	150	118	74	93	119
LS+e	109	248	108	102	98	104	106	108	138	130	109	99
BAU+e	118	60	138	81	96	110	111	108	70	63	71	95
WM-e	81	69	125	59	50	100	95	99	56	46	41	80
GS-e	111	173	134	102	90	117	112	113	82	107	81	100
NE-e	131	88	177	88	72	129	130	130	112	60	84	102
LS-e	120	243	109	103	98	100	105	107	129	124	110	99
BAU-e	99	59	129	66	88	101	104	104	68	58	60	88

Water use shows considerable variation amongst scenarios, mainly reflecting differences in the domestic production of root and vegetable crops. BAU shows a decrease in total demand associated with increased efficiency in use and reduction in irrigated potatoes. WM shows a reduction in demand for irrigation water due to greater dependency on imported produce. GS shows an increase relative to BAU reflecting increased domestic demand associated with healthier diets and a greater proportion of supply met by domestic producers compared to WM. The LS scenario assumes a considerable increase in home production of roots and vegetables, much of it irrigated: water demand increases by 30% in spite of measures to increase crop yield per unit of water applied.

The total use of N fertiliser changes very little amongst the scenarios, although the rates of application vary per ha, as do the number of ha actually farmed. There is an increase in NE due to higher production levels and an increase (relative to current levels) in total N use for GS with energy cropping and for both LS scenarios. In the latter case, lower average rate of N use per ha are offset by the increase in the farmed area. P and K fertiliser use mirrors N fertiliser.

The probability of Nitrate leaching is, however, likely to increase under all scenarios, varying in accordance with land use, soils types and application rates. Under WM, intensification of production on a reduced area is associated with higher N application rates, because of the higher offtake of higher yielding varieties and thus greater probability of leaching. However because of the smaller area required by the demand, the total nitrate leaching is much the same. However it is concentrated in the areas under continued agriculture. Thus, diffuse pollution from agriculture will increase in areas remaining in agriculture, unless measures are taken to control it. Note that this follows from the assumption that doubling the yield requires double the fertiliser. Insofar as doubling the yield can be achieved by improving the harvest index (grain:straw ratio) then the nitrate leaching should remain constant with increased production and hence reduce nationally.

Soil erosion reduces in total in all scenarios compared to the current situation. The largest reductions occur under WM because the land taken out of intensive production is that which currently contributes most to erosion. LS shows a relatively high erosion risk due to continued and in some cases increased cultivation on soils which are most vulnerable.

The use of herbicide associated with control of blackgrass, reflects the incidence of cereals grown continuously. Most scenarios involve greater use of 'break' crops, whether oil seed rape for energy production or protein crops to purposely diversify production. Continuous wheat production on the same land is less prevalent, and hence the demand for blackgrass herbicides is reduced. It is notable that the main increase is in the GS+e scenario, which meets demands for cereals but not for oil seed rape.

4.2.5 Alternative systems

Four other future scenarios were considered in which technical changes in the production of crops were considered alone. These were

- Integrated management – in which lower levels of inputs, notably pesticides were imposed.
- Alternative machinery – in which field work rates were substantially increased by the use of large machinery and combined operations
- Reduced tillage – allows only 20% of the area to be ploughed each year.
- Genetically modified crops – in which herbicide tolerant crops were introduced (winter wheat, oilseed rape, sugar beet and forage maize) with a yield and herbicide benefit but a seed cost and price penalty.

The details are listed in Appendix 4.2 to this chapter, with additional information in Appendix B Topic Paper 10.

Future scenarios are characterised by different types and proportions of farming systems. These constitute distinguishing ‘design’ features of a scenario, such as the use of precision farming as a means of reducing average agro-chemical costs per ha in a technological advanced but price competitive WM, or the use of integrated crop management systems as part of a commitment to sustainability in GS. In other cases, however, alternative farming systems could be promoted as a part of a ‘response’ to concerns about particular pressures associated with scenarios. An example might be the adoption of precision farming in order to comply with the regulatory requirements of GS.

Table 4.8 shows the effect of these alternative arable farming systems on selected economic, social and environmental indicators for BAU case (2050), and the relative effect on crop areas. Figure 4.5 shows the effects of these alternative systems on land use for three selected regions.

Integrated management Herbicide use more than halves, and soil erosion is relieved. However the method has the effect of reducing the profitability of cereals and hence substantially reducing the area of cereals grown. The area is taken up by other crops, including root and vegetable crops, with increased demand for irrigation water. The impact of ICM is greatest in the Eastern part of England, where cereal production is currently a dominant land use. As with the defined prices, it is likely that the supply/demand balance would cause an change in prices of the commodities.

Alternative machinery This increases the profitability, and hence areas, of cereals and oilseeds, at the expense of grass. There is an associated increase in herbicide use. Figure 4.6 confirms that wheat growing increases for the regions shown. Because of the move to less suitable areas, soil erosion also increases.

Reduced tillage The main effect is to cause the amount of herbicide to increase dramatically as chemical control now has to replace mechanical control. Arable labour is substantially reduced and profits increase. This indicates the typical direction when profits are under pressure by reduced prices as the mechanism to recover a viable farm – replace labour with herbicides. Another consequence is to increase the profitability of milk production relative to arable crops.

Genetically modified crops tend to increase in area relative to other crops, notably grass, assuming they can deliver high yields at reduced pesticide and herbicide costs. GM could help reduce costs and retain viability under the relatively low prices associated with GM-feasible scenarios (namely WM and NE), although increased production could put further downward pressure on commodity prices. There is concern about possible transfer of genetic material to natural species.

Table 4.8 : Impact of alternative arable farming systems on selected economic, social and environmental indicators for BAU case (2050), % change on current

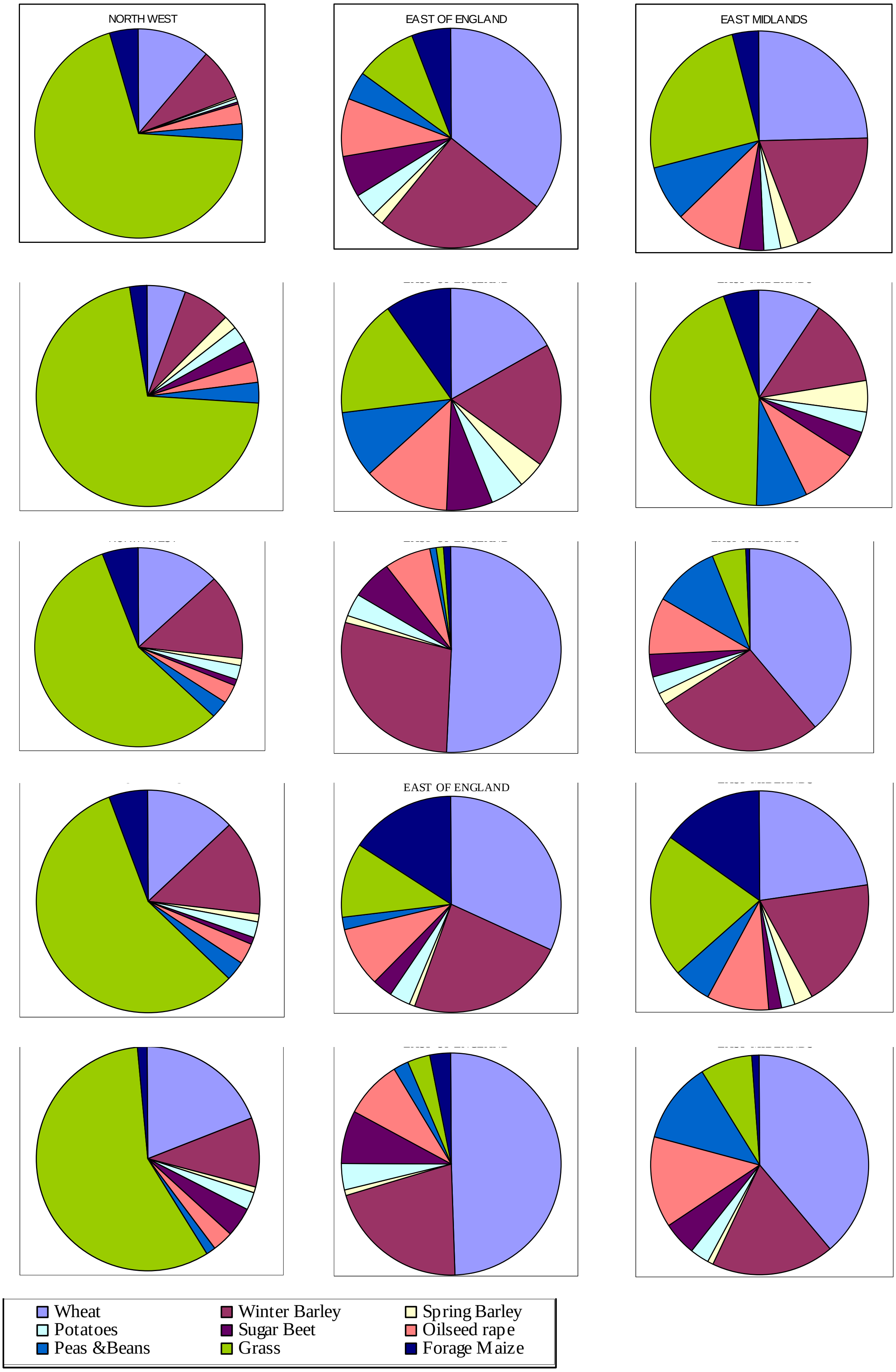
	Nitrate leaching	Blackgrass herbicide	Soil erosion	N fertiliser	Water	Profit	Arable Labour
Integrated management	103	44	91	102	132	99	85
Alternative machinery	99	153	122	95	95	110	111
Reduced tillage	92	180	122	95	82	108	78
Genetically modified	97	56	114	98	96	113	125
	Cereal	Oilseed	Sugar Beet	Roots	Protein	Milk	
Integrated management	51	103	103	118	116	121	
Alternative machinery	150	94	101	95	88	70	
Reduced tillage	100	104	51	82	76	107	
Genetically modified	137	129	174	96	96	77	

4.3 Summary

Lowland land use was modelled under five future possible scenarios through to 2050. Estimates were made of demand for agricultural commodities, including bio-energy crops, to be met from domestic resources, consistent with the features of scenarios. The results show that land use and crop and livestock production vary considerably amongst scenarios according to a mix of demand-side and supply-side characteristics.

The environmental 'footprint' of farming also varies amongst scenarios. Although intensive farming under market driven scenarios generates potentially high environmental burdens in farmed areas, there is some surplus lowland which could be taken up for other purposes, including extensive farming, nature conservation, woodlands and forestry. However, where environmental requirements constrain yield potential, this is not the case and there is pressure on land resources. The next chapter considers the implications of future scenarios for extensive grassland, mainly upland areas, and the degree to which changes in lowland farming systems have potential to affect outcomes in upland areas.

Figure 4.5: Regional variations in land use associated with alternative farming systems. Top row current, following rows integrated management, slternative machinery, teduced tillage and genetically modified.



Appendix 4.1

Estimating required future production for agricultural commodities

Initial modelling of scenarios using scenario-defined agricultural commodity prices as input variables proved problematic, generating results which were either infeasible or unstable. For this reason, a two staged approach was adopted:

- First, estimates were derived of agricultural production required to be met from farms in England and Wales for each scenario; and
- Second, through modelling of each scenario, a set of farm gate prices was derived which generated sufficient supply from domestic producers to satisfy demand.

A4.1 Factors influencing Demand for Agricultural Commodities

Estimates of consumer demand in England and Wales for the major food commodities were derived for each scenario for the years 2012, 2025 and 2050. A spreadsheet model was developed for this purpose. Estimates of demand to be met domestically were based on assumptions regarding:

Table A4.1 : Factors influencing demand for agricultural commodities met from domestic sources

	Examples	**BAU**	**WM**	**GS**	**NE**	**LS**
Population growth,	% per annum	0.25	0.29	0.22	0.25	0.175
National income growth	% per annum	2.00	2.75	2.25	1.75	1.00
Income elasticity of demand by commodity	Demand:GDP	0.12	0.10	0.12	0.15	0.17
Tastes and preferences by commodity	Eg increase in wheat at expense of meat by 2025	1.11	1.2	1.15	1.05	1.00
Technical efficiency of use, eg livestock feed energy conversion	Eg increase in dairy productivity	125	165	130	135	95
Crops for bio-fuel (cereals, oil seed, sugar beet and potatoes)	PJ produced by 2050	91	59	187	91	155
% self sufficiency (net export:import ratio) by commodity	Ratio versus current eg wheat	0.95	0.8	0.9	1.05	0.91

These assumptions varied for each scenario. Clearly a 10% increase in population will increase the requirement for food by 10%, everything else remaining the same. However, increasing per capita income is likely to increase preference for higher quality foods, such as a shift from staples such as cereals and potatoes to meat. The scenarios also imply different changes in food preference, such as a trend towards organics, vegetarianism and healthy foods. There are also differences amongst scenarios in the degree of self sufficiency. By assuming values for these changes, and considering the main food groups, it was possible to calculate the resulting demands.

Table A4.1 lists the categories of crop and animal products considered, with the estimates of current supply, demand and self-sufficiency used. The estimates incorporate use of crop products for human food and animal feed. For example, wheat comprises milling wheat for human consumption (bread, biscuits, cakes, etc) and feed wheat for animal feed. It is acknowledged that this is a simple division and there are other outlets and by-products such as bran which cross from the human to animal category. However, milling and feed account for the majority of the crop and it is unlikely that finer divisions, even if separate values could be derived for them, would change the final estimate of changes in wheat demand by a significant amount.

Wheat for animal feed can similarly be divided into the proportion which is consumed by the different classes of animals (chicken, pork, dairy, etc). Changes in the number of these animals cause pro-rata changes in their requirement for wheat. Improvements in technical efficiency of animal production (feed conversion ratio) will also reduce the need for wheat. Equivalent considerations apply to other crops.

Table A4.2 : Categories of crop and animal considered with estimates of current demand for crop and livestock products used

Index	Category	Current demand E&W, 000t	Current production E&W, 000t	Current % self sufficiency
1	Wheat: bread	7051	6500	92
	Feed	5090	6500	128
2	Barley: malt	1900	1289	147
	feed	3400	3400	100
3	Oilseed rape	1455	1324	91
4	Sugar beet	15208	15208	100
5	Potatoes	7648	6501	85
6	Vegetables	6440	4186	65
7	Beef	1157	868	75
8	Dairy(milk)	13569	13840	102
9	Sheep meat	306	306	100
10	Pork	1068	867	82
11	Chicken	1884	1714	91
12	Protein	1481	531	36
13	Peas	249	249	100
14	Beans	618	618	100

Separate consideration was given to estimating demand for bio-fuels under each scenario, sourced from wheat, oil seed rape, sugar beet and potatoes. Meeting or exceeding obligations under the EU Bio fuel Directive for example from domestic sources significantly increases demand for these commodities.

Demand estimates were derived for milk and meat products, with allowance for the demand for animal feeds to be met from domestic cereal and protein production, including crop residuals from crops grown for biofuel where relevant, especially oilseed rape. There are a large number of protein feeds used but the major ones are soya - imported high protein, peas and beans – homegrown high protein, though with a considerably lower protein content than soya, and oilseed rape meal – high protein residue. The current level of these represents the amount of protein (nitrogen) currently fed to animals and the proportion of this fed to each type can be estimated (TableA4.3). As the number of animals and the technical efficiency changes, the requirement will change. Given the export coefficient of soya, this allows the home-grown protein requirement to be calculated, from which the residue from oilseed rape can be deducted. The balance is then the quantity of homegrown peas/beans required.

Note that unlike an economic model based on prices, the scenarios define a level of self-sufficiency. This can lead to some untenable results due to conflicts between the various assumptions. In the calculation of protein demands, the quantity of peas/beans to be grown can be negative which is impossible. An example is a scenario which requires a large area of oilseed rape production for energy and a high level of soya imports due to globalisation. At a low level of peas/bean production, prices would most likely be very low leading, from the point of view of an economic model, to their replacing imported soya – in other words an increase in the level of self-sufficiency in protein.

A4.1 Method

Let p be the rate of population growth, then increase in population after y years $P=(1+p)^y$.

Let g be the rate of GDP growth, then after y years $G=(1+g)^y$ and rate of growth of GDP per capita is $R=G/P-1$.

Let e_j be the income elasticity of the consumption of the jth commodity, expressed as the ratio between the increase in consumption of j and the increase in GDP per capita.

Let m_k be the rate of market switch of human food consumption due to consumer preference (ie health not wealth), where k=1 is the switch from flour products to meat consumption, measured as the quantity of cereals used for flour now divided by the amount used in a future year; 2 is from malting barley products to meat, 3 is from oil products to milk products, 4 is to sugar products, 5 is to potatoes, 6 is to vegetables, 7 is to red meat from white meat, 8 is to milk products, 9 is to sheep meat, and 10 is to pork from chicken. Define $M_k=(1+m_k)^y$.

Let C_i^j be the consumption of product i, type j. For example for wheat i=1, flour j=1. Let I_i^j be the corresponding current consumption and S_i^j the supply ie the home-grown production.

For bread wheat from these definitions we get the formula: $C_1^1 = I_1^1 P(1+e_1 R)/M_1$ (1)

and similarly for malting barley.

The market switch to meat means the amount transferred from wheat and barley (000t of cereals):

$$T_m = I_1^1 P(1+e_1 R)(1-1/M_1) + I_2^1 P(1+e_2 R)(1-1/M_2) \tag{2}$$

are replaced by meat products (this is negative ie from meat if M<1). Given the typical moisture content of meat of 65% and assuming meat is 3 times as nutritious per kg as wheat, the conversion ratio is 1kg wheat β = 1.235 kg meat. Assuming that the transfer is in the same proportion as the current consumption of meat products,

$$\alpha_i = I_i /(I_7 + I_8 + 0.1 I_9 + I_{10} + I_{11}), \tag{3}$$

then equation 1 for beef becomes:

$$C_7 = (I_7 P(1+e_7 R) + \alpha_i \beta T_m)/M_7 . \tag{4}$$

The same equations apply to sheep and the transfer of red to white meat T_w is a replica of equation 2.

Table A4.3 : Rate of change data used to calculate demands for each scenario

	BAU	WM	GS	NE	LS		
Annual growth rates							
% population, (p)	0.25	0.29	0.22	0.25	0.18		
%GDP, (g)	2.00	2.75	2.25	1.75	1.00		
Income elasticities, (e)						**% bio-energy**	**GJ/t**
Wheat	0.12	0.10	0.12	0.15	0.17	55	26.9
Barley	0.12	0.10	0.12	0.17	0.20		
Oilseed rape	0.10	0.10	0.11	0.12	0.15	25	40.6
Sugar beet	0.00	0.00	0.00	0.05	0.10	15	26.9
Potatoes	0.09	0.02	0.05	0.15	0.20	5	26.9
Vegetables/carrots	0.22	0.25	0.25	0.20	0.30		
Beef	0.25	0.20	0.22	0.23	0.25		
Dairy	0.05	0.02	0.05	0.07	0.10		
Sheep	0.20	0.15	0.18	0.22	0.25		
Pork	0.25	0.20	0.28	0.26	0.30		
Chicken	0.16	0.16	0.18	0.20	0.25		
Market switch by 2025 from (m)							
Wheat	1.11	1.20	1.15	1.05	1.00		
Barley	1.00	1.05	1.00	1.00	1.00		
Oilseed rape	1.00	1.00	1.05	1.00	1.10		
Sugar beet	0.90	0.90	0.85	1.00	1.00		
Potatoes	0.90	0.85	0.90	1.00	1.00		
Vegetables/carrots	1.00	1.00	1.10	0.90	1.10		
Beef	0.95	0.90	0.80	1.00	0.95		
Dairy	0.95	0.90	0.95	1.00	1.10		
Sheep	0.95	0.95	0.95	1.10	1.00		
Pork	1.00	1.05	1.10	1.00	1.00		
Bio-energy production, GJ by 2025 (B)							
	58951	26961	122931	42956	90941		

The equations for oilseed rape, sugar beet and potatoes are identical to equation 1. The equation for milk is identical to equation 4 with the addition of an extra transfer from oil. The equation for pork is identical to equation 4 with an additional term for transfer from red meat. For chicken there is also an additional transfer from pork and no transfer term (M).

There are a large number of feed ingredients actually used for livestock, many but not all of which are by-products. For just on sector there are a wide range of possible products blended for different purposes. Total use of ingredients is surveyed but not by sector. The following estimates (λ_i^w) were derived for the wheat (w), barley (b) and protein (p) use by different commodity sectors (i), from various sources of data:

% of total use in animal feed by type of livestock	Wheat	Barley	Protein
Chicken	54.3	20.7	31
Pork	28.6	21.7	16
Dairy	10.5	27.4	32
Beef	4.5	20.7	14
Sheep	2.1	9.5	6

Let γ_i be the proportional change in animal i (i = 7 to 11). If yi is the livestock yield increase which is assumed to be half due to increases in efficiency (effective Food Conversion ratio) and half due to larger animals (for example higher milk yields), then the effective amount of beef animals for feed calculation purposes is $C_7^* = C_7 / \sqrt{y_7}$. The actual number of animals is also the number of current size animals reduced by this factor. Then the amount of feed wheat required is given by

$$C_1^2 = \sum_{i=7}^{11} (\gamma_i \lambda_i^w / \sqrt{y_i}) I_1^2 - \rho_1 \qquad (5)$$

where ρ is a factor for wheat and barley due to changes in protein feeds (see below). The same equations apply to barley and protein.

Protein is provided by imported products, mainly soya, by-products of crops such as oilseed rape and protein crops such as peas and beans. In this analysis only the by-product of oilseed rape is considered as it increases by a large amount due to energy crop production. 60% of the oilseed crop is a livestock feed with a protein content of 39%. . Let the amount of protein imported be A. Then the amount of protein required from pea and bean crops is: $r = C_{12} - A - 0.6\,0.39 C_3$. Currently the ratio of pea to bean production is 66 to 183, so using the same ratio, the future production of peas required is $C_{13} = 66r/(66+183)/p_{13}$ where p13 is the protein content of peas (26%). The equivalent for beans is $C_{14} = 183r/(66+183)/p_{13}$ where p_{14}=29%.

Table A4.4 : Data on livestock yields used to calculate demands for each scenario (y)

Livestock yields	BAU	WM	GS	NE	LS
Dairy	100	100	100	100	100
2012	105	115	110	110	100
2025	110	135	120	125	95
2050	125	165	130	135	95
Beef	100	100	100	100	100
2012	105	110	105	105	95
2025	110	120	110	115	100
2050	120	135	120	125	95
Sheep	100	100	100	100	100
2012	105	110	105	105	100
2025	110	120	110	110	105
2050	125	130	120	125	105
Pig	100	100	100	100	100
2012	105	110	105	105	100
2025	110	120	110	110	105
2050	125	130	120	125	110
Poultry	100	100	100	100	100
2012	105	110	105	105	100
2025	110	120	110	110	105
2050	125	130	120	125	115

In addition a change from soya to, for example, beans, increases the dry matter which provides the required amount of protein and thus incidentally supplies more energy than the protein-equivalent amount of soya. This increased supply must be deducted from the requirement for feed wheat and barley:

$$\rho_i = I_i / (I_1 + I_2) \sum_n (C_n - I_n) / p_n \quad \text{for i=1,2} \qquad (6)$$

where the n are the four protein feeds.

Table A4.5: Current level of self-sufficiency expressed as the ratio between production and consumption, and scenario rates of change by 2050.

		Ratio of 2050 value to current value				
	Current	**BAU**	**WM**	**GS**	**NE**	**LS**
Wheat	1.10	0.95	0.80	0.90	1.05	0.91
Barley	1.17	0.95	0.80	0.90	1.05	0.85
Oilseed rape	0.91	0.99	0.88	0.99	1.10	1.10
Sugar beet	1.00	0.85	0.70	0.80	1.10	1.00
Potatoes	0.85	0.94	0.94	1.06	1.18	1.18
Vegetables/carrots	0.65	0.92	0.85	1.08	1.15	1.31
Beef	0.75	0.93	0.80	1.00	1.13	1.20
Dairy	1.02	0.95	0.90	0.95	1.05	0.98
Sheep	1.00	0.95	1.00	0.90	1.10	1.00
Pork	0.82	0.85	0.79	0.91	1.34	1.22
Chicken	0.91	0.93	0.88	0.99	1.15	1.10
Protein	0.36	1.00	0.80	1.00	1.25	1.40

Let t_i be the current import/export coefficient expressed as the ratio of production to consumption (self-sufficiency). Thus a value les than one indicates a product which on balance is imported and a coefficient of more than one indicates that surplus is exported.

Let u_i be the rate of change of this coefficient with time, thus in year y, the coefficient is $T_i=t_i(1+u_i)^y$.

Although there is scope for substitution of other fossil energy uses with bio sources such as use for plastics and textiles, many of these uses employ by products of fuel extraction. Substitution of raw fossil energy for these alternative uses would effectively relieve pressure on and substitute for fossil fuel demand which is a dominant element of energy demand. It is therefore reasonable to use substitution of fossil fuel energy as the basis for estimating the potential market for energy crops.

The biofuel directive requires 5.7 % use of biofuels as % of all transport fuel uses. There is a technical max of 5% content of bio fuels in petrol, whereas for diesel, this can be 100%. By the 2020s it is likely that biofuel technology will have moved on with a new breed of fuels , with greater scope for biofuels as a petrol substiute. In the mid term the 5% component limit will not constrain the market for non-diesel fuels. There are also opportunities for co-firing biofuels in power stations.

Table A4.6 : Assumption of energy sourcing from bio-fuels

% of predicted 2010 fuel oil consumption supplied by bio-fuels					
	BAU	**WM**	**GS**	**NE**	**LS**
2012	3	1	6	1	4
2025	4	2	8	3	6
2050	6	4	12	6	10

Table A4.6 gives the proportion of energy supplied as biofuels in each scenario. The 2010 fuel oil consumption is 1600 10^9 MJ. Let B be the GJ of biofuel energy produced in year y, a proportion bi of which is produced by crop i at the rate of fi GJ/t. (see Table A4.2)

Then the home-grown supply of wheat required is the sum of the wheat for bread, feed and energy:

$$S_1 = (C_1^1 T_1^1 + C_1^2 T_1^2) + Bb_1 / f_1 \qquad (7)$$

The equations for each product are equivalent to this.

Estimates of demand to be met from domestic sources in 2050 are shown in Table A4.7 expressed as a percentage of that for 2004.

Table A4.7 : Estimated change in the demand for agricultural commodities to be met from domestic sources by scenario for 2050 (including bio-fuels)

Increase in demand at 2050					
	BAU	**WM**	**GS**	**NE**	**LS**
Wheat	117%	98%	137%	142%	129%
Barley	112%	93%	113%	134%	103%
Oilseed rape	172%	153%	212%	186%	184%
Sugar beet	80%	67%	70%	134%	120%
Potatoes	98%	82%	108%	156%	146%
Peas	38%	9%	22%	124%	185%
Beans	38%	9%	22%	124%	185%
Vegetables/carrots	134%	151%	205%	126%	199%
Beef	134%	119%	106%	155%	135%
Dairy (milk)	102%	81%	104%	115%	142%
Sheep Meat	118%	140%	119%	174%	119%
Pork	130%	161%	213%	180%	151%
Chicken Meat	131%	144%	151%	147%	131%

Appendix 4.2

Definition of Alternative Farming Systems

(Further information is given in Appendix B Topic Paper 10)

Alternative machinery

The difference compared to the conventional system is that power harrow, drill and roll are separate operations in conventional and here are assumed to be joined as one operation for the crops Winter and Spring Wheat, Barley, Rape, Beans and Peas.

The conventional system workrates (h/ha) are Power harrow = 0.43, drill = 0.61, roll = 0.29. Total = 1.33. In alternative system this is Combined power harrow, drill and roll = 0.61. This applies to all drilling operations - cereals, oilseed rape, grass, peas and beans.

Reduced tillage

In this system a reduced tillage system is used and 20% of the land is ploughed annually. Crop protection costs increase by 11% (due to no ploughing)

Integrated crop management

The difference between this system and conventional systems is that the inputs decrease: nutrients (-12 to -13%), herbicides (-40 to -24%) and pesticides (-48 to -30%). Crop yields also decrease (-12 to -8%) but has been found that net margins can increase by 7%.

The system is modelled by imposing a limit that the amount of blackgrass herbicide used must be 50% of the amount used in the conventional case for every soil/climate combination. The same restriction is applied to wild oat herbicide. The NPK fertiliser input of every crop is reduced by 10% and yields are reduced by 10%. The sowing operation for a winter crop must be delayed by one month from the conventional case.

Genetically Modified crops

The following additional GM crops were included as options available to the model:

1) Winter Wheat Glyphosate resistant.
2) Winter Wheat Glyphosate and Fusarium resistant (assumed that the Glyphosate would be created before the Fusarium and so would not have just Fusarium resistant wheat).
3) Winter and Spring Oil Seed Rape, Glufosinate resistant
4) Sugar Beet, herbicide tolerant
5) Forage Maize, Glufosinate tolerant

For all the GM crops, the following input and output changes were applied: increase seed cost by 28%, decrease price of crop by 5%, increase yield of crop by 4%.

Table A4.8 : Details of GM crops

Crop	Seed price (£/unit)		Price (£/ha)		Yield (t/ha) standard crop (e)	Yield (t/ha)
	Standard crop (a)	GM crop (b)	Standard crop (c)	GM crop (d)	(e)	GM crop (f)
Winter wheat	0.29	0.37	76	72	(11.841-(9.211*(0.9907^(NFert)))-(0.0075*(NFert)))*(0.743+0.1714*(SType))	1.04e
Sugar beet	15	19.20	30	29	(11.841-(9.211*(0.9907^(NFert)))-(0.0075*(NFert)))*(0.743+0.1714*(SType))	1.04e
Winter oilseed rape	6	7.68	125	189	(11.841-(9.211*(0.9907^(NFert)))-(0.0075*(NFert)))*(0.743+0.1714*(SType))	1.04e
Forage Maize	3	3.84	-	-	(25+5.00*SType)	1.04e

Table A4.9 : Details of costs of GM crops

Crop	Other cost in database standard crop (a)	Nix Cost (b)	Herbicide % (d)	Fertiliser % (e)	Other % (f)
Winter wheat	77	105	43	45	12
Sugar beet	404	140	85		
Winter oilseed rape	136	90	65	25	10
Spring oilseed rape	63	55	65	25	10
Forage Maize	34				

1) Winter Wheat Glyphosate resistant

We assume that the cost of the herbicides is ½ of current costs. So from the £105 cost need to reduce the herbicide part by 50%

Variable cost = $\left(\frac{100-d}{100}\right)b + \left(\frac{d}{200}\right)b$

All non-herbicide cost + ½ herbicide cost = 85.43

2) Winter Wheat Glyphosate and Fusarium resistant

We assume that the cost of the herbicide and fungicide is ½ of current costs. So from the £105 cost need to reduce both the herbicide and fungicide part by 50%

Variable cost = $\left(\frac{d}{200}\right)b + \left(\frac{e}{200}\right)b + \left(\frac{100-d-e}{100}\right)b$

½ herbicide cost+ ½ fungicide cost+ all non-herbicide cost = 58.71

3) Winter and Spring Oil Seed Rape, Glufosinate resistant

Similarly:

(55*0.35) + ((55*0.65)/2) = 37.13

(90*0.35) + ((90*0.65)/2) = 60.75

4) Sugar Beet, herbicide tolerant

Transport costs make up a huge proportion of the "other variable costs" and are estimated as 404 – 140 = 264. Then the new spray cost due to using different sprays, is added to this transport cost:

Variable cost = $\left(\frac{100-d}{100}\right)b + \left(\frac{d}{200}\right)b + 264$

All non-herbicide cost + ½ herbicide cost = 341.88

5) Forage Maize, Glufosinate tolerant

No data was available on the proportion of costs spent on herbicide and other items. Atrazine which is to be banned costs, £15/ha and is being replaced by another herbicide costing £40/ha, so part of the saving is that the costs are due to increase substantially and genetic modification will reduce that back to present levels! For the analysis we assumed £15 is non herbicide and that glufosinate costs £10/ha giving £25/ha.

Chapter 5 : Modelling Future Scenarios in the Uplands

5.1 Context and Approach

The rearing and fattening of cattle and sheep is an important component of farming systems in England and Wales, comprising 4.8 M beef animals and 12.5 M sheep. A large proportion of these animals occupy areas classified as upland, comprising land typically above 240 m OD, accounting for 1.5 M ha. In the analysis reported here, however, areas that are, for reasons of hillslope and/or soils, unsuited to intensive lowland agriculture (including intensive grassland), are also assumed available for extensive grassland production along with conventionally defined uplands.

There is a complex symbiotic relationship between lowland and upland (and hill) livestock farming involving movement of animals from one to the other to exploit seasonal patterns of grass growth and to suit particular stages of animal production, whether breeding or fattening. There are limited data, however, to indicate the share of the existing total livestock (excluding dairy) population which is carried by the uplands. It is unclear how this might change in response to changes the demand for livestock products and as a result of changes in the productivity of livestock systems themselves, whether lowland or upland.

In order to derive estimates of land use in the uplands for future scenarios, a step-wise process was used to determine, for a given demand for cattle and sheep meat products, the proportion that is sourced from the uplands (see Appendix 5.1). It is assumed that the lowlands offer comparative advantage in grassland and hence livestock production, due to better soils, a longer growing season and a more favourable climate during the growing season. In the absence of interventions to overcome economic disadvantage, the uplands are assumed to act as a residual supplier, meeting that part of market demand which is not met by lowland producers – in part because of the comparative advantage of arable versus grassland production, due to location and/or price.

The procedure involved the following steps.

- dairy, cattle and sheep numbers were estimated by region for the current situation from census results,
- areas of lowland and upland grassland were estimated from Census and Land Cover data, also classified by region,
- estimates of grassland productivity (t dry matter/ha) were obtained for lowland and upland grassland (using SWFM and the Macaulay HillPlan model respectively), allowing for regional variations,
- typical stocking rates by type of stock (t dry matter/head) were derived for lowland and upland grassland,
- priority in lowland grass was given to dairy cows and the balance of area made available for cattle and sheep, assuming a ratio of 4:1 respectively,
- numbers of cattle and sheep which could not be accommodated on the lowlands were assumed to occupy available upland areas, and
- areas of upland use for each region and in total, expressed as a proportion of the total upland, were thus estimated.

This procedure was also used to estimate upland stock numbers and land use for future scenarios allowing for differences in:

- demand for milk (as it affects lowland grass use), cattle and sheep meat products,

- lowland grassland available for cattle and sheep,
- grassland yields (t/ha), and
- livestock yields (kg/head).

The impacts of the upland stocking rates derived for each of the future scenarios were then estimated using HillPlan, a grazing management model that was developed at the Macaulay Institute (2005).

5.2 Estimates of Livestock Numbers for Future Scenarios

Table 5.1 shows the estimated number of dairy cows, cattle and sheep by scenario for 2050, in each region and for England and Wales in total. The totals arise from the demand estimates described earlier for dairy and livestock products converted into livestock numbers allowing for changes in yields per head and grassland productivity, all of which vary by scenario.

Table 5.1 : The number of animals in each 2050 scenario by region (% of current)

	Current ('000 head)	BAU	WM	GS	NE	LS
Dairy						
North East	21	0	0	119	10	203
North West	304	75	70	86	93	142
Yorks & Humber	110	85	2	122	100	181
East Midlands	105	138	24	91	133	92
West Midlands	205	50	45	91	129	136
Eastern	31	147	70	40	87	22
South East	103	118	87	81	105	163
South West	495	111	80	90	93	148
Wales	272	77	74	92	87	164
Total	**1645**	**91**	**63**	**91**	**99**	**146**
Beef						
North East	303	110	0	99	86	135
North West	555	118	115	107	145	175
Yorks & Humber	429	125	6	97	146	147
East Midlands	361	146	42	88	154	126
West Midlands	527	156	76	89	150	127
Eastern	196	210	195	63	168	27
South East	389	120	177	94	154	100
South West	1100	111	154	110	147	145
Wales	861	109	111	101	127	174
Total	**4720**	**125**	**104**	**99**	**141**	**141**
Sheep						
North East	21	147	16	105	308	117
North West	304	86	111	115	130	128
Yorks & Humber	110	153	17	108	221	121
East Midlands	105	115	51	110	147	116
West Midlands	205	152	94	105	139	112
Eastern	31	385	691	113	275	56
South East	103	114	331	98	148	97
South West	495	79	191	116	137	122
Wales	272	88	110	118	137	128
Total	**1645**	**110**	**126**	**112**	**158**	**120**

For dairy, BAU shows a 10% decline in the dairy herd. By comparison, numbers fall by over one third for WM due to reduced milk demand and high yields. Strong demand under LS combined with relatively low yields results in a 50% increase in the dairy herd.

For beef, increased demand is partly offset by increases in yields per head for most scenarios. Livestock numbers are stable under GS, but rise under most other scenarios. Strong demand for local produce under NE and LS leads to increases in herd size.

For sheep, total numbers increase under all scenarios. Strong demand under WM and particularly NE, results in increased numbers of heavier sheep.

Changes in livestock numbers by region reflect relative comparative advantage not only in livestock production but in farming as a whole. Under the WM scenario, in which there is a general surplus of farm land, grasslands in the north east and east midlands are abandoned in preference to those in southern and eastern areas. These latter areas also have relative advantage in arable farming.

5.3 Land Use and Stocking Rates in the Uplands

Table 5.2 : Stocking rates (head/ha) of beef cattle and sheep on the uplands by 2050 scenarios.

	Current	BAU	WM	GS	NE	LS	BAU	WM	GS	NE	LS
	Beef	**without energy**					**with energy**				
North East	0.64	0.79	0.32	0.39	0.91	1.65	0.89	0.36	0.39	0.70	1.62
North West	1.01	1.02	0.40	0.46	1.06	2.62	1.17	0.44	0.62	0.74	2.56
Yorkshire and the Humber	0.92	1.07	0.44	0.42	1.23	2.39	1.18	0.47	0.56	0.95	2.33
East Midlands	0.77	0.80	0.42	0.36	0.81	2.06	0.87	0.47	0.48	0.59	2.01
West Midlands	1.45	1.64	0.69	0.66	1.85	3.75	1.88	0.77	0.88	1.06	3.66
Eastern	0.79	0.69	0.40	0.36	0.68	2.03	0.79	0.29	0.48	0.57	1.99
South East	0.65	0.57	0.22	0.30	0.56	1.67	0.65	0.24	0.39	0.47	1.63
South West	0.83	0.73	0.28	0.38	0.72	2.14	0.83	0.31	0.50	0.60	2.09
Wales	0.77	0.81	0.28	0.36	0.85	1.99	0.89	0.31	0.48	0.61	1.94
	Sheep	**without energy**					**with energy**				
North East	3.50	2.42	2.16	4.18	4.44	4.51	2.74	2.43	3.56	6.01	4.46
North West	5.55	3.13	2.68	5.01	5.19	7.15	3.59	3.03	5.65	6.32	7.07
Yorkshie and the Humber	5.05	3.29	2.96	4.56	6.00	6.52	3.62	3.22	5.14	8.10	6.44
East Midlands	4.21	2.44	2.84	3.91	3.93	5.61	2.68	3.23	4.41	5.01	5.54
West Midlands	7.92	5.02	4.65	7.16	9.03	10.22	5.76	5.25	8.07	9.03	10.10
Eastern	4.30	2.11	2.67	3.89	3.33	5.55	2.42	2.01	4.38	4.90	5.48
South East	3.54	1.74	1.46	3.19	2.74	4.56	1.99	1.65	3.60	4.03	4.51
South West	4.52	2.22	1.87	4.08	3.50	5.83	2.54	2.11	4.60	5.15	5.76
Wales	4.20	2.46	1.87	3.91	4.12	5.42	2.73	2.11	4.41	5.23	5.36

Table 5.2 shows the estimated stocking rates in the uplands for regions with significant upland areas for the future 2050 scenarios, including energy crops. Market demand for livestock products combined with changes in land use and productivity in the lowlands result in reduced overall stocking rates in the upland areas (compared to current stocking rates) under most scenarios. Under WM, the stocking rates are generally under half the current rate. Under LS, however, a shortage of capacity in the lowlands increases pressure on the uplands: a near doubling of upland stocking rates is needed to meet demand.

In scenarios where stocking numbers are reduced, this could involve a general reduction in stocking rates over the whole area, or alternatively the retention of stock in more productive areas and the abandonment of poorer land. For example under GS, 60% of the upland area could be used and 40% abandoned, or the overall stocking rate across the uplands could be reduced.

Under the WM scenario there is more likelihood of a proportion of the land in the uplands being abandoned by agriculture. The highest stocking rates result from the LS scenario. The BAU scenario results in slightly higher beef stocking rates but lower sheep numbers. The GS and NE scenarios are broadly similar. For any given scenario, there is little difference between the 'with energy crops' and 'without energy crops' options.

5.4 Modelling the Impact in the Uplands

5.4.1 Modelling environmental impacts

As the major environmental impacts in the uplands are likely to be manifest through changes in vegetation, the emphasis was on modelling this impact. For each of the future scenarios the effect of the predicted stocking rates in the uplands of each of the regions on the vegetation cover was predicted using HillPlan (Macaulay, 2005).

A detailed description of HillPlan is given in Appendix 5.2. Briefly, HillPlan predicts the effect on a range of upland vegetation communities of grazing by different species of grazer, depending on the stocking density, seasonal pattern of grazing and other factors.. HillPlan is essentially a farm-scale model, and so it was assumed that each region was in effect a single large farm. HillPlan has a series of linked sub models. The model is supplied with a description of the different types of vegetation and the numbers of different types of grazing livestock present at different times of year. A grass growth model and a heath growth model use climate data to predict vegetation growth. A foraging model distributes the animals across the landscape and predicts the offtake of each vegetation type. Finally a vegetation dynamics model estimates the long-term changes in vegetation. A range of other outputs can be generated including vegetation height, utilisation rates of different vegetation types and animal dry matter intake. However for the present analysis the change in vegetation types was considered the principal long-term output variable. Checks were made however on levels of animal intake to determine if sufficient forage was available to support animal production.

The land cover for the uplands in each region was derived from the land cover map of England (http://www.magic.gov.uk/) – see Table 5.3. Land cover data was not available for Wales and so Wales has been excluded from this analysis. Upland areas were assumed to be:

- not lowland which are suited to intensive farming, including intensive grassland (as defined in Chapter 4)
- excusive of urban areas
- above 100m altitude

The land cover types in the land cover map were converted to the equivalent vegetation types (and associated soil types) represented in HillPlan.

Since HillPlan needs climate data as input, the centroid for each of the upland areas was determined and meteorological data from stations in the region were used. However the model was set to use an interpolated climate model based on data from several nearby stations. The climate data used for each region was therefore an interpolated climate for the centroid of each region, in which the data from several stations were used with an inverse distance weighting.

The 'Patch Structure' of a farm (i.e. the hierarchical breakdown of the farm area into vegetation type areas within vegetation patches within land management units (or fields) within the farm) is an important input into the HillPlan model and affects the possible changes in vegetation over the course of a simulation. This is how the model was designed to operate and correctly provides a degree of spatial discrimination between physically distinct areas in a farm. However, the modelling of an entire region as a single farm within HillPlan required that a patch structure be imposed on the region which is a highly simplified version of reality. In effect, each region was split into 4 large patches containing: 1) improved grassland, bracken and some rough grazing 2) dry moorland and rough grazing 3) wet moor and grassland 4) bog areas. The outputs from the modelling therefore ignore localised effects which may be important.

Table 5.3 : Average altitude (m) and cover (% of area) in the uplands of each region in England

Region	Average altitude	Bog	Bracken	Grass/ Shrub Heath	Heath/ Grass	Managed grassland	Marsh/ Rough Grass	Shrub/ Heath	Other
1 East Midlands	192	0.0	0.8	1.5	9.6	38.6	1.0	2.1	46.4
2 Eastern	140	0.0	0.2	0.0	0.6	41.0	3.0	0.0	55.1
3 London									
4 North East	323	2.8	2.5	14.4	22.4	24.7	1.2	6.8	25.2
5 North West	305	0.6	7.4	7.6	31.7	35.9	0.6	2.5	13.7
6 South East	137	0.0	0.1	0.8	1.6	40.7	2.5	0.4	54.0
7 West Midlands	225	0.0	1.2	2.6	10.5	50.5	1.5	1.4	32.3
8 Yorkshire and the Humber	309	1.0	6.1	12.9	25.1	28.3	0.6	8.4	17.7
9 South West	208	0.2	2.1	1.7	12.0	51.2	2.5	0.7	29.5

The model was tested by running for 50 years with the current stocking rates, as determined from census data, following the procedure outlined above to determine the stocking rate in the uplands. The current stock levels were generally sustainable in terms of providing sufficient intake for the animals and incurring little change in overall vegetation structure over the course of the simulation. There were a couple of exceptions to this, however. The Eastern and, in particular, the West Midlands regions have insufficient grazing for the given stock numbers. The model suggested that the cattle and sheep in the West Midlands would have virtually nothing to eat through the winter (see Figure 5.1). There are a number of reasons why this may not happen in practice. The model assumes that all the feed requirements of the animals are met from the grazing resource. In reality, supplementary feed may be brought in from another region of from the lowlands in the same region. This could apply particularly if there is a high number of finishing animals in a region.

HillPlan simulations were run for 50 years, using the present vegetation types as the starting conditions for each of the future scenarios for each of the regions. Although simulations were run both for the 'with energy' and 'without energy' options, since the stocking rates were very similar in both these options for any given scenario, the effects on the vegetation, as would be expected, were similar. Thus only the 'with energy' options are presented.

Under the future scenarios, intake levels vary depending on the stocking rate, but are generally reasonable for most regions (except, as noted above, for West Midlands and Eastern) under most scenarios. The exception is the LS scenarios in which the stocking levels were always higher than current levels and provided lower intake levels for all animals. This is discussed more fully below.

5.4.2 Environmental impacts of future scenarios on the uplands

A graphical example of the type of vegetation change predicted for one of the future scenarios is given in Figure 5.2.

Table 5.4 gives a brief description of the vegetation changes for each scenario in each region. Table 5.5 gives more quantitative data. For ease of interpretation the vegetation categories have been combined in Table 5.5 into three broad categories – heath, rank vegetation and bracken, and grassland. The stocking index given in the tables is the overall stocking rate relative to the current stocking rate for the region. Note that as the scenarios are given in the same order throughout (i.e. in increasing order of *average* stocking rate) the descriptions within each region do not necessarily follow a strictly increasing stocking level as the scenarios have different relative stocking rates within different regions. The vegetation options in the model are:

- Molinia = grassland dominated by *Molinia Caerulea* (Purple Moor Grass or 'Flying Bent')
- Rank Grassland = Tall grassland of a variety of species
- Dry Heath = Dry Heather Moorland
- Rough Pasture = grassland dominated by rough grass species such as *Molinia caerulea* (Purple Moor Grass) and *Nardus stricta* (Moor Mat Grass)
- *Festuca/Agrostis* Grassland = semi natural grassland dominated by *Festuca* and *Agrostis* grass species
- Bracken = vegetation dominated by Bracken (*Pteridium aquilinum*)
- Improved grassland = grassland that has been improved by management e.g. re-seeding with sown species (e.g. ryegrass, white clover)

Whether an increase or decrease in any of these is regarded as environmentally beneficial or detrimental depends on the particular management objectives. Each of these vegetation types varies in the types of fauna that they support. Currently any decrease of dry heath would be regarded as undesirable as heather moorland is regarded as an internationally important habitat and the UK (especially Scotland) is one of the few places where it exists. Bracken can be regarded as environmentally undesirable as it does not support much wildlife, is carcinogenic. Improved grassland is generally regarded as an impoverished habitat. Festuca/Agrostis and Rough Pasture are not particularly useful habitats, but they do support moorland birds. Rank Grassland, given its structural complexity can support a wider range of wildlife (insects, small mammals, birds).

It is important to note that HillPlan does not include scrub or woodland as vegetation types. Scrub vegetation type might be expected to appear and/or expand under low grazing pressure. Where there is a large increase in the area of rank grassland or bracken it is reasonable to assume that there could be an increase in scrub vegetation and in the long-term re-generation of woodland, depending on availability of seed sources and other local factors.

It should also be noted that the model has not predicted the impact of changing numbers of wild herbivores. Where stocking rates are substantially reduced it is possible that in the long-term that there could be a significant increase in the density of deer, hares and rabbits, which could have a large impact on the vegetation.

So in summary we can say that from an environmental point of view: heath = good bracken = bad improved grassland and Festuca/Agrostis grassland = moderate rank pasture = moderate/good

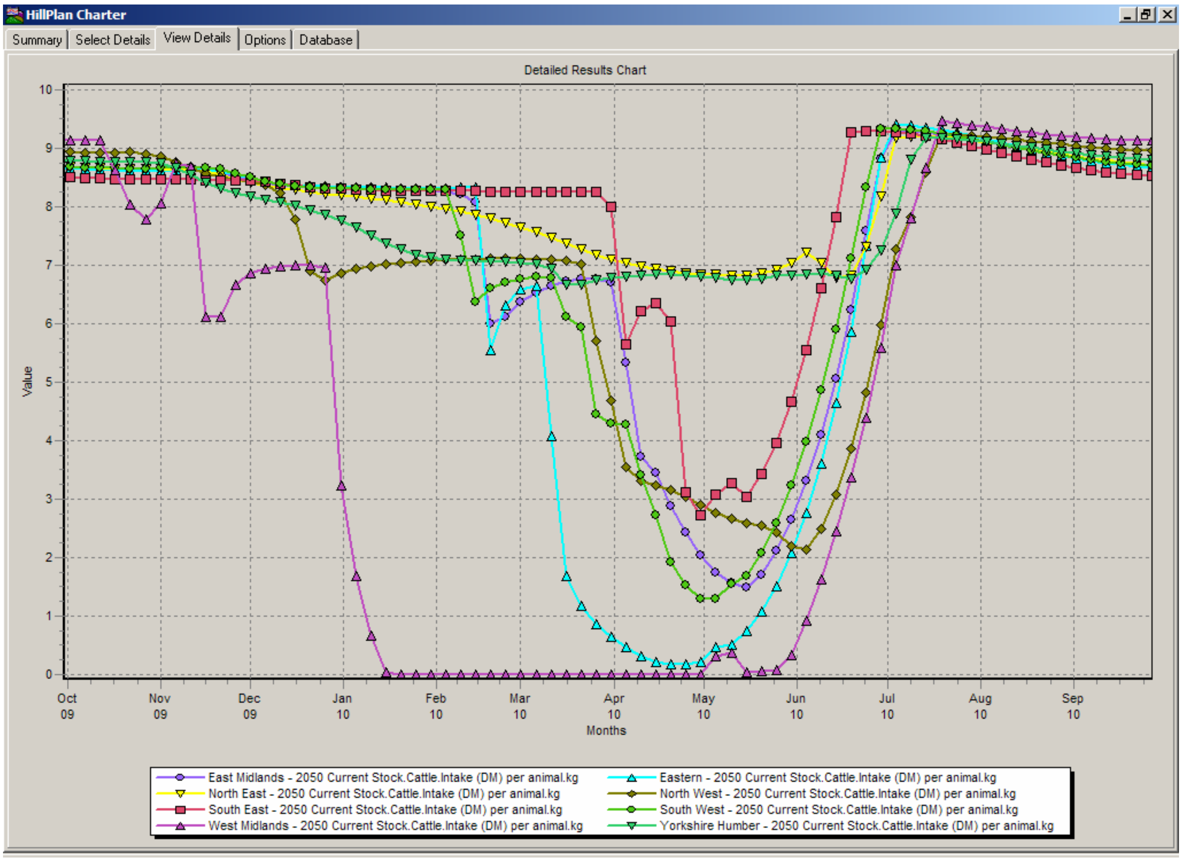
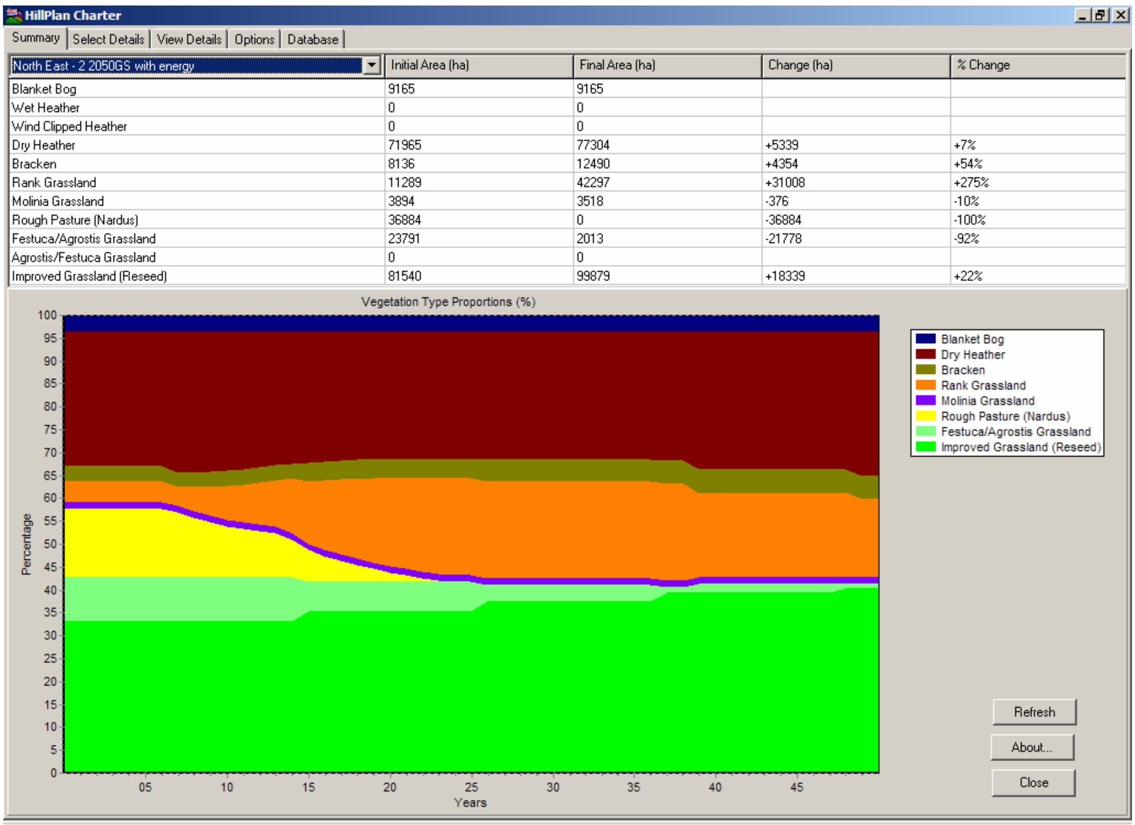


Figure 5.1 : Daily intake (kg DM per animal) for cattle for a year (Oct-Oct) at the current stocking rate in each region



North East - 2 2050GS with energy	Initial Area (ha)	Final Area (ha)	Change (ha)	% Change
Blanket Bog	9165	9165		
Wet Heather	0	0		
Wind Clipped Heather	0	0		
Dry Heather	71965	77304	+5339	+7%
Bracken	8136	12490	+4354	+54%
Rank Grassland	11289	42297	+31008	+275%
Molinia Grassland	3894	3518	-376	-10%
Rough Pasture (Nardus)	36884	0	-36884	-100%
Festuca/Agrostis Grassland	23791	2013	-21778	-92%
Agrostis/Festuca Grassland	0	0		
Improved Grassland (Reseed)	81540	99879	+18339	+22%

Figure 5.2 : The predicted change in vegetation in the uplands of the North East Region over a period of 50 years under the Global Sustainability scenario.

Table 5.4 : Descriptions of vegetation change over the 50 year simulation for each scenario within each region.

East Midlands	Initially mostly (c. 70%) Improved Grassland, the rest dominated by Dry Heath and Rough Pasture.
ZERO	Improved Grassland area remains unchanged. Transition over 20 years from Rough Pasture to Rank Grassland and Bracken (Scrub ?). Dry Heath fairly steady.
WM	Improved Grassland area remains unchanged. Transition over 20 years from Rough Pasture to Rank Grassland and Bracken (Scrub ?). Dry Heath fairly steady.
GS	As above
NE	Quick transition from Rough Pasture to Festuca/Agrostis Grassland followed by a slow transition of the Festuca/Agrostis Grassland to Bracken.
BAU	As above.
CUR	As above.
LS	Improved Grassland area remains relatively unchanged. Collapse in all other types into a Festuca/Agrostis Grassland.
Eastern	Initially mostly (>90%) Improved Grassland with around 10% Molinia Grassland and traces of other types.
ZERO	Little change except for an increase in Bracken.
WM	As above
GS	As above, but slightly more Bracken.
NE	Molinia replaced (over 10 years or so) by Festuca/Agrostis Grassland which then undergoes a slow transition to Bracken.
BAU	As above, but the switch from Molinia to Festuca/Agrostis Grassland is less pronounced.
CUR	As NE.
LS	As NE but quicker.
North East	Initially about one third Improved Grassland and one third Dry Heath with the rest dominated by Rough Pasture and Festuca/Agrostis Grassland.
ZERO	Improved Grassland and Dry Heath remain fairly stable but Rough Pasture then Festuca/Agrostis Grassland gradually replaced by Rank Grassland
WM	As above, but slightly quicker
GS	As above, but slightly quicker.
NE	As above, but quicker again.
BAU	As above, but with Festuca/Agrostis Grassland persisting.
CUR	As above.
LS	Improved Grassland remains stable, Dry Heath declines and the rest collapses into a Festuca/Agrostis Grassland.
North West	Initially about one third Improved Grassland and one third Dry Heath with the rest dominated by Rough Pasture and Bracken.
ZERO	Slight increase in Dry Heath at the expense of Festuca/Agrostis Grassland.
WM	As above
GS	Rough Pasture transition into Festuca/Agrostis Grassland over 10-15 years.
NE	As above, but followed by a further increase in Festuca/Agrostis Grassland and slight decline in Dry Heath
BAU	As above, but quicker and more pronounced decline in Dry Heath.
CUR	As above, but quicker still.
LS	Slight increase in Improved Grassland and collapse of everything else except Bracken into a Festuca/Agrostis Grassland.
South East	Initially dominated by Improved Grassland (90%) and the rest split between Molinia, Dry Heath and Rough Pasture.
ZERO	Fairly stable except for Festuca/Agrostis Grassland and Rough Pasture being replaced by Bracken.
WM	As above, but less pronounced switch to bracken.
GS	As above.
NE	As above.
BAU	Stable.
CUR	Collapse of all types bar Improved Grassland and Dry Heath into Bracken.
LS	As above, with collapse of Dry Heath as well.

South West	Initially dominated by Improved Grassland (>70%) with the remainder consisting mostly of Dry Heath or Molinia.
ZERO	Transition from Rough Pasture into Rank Grassland and Festuca/Agrostis Grassland followed by slow decline of Festuca/Agrostis Grassland into Bracken.
WM	As above.
GS	As above.
NE	As above.
BAU	Quick transition of Rough Pasture to Festuca/Agrostis Grassland, then stable.
CUR	Quick transition of Rough Pasture to Festuca/Agrostis Grassland, then slow decline of Festuca/Agrostis Grassland and Dry Heath into Bracken.
LS	Improved Grassland unchanged, but collapse of all else, bar Bracken, into Festuca/Agrostis Grassland.
West Midlands	Initially dominated by Improved Grassland (75%) with the remainder consisting mostly of Dry Heath or Molinia.
ZERO	Transition from Rough Pasture into Rank Grassland and Festuca/Agrostis Grassland followed by a slow decline of Festuca/Agrostis Grassland into Bracken.
WM	Quick transition of Rough Pasture to Festuca/Agrostis Grassland, followed by a decline of Dry Heath into Bracken.
GS	As above.
NE	Improved Grassland unchanged, but collapse of all else, bar Bracken, into Festuca/Agrostis Grassland.
BAU	As above
CUR	As above
LS	As above
Yorkshire Humber	Initially about one third Improved Grassland, one third Dry Heath and an even spread of the remainder between other types.
ZERO	Stable Improved Grassland and Dry Heath, but transition from Rough Pasture and Festuca/Agrostis Grassland into Rank grassland.
WM	As above, but slightly quicker.
GS	As above, but slightly quicker again.
NE	Improved Grassland and Dry Heath fairly stable, but the rest, bar Bracken, collapses into Festuca/Agrostis Grassland.
BAU	As above, but with an increase in Improved Grassland and a decrease in Dry Heath
CUR	As above
LS	As above but with pronounced increase in Improved Grassland, decrease in Dry Heath.

Table 5.5 : Predicted changes in areas of main classes of vegetation (Heath, Rank Vegetation + Bracken and Grass) over a 50 year simulation for each region under each scenario.

Scenario	Region	Current Area (000ha)			2050 Area (000ha)			% Change			Relative % Change		
		Heath	Rnk+Brckn	Grass	Heath	Rnk+Brckn	Grass	Heath	Rnk+Brckn	Grass	Heath	Rnk+Brckn	Grass
Zero Stock	North East	81	19	146	92	60	95	+13%	+208%	-35%	+4%	+16%	-21%
	Yorkshire Humber	103	44	203	114	106	130	+11%	+141%	-36%	+3%	+18%	-21%
	North West	113	45	295	137	58	258	+21%	+27%	-12%	+5%	+3%	-8%
	East Midlands	22	6	152	17	29	135	-22%	+347%	-11%	-3%	+12%	-10%
	South East	2	0	57	1	2	55	-19%	+425%	-3%	-1%	+3%	-2%
	South West	44	14	359	32	45	339	-26%	+221%	-6%	-3%	+7%	-5%
	Eastern	0	0	3	0	0	3	-36%	+221%	-1%	-0%	+1%	-1%
	West Midlands	14	4	114	12	13	107	-14%	+247%	-6%	-2%	+7%	-5%
	Total	379	133	1329	406	312	1123	+7%	+134%	-16%	+1%	+10%	-11%
WM	North East	81	19	146	88	54	105	+8%	+177%	-28%	+3%	+14%	-17%
	Yorkshire Humber	103	44	203	111	94	145	+8%	+114%	-29%	+2%	+14%	-17%
	North West	113	45	295	145	51	256	+29%	+13%	-13%	+7%	+1%	-8%
	East Midlands	22	6	152	12	27	141	-44%	+323%	-7%	-5%	+11%	-6%
	South East	2	0	57	1	2	55	-19%	+425%	-3%	-1%	+3%	-2%
	South West	44	14	359	30	49	338	-32%	+248%	-6%	-3%	+8%	-5%
	Eastern	0	0	3	0	0	3	-36%	+221%	-1%	-0%	+1%	-1%
	West Midlands	14	4	114	0	19	113	-100%	+406%	-1%	-11%	+11%	-1%
	Total	379	133	1329	388	296	1156	+3%	+122%	-13%	+1%	+9%	-9%
GS	North East	81	19	146	86	55	105	+7%	+182%	-28%	+2%	+14%	-16%
	Yorkshire Humber	103	44	203	111	87	151	+8%	+100%	-26%	+2%	+12%	-15%
	North West	113	45	295	92	52	309	-19%	+15%	+5%	-5%	+2%	+3%
	East Midlands	22	6	152	13	27	141	-43%	+319%	-7%	-5%	+11%	-6%
	South East	2	0	57	1	2	55	-29%	+384%	-2%	-1%	+3%	-2%
	South West	44	14	359	28	50	338	-36%	+257%	-6%	-4%	+9%	-5%
	Eastern	0	0	3	0	0	3	-40%	+229%	-1%	-0%	+1%	-1%
	West Midlands	14	4	114	0	17	115	-100%	+342%	+1%	-11%	+10%	+1%
	Total	379	133	1329	331	291	1220	-13%	+118%	-8%	-3%	+9%	-6%
NE	North East	81	19	146	87	51	109	+7%	+160%	-25%	+2%	+13%	-15%
	Yorkshire Humber	103	44	203	82	29	239	-20%	-35%	+18%	-6%	-4%	+10%
	North West	113	45	295	78	41	335	-31%	-10%	+14%	-8%	-1%	+9%
	East Midlands	22	6	152	16	24	141	-29%	+274%	-7%	-4%	+10%	-6%
	South East	2	0	57	1	2	55	-29%	+384%	-2%	-1%	+3%	-2%
	South West	44	14	359	28	51	338	-36%	+261%	-6%	-4%	+9%	-5%
	Eastern	0	0	3	0	0	3	-100%	+1743%	-7%	-1%	+7%	-7%
	West Midlands	14	4	114	0	4	128	-100%	+2%	+12%	-11%	+0%	+11%
	Total	379	133	1329	292	201	1349	-23%	+51%	+1%	-5%	+4%	+1%
BAU	North East	81	19	146	85	47	115	+5%	+140%	-21%	+2%	+11%	-13%
	Yorkshire Humber	103	44	203	76	28	245	-25%	-36%	+21%	-7%	-5%	+12%
	North West	113	45	295	60	40	354	-47%	-13%	+20%	-12%	-1%	+13%
	East Midlands	22	6	152	17	23	141	-25%	+266%	-7%	-3%	+9%	-6%
	South East	2	0	57	1	2	55	-37%	+417%	-2%	-1%	+3%	-2%
	South West	44	14	359	42	22	352	-3%	+56%	-2%	-0%	+2%	-2%
	Eastern	0	0	3	0	0	3	-48%	+1857%	-7%	-0%	+8%	-7%
	West Midlands	14	4	114	0	2	129	-100%	-34%	+13%	-11%	-1%	+12%
	Total	379	133	1329	282	164	1395	-26%	+23%	+5%	-5%	+2%	+4%
Current Stock	North East	81	19	146	87	48	112	+7%	+150%	-24%	+2%	+12%	-14%
	Yorkshire Humber	103	44	203	81	28	240	-21%	-36%	+18%	-6%	-5%	+11%
	North West	113	45	295	48	39	366	-58%	-14%	+24%	-14%	-1%	+16%
	East Midlands	22	6	152	10	28	143	-56%	+336%	-6%	-7%	+12%	-5%
	South East	2	0	57	1	5	52	-36%	+1133%	-7%	-1%	+8%	-7%
	South West	44	14	359	1	94	322	-99%	+568%	-10%	-10%	+19%	-9%
	Eastern	0	0	3	0	0	3	-100%	+1693%	-6%	-1%	+7%	-6%
	West Midlands	14	4	114	0	2	129	-100%	-35%	+14%	-11%	-1%	+12%
	Total	379	133	1329	227	246	1368	-40%	+84%	+3%	-8%	+6%	+2%
LS	North East	81	19	146	58	8	181	-29%	-59%	+24%	-9%	-5%	+14%
	Yorkshire Humber	103	44	203	27	37	286	-74%	-15%	+41%	-22%	-2%	+24%
	North West	113	45	295	0	41	412	-100%	-10%	+40%	-25%	-1%	+26%
	East Midlands	22	6	152	0	5	176	-100%	-27%	+16%	-12%	-1%	+13%
	South East	2	0	57	0	5	54	-100%	+1080%	-5%	-3%	+8%	-5%
	South West	44	14	359	0	26	391	-100%	+84%	+9%	-11%	+3%	+8%
	Eastern	0	0	3	0	0	3	-100%	+1350%	-5%	-1%	+6%	-5%
	West Midlands	14	4	114	0	2	130	-100%	-37%	+14%	-11%	-1%	+12%
	Total	379	133	1329	85	124	1632	-78%	-7%	+23%	-16%	-1%	+16%

As pointed out above, under some scenarios, and in particular the WM scenario, there may be upland areas that are abandoned by agriculture. In these cases Hillplan predicts an increase in the amount of bracken and rank vegetation. In reality in the absence of any land management there is likely to be a considerable increase in scrub vegetation and possibly woodland, but HillPlan does not include scrub and woodland in the vegetation dynamics sub-model. Such an increase in scrub and woodland is likely to result in a large increase in a number of wildlife species including invertebrates, woodland birds and mammals. Moorland birds are however likely to decline due to the loss of habitat. In areas where there is a large decrease in the numbers of domestic livestock, or a removal of all livestock, it is possible and indeed likely that there could be an increase in the number of wild herbivores, such as deer, hares and rabbits. If the density of these species was high enough this could prevent scrub and woodland regeneration, as is happening in parts of the Highlands of Scotland.

The highest stocking densities were predicted for the LS scenario. In this scenario there is large loss of heath and a large increase in grassland due to the very high grazing pressure. Indeed under the predicted stocking densities the level of grazing pressure is such that intake by individual animals is likely to be low and animal performance will suffer. The grazing pressure in certain localities is likely to be extremely high, possibly resulting on removal of vegetation and erosion. The very high grazing pressure is likely to be detrimental to wildlife. However in reality the LS option would almost certainly have policies to prevent such environmental damage. The consequences would be a lower stocking density, but an inability to meet the market demand for livestock.

The BAU scenario differs little from the current position. There is a gradual loss of heath with either a small decline or slight increase in the area of grassland and a slight increase in the area of bracken and rank vegetation. The GS and NE scenarios also show a small reduction in heath in most regions, being replaced by grassland and rank vegetation.

Table 5.6 integrates all these changes in species composition into a single score, using a score of 3 for heath and 0 for bracken.

Table 5.6 : Integrated analysis of the value of species on the uplands

	Current	**BAU**	**WM**	**GS**	**NE**	**LS**
North East	2.1	2.1	2.3	2.3	2.4	1.0
North West	1.4	1.6	2.1	2.0	1.8	1.0
Yorkshire And The Humber	1.4	1.4	1.9	2.0	1.5	1.2
East Midlands	1.5	1.5	1.5	1.5	1.3	1.0
West Midlands	1.0	1.0	0.8	0.8	1.0	1.0
Eastern	0.7	0.8	0.9	0.5	0.7	0.6
South East	0.9	0.9	0.9	1.0	1.0	0.8
South West	1.5	1.5	1.6	1.5	1.5	1.0
TOTAL	**10.5**	**10.8**	**11.6**	**11.6**	**11.2**	**7.6**
Rating		**0**	**+2**	**+2**	**+1**	**-3**

5.4.3 Modelling social impacts

Social impacts are likely to be felt though changes in labour use. Standard figures for the amount of labour required for upland beef and sheep enterprises (SAC 2004) were used to calculate the labour requirement to manage the different numbers of beef cattle and sheep in the different future scenarios.

5.4.4 Social impacts of future scenarios in the uplands

Table 5.7 shows the number of man years needed to manage the predicted numbers of livestock in the uplands in each region under each of the future scenarios. As explained above, there is little difference in the predicted stock numbers in the 'with' and 'without energy' cropping options and so employment opportunities are similar.

Table 5.7 : Labour requirements for livestock management (man years) in each region of England for the future scenarios

	Current	BAU	WM	GS	NE	LS	BAU	WM	GS	NE	LS
	Beef	**without energy**					**with energy**				
North East	686	918	347	353	393	1453	949	383	383	696	1524
North West	2443	2645	986	1009	1009	5340	2867	1090	1090	1978	5593
Yorkshire & Humber	1453	2261	667	696	757	3109	1938	737	757	1393	3240
East Midlands	1312	1453	731	545	565	2887	1534	807	585	1312	3008
West Midlands	1867	2221	895	837	969	3987	2423	989	797	1706	4159
Eastern	30	30	9	10	20	70	30	10	10	30	70
South East	444	424	146	161	151	7938	444	161	191	272	979
South West	3301	3139	1105	1231	1191	7006	3301	1221	1433	2029	7319
Total	**11536**	**13091**	**4886**	**4842**	**5055**	**31790**	**13486**	**5398**	**5246**	**9416**	**25892**
	Sheep	**without energy**					**with energy**				
North East	1212	882	763	1033	1225	1425	908	843	1219	1042	1451
North West	4446	2530	2194	2971	3141	52301	2716	2425	3462	2988	5319
Yorkshire & Humber	2582	2174	1488	2030	2366	3030	1850	1644	2412	2085	3092
East Midlands	2327	1389	1618	1621	1752	2814	1461	1788	1863	1981	2870
West Midlands	3311	2131	1985	2451	2994	3893	2301	2193	2579	2563	3968
Eastern	5557	29	23	35	55	65	29	26	42	45	68
South East	781	405	328	480	487	915	421	362	604	408	935
South West	5828	3030	2461	3596	3648	6845	3145	2720	4537	3066	6973
Total	**26044**	**12570**	**10860**	**14217**	**15668**	**71288**	**12831**	**12001**	**16718**	**14178**	**24675**
Grand total	**37580**	**25661**	**15746**	**19059**	**20723**	**103078**	**26317**	**17399**	**21964**	**23594**	**50568**

It is estimated that currently there are almost 38,000 man years of employment provided by the upland livestock sector in England. This is made up of 12,000 in the beef sector and 26,000 in the sheep sector. The BAU scenario shows little change in the beef sector, but a substantial reduction in the sheep sector.

Since the WM scenario results in a significant reduction in livestock numbers in the uplands there is a parallel decrease in employment under this scenario. The LS scenario results in an overall predicted 40% increase in employment due to the predicted increase in stock numbers. However, as demonstrated above the predicted numbers of livestock is not environmentally sustainable. The GS and NE scenarios both result in a reduction in labour requirements of about 40% compared to the current situation.

5.6 Summary

Upland land use was assumed to supply that part of livestock production not met by the lowland sector. The environmental 'footprint' of farming on the upland varies amongst scenarios according to pressures on lowland resources. Intensive lowland farming under market driven scenarios tends to reduce the pressure on uplands, in some cases leading to abandonment of least productive areas, providing opportunity for managed restoration of upland vegetation. However, in scenarios where constraints are placed on intensive production in the lowlands to meet environmental objectives, this can lead to increased pressure and potential environmental deterioration in the uplands.

Appendix 5.1

Estimating the Sheep and Beef on the Uplands in Future Scenarios

A5.1.1 Integration of baseline solution with census data

Table A5.1 lists the areas of forage from the 2004 England and Wales census (Defra, 2004), the areas of managed grassland from the Land Cover dataset and annual grass yields for these regions calculated by the Macaulay Hillplan model. The areas of lowland (less than 100m altitude) and upland grass are adjusted pro-rata so that they equal the census values for total temporary and permanent grass. The average yield over the UK for the lowland is calculated from this data and is used to convert all areas to equivalent areas of 'standard' grass. Rough grazing is assumed equal to 0.1 standard hectares. Thus for each region we obtain a total area of standard grass.

Table A5.1 : 2004 Census data, the areas of managed grassland from the Land Cover dataset and corresponding data on grass yields

					Macaulay data					
	temporary grass area	permanent grass area	rough grazing area	maize area	Area Lowland	Area Upland	Yld Lowland	Yld Upland	No fert yld lowland	No fert yld upland
		000ha								
North East	31	212	142	0.2	146.5	81.5	8141	6790	4900	4093
North West	100	480	168	9.6	251.3	197.5	9189	7536	5527	4539
Yorkshire And The Humber	58	303	124	2.7	183.0	126.2	9533	7535	5734	4538
East Midlands	52	271	35	8.0	145.2	131.6	11025	9101	6630	5475
West Midlands	98	382	20	15.0	336.0	99.1	10482	9270	6304	5576
Eastern	31	158	28	6.5	320.6	2.0	10614	9674	6384	5818
South East	82	346	30	18.0	490.3	48.7	10898	10208	6554	6139
South West	221	856	95	47.5	563.6	305.1	10757	9691	6469	5829
Wales		1010	383		515.3	494.7	9189	7536	5527	4539
Total	673	4017	1025	107.4	2951.8	1486.4	10276	8635	6180	5197
							9693.5			

Table A5.2 lists the dairy, beef and sheep from the same England census. Given a forage area per dairy cow, beef cow and breeding ewe, these also can be converted to equivalent areas of standard grass. It should be noted that a dairy cow unit includes followers, a beef unit includes all sizes of animal being fattened and a breeding ewe includes lambs and lambs being fattened. Approximate values are known and using these as a starting point, forage areas per cow and breeding ewe were fitted to minimise the error in the difference between the forage available and used per region. The final values are not unreasonable - for example typically about 0.5ha per cow and a follower factor of 1.3. Note that with beef there is no account taken of indoor fattening with cereals.

Inevitably for each region there is an error in match of the amount of animals and forage. This could be because the grass yield has been incorrectly estimated (it should be noted that the dry areas suggest yield should be lower, and the wet areas that yields should be higher). Or because of the structure of the industry, with animals being bred in the north and finished in the south, which would result in more smaller animals giving an apparent higher yield versus more larger animals giving an apparent lower yield. Al future yields were corrected to remove these errors. Thus the yield factor shown in the final column of Table A5.2 is effectively used in the following analysis to increase or reduce the grass yields calculated by Hillplan and shown in

Table A5.1. Thus we now have a consistent set of census data for both the animals and their forage area

Table A5.2 : 2004 Census data on dairy, beef and sheep

	000head							equivalent values				
	dairy number	beef number	breeding herd replacement number	other cattle over 1 year number	cattle under 1 year number	beef total	breeding ewes number	dairy	beef	Sheep	TOTAL l forage area	Yld factor
North East	21	78	31	81	90	279	906	13.5	146.8	85.5	245.7	1.191
North West	304	91	182	150	233	655	1440	197.4	344.2	135.9	677.6	1.273
Yorkshire & Humber	110	84	80	144	167	475	1025	71.6	249.3	96.8	417.7	1.230
East Midlands	105	74	72	143	142	431	593	68.3	226.5	56.0	350.7	1.006
West Midlands	205	88	115	176	194	573	1113	133.0	301.0	105.0	539.0	1.032
Eastern	31	44	28	58	66	197	173	19.9	103.4	16.3	139.6	0.647
South East	103	76	68	113	128	385	677	67.2	202.2	63.9	333.3	0.667
South West	495	195	277	389	447	1307	1658	322.1	686.7	156.5	1165.3	0.962
Wales	272		217	119	185	521	4958	176.5	273.5	467.9	917.9	1.007
Total	1645	730	1069	1372	1652	4823	12544	1069.3	2533.6	1183.8	4786.8	1.000
Value as standard grass	0.65	0.5253	0.09438									

Table A5.3 shows the data from the land use model for the baseline run for the areas of grass and maize in the lowland regions. These are naturally not identical as they are calculated on a completely different basis, being the areas where intensive grass production is profitable versus the alternatives of arable or not at all profitable for intensive production. The latter areas are negligible in the baseline run. From above we already know the areas of grassland in the uplands and rough grazing.

Table A5.3 : Baseline data from the lowland model and calibration factors compared to census data

	000ha					Equiv values					
MODEL	Grass	Maize	Upland from Macaulay (adjusted)	Rough grazing	TOTAL	Grass	Maize	Upland from Macaulay	Rough grazing	TOTAL	Yield factor
North East	223	0	81.2	142.0	446.3	187.4	0.0	56.9	14.2	258.5	0.95
North West	304	9	238.6	168.0	719.1	288.0	8.6	185.5	16.8	499.0	1.35
Yorkshire And The Humber	216	6	137.8	123.6	483.2	212.0	6.2	107.1	12.4	337.6	1.24
East Midlands	211	33	143.7	35.3	422.6	239.6	32.9	134.9	3.5	411.0	0.85
West Midlands	206	20	102.2	20.2	347.7	222.4	19.6	97.8	2.0	341.8	1.58
Eastern	97	60	1.1	28.2	186.4	105.9	60.4	1.1	2.8	170.2	0.82
South East	379	54	36.2	30.3	499.9	426.1	54.5	38.1	3.0	521.6	0.64
South West	846	53	353.8	94.7	1347.4	939.0	52.6	353.8	9.5	1354.9	0.86
Wales	515	6	462.7	383.0	1366.7	488.4	5.8	359.7	38.3	892.2	1.03
Total	2996	240	1557.4	1025.4	5819.4	3109.0	240.5	1334.8	102.5	**4786.8**	1.00

Converting all these areas to their standard grass equivalent, gives the total area of grass in each region, which are comparable to the same total areas above from the census data. The yield factors needed to correct the regions are very similar to those derived from the census data. All future yields were corrected to remove these errors. Thus the yield factor shown in the final column of Table A5.3 is effectively used in the following analysis to increase or reduce the grass yields calculated by Hillplan and shown in Table A5.1. Future results will then be directly comparable with present results. The largest area of concern is the West Midlands where the model identifies considerably less grass than in the census.

The next step is to allocate the animals in the census between the different types of land and regions in a consistent way that can also be applied to all future predictions of grass areas, yields and animal numbers. Table A5.4 shows the allocation procedure for dairy, beef and sheep.

a) Dairy are first allocated to the lowland grass. This leaves an area remaining to be allocated

b) The remaining lowland grass is then allocated to beef and sheep in the (arbitrary) ratio 4:1. There is no specific data available to suggest an appropriate ratio and certainly not to allow different ratios for different regions where the numbers are confounded by uplands and hills. The Eastern region which has virtually no upland or rough grazing, suggests a ratio slightly higher than this, but for other regions that ratio is impossible. This leaves a number of sheep and beef to be allocated to the uplands and rough grazing.

c) All the remaining beef are assumed to be grazed on upland (not rough grazing). The beef are distributed between regions according to the (food-equivalent) upland areas in each region. This leaves an area of upland unallocated

d) The remaining upland is allocated to sheep. This leaves some sheep unallocated.

e) The remaining sheep are allocated to the rough grazing according to its regional availability.

Table A5.4 : Allocation procedure for dairy, beef and sheep for baseline case

	000ha		equiv				Propn Beef in lowland = 0.8							
ALLOCATION	**Grass**	**Maize**	**Grass**	**Maize**	**dairy number**	**dairy land**	Grass&Maize remaining	80% for Beef	20% for sheep	**NEW beef distbn**	area needed for beef	Upland left for sheep	NEW sheeep distbn	area for sheep
North East	223	0	187.4	0.0	21	13	164.7	250.8	349.0	51.9	27.3	26.8	133.8	12.6
North West	304	9	288.0	8.6	304	197	205.5	312.9	435.4	241.8	127.0	124.9	226.2	21.3
Yorkshire And The Humber	216	6	212.0	6.2	110	72	198.3	302.0	420.3	127.1	66.8	65.7	151.6	14.3
East Midlands	211	33	239.6	32.9	105	68	164.3	250.2	348.2	110.5	58.1	57.1	29.9	2.8
West Midlands	206	20	222.4	19.6	205	133	248.6	378.6	526.9	148.0	77.7	76.5	31.6	3.0
Eastern	97	60	105.9	60.4	31	20	116.5	195.2	148.2	0.9	0.5	0.4	23.0	2.2
South East	379	54	426.1	54.5	103	67	239.9	365.3	508.3	23.4	12.3	12.1	19.2	1.8
South West	846	53	939.0	52.6	495	322	530.8	808.4	1124.9	292.0	153.4	150.9	80.7	7.6
Wales	515	6	488.4	5.8	272	176	331.9	505.5	703.4	355.2	186.6	183.5	390.6	36.9
TOTAL	2996	240	3109.0	240.5	1645	1069	2280.1	3472.4	4831.9	1350.7	709.5	625.3	1086.5	102.5
					Lowland					Upland			Rough Grazing	

One thus has for each region the beef and sheep using the land. Because the stocking rates have been fitted above, this procedure exactly matches animals and grass in the baseline case. For the future this is not the case. Therefore it is assumed that the stocking rate on the uplands falls (rises) as the number of animals on the uplands relative to grass available falls (rises). This can be for different reasons, such as the available lowland area and/or grass yield increasing, or the change in demand for milk, beef and lamb.

Tables A5.5 and A5.6 show the results of applying the same procedures to a future scenario 2050 GS with energy. Abandoned land in the lowlands is treated in the same way as upland but with the lowland yield enhanced by the scenario yield factor for grass. (An alternative would be to assume that this lowland area would not be fertilised, but the yield is then lower than the upland and it seems more reasonable to assume upland would defer economically to lowland. An alternative argument is that these must be the poorest lowland soils, the fertilised yield overestimates their value and the average upland would be a better estimate). Table A5.5 shows the equivalent areas and the technology increases in yields of grass and maize.

Table A5.6 shows the allocation of animals to land by region for GS. The scenario also includes increases in demand which mean that milk production increases from 14,117,000 t to an equivalent feed requirement of 14,636,000t (Equivalent because it allows for future increases in efficiency of milk production from the same amount of feed). Similarly beef increases from 651 to 690 and sheep from 306 to 363.

Table A5.5 : Area of forage available in 2050 GS with energy scenario

ALLOCATION	Grass	Maize	Abandoned	Upland	Rgrazing	Eqv	Inc in yield	inc in maze yield
North East	17	0	292	81	142	330	1.15	
North West	326	5	0	239	168	516	1.23	1.16
Yorkshire And The Humber	211	7	81	138	124	414	1.22	1.15
East Midlands	312	20	9	144	35	524	1.20	1.16
West Midlands	231	8	0	102	20	357	1.22	1.15
Eastern	101	22	0	1	28	137	1.22	1.15
South East	385	33	0	36	30	508	1.22	1.15
South West	904	34	0	354	95	1400	1.24	1.15
Wales	517	3	60	463	383	948	1.23	1.15
TOTAL	3005	131	442	1557	1025	5134		

Table A5.6 : Allocation procedure for animals to land in 2050 GS with energy scenario

ALLOCATION	Grass	Maize	New dairy number	dairy land	Grass&Maize remaining	80% for Beef	20% for sheep	New beef number	New sheep number	area needed for beef	Upland left for sheep	Rgrazing distbn
North East	17	0	2	1	14.4	21.9	30.5	133	1512	69.8	124.0	143
North West	326	5	321	208	314.2	478.5	665.9	104	1186	54.8	97.3	242
Yorkshire &Humber	211	7	110	71	250.8	382.0	531.6	105	1190	54.9	97.5	162
East Midlands	312	20	140	91	293.4	446.9	621.8	52	592	27.3	48.5	32
West Midlands	231	8	217	141	352.8	537.3	747.7	64	726	33.5	59.5	34
Eastern	101	22	22	14	117.0	178.1	247.9	0	4	0.2	0.3	25
South East	385	33	100	65	297.6	453.2	630.6	10	115	5.3	9.4	21
South West	904	34	525	341	758.0	1154.4	1606.4	126	1433	66.1	117.5	86
Wales	517	3	270	175	449.0	683.8	951.5	183	2083	96.1	170.8	417
England Total	3005	131	1706	1109	2928.8	4336	6034	777	8842	408	725	1161
	lowland							upland				

Stocking rate = 0.6035

As there is a larger area of lowland grass for beef and sheep and the yields of grass are higher, a greater number of beef (and sheep) are grazed on the lowlands, and fewer remain for the uplands.

The scenario thus requires a reduction in stocking rate, and the data provide a means of calculating the implied stocking rate – in this case 0.60.

Finally Table A5.7 brings the results of the analysis together for analysis by the Macaulay's Hillplan model. This shows a) the baseline beef and sheep numbers in each region, the upland area and the stocking rates, b) the new beef and sheep numbers, the area including the abandoned area of the lowlands, and the scenario stocking rates. These show large reductions in stocking rate of beef and consequent increases in sheep. To represent real stocking rates the listed stocking rates should be divided by the yield factors for each region in Table A5.3. Thus the West Midlands should be divided by 1.5.

Table A5.7 : Stocking rate of beef and sheep on uplands for analysis by Hillplan model for 2050GS with energy scenario

Results for Macaulay Hillplan model - 2050GS wtih energy	Incr in yield due to scenario	Beef number	Sheep number	Old beef number	Old sheep number	Upland + extensive lowland	Old upland	Beef/ha	Old beef/ha	Sheep/ha	Old sheep/ha	Macaulay upland area
North East	1.15	133	1314	52	284	372.8	81.2	0.36	0.64	3.52	3.50	81.5
North West	1.23	104	1031	242	1323	238.6	238.6	0.44	1.01	4.32	5.55	197.5
Yorkshire & Humber	1.22	105	1034	127	696	219.0	137.8	0.48	0.92	4.72	5.05	126.2
East Midlands	1.20	52	514	111	605	152.7	143.7	0.34	0.77	3.37	4.21	131.6
West Midlands	1.22	64	631	148	810	102.2	102.2	0.62	1.45	6.17	7.92	99.1
Eastern	1.22	0	4	1	5	1.1	1.1	0.34	0.79	3.35	4.30	2.0
South East	1.22	10	100	23	128	36.2	36.2	0.28	0.65	2.75	3.54	48.7
South West	1.24	126	1245	292	1598	353.8	353.8	0.36	0.83	3.52	4.52	305.1
Wales	1.23	183	1809	355	1944	522.8	462.7	0.35	0.77	3.46	4.20	494.7

Table 5.1 in the main body of the Technical Report gives the number of animals required under each scenario for 2050 as a result of the demand calculations described in Chapter 3.5. Note that these are numbers allow for the yields per head assumed for each 2050 scenario.

Table 5.2 in the main body of the Technical Report lists the corresponding stocking rates for all the scenarios. With WM2050 plus energy cropping, due mainly to the large increase in yields, there is a major reduction in stocking rates for beef and for sheep on the uplands as a greater proportion of the required demand can be supplied from the lowlands. Under energy cropping scenarios, there is an increase in the average stocking rates of sheep under GS and NE, reflecting competition from energy crops in the lowland sector. With LS2050, a combination of low crop and livestock yields and limited availability surplus of land in the lowland sector, tends to increase pressure on the uplands.

Appendix 5.2

Description of the HillPlan model

HillPlan is a modelling tool that has been developed to forecast, amongst other things, the changes in vegetation in upland United Kingdom under a range of livestock management strategies. The structure of HillPlan is shown in Figure 1.

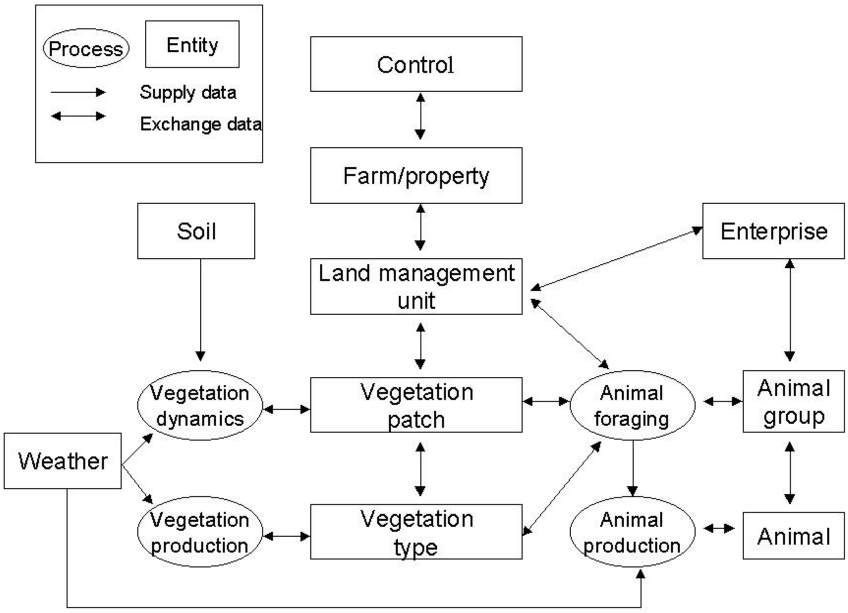


Figure A5.1 : The structure of HillPlan

The tool includes a model with a number of linked sub-models (Figure 1) that represent the relevant processes. The seasonal pattern of vegetation production is modelled for grass, based on Hutchings & Gordon (2001), using input data on weather, soils and fertiliser levels to predict grass production with a daily time step. An empirical model of heather (*Calluna vulgaris*) production is based on Palmer (1997) and Read, Birch & Milne (2002) using weather, soil and defoliation data as inputs. Thirteen different vegetation types are represented. Animal foraging behaviour is based on a modification of the ideal free distribution (following Armstrong, Gordon, Grant, Hutchings, Milne, & Sibbald (1997), in which instantaneous rates of intake are estimated, for each vegetation type, from bite mechanics and the nutritive value of the vegetation selected and then animals are distributed in the landscape as a function of the relative estimated intake rates. Long-term changes in the proportion of plant species are predicted based on Birch (1999) and Birch, Vuichard & Werkman (2000) using relative growth rates of different species.

These sub-models are implemented in a framework within which the user specifies the areas of different land management units (or fields). Each land management unit comprises a series of vegetation patches containing different vegetation types. The areas of patches and types must be specified. The numbers and species of domestic livestock (sheep and cattle) and their basic characteristics (large, medium or small body size) and the dates during which they occupy each land management unit are also required as input data. For this project each region was regarded as one land management unit.

The main output is the change in area of different vegetation types over time, although a large number of intermediate and explanatory variables can be output, of which some of the more important are animal intake, utilisation rates of different vegetation types and grass height.

The model can be run for a number of years. Normally the model is run for a longer period of time than that which is of immediate interest to the user. This is because the outputs should not be regarded as precise predictions of the exact timescale of changes, but rather as indicative of the likely trends. By selecting a longer run that that which is actually required this ensures that the user does not miss any changes occurring immediately beyond the period of interest. HillPlan Version 1.4.0.435 was used for this study.

Chapter 6 : Policy Implications and Priorities for Research

Scenario analysis used narratives and metrics to map possible agricultural futures for England and Wales. This chapter considers the outcomes of these possible futures when judged against a set of economic, social and environmental indicators. It also explores the implications of these outcomes for informing agricultural and environmental policy and for identifying priorities for research to enhance the future sustainability of farming systems and thereby serve the public interest.

6.1 Approach

Future scenarios, comprising BAU, WM, GS, NE and LS, are themselves based on dominant policy regimes, evident in the narratives and numeric values used to construct them. For example, WM assumes a utilitarian, market driven policy regime with a minimum of regulation, compared to GS where there is intervention to meet social and environmental objectives. It is inappropriate therefore to suggest major changes to policy in ways which are inconsistent with a particular scenario: they are what they are. Major changes in policy would imply a shift in scenario. There may however be ways of modifying or reshaping some features in order to better meet the public good.

The approach adopted here points out:

- the performance of future scenarios judged against the current views of sustainability and public good;
- the major areas of concern that might arise as a consequence of this performance;
- the degree of uncertainty associated with these areas of concern;
- the implications for possible policy intervention in ways consistent with the scenario;
- the implications for research to address these concerns.

It may be considered inconsistent to judge future scenarios, which are themselves a reflection of future societal preferences, against current views of sustainability. The assumption that current views of sustainability provide a reasonable basis for judging the future may be unfounded. However, the approach takes the view that, if these are the futures, they will present challenges to the existing paradigm of sustainability and we may wish to equip ourselves to deal with them.

Scenarios are possibilities: it is likely that actual futures will be different from those described here. It is apparent, however, that common themes arise across all scenarios. It is important to pick out these in so much as they, and their solutions, are likely to be relevant across a broad range of possible futures.

6.2 Agricultural Futures and Sustainability

Drawing on the preceding analysis, Table 6.1 reviews the performance of future scenarios judged against sets of economic, social and environmental criteria which reflect dominant current views of sustainability. The relative importance of parameters within each set is identified from policy statements (such as Defra 2002a; PCFF, 2002), with weights (from 1 low to 3 high) attached accordingly. Scores for each parameter for each scenario were derived from the quantitative results from modelling. Scores denote the direction (- denotes unfavourable and favourable) and relative magnitude (0 to 3, high) of the change in the parameter value for a given scenario.

For a given parameter, that scenario which generated the highest deviation from the current situation (irrespective of sign) was assigned a score of 3, and then given a sign according to whether this was a positive or negative deviation from the current situation . Parameter values for other scenarios were then given scores relative to the aforementioned extreme value and distance from the current situation. For example, consumer food prices (based on farm gate prices) has medium importance and LS, with highest average prices, shows the greatest relative change in prices, in this scenario an increase. Hence the score of -3, high prices being deemed undesirable against this indicator. Scores for other scenarios for consumer food prices (ex farm gate) are scored relative to LS the extreme case.

Economic criteria combine the parameters of farm incomes, value added from agriculture, dependency on subsidies, food security, consumer food prices, and land productivity. There is considerable variation amongst scenarios in performance against individual parameters, but there is consistency of performance within any one scenario.

BAU and WM are associated with relatively low average farm incomes, low value added by the farming sector, and low food security. However, they show relatively low dependency on government support and low consumer food prices. By comparison, GS has relatively high average farm incomes, increased value-added from farming, and high levels of overall production. However, dependency on government support is high. NE shows the highest level of food security and production, but low average farm incomes, calling for high levels of government support (which is likely to be delivered through a deficiency payment regime). LS has relatively high farm incomes, value added and government support. Food prices are high, and although total production increases, food security declines.

Social criteria combine the parameters of employment, status of family farms, security of livelihoods and support to upland farms. Once again there is variation in parameter values amongst scenarios. BAU and WM perform least well against this indicator set. WM results in significant decline in employment, family farms are under pressure, and rural livelihoods, in so much as they depend on farming, are more vulnerable, especially in marginal areas. However land is freed for recreational pursuits. Other scenarios, namely GS, NE and LS tend to protect and enhance employment, farm ncomes (as shown above) and viability of family farms, including those in less favoured areas.

Environmental criteria cover a range of parameters to reflect the environmental burden imposed by scenarios, namely agrichemical use, risk of diffuse pollution, bio-energy production, energy and water use, risk of soil erosion, potential for on-farm and off-farm biodiversity, and pressure on uplands. Predictably scenarios vary according to the extent to which environmental objectives are built into farming practices.

BAU shows a continuing increase in agrochemical usage and pollution risk, although changes in cropping reduce water use and erosion risk. Energy use remains relatively high, but there is some scope for enhancement of both on-farm and off farm biodiversity, the latter through some release of land. There is some alleviation of pressure on uplands, with implications for continued diffuse pollution and flood generation from this source.

WM places a high burden on the environment in farmed areas, with relatively high use of agrochemical and energy and reduced biodiversity. However, because farming is now focussed on a smaller area and land is freed for other uses, the overall average burden is moderated: land prone to erosion is farmed less and areas are freed for conservation management. Improved efficiency in irrigation (more crop per drop), together with increased imports of vegetables, reduces the use of irrigation water. These factors serve to reduce the environmental footprint of WM.

GS shows a moderate environmental burden in farmed areas relative to WM with continued use of agro-chemicals but increased use of water for irrigation of roots and vegetables. Compliance with good environmental practice enhances on-farm biodiversity, but surplus land is not generally available for dedicated conservation management. Pressure on the uplands continues.

NE is characterised by intensive farming systems with a high environmental burden associated with high usage of agrochemicals and risk of pollution. With an intensive livestock and mixed cropping regime, energy and water use are high. On-farm biodiversity declines, although there is scope to release land for off-farm conservation management, both in lowland and upland areas.

LS comprises a greater proportion of low input: low output farming systems, including organics. As a consequence all potential farm land is used. Agrochemical use is low, although there remain problems of diffuse pollution and soil erosion where soils, climate and hillslope favour such processes. On-farm biodiversity is enhanced due to environmentally beneficial practices, but pressure on land for food production food leaves very limited land for designated off-farm conservation. The pressure on the lowlands also transfers to the uplands where higher stocking rates increase the probability of soil compaction, runoff and pollution with negative consequences for environment.

The BAU case suggest a moderate relative performance across all criteria compared to other scenarios. Based on trends to date and extrapolation of current, it represents a compromise scenario which in many ways seeks to reconcile competing social, economic and environmental criteria

LS has an overall negative score: its relatively extensive systems, although reducing the burden per ha farmed, increase the total pressure in both lowlands and uplands, with limited scope for land release for nature conservation.

Figure 6.1 summarises measures of sustainability by scenario, weighted according to the relative importance of parameters within indicators sets. Summing the weighted scores over all indicator sets suggests that GS provides the greatest aggregate benefit, followed by LS. The advantage of GS reflects a balance of positive contributions across the three main indicator sets. The aggregation of these scores must be interpreted cautiously.

There is relatively little variation amongst scenarios in economic terms: advantage in one parameter being offset by disadvantage in another. GS and WM appear to perform best in terms of economic criteria, GS delivering relatively strong productivity, food security, and rewards to farmers but with relatively high food prices and continuing support for farm incomes. high food security and moderate food prices. The economic performance of WM is compromised by reduced total value added and low food security, whereas NE and LS rely on high levels of support.

LS, NE and GS score highest against social criteria due to contribution to employment and livelihoods. WM scores poorly because agriculture's contribution to the rural economy declines.

In environmental terms, WM makes the greatest contribution to environment, mainly because the relative decline in the size of the farming sector reduces the overall environmental burden. Marginal areas, including those associated with high risk of soil erosion and pollution, are taken out of production. 'Hots spots' of environmental concern may however arise in areas which continue in intensive farming. GS shows some relative advantage due to measures to protect the farmland environment. NE, with its emphasis on intensive agricultural production, scores badly on environmental criteria, and LS, somewhat surprisingly, has a relatively high average environmental burden due to its inability, compared to other scenarios, to release land from agriculture

Table 6.1 : Measures of sustainability for future scenarios 2050

Economic

	Farm incomes: profit £/farmed ha	Total value added from agriculture	Dependency on subsidies: Subsidy as % of farm income	Food security: Production as % of total domestic demand	Consumer food prices: farm gate prices: £/unit	Production :production weighted by farmed area	Mean score
Importance	M	M	H	M	M	L	
Weight	2	2	3	2	2	1	
BAU	-2.6	-2.3	-1.0	1.0	0.8	2.3	**-0.6**
WM	-3.0	-3.0	3.0	-1.0	0.6	2.8	**-0.1**
GS	3.0	1.8	-2.0	1.0	-1.7	2.0	**0.3**
NE	-2.1	-1.6	-3.0	3.0	0.2	3.0	**-0.6**
LS	3.0	1.8	-2.0	-3.0	-3.0	0.5	**-0.7**

Social

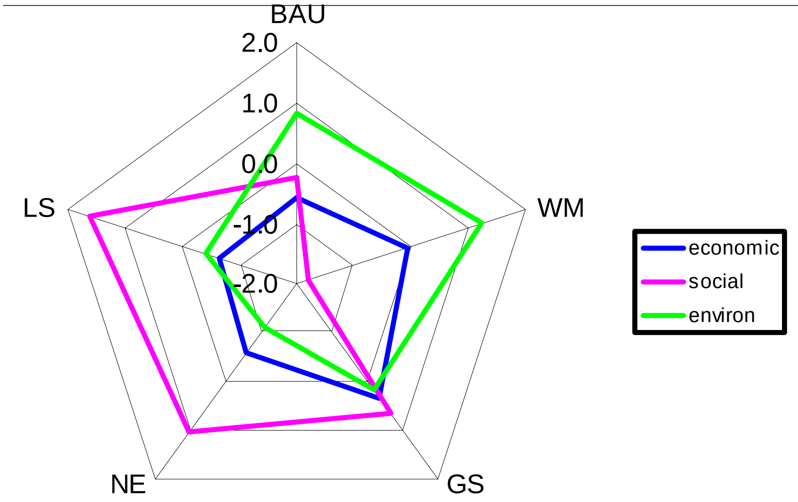
	Employment: number of persons full time	Status of Family farm: viability of farm managed by a family unit	Rural livelihoods: security of livelihoods	Land available for social use	Support to upland rural communities	Mean score
Importance	M	L	H	M	M	
Weight	2	1	3	2	2	
BAU	-1.8	-1.0	-1.0	1.6	1.0	**-0.2**
WM	-3.0	-3.0	-3.0	3.0	-3.0	**-1.8**
GS	-0.6	1.0	1.0	0.0	2.0	**0.7**
NE	-0.4	2.0	2.0	0.7	1.0	**1.1**
LS	0.6	3.0	2.0	0.0	3.0	**1.6**

Environmental*

	Chemical fertiliser: KgN/ha	Diffuse Pollution: nitrate leaching	Black grass herbicide	Water use: volume of irrigation water	Erosion Risk: erosion of vulnerable soils	Bio-Energy prodn	Energy Use: Total energy units used	On farm biodiver-sity: crop and landscape value	Off farm Bio-diversity: land available for managed conservat-ion	Pressure on uplands: stocking rates	Mean score
Importance	L	H	M	M	H	M	H	H	M	H	
Weight	1	3	2	2	3	2	3	3	2	3	
BAU	-0.6 (-1.4)	-1.1 (-1.6)	2.7 (0.7)	2.3 (1.4)	0.3 (-2.3)	1.5	0.9	1.0	1.0	0.7	**0.8 (0.2)**
WM	-0.7 (-2.6)	-1.1 (-2.3)	3.0 (-1.2)	3.0 (1.3)	3.0	0.9	1.8	-2.0	3.0	1.9	**1.2 (0.5)**
GS	-1.2 (-1.0)	-1.0 (-0.8)	-3.0	0.9 (1.0)	0.4 (0.8)	3.0	-1.1	2.0	1.0	0.2	**0.2 (0.3)**
NE	-3.0	-3.0	0.1 (-0.9)	-1.4 (-2.4)	1.6 (2.8)	1.5	-3.0	-3.0	-2.0	0.6	**-1.1 (-1.2)**
LS	-0.2	-0.2	-0.2	-2.9 (-3.0)	0.1 (0.4)	2.5	0.2	2.0	-3.0	-3.0	**-0.4 (-0.4)**

* Figures in parenthesis show relative scores per ha of intensively farmed areas where different from total area estimates

Figure 6.1 : Sustainability appraisal of future scenarios, 2050



Overall weighted scores *Figures in parenthesis reflect environmental impacts in intensively farmed areas

Scenario	Economic	Social	Environmental	Mean score*
BAU	-0.6	-0.2	0.8	**0.0 (-0.2)**
WM	-0.1	-1.8	1.2	**-0.2 (-0.5)**
GS	0.3	0.7	0.2	**0.4**
NE	-0.6	1.1	-1.1	**-0.2**
LS	-0.7	1.6	-0.4	**0.2**

6.3 Questions for Policy Makers

The preceding analysis confirms that the common policy challenge is how to achieve a balance amongst economic, social and environmental objectives under a range of possible futures; reducing the environmental pressures of market oriented scenarios and improving the economic performance of environmentally benign scenarios. Key questions which face policy makers under a range of possible futures include the following.

What are the future demands for agricultural commodities which drive agricultural and rural change?

Although scenario analysis prescribes rather than predicts demand-side requirements for agricultural commodities and the extent to which these are met from domestic sources, they demonstrate the need for a framework to derive robust estimates of demand as a basis for guiding supply side responses and policy interventions. There is considerable uncertainty and lack of knowledge on this critical topic, for example how changing incomes and dietary preferences over the longer term affect demand for food commodities, how the demand for bio-fuels can provide by-products which help meet the demand for animal feeds, and how possible changes in world agricultural markets affect national self sufficiency and security of supply in agricultural products.

What environmental objectives should be set for agriculture and the rural sector and how can these be valued?

There is a clear to need to determine what society expects of its agricultural and rural sector. Scenarios demonstrate the impact of varying priorities for agricultural production and environmental services in accordance with social preferences and governance. They show that there is both potential conflict and synergy amongst economic, social and environmental objectives, although the nature of this varies considerably amongst scenarios. Under NE and LS, and intensively farmed areas under WM, pressure on land resources may require measures to balance the needs of farming and other uses of the countryside. Where agricultural land is abandoned under BAU and WM, the benefits of a managed landscape are put at risk, but its conversion for conservation, forestry and woodland could provide a range of other environmental services, including public access.

How can strategic agricultural and environmental assets be maintained to provide the flexibility needed to deal with uncertain futures?

Several scenarios indicate land being removed from agricultural production. Given the strategic importance of food security and critical natural capital, there is a need to identify how best to reduce potential vulnerability under a variety of possible futures, including the uncertainty associated with changes in global climatic and political conditions. Hence there is a need to maintain such land and related soil and water resources in good agricultural and environmental condition. This also applies to physical infrastructure such as land drainage and the competences of farm managers and workers.

How can employment and rural livelihoods be secured without dependency on excessive government subsidy?

In all scenarios, employment in farming appears to be conversely related to the degree of government support. Where retention of farm based employment is deemed important, there is a need to identify farming systems, technologies and institutional arrangements which particularly enhance the viability of relatively small and medium sized enterprises, reducing their dependency on government support.

How can the environmental performance of farming systems be improved without compromising potential productivity gains, and vice versa?

This is a generic challenge for all scenarios, requiring a clear understanding of the relationship between farming technologies and practices and their environmental 'footprint' in a specific context. Under predominantly production oriented scenarios (WM, NE) there is a particular need to determine how the yield potential of farming technologies can be realised without damaging the environment. This requires the design and promotion of biological and other technologies, including husbandry practices such as crop establishment, fertilization and protection, and livestock feeding and breeding regimes which exploit yield potential without increasing environmental burden. This may include assessment of the potential environmental contribution of genetic modification for crops and livestock, and the use of information and communication technologies to improve and monitor the economic and environmental performance of farming systems. The adoption of new potentially cleaner technologies will require improved education and training of farmers and service providers.

Under scenarios which give priority to environmental objectives (GS and LS) the challenge is how to enhance the yield performance of environmentally sensitive farming. This will require the further development and promotion of genetic, farming and other technologies suited to given situations, including integrated crop management, low input, organic, and alternative tillage systems. Where social objectives are important, these need to be suited to small scale farm enterprises.

How can agriculture adapt to future changes in energy supply and demand?

This is a common challenge for all scenarios, requiring agriculture to be energy efficient as well as a potential source of bio-fuels. There is considerable scope and need under all scenarios for the production of bio-fuels, supported by appropriate technology, technical assistance and market development, integrating this with the production of animal feeds.

What is the best strategy for managing land released from agriculture?

Two scenarios (WM and BAU) release relatively large areas of land from intensive agriculture, with consequences for people and environment. This could lead to rural depopulation and a deterioration of valued farm landscapes. It could, however, offer opportunity for the restoration of semi-natural landscapes and managed biodiversity in woodlands and wetlands, at the same time supporting rural livelihoods. There is a need for a strategic assessment of alternative uses for land no longer needed for agriculture, especially in upland areas, linked to a review of social priorities for rural services and the environmental reference point referred to earlier.

How can the impact of climate change be moderated?

Within the time frame of the study, the prescribed impacts of economic, policy and technological change are perceived to outweigh the likely impacts of climate change. There is a need, however, to determine how choice of farming systems and practices can mitigate negative or enhance positive impacts of climate change.

In summary, the main concerns are how best to exploit the potential synergy orovercome the potential conflicts associated with the increasing call for farming and rural land use to deliver multiple objectives, and what combination of technologies and policies would best do this under a range of possible futures.

6.4 Research Priorities

The main policy concerns referred to above can help to inform a research agenda to plug gaps in knowledge and address uncertainties. The overall purpose is to improve the sustainability of farming systems, providing flexible solutions which are potentially relevant for a range of possible futures.

Suggested research priorities are summarised in Table 6.2 organised around the Drivers-Pressures-State-Impact-Response framework. This exploration of futures confirms the need to better understand:

the influence of policy, markets, technology and environmental change on rural land use and agricultural practices;

the effect of land use, farming systems, technology, farmer behaviour and climate change on the state of the rural environment and the various services it provides; and

the consequences for economic and social welfare.

In this respect there is a need to continuously review the main purposes to be served by the agricultural and rural sectors, including food production and security, livelihoods, public health, biodiversity and environmental services. There is a clear need to develop a decision support tool to assess the feasibility of alternative land uses and farming systems when judged against the range of objectives to be met. It is also imperative that polices are designed to integrate these multiple objectives cost effectively. There is a particular need, for example, to determine the extent to which market forces can be relied upon to deliver environmental services, and how compliance requirements can secure these wider benefits.

These recommendations, drawing on modelling future scenarios, are consistent with a number of those made by the Sustainable Farming and Food Research Priorities Group (Defra, 2005) which made its first report at the time of writing this futures report.

6.5 Conclusions and Recommendations

This investigation, through the use of scenario analysis, shows how long term futures for agriculture in England and Wales, shaped by differences in social preference and governance, generate different economic, social and environmental outcomes and impacts for the farming sector, the countryside and the wider rural sector. The study has gone beyond descriptive narratives of future agricultural scenarios to derive quantitative estimates of inputs, activities and outcomes which can be judged against current perceptions of sustainability.

Agricultural futures are mainly a product of the interplay between what society wants from its rural sector and the responses of land managers to the incentives given and the natural and man-made resources available to them. Although different scenarios reflect different priorities and ways of meeting them, analysis shows a common tendency towards potential imbalance in the demand for and supply of agricultural and environmental services. Scenarios tend to become unstable overtime and then converge in attempts to reconcile the multiple yet often conflicting objectives required of the rural sector. In this respect, the main challenges for policy makers are common to all scenarios, namely: securing adequate food supply, supporting rural livelihoods, minimising the environmental impacts of intensive farming, maximizing the production capacity of environmentally benign farming, exploiting the potential offered by land released from intensive agriculture where this occurs, and assessing the impacts of change, including that associated with climatic change, at the regional level (particularly in less favoured upland areas).

From a research perspective, there is a clear need to derive a better understanding of the demand for goods and services provided by agriculture, how technologies can be harnessed to meet these needs in ways which appeal to land managers, and how interventions by Government and others can help.

The analysis here necessarily involved many assumptions regarding the formulation of scenario narratives, the values chosen for critical input parameters and the many relationships represented in the modelling process. The analysis operated at a highly aggregated regional and sectoral scale rather than at the detailed scale of individual farm types and sizes. Furthermore, policy interventions have been embedded within the definition of scenarios rather than considered as additional measures which could be taken to address particular concerns. Having developed a quantitative framework for scenario analysis, however, the approach could be further developed to allow model results to influence interactively the scenario parameters such as, for example, the rate of change of land use and the level of imports and exports (reflecting rest of the world changes in each scenario), and also to test the efficacy of further policy measures. There is considerable scope to refine the scenarios and the quantitative relationships within them to support detailed policy analysis. The framework could also be used to support a normative approach to scenario analysis; identifying policy interventions which will help to achieve desirable future outcomes.

Table 6.2 : Research to inform future design of policy for sustainable agriculture

Drivers	Pressures	State	Impacts	Responses
Policy, market and technological drivers. Climate change	Land use and farm management practices	Land, water, air quality and ecological functions	Economic and Social Welfare	Choice of policy instrument
Research purposes ***Understanding relationships***				
Drivers of demand for agricultural and environmental products and services. Farmer motivation Effects of policy and regulation. Technology as a driver of change. Changes in natural resources and climate. Assessment of risk and uncertainty.	Farming systems: design and appraisal of sustainable crop and livestock production, land and water management, waste and energy and related technologies. Understanding farmer behaviour: including adoption of best technologies and cooperative working.	Links between farming practices and the state of the environment, and processes such as erosion, run-off and pollution. Monitoring the state of environmental assets. Valuation of eco-system services, such as nutrient recycling and recreational benefits and role of agriculture. Issues of scale.	Links between state of the environment and the outcomes associated with food supply, food security, rural livelihoods and society, and environmental quality and biodiversity. Understanding the impacts on people of changes in environmental quality of farmed areas. Issues of scale.	Effectiveness, efficiency and equity of policy interventions. Prioritisation of research and technology development. Understanding policy synergy and conflict. Development of framework for (a) objective assessment of sustainability of farming and (b) analysis of policies to promote sustainable agriculture.
Designing policy interventions				
To modify drivers : eg informing consumer choice, policy design, technology development, reducing uncertainty.	To alleviate pressures: eg codes of good agricultural and environmental practice, environmental stewardship, alternative farming systems, farmer education and training programmes.	To protect and enhance state of environment: eg special designated areas, land use regulation, integration of farming and biodiversity action plans, management of 'abandoned' areas.	To mitigate impacts: eg maintenance of strategic farming assets, support to vulnerable rural communities, land and water restoration.	To design policies to influence drivers, pressures, state and impacts to enhance the sustainability of agriculture eg regulation, economic instruments, voluntary measures, research and extension.

7. References

Annetts, J.E. and Audsley, E. (2002) Multiple objective linear programming for environmental farm planning. *Journal of the Operational Research Society*, 53 (9), 933-943.

Armstrong, H.M., Gordon, I.J., Grant, S.A., Hutchings, N.J., Milne, J.A., & Sibbald, A.R. 1997 A model of the grazing of hill vegetation by sheep in the UK. II. The prediction of offtake by sheep. *Journal of Applied Ecology*, 34: 186-207.

Ball, V.E., Bureau, J. Butault, J. and Nehring, R., (2001) Levels of farm sector productivity: an international comparison. *Journal of Productivity Analysis*, 15, 5-29

Barnes, A.P. (2002) Publicly-funded UK agricultural R&D and 'social' total factor productivity. *Agricultural Economics*, 27, 65-74

Berkhout, F. and Hertin, J. (2002) *Foresight Futures Scenarios: Developing and Applying a Participative Strategic Planning Tool*. Science and Policy Research Unit. Brighton: University of Sussex.

Birch, C.P.D. (1999) A new generalized logistic sigmoid growth equation compared with the Richards growth equation. *Annals of Botany*, 83: 713-723.

Birch, C.P.D., Vuichard, N., & Werkman, B.R. (2000). Modelling the effects of patch size on vegetation dynamics: bracken (*Pteridium aquilinum* (L.) Kuhn) under grazing. *Annals of Botany*, 85 (Supplement B): 63-76.

CEC (2000) *Indicators for the Integration of Environmental Concerns into the Common Agricultural Policy*. Communication from the Commission to the Council and the European Parliament. COM(2000) 20 final, Commission of the European Communities, Brussels

Defra (2002a). *The Strategy for Sustainable Farming and Food: Facing the Future.* London: Department for Environment, Food and Rural Affairs.

Defra (2002b) *Farming and Food's Contribution to Sustainable Development. Economic and Statistical Analysis*. London: Department for Environment, Food and Rural Affairs. Defra Publications

Defra (2003a) *Agriculture: in the UK 2002*. The Stationery Office, London.

Defra (2005a). *Agriculture in the UK, 2004.* London: Department for Environment, Food and Rural Affairs. Defra Publications

Defra (2005b). *The First Report of the Sustainable Farming and Food Research Priorities Group*. Department for Environment, Food and Rural Affairs, London

Defra. (2003b) *Diffuse Water Pollution from Agriculture*: The Government's Strategic Review: Stakeholder Discussion Paper . Department for Environment, Food and Rural Affairs, London

Dti (2002). *Foresight Futures 2020 Revised scenarios and guidance*. Department of Trade and Industry,.HMSO. London.

EC (2003) The Nomenclature of Territorial Units for Statistics (NUTS) European Commission. http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_154/l_15420030621en00010041.pdf

Environment Agency (2002) *Agriculture and Natural Resources: Benefits, Costs and Potential Solutions.* Environment Agency, Bristol

Gopinath, M., Arnade, C., Shane, M, and Roe, T (1997) Agricultural competitiveness; the case of the United States and major EU countries. *Agricultural Economics*, 16,99-109

Hartridge, O and Pearce, D (2001) *Is UK Agriculture sustainable? Environmentally adjusted economic accounts for UK agriculture*. CSERGE-Economics, University College London

HCEFRAC (2003). *The Water Framework Directive, House of Commons, Environment, Food and Rural Affairs Committee*, Fourth Report of Session 2002-2003, March 2003, The Stationery Office, London

Hutchings, N.J. & Gordon, I.J. (2001). A dynamic model of herbivore-plant interactions on grasslands. *Ecological Modelling*, 136: 209-222.

Koeijer, T.J. de, Wossink, G.A.A., Renkema, J.A., and Struik, P.C (2002). Measuring agricultural sustainability in terms of efficiency: the case of sugar beet growers. *Journal of Environmental Management*, 66, 9-17

Macaulay Institute (2005) *Decision Support Tools to Link Ecology and Land Management: Development of HillPlan.* http://www.macaulay.ac.uk/hillplan/, accessed 1.10.05.

MAFF (now Defra) (2000) *Towards Sustainable Agriculture: A Pilot Set of Indicators* http://www.maff.gov.uk/farm/sustain.htm

Magic Interactive Map (2004) available on http://www.magic.gov.uk/.

Morris, J., Audsley, E., Pearn K. and Rickard, S. (2005) Future directions for productivity in UK agriculture, **in** Sylvester-Bradley, R and Wisemann J, (ed) *Yields of farmed species: constraints and opportunities in the 21st century.* University of Nottingham Press, Nottingham

Morris, J., Audsley, E., Wright, I.A, McLeod, J., Pearn, K., Angus, A. and Rickard, S. (2005). *Agricultural Futures and Implications for the Environment.* Main Report, Technical Report and Supporting Appendices. Defra Research Project IS0209. Bedford: Cranfield University. Available on hppt//www.silsoe.cranfied.ac.uk

OST (2002) *UK Foresight Futures 2020: Revised Scenarios and Guidance*. London: Office of Science and Technology, Department for Trade and Industry, London

Palmer, S.C.F. (1997). Prediction of the shoot production of heather under grazing in the uplands of Great Britain. *Grass and Forage Science*, 52: 408-424.

Pannel, D.J. and Glen, N.A.(2000) A framework for the economic evaluation and selection of sustainability indicators in agriculture. *Ecological Economics*, 33, 135-149

PCFF (2002) *Farming and Food a Sustainable Future: Report of the Policy Commission on Farming and Food*. London: Cabinet Office, UK Government. http://archive.cabinetoffice.gov.uk/farming/pdf/PC%20Report2.pdf

Pretty, J N, Brett, D, Gee, D, Hine, R E, Mason, C F, Morison, J I L, Raven, H, Rayment, M D, van der Bijl, G (2000) An assessment of the total external costs of UK agriculture. *Agricultural Systems* 65, 113-136

Pretty, J. (1998) *The Living Land: Agriculture, Food and Community Regeneration in Rural Europe*. Earthscan, London.

Pretty, J.N. and House, J. (1993). *Sustainable Agriculture in Britain: recent achievements and the new policy challenge*. IIED, London.

Rickard, S., Morris, J., and Audsley, E. (2005) Possible futures for agriculture in Northern Europe during a period of policy reform, **in** Sylvester-Bradley, R and Wisemann J, (ed) *Yields of farmed species: constraints and opportunities in the 21st century*. University of Nottingham Press, Nottingham

Rounsevell, M.D.A., Annetts, J.E., Audsley, E., Mayr, T. and Register, I. (2002) Modelling the spatial distribution of agricultural land use at the regional scale. *Agriculture, Ecosystems and Environment*, 95 (2-3), 465-479

Sylvester-Bradley, R. and Wiseman, J. (eds) (2005). *Yields of Farmed Species, Constraints and Opportunities in the 21st Century* .Nottingham: Nottingham University Press, UK. 651 pp.

Thirtle, C., and Holding, J. (2003) *Productivity in UK Agriculture: Causes and Constraints*. Report to Department for Environment, Food and Rural Affairs. Wye, Kent: Imperial College at Wye, University of London.

UNSEEA (2003) *System For Economic And Environmental Accounting* (SEEA) http://unstats.un.org/unsd/environment/seea2003.htm

Wilson, P., Hadley D., and Asby, C. (2001) The influence of management characteristics on the technical efficiency of wheat farmers in eastern England. *Agricultural Economics*, 24, 329-338

Agricultural Futures and Implications for the Environment.

Morris, Joe

2005-11-01T00:00:00Z