Research in Context; Agriculture in 21st Century Britain

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The other contributors to this volume have concentrated upon the past, current and future impacts of research and development on livestock agriculture. Agriculture has been shaped by technology since its beginnings, and there is no reason to doubt that this influence will continue. My scientific career has spanned the elucidation of the genetic code and the development of the microcomputer and it will be interesting to assess with hindsight the relative impact on farming of cheap, miniature, high-capacity computing power against molecular biology and targeted DNA manipulation. However, I would assert that the impact of these and other technological advances on UK agriculture over the next twenty years will be strongly affected by the social and political environment that prevails over their implementation.

It is convenient to consider three broad phases in agriculture since the end of World War II. Initially, food security was the major political driver for agriculture. The subsidy system was set up to reward increased production, and research was directed towards yield improvement under non-limiting inputs. Overall primary production exceeded 70% of requirements by the 1970s. Many of the changes in practice were directed towards greater intensification, as with fertiliser usage in the arable sector and concentrate usage in the dairy sector.

Since the 1980s, and more particularly since British membership of the European Union, food security has ceased to be a significant political issue. By the Ministry of Agriculture, Fisheries and Food's own

**Figure 7.1** An image of our attractive British countryside: not just production, but amenity value also
figures (MAFF, 1999), we currently produce over 80% of our own requirements for foodstuffs that can be produced in the UK (68% of total needs). The steady increase in food imports that underlies these figures is itself driven by the low global price for commodities, a further indicator of increased global food security. By contrast, the high cost of production-based subsidies has influenced the political debate much more, despite intensive lobbying by some sectors of European agriculture. Over the last ten years, there has been a progressive drive towards maintaining margins by reducing inputs as well as by increasing outputs. This has driven research into precision agriculture, input management, breeding for environmental tolerance and the development of extensive (grass-based) animal production systems.

In recent years, the nature of the debate has shifted once again. The political drivers now relate strongly to public health, food safety and environmental protection. Progressive globalisation of agricultural trade seems inevitable, and this means that it will become increasingly uneconomic for many UK farmers to sell unsubsidised products at world commodity prices. UK farmers will have to grow the food people want at a price that they are prepared to pay, taking into consideration the manner in which the food is produced. Government intervention will shift progressively to environmental support.

If these political and social drivers remain, I consider it to be of limited value to predict in isolation the effects of technology push. Agriculture has always been flexible and pluriactive, and I believe that market pull (including socially and politically driven market effects) will exert an increasing effect on the research agenda. In this review, I wish to consider briefly the likely framework of technological advances, together with the linkages between what is possible and what is desirable. This part of the review is structured around the consideration of four contrasting farming scenarios.

Future technological drivers

Many of these have been dealt with in some detail in the other chapters. In developed countries, I would regard the reduction of inputs, the improvement of product quality and the minimisation of adverse environmental consequences as being targets that will reduce costs, sustain markets and promote consumer confidence. In each of these areas, there are major opportunities for the adoption of new technologies that are themselves the direct outputs of research (Table 7.1). What is much more difficult to predict is the extent to which individual new technologies will be taken up by farmers.

The development of new technologies is not always coupled tightly to strategies about how they might be employed. It is doubtful, for example, that the enormous impact of computer games was high on the list of benefits envisaged during the early stages of integrated circuit design. Agricultural biotechnology can support a range of different systems. The current GM crops (particularly those with herbicide tolerance or pest resistance) are aimed at minimising production costs through lowered inputs, reduced pre-harvest losses and greater reliability, but future developments will also address yield per se, as well as product quality and the minimisation of environmental impact. In all these cases, appropriate refinement of management systems will also be necessary if the maximum benefit is to be derived.

The problem here is that the agronomic benefits of new technology are increasingly offset by social, economic and political considerations. Farmers are more and more inclined to ask how any altered
practice will help to sustain farm income, rather than consider how it might promote good or efficient husbandry. It is for this reason that I argue the need to consider in much more detail the capacity of different elements of 21st Century UK agriculture to absorb and respond to biotechnological and engineering advances.

How compatible are emerging technologies with agriculture's future role in the UK?

Assumptions
Any scenario-building exercise must be based upon assumptions. In broad terms, the ones that I have used are based upon the NFU document “Real Choices” but have been influenced by subsequent discussions about Agenda 2000 and the preliminary inputs into the next round of the World Trade Organisation talks. The assumptions are summarised in Table 7.2, and are based upon the continued globalisation of agriculture, increasing impact of consumer preference in developed countries, reductions in or abolition of direct production subsidies and no major increases in the relative costs of agricultural commodities due to global shortfalls in production. Under such circumstances, it is difficult to be optimistic about the overall ability of UK agriculture to compete globally in commodity production. The scenarios that I outline below are, therefore, predicated on the targeting of higher added value production, and attempt to highlight the contrasting ways in which biotechnology could be applied, depending upon where this added value is to be generated.

Table 7.1 Likely impacts of new technologies on grassland agriculture, 2000-2010

<table>
<thead>
<tr>
<th>Aim</th>
<th>Plant Breeding</th>
<th>Management</th>
</tr>
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<tbody>
<tr>
<td>1. Reduce Inputs</td>
<td>Improved tolerance to biotic and abiotic stress</td>
<td>Decision support systems for fertilizer application</td>
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<td></td>
<td>Development of indicator plants with reporter genes linked to stress-sensitive promoters</td>
<td>Precision spraying linked to global position sensing</td>
</tr>
<tr>
<td></td>
<td>Improved uptake of water and nutrients</td>
<td>Pest and disease monitoring and modelling</td>
</tr>
<tr>
<td></td>
<td>Control of primary metabolism to produce more and better oils, starches and sugars and to promote rapid ensiling and efficient digestion</td>
<td>Integrated pest management</td>
</tr>
<tr>
<td></td>
<td>Slower plant-catalysed degradation of protein in silo and rumen</td>
<td>Management of cutting and grazing to promote high quality growth rather than optimal biomass production</td>
</tr>
<tr>
<td></td>
<td>Improvement of milk and meat quality by altered forage composition</td>
<td>Use of more effective silage inoculants to preserve quality</td>
</tr>
<tr>
<td>2. Improve quality</td>
<td>Improved uptake of inputs (see 1 above)</td>
<td>Optimised grazing regimes to promote good diet selection and intake</td>
</tr>
<tr>
<td>3 Minimise environmental degradation</td>
<td></td>
<td>Tactical application of fertiliser linked to soil analysis and on-farm process modelling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Utilisation of farm wastes as part of nutrient supply, linked to analysis and modelling</td>
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</tbody>
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Scenarios

Integrated intensive systems
Oliver farms 500 hectares of Class 1 agricultural land in East Anglia. He produces mainly premium cereals for brewing and bread-making, both grown under contract for a grain trading company that is itself a subsidiary of a brewing/food processing combine. The varieties that he grows have been bred commercially to specifications agreed with the grain company, and defined management practices are specified prior to each growing season. Currently these varieties are bred using marker-assisted selection, but there are GM versions with improved quality traits being used on nearby farms to gauge consumer opinion.

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Table 7.2 Assumptions on trends in global agriculture between 2000 and 2010

<table>
<thead>
<tr>
<th>Arena</th>
<th>Assumptions</th>
</tr>
</thead>
</table>
| Global economic| • Rate of increase of total food production will continue to exceed rate of increase in demand  
• There will be progressive movement towards a global agricultural market via the abolition of tariff barriers and production subsidies  
• Payments to farmers for non-production (environmental or social) outputs will remain |
| European economic| • Reduction in CAP expenditure will become an increasing priority as EU enlargement progresses. This will be achieved via reductions in production subsidies.  
• There will be continued pressure for increased environmental benefits to be derived from agriculture, even at the expense of production. Subsidy payments will increasingly be linked to such benefits  
• The proportion of income spent on unprocessed food will not rise significantly  
• Average disposable incomes within the EU will continue to rise  
• Agricultural land prices will fall, particularly in areas where there is no pressure for alternative development |
| European social | • Consumers will attach increasing importance to the safety and quality of food and food production systems  
• An increasing minority of consumers will purchase higher value products (e.g. organics) in order to seek reassurance on safety and quality  
• Food safety strategies will form a larger part of government involvement in agriculture  
• Integrated environmental management strategies aimed at meeting targets for sustainability will form a larger part of government involvement in agriculture  
• GM technologies will not be banned, but will not command wide acceptance |
The management practices make considerable use of decision support systems (DSS). The models used in these systems are driven by meteorological, soil and pest data from a number of multi-sensor arrays (e.g. Figure 7.2). The sensor system is run under contract by an agricultural advisory company who integrates data from arrays across a number of farms. All Oliver’s cultivation and harvesting activities are also sub-contracted to a firm that guarantees precision inputs based on a 1m² resolution map of the entire holding, using direct transfer of outputs from the DSS. This precision management permits Oliver to stay within the terms of his water abstraction agreement, and his pollutant release quota. Both of these are also monitored by sensors that feed data into the farm and directly to the regulatory agency.

Oliver still grows break crops, although some of his neighbours have moved to continuous cereal systems with more intensive soil and pest monitoring. GM oil seed rape for industrial use is the major break, although he also grows some GM flax for biocomposite manufacture. He handles the farm with one full-time administrative assistant and one

Figure 7.3  Speciality Cheeses (Photo supplied by The Food Directorate of the Welsh Development Agency)
full-time farm manager, who hires labour as required from a labour-only sub-contractor.

**High added value niche production**

Owen farms some 200 hectares of level land in the Vale of Clwyd. He runs the enterprise as an organic dairy unit that supplies milk for cheese-making to a local co-operative. The co-operative has developed a number of prize-winning speciality cheeses that are sold through major multiple outlets under contract (Figure 7.3). However, there is also a local marketing initiative that targets specifically hotels, restaurants and speciality shops catering to tourism. Owen also sells this produce through a farm shop that also serves as a café and starting point for a series of farm walks linking a number of neighbouring farms. Maintenance of the woods and old meadows that form part of these walks attracts a number of conservation grants and is linked to local training initiatives in tourism and environmental management.

Owen uses modern varieties of grasses, forages and cereals (mainly oats) where the seed has been produced under organic certification. Both these varieties and the cattle that feed from them have been bred using marker-assisted selection. The cattle breeding programme emphasises performance under forage systems, together with milk quality. Owen is, however, considering shifting to dual purpose animals and undertaking some organic beef production, since currently there is no market for calves not needed for herd replacement purposes. Secondary breeding objectives for forages have included natural anthelmintic properties and optimal protein and fermentable carbohydrate profiles. A range of alternative legume crops are grown under rotation and harvested for silage (Figure 7.4). Individual feeding access to additional rations both at grazing and in parlour is linked to individual milk monitoring via animal tagging and metabolite sensing and used both in herd improvement and individual cow management. Owen employs his wife as the farm secretary, his son as head herdsman, and two local agricultural workers. He contracts out all of his silage making. The co-operative runs a small organic pig unit to utilise the whey from cheese-making.

**Pluriactive farming**

Quentin owns 200 hectares of land near Hereford, on the edge of the Wye Valley. His main employment is as a computer systems consultant, and his wife undertakes contract catering. He does not come from a farming background. Half of his land is steep and wooded, and income is generated via a mixture of conservation grants and leasing concessions for coppicing. Coppicing is the appropriate woodland management option and links to local production of charcoal, firewood and green wood products. The remainder of the land is used for sheep grazing, beef finishing, pony trekking and vegetable production. The animal grazing land is sub-let to local producers under a conservation regime that is intended to restore biodiversity by input management. Once key biodiversity indicators are achieved, further grants are payable. The pony trekking is a joint venture, with Quentin providing access, some pasture and hay. The vegetables are cultivated to organic...
standards for the catering business, although they are not registered since none are sold directly. No full-time labour is employed on the farm, although there is a part-time gardener/handyman. All machinery and labour is hired as needed. The farm plan is predicated almost entirely on maximising payments for environmental goods, access and tourism activities. All monitoring is undertaken by the grant-giving agencies, although business IT is used extensively to keep track of the various activities. Agricultural technology has a limited impact on his system, although there is a limited amount of reseeding with new clover varieties into existing pastures.

Conservation farming
Malcolm manages 2000 hectares on the North Yorks moors for the Royal Society for the Protection of Birds. The major aim of the enterprise is to restore overgrazed land and to increase the diversity of wildlife (Figure 7.5). Sheep and beef cattle are used for selective grazing according to a regime based upon intensive monitoring of indicator species (birds, mammals and insects) by volunteers. The grazing animals are fed to organic standards and sold as such through selected outlets, including local hotels and restaurants. Winter feed is generated by a mixture of hay, silage and spring-sown cereals, chosen to maximise habitat diversity. Herd size is controlled based upon the conservation activities to be undertaken, and the breeds are those (such as Welsh Black cattle) whose value in grazing out or trampling unwanted species has been established. Plant varieties are selected from current lists on the basis of their agronomic suitability e.g., for hay making. Animals are tagged with miniature global position sensors so that their activities in vegetation management can be controlled accurately. The reserve has a large staff, most of whom spend a small proportion of their time on the farming activities. Only Malcolm is a trained agriculturist and works full-time as a farmer. Contractors carry out all specialist activities.

Conclusions
These facile scenarios serve to illustrate the potential range of engagement with both biotechnology and precision management that could result from the progressive globalisation of agriculture and the increased range of options for UK land use. The pattern of different intensities of cultivation will depend upon location, with peri-urban areas strongly affected by the proximity of large markets for fresh produce and generally higher land prices. Patterns of payment by government will also have a marked effect. Currently grants are payable on a farm by farm basis, even though the benefits of setting targets at the landscape scale are considerable.
If there is any truth in these forecasts, then deducing the future impact of biotechnology will depend very heavily upon the balance between these different types of enterprise. This, in turn, will be driven almost entirely by social and economic factors. Agricultural biotechnology will, in my view, have to be in a position to respond to “market pull” even when some of the forces for change are not production oriented. Biotechnology could make a considerable impact in areas such as bioremediation, or in the breeding of plants specifically for the built and recreational environment, and I think we need, as researchers, to take a broader view of our beneficiary community than we have in the past.

This review is predicated upon the idea that UK agriculture will adapt to globalisation through high-value production and pluriactivity. There are, however, at least two alternative views that, if true, would markedly affect my conclusions. The first is that consumers will not pay extra for UK food, even though it is of higher quality and produced in a more sustainable manner. In this case, agricultural production will be exported to lower-cost areas where UK production constraints (both physical and regulatory) do not apply. Challenges associated with the application of agricultural technology then become largely irrelevant. There are plenty of examples where this process has already happened in the UK manufacturing sector, and it is by no means impossible for it to happen in agriculture. If it does, then many farms will fail, and new land use patterns will emerge that will emphasise recreational and environmental goods. The challenge here will be to find replacements for farmers to implement land management policies.

The second is that demand for agricultural commodities will rise faster than our capacity to meet that demand. There are indications that this may happen in the case of grain for animal feed, driven by rapidly increasing prosperity in some developing countries (Table 7.3). If this does happen, then more of the current UK production systems would be sustainable without production subsidy, and there would be an equivalent increase in the extent of biotechnological inputs into intensive systems.

There is no doubt that technology will continue to influence agriculture on a global scale. New pests and diseases will appear in new locations and management systems will have to develop in responses to changes in climate, soil, flora and fauna. All the scientific advances that I have outlined could, in principle, impact on the development of that technology. What is less clear, however, is the extent to which this process will be significant in UK terms. Here the interplay of factors is more complex than it has been in the recent past. Agriculture has survived in this country by being flexible, and technology has been a key driver for this flexibility. I would suggest that UK capacity in this area needs to be maintained if we wish to benefit from the changes that lie ahead, particularly given the uncertainty over what these benefits will be.

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### Table 7.3 World demand for cereals for animal feed (Mt) in 1993 and as predicted for 2020. The 2020 predictions are given for three levels of economic activity (Rosegrant and Ringler, 1999).

<table>
<thead>
<tr>
<th></th>
<th>1993</th>
<th>2020 Baseline</th>
<th>2020 Moderate Crisis</th>
<th>2020 Severe Crisis</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>73</td>
<td>183</td>
<td>178</td>
<td>154</td>
</tr>
<tr>
<td>Asia developing</td>
<td>32</td>
<td>70</td>
<td>68</td>
<td>65</td>
</tr>
<tr>
<td>Total developing</td>
<td>134</td>
<td>418</td>
<td>409</td>
<td>378</td>
</tr>
<tr>
<td>World</td>
<td>636</td>
<td>945</td>
<td>928</td>
<td>885</td>
</tr>
</tbody>
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