Summary

As a consequence of extensive debate the challenges of achieving global food security are well understood.

It is now vital that policy makers identify the specific solutions needed to ensure farmers and growers in all parts of the world, including the UK, can respond through the sustainable intensification of agriculture.

There are three essential ingredients. First, a better structured and more coherent science framework is required that takes basic research, translates this to applied science and that has the means to deliver this onto farms in the UK.

In a climate of fiscal restraint, there may be a need to rebalance public funding towards applied research and to seek out more public/private partnerships. It is important that the farming industry specifies its priorities in terms of research that is needed over the next 5-10 years.

Secondly, there is a need to recognise and address systemic failures in the food supply chains through a combination of regulatory mechanisms to remove abusive practices and introduce a change in buying behaviour towards long-term alignment.

This will create a climate in which investment and sustainable intensification can be fostered.

Thirdly, we need to ensure that agricultural policies such as the CAP stimulate rather than inhibit sustainable intensification.

Industry and farmers must cooperate, but government retains an important role. This is not merely as an arbiter, but in guiding strategy particularly for public funded research. Here most importantly we need to move beyond talking about sorting out a “broken pipeline” to actually fixing it.

Introduction

The challenges of global food security are becoming clichéd in an increasingly rhetorical debate amongst academics, policy makers and governments.

The challenges including lifting agricultural productivity, reducing environmental impacts, addressing poverty and facilitating access are well understood.

What is considerably less clear is how these challenges should be addressed, by whom, how, where and at what cost.

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There is a desperate need to move beyond the narrative laid out most notably in the Foresight report of 2011 (Global Food and Farming Futures) (1) and start mapping out the key actions that must be taken in the next decade, if not sooner.

We believe that the focus on 2050 as a defining moment for global food security has allowed some commentators and NGOs to suggest that we can put off the big decisions. Some argue that agricultural productivity will increase as farmers and scientists respond to market demands.

Others believe simply cutting waste and changing global diets will provide the answers without a need to increase production. In our view neither position is tenable.

Making the case for sustainable intensification

Agricultural land and other key factors of production, especially water, are either expensive to produce or finite.

What is more, farm output must be generated from already depleted and vital natural resources which must be preserved. The demographic changes we face not only affect demand for food but also put pressure on energy, natural resources and water.

The term sustainable intensification was first formally coined by the Royal Society in its October 2009 report (2) to encapsulate the most important single response to the global challenges of food security, environmental protection and climate change.

Yet the term is contentious and can suffer from a lack of clarity in its execution. We tend to see things quite simply: producing more, impacting less.

Sustainable intensification is not a new concept or philosophical ideal; indeed it is something that many farmers have already been making great advances towards.

They have maintained or moderately increased production over the last four decades without increasing the overall volume of inputs. As an example, the volume of nitrogen fertiliser used on farms in the UK has fallen by 36% since the mid-1980s (Figure 1).

It is important to understand what sustainable intensification means for farming in the future. UK agriculture is a dynamic industry that has constantly evolved to adapt to changing circumstances in markets, policy, technology, techniques and labour.

Sustainable intensification is already being adopted by many farm businesses, for example, the use of precision farming technology for yield mapping using GPS and advances in agricultural engineering are increasingly common place on many farms.

More livestock and dairy farms are using computer software to optimise fertiliser use on grassland and tailor nutritional requirements for cattle. Significant advances have been made in breeding genetics in the pig and poultry sectors.

In many cases, sustainable intensification is about quite subtle changes to optimise inputs both spatially and temporally (whether they be pesticides, herbicides or nutrients) that, scaled up, make a significant difference to the productivity of farm businesses over time.

Collectively it means less waste, better crop performance, lower costs and better outcomes for the environment.

Recent studies in Australia have shown that simply using the controlled traffic farming systems to minimise soil compaction can result in improvements in wheat yield of up to 15% (3).

There is still enormous scope to exploit this technology further in areas such as crops sensing for disease and quality, real-time monitoring of animal health and welfare as well as the controlled management of farm vehicle operations (4).

The role of UK agriculture

Few people doubt that achieving food security requires significant increases in agricultural production.

However, some commentators and NGOs (indeed some government officials) dispute the belief that production must also rise in the UK.

In 2009, the House of Commons EFRA Select Committee (5) argued that the UK has a 'moral duty' to increase food production, not only to address concerns about declining self-sufficiency at home, but also to play a part in the global response to growing demand.

The UK will never be a major global agricultural exporter. However, its geographical position, good trade links and manufacturing capability should enable it to respond to what will be an inevitable growth in demand from international markets for food.

Whilst no-one can dispute the fact that developing countries must deliver the lion's share of an increase in production, few believe that they will be in a position to completely satisfy growing demand sustainably. The developed world must also play its part.

Global supply will be impacted by climate change. Recent years have already seen weather events impact on the global output of key agricultural commodities and contribute to volatile prices.

A 2% rise in average global temperatures will generate further extreme weather events, place greater stresses on production in certain parts of the world, and exaggerate the annual variations in global supply.

Some of the world's major exporting regions may suffer the effects of salina- tion and heat stress (Figure 2). It will also cause shifts in the ranges of pests and diseases, as has already occurred with bluetongue and Schmallenberg viruses in Europe.

By contrast, the impact of climate change in the UK may be relatively more benign.

The Commission on Sustainable Agriculture and Climate Change Report (6) talks of the "safe operating space" as defined by climate change within which global food production must exist. There will be a greater onus on those parts of the world that can produce more to do so, including the UK.

Changing diets, reducing waste and reducing agricultural greenhouse gas emissions will only take us so far. Agriculture must also produce yield improvements and increased efficiencies to keep within the "safe operating space" and innovation will have a key role.

Three vital needs

In an attempt to move beyond the rhetoric and clichés, we believe that it is incumbent on farmers' organisations to start identifying what really is needed in the next 5-10 years to ensure that the sector can address the challenges. .

In perhaps its simplest encapsulation (and leaving aside some significant policy and regulatory hurdles that lie ahead), we see three basic requirements that will enable UK farmers to achieve sustainable intensification.

1. A better structured science framework.

The results of scientific and, technological work and their subsequent commercialisation are absolutely crucial to ensuring that future demands for food, fuel and fibre can be met from a limited land area.

Lately, discussion of agricultural science has focussed on the highly politicised issue of genetically modified crops (GMs). For the avoidance of doubt, let us be clear – we believe that the farming industry will need a full range of techniques and approaches, including GM to meet the challenges.

However, no single technology, tool or farming system will solve all the problems and feed the world.

Just as we must move beyond clichés, we must also move beyond the polarising rhetoric that dominates debate on GM.

Achieving tangible advances requires a science framework that addresses four things:

a. Basic research that challenges the boundaries of conventional wisdom.

b. Investment in the research that farmers can then apply to their businesses.

c. Knowledge transfer and extension networks that secure take-up of the best available technologies and techniques and also effective feedback to the research sector.

d. Empowerment of the agricultural industry to take forward and apply this new knowledge and innovation through skills and training, particularly in the areas of business and entrepreneurial expertise.

The UK has traditionally been a world leader in agricultural research & development (R&D), but it is essential that this reputation is continued and furthered over the coming years.

It is also important to see the role of UK R&D in the wider global context.

Many UK R&D centres have great traditions as global experts on issues such as climate change and animal health. The knowledge from these institutions benefits not just UK farmers and growers, but can be applied globally to assist in securing food supplies.

The “early discovery stage” of R&D, often referred to as basic science, remains strong in the UK. We have recently seen significant strategic investment from the Biotechnology and Biological Sciences Research Council (BBSRC) to help in meeting challenges such as sustainably feeding the growing world population and finding alternatives to dwindling fossil fuels.

These projects, such as current work to develop the next generation sequencing techniques which will enable the provision of fine mapping to the level required as a knowledge base for the plant breeding programmes of the future (7). These projects

may seem a long way from the day to day practicalities of farming, but they are a vital stage in the R&D process.

However, the general trend in the UK and worldwide since the 1980s has been for a substantial cut in publicly-funded agricultural science. This has been particularly noticeable in the near market applied sciences and in the translation/demonstration of research applications, which are critical steps in taking ideas through to commercialisation.

This has been frequently referred to as the fracture in the “discovery pipeline”, an issue noted in numerous reports including the (see: All Party Parliamentary Group on Science & Technology in Agriculture report of 2010 (8) and the NFU’s own Why Science Matters for Farming report of 2008 (9)).

More emphasis needs to be placed on taking the results of basic research and turning it into actual products, technologies and practices that can be applied by farmers and growers on a commercial scale.

This includes more independent applied research to ensure we retain the key skills. Many smaller research groups provide this vital function of applying fundamental knowledge to practical application, yet rarely benefit from core funds to help underpin their skills, facilities and services.

In the current financial environment, spending, even on such vital areas of research, is significantly constrained. So there is a need for a re-balancing of public funds and for Government to urgently explore ways this area can be supported through new funding models. These may well be a hybrid of public and private core funds.

There is also a need for Government to take a role in supporting research where there is market failure. An example is the development of plant protection products for minor crops, such as common field vegetables. Following the EU review of available products there are notable gaps in the armoury of those available for use in some minor crops in the UK.

The high costs, and long run-in times for the development of new products, combined with a relatively small crop, reduce the commercial attractiveness for private sector investment.

To put this into context, a briefing from the Fruit and Vegetables Task Force (10) on the approvals process for plant protection products stated that the registration process of new products can take on average about 5 years and cost between £200,000 and £2 million for biological products, with estimates from agri-chemical companies suggesting even greater costs and timescales in the region of 10-15 years for chemical pesticides.

There is no Government funding for research into minor uses of herbicides and the UK spends less than any other European country in this area. This means that in the UK the cost of finding solutions to pest and disease control for small area crops is already largely borne by growers through industry levy bodies.

As funds for research are relatively scarce, the agricultural industry needs to be better at articulating what its priorities are so that we see research effort and resource focussed in areas where substantial advancements could be collectively achieved and move away from the disjointed and scatter-gun approach that currently prevails.

Rather than perpetual 3-year short-term projects that currently prevail there is also a need for long-term programmes which require a long-term strategy led by Government, but in cooperation with industry and science against which these long-term programmes can be aligned.

There have been various reports (8) in recent years from which research priorities with reoccurring themes can be identified. The list is not in any way meant to be exhaustive, but it high- lights some of the key areas where collaborative research focus and translation effort could yield worthwhile results (Table 1).

The structure of agriculture can also provide a barrier to the uptake and commercialisation of research.

As presented in our evidence to the recent Science & Technology Select Committee inquiry (12), discounting the very smallest farms, 96% of England's agricultural output is generated by about 56,000 farm businesses. These cover many different sectors with a variety of issues and commercial opportunities.

This fragmentation presents a significant challenge for intermediaries to 'take' commercialisation to the farm gate. This is compounded by the fact that despite an instinctive drive to innovate and experiment, many small farming businesses are often time and resource poor giving them little opportunity to explore commercial application of new R&D technology.

The Technology Growth Report: How to Unlock Sustainable Growth in the UK (13) attempts to identify common challenges and solutions across similarly diverse industries and there may be lessons to be learnt from this to drive further action (14).

Getting more from existing knowledge to improve management, be it understanding soils, optimising water use, improving rotations, or modifying feeding regimes is vital.

Yet, one of the greatest challenges for the agriculture industry is securing the application of knowledge and best practice and strengthening both the science-push and the market-pull for research.

At the moment, knowledge exchange is essentially market driven; many of the best farming businesses are taking advantage of a wide range of consultants, including agronomists and nutritionists, to perfect business techniques.

There is significant opportunity to determine how public/private partnership could work better in this vital area by aligning the delivery of publicly funded research with the advisers who are presently visiting farms. Moreover, the challenges that a purely demand led approach creates, in terms of lack of acceptance and inadequate provision of advice concerning environmental sustainability.

These are key points which have already been identified in the House of Lords European Union Committees report ("Innovation in EU Agriculture") (15).

The Agriculture and Horticulture Development Board (AHDB) has a pivotal role here as one of the key players in the provision of knowledge transfer directed at helping agriculture and horticulture be more competitive, profitable and environmentally sustainable.

The development of a better partnership between industry sectors, existing industry initiatives and research providers will lead to an improved rele- vance of research.

2. A better structured science framework.

There is a growing recognition in the business community and at least in parts of government that a complete laissez-faire approach to market economics will not deliver sustainable eco- nomic growth.

This does not mean abandoning market principles, but it does mean accepting that markets are imperfect, subject to volatility, distortion and abuse.

Financial instability, supply constraints, low stock levels and extreme weather events have all combined to make volatility more pronounced since 2007. More significantly, farmers' exposure to volatility has grown owing to globalisation and reductions in price and market support through successive reforms of the CAP.

Can volatility be mitigated? Yes it can. Many arable farmers have taken advantage of financial instruments to hedge currency, output prices (through futures and options) and to some extent inputs.

It would make sense to create a climate in which these tools become more widely available to farmers in all sectors. This indicates that liquidity in commodities exchanges should be maintained.

While there may be a case for regulation of agricultural commodities trading, it is important that demonization of financial 'speculation' avoids stifling the development of financial instruments in sectors such as dairy products.

Following two Competition Commission enquiries there has been some acceptance that the nature of the grocery market in the UK is imbal- anced. Abuse of market power by major grocery retailers risks undermining long-term consumer choice by stifling innovation amongst farmers and manufacturers.

The UK Government has now tabled legislation that will introduce an Adjudicator to police the existing legally binding Groceries Supply Code of Practice that should be a major step forward in addressing abuse of power and thus create a more stable, predictable climate in which farmers can invest.

Further steps are necessary to prevent other food businesses from abusing market power. The best example is the dairy sector where milk processors use exploitative terms and conditions in milk contracts to adjust prices on a whim with no certainty or predictability. Regulation can play a role in subtly rebalancing market power in a way that shares risk more equitably.

Ultimately, the food industry must move from a culture of short-term exploitation to one of long-term partnership. In recent years several major retailers have taken steps to forge stronger relationships with British farmers through development groups, longer-term contracts and even specific pricing models.

These approaches come in response to consumer demand for local food, as well as a desire to drive the environmental sustainability agenda through the supply chain. In future, it would appear to be increasingly in the interests of major retailers and food service companies to secure supplies close to home to help manage the risk that volatility and insecure supply may pose to their businesses.

The challenge is to move away from the short-term imperatives that tend to drive business performance. Whilst there has been recent political pressure from all sides for business to avoid a short-term attitude there is little visible sign that the performance of retail buyers is measured by anything other than quarterly profit and loss.

A culture change across business and the shareholders that invest in major companies will be essential to create a climate in which farmers can invest for the long-term.

3. The Common Agricultural Policy

A discussion of the most fitting regulatory and policy framework to foster sustainable intensification is not possible in this review. However, a fuller assessment requires a comment on the reform of Europe's Common Agricultural Policy.

While market forces are increasingly shaping the direction of UK agriculture, the CAP will continue to wield significant influence on the wellbeing of the sector; and this must lead to a fair treatment for UK farmers. While the future of the Eurozone may be shrouded, commitment to the CAP and supporting farm incomes across Europe remains strong.

Progressive reform, moving farmers away from dependency on direct income support is desirable, but this must be achieved evenly across the EU, not through an experiment on UK farmers.

The risk is that the direction chosen by the European Commission may entrench support rather than help farmers to become more competitive.

Some elements of the Commission's proposals run the risk of undermining the competitiveness of parts of European farming, by obliging farmers to set-aside productive land or to grow three crops where two would be agronomically and economically better.

The tendency in the UK is to see the CAP as a necessary evil (or just plain evil in the eyes of Treasury economists). Yet the CAP can be a powerful and positive policy instrument in achieving two specific objectives: fostering investment and delivering ecosystem services.

The CAP plays an important role in facilitating on-farm investment in physical and human capital. It does this not only through rural development programmes but also through direct payments that provide a degree of income stability and a hedge against volatility, as well as a means of leveraging commercial lending from banks.

It is also right that the policy should foster sustainable production. Incentivising and encouraging the right management techniques in the right locations through targeted measures is a better approach than blanket measures that may not secure the desired outcomes.

One particular opportunity and challenge for the CAP in terms of driving innovation will be to make the most effective use of Rural Development Programme funds, and how they interact with the results of research generated under the proposed new EU Research and Innovation Framework funding stream for 2014-2020, Horizon 2020.

£4.5billion has been specifically ringfenced for food and agriculture R&D. This doubles the funding allocated for the previous seven year programme and it is critical that farmers benefit from this investment.

The new European Innovation Partnership (EIP) on Agricultural Productivity and Sustainability will have a network function to link related actions of Rural Development Programmes and the research funded under Horizon 2020. In particular the EIP aims to catalyse coordination and foster sustainability and to link with the growth and sustainability objectives under Europe 2020.

It is hoped that the European Innovation Partnerships (EIP) will help in bridging the gap between scientific research and the implementation of research results by farmers and agribusiness.

The Commission's ambition is for the two instruments (i.e. Horizon 2020 and the Rural Development Programme activities funded under CAP) to work in tandem. This will not be easy given the very different sys- tems of governance of these two funding steams.

There are potentially very positive opportunities for industry to progress the uptake of research on farm. However, involvement of farmers in the research process from the start and a significant improvement on the bureaucratic system of previous EU Framework Programmes, will be crucial to the success of the new concept.

Conclusion

Agriculture and the food chain are unlike industries which can run and refine prototypes endlessly.

James Dyson famously had 5127 failed prototypes before producing the bagless vacuum cleaner (16). The very nature of agriculture means that it is influenced by the natural environment over which we have little control and this will impact on the uptake and success of research and development.

It is often said that there is no quick fix to the food production challenge. We need to identify and initiate the necessary agricultural research immediately to allow for the time needed to do the basic research, develop and apply ideas and ensure uptake by the industry.

The UK Cross-Government Food Research and Innovation Strategy quoted extended lag periods of 15 – 25 years between research expenditures and adoption at farm level (17). Breeding programmes for some fruit crops can take even longer. The year 2050 seems outside the lifespan of most of the practitioners in agricultural policy.

Perhaps this is why the current debate appears to be going around in circles? Yet by 2025, there will be an additional billion people on the planet including an extra 500 million in Africa (18).

A long-term, strategic view on scientific research is needed now so we are well-placed to meet the future challenges to agriculture.

Recognition of the challenges ahead has prompted science-based initiatives and groupings.

It is undoubtedly positive that scientific research is considered to be of increased importance but these approaches must be coherent and compatible. There is an inherent risk that this serves to perpetuate the talking but leads to hesitation when it comes to action.

In short, we need to put the strategy back into UK agricultural science so that research programmes can be aligned.

Much of UK Cross-Government Food Research and Innovation Strategy (17) strategy recognises the importance of strengthening existing initiatives and promoting a more collaborative and strategic approach to ensure long-term sustainability of national research capacity.

However, it fails to address some of the fundamental challenges, such as how to facilitate better collaboration between the public and private sectors, reduce bureaucracy, long timescales and rebuild research capacity in critical areas.

The industry needs to articulate better to Government what it needs. This is why the NFU is supporting an initiative funded by the Technology Strategy Board to pull together sector-based reviews and provide a concise, coherent and integrated assessment of the R&D needs of the land-based industry up to 2030.

It would be naïve to believe there won't be conflicts, not just in the compromises and trade-offs that may exist between environmental and production ambitions, but also between individual farming sectors.

That is why the Government has a pivotal role to help facilitate developing and driving this strategy.

The Government's Natural Environment White Paper (19) has taken the first steps by announc- ing its intention to bring farming and environmental stakeholders together to identify how an increase in production can be achieved at the same time as improving the environment.

The resulting Green Food Project (20) is due to report in July 2012. It is hoped that this will start to identify not only the clear advantages and ten- sions that exist in achieving these two aims, but also, what actions must be taken by industry and policy makers to secure sustainable intensification of UK agriculture.

Increasing food production will be a challenge for farmers across the world. A critical part will be for industry and government to prepare the public for the actions that must be taken to achieve sustainable intensification and the consequences of inaction.

The UK's key public funders of food- related research are working together under the Global Food Security programme (21) to meet the challenge of providing the world's growing population with a sustainable, secure supply of nutritious food from less land and using fewer inputs.

Part of the programme includes public engagement on topics of high interest such as production/economics of farming; use of agrochemicals and new technologies; competing definitions of sustainability; equity and other ethical issues around access to food; the role of consumer choice, and the need for healthy diets and safety of food supplies.

It is clear that engagement and dialogue will be essential for building trust and confidence in the science within the programme.

It is important to raise awareness of the contribution farmers make to the economy, the environment and to the security and quality of the nation's food. Above all, we must ensure that it is a step that faces us and not a leap.

We need to make continual progress, put the necessary building blocks in place and face it with the support of our suppliers, customers and policy-makers.

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Figures

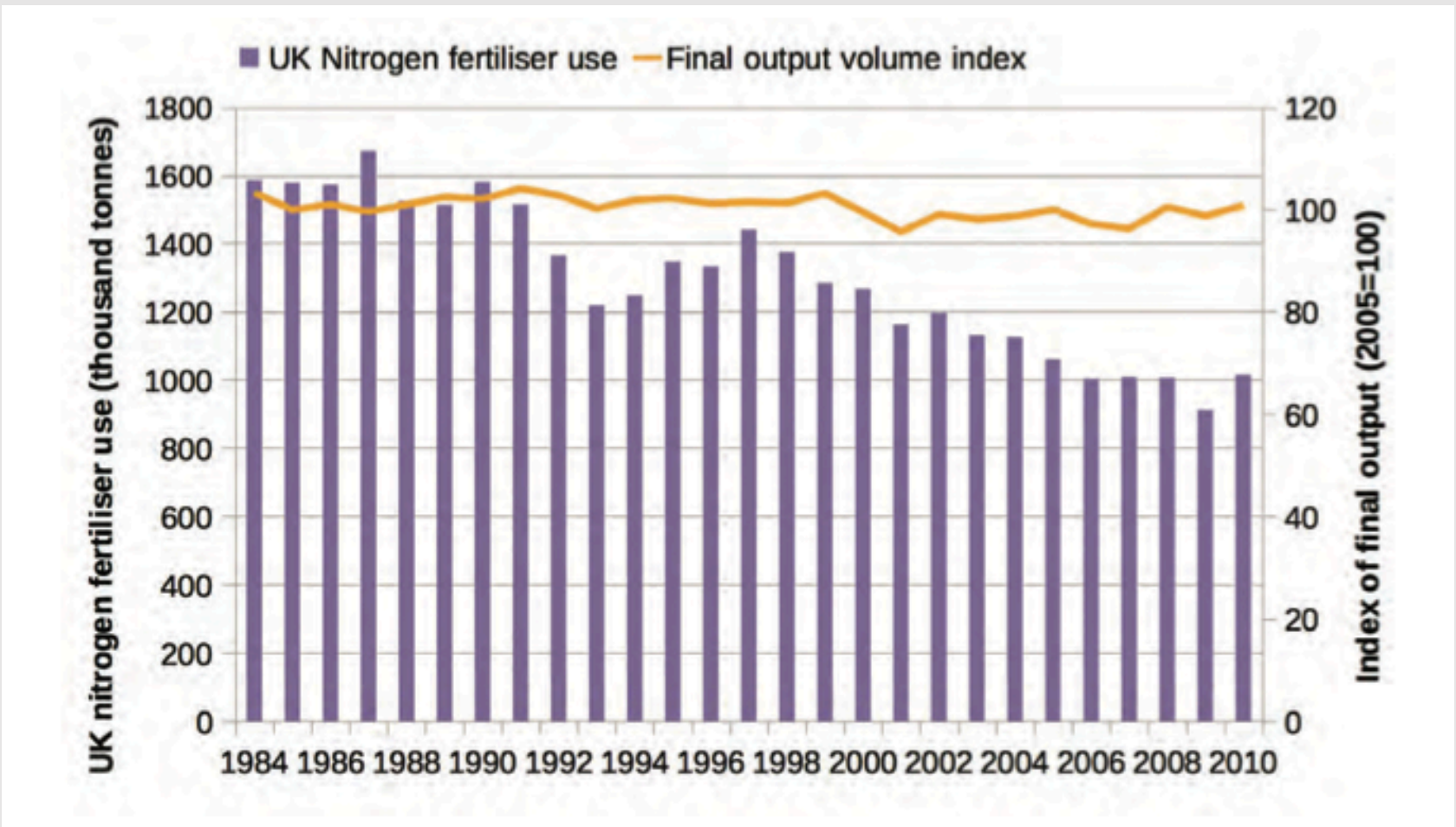

Figure 1.

Figure 1: UK nitrogen fertiliser use and output volumes 1984-2010. Source: Defra Agriculture in the UK 2010 (chart 13.4 & table 10.1)

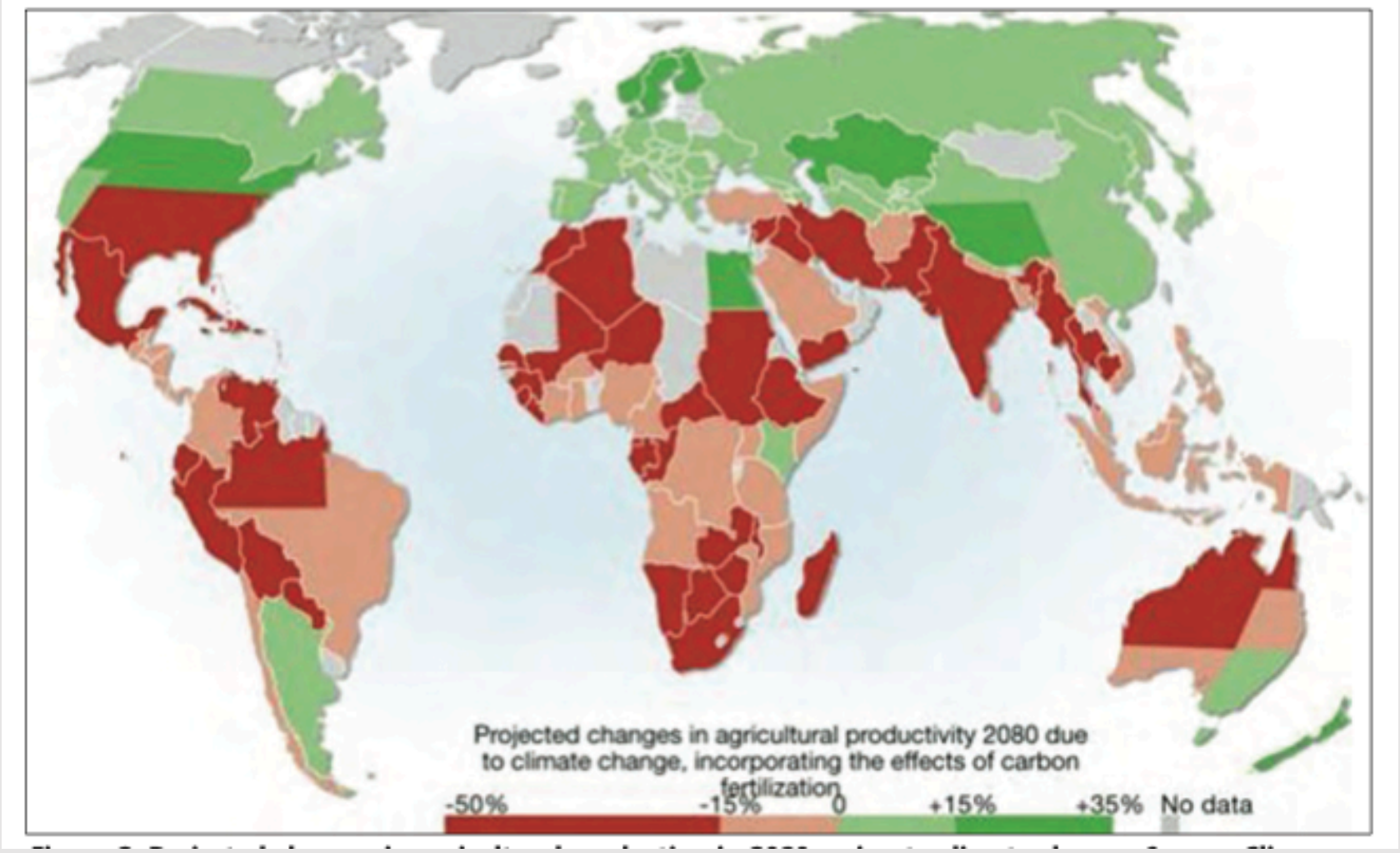

Figure 2.

Figure 2: Projected changes in agricultural production in 2080 owing to climate change: Source: Cline. 2007. Projections assume a uniform 15% increase in yields from the fertilization effect of rising CO2 in the atmosphere on some plant species.

Key research priorities	The opportunities and challenges
Closing the yield gap	British varieties can yield 15 to 16 t/ha in New Zealand as opposed to 10-12 t/ha in the UK so the genetic capacity is there indicating gains could be made agronomically by improving current sub-optimal management. Additional gains may be achieved for example through breeding programmes to improve the efficiency of photosynthetic pathways using the same amount of sunlight or by increasing nutrient use efficiency. Pre-breeding research needs to include all major crop species.
Future climatic stresses	Plant breeding for improvements in water uptake (e.g. root structure) and water conservation (e.g. leaf structure and behaviour during stressed conditions to minimise evaporation rate) to cope with the more extreme rainfall patterns in the future.
Optimising inputs through precision farming technology and advances in agricultural engineering	All areas of agriculture and horticulture continue to benefit from advances in agricultural engineering, such as spray nozzle development which improves product targeting and reduces spray drift. GPS technology for mapping and predictive modelling/smart plants/precision techniques. Optimising the spatial and temporal placement of products (both nutrients and plant protection products) has the potential to make more efficient use of costly inputs. A reduction in energy use, soil damage and labour costs through new controlled traffic systems for farm machinery.
Continued improvements to animal feed and nutrition	Maximising outputs but minimising environmental impact of livestock systems such as reducing methane emissions: by continued advances in breeding techniques and improving livestock nutrition, by improving the quality of supplementary feeding and of grassland leys and by precision techniques in dietary management and monitoring.
Better detection and avoidance of animal disease	Animal diseases have damaged the livestock sector over the last two decades. Some recent research has identified a short window where Foot and Mouth Disease can be detected before it becomes infectious and so spread rampantly. Mastitis reduces dairy cow welfare and milk quality, costing the UK dairy industry around £200 million per year. Further investment into the causes and pathways of infection and selection for resistance to mastitis and development of vaccines could help reduce occurrence. Remote sensing technology may also contribute to better animal monitoring for health and welfare.
Better detection and avoidance of plant disease	Recent development in plant breeding such as the blight (*Phytophthora infestans*) resistant potatoes and aphid repelling wheat may contribute to a reduction in the need for using plant protection products Agricultural engineering and remote sensing technologies may help with the modelling of outbreaks of crops pests and diseases and aid early detection and control.
Fixing nitrogen	Incorporating nitrogen-fixing capability into non-leguminous plants is a theoretical possibility, and experiments have brought this a step closer by providing a better understanding of underlying mechanisms (11)
Optimising the nutritional benefits and quality attributes of food	Increasing tonnes/ha or energy/ha has been a goal – but maximising nutritional value/ha of food is also a necessary goal. This could include breeding programmes to introduce human health benefits such as additional nutrients or improving the post-harvest processing characteristics and shelf life contributing to reducing waste in the food chain.
Intercropping to enhance pest and disease control	There are lessons to be learnt from the organic sector when it comes to managing pests and predators and making ecosystems work in our favour. Improvements in our understanding of the relationships between soil, pests and diseases gained through organic systems have a contribution to make to complement new technology.
Explore cross over between sectors	For example, novel opportunities to use the waste from one sector as a valuable input for another.

Figure 3.

Table 1: Priority areas for collaborative agricultural research and translation

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1st March 2013

Comments