Crop Production Technology:

The Effect of the Loss of Plant Protection Products on UK Agriculture and Horticulture and the Wider Economy

ANDERSONS

THE ANDERSONS CENTRE

aic agricultural industries confederation

NFU

Crop Protection Association

EXECUTIVE SUMMARY

- Plant Protection Products (PPP) are subject to rigorous testing and safety assessments. But, the regulatory environment has become increasingly challenging to established PPPs and product innovation.
- Three main policies threaten the availability of PPP;
  - the approval process at EU level
  - the implementation of the Water Framework Directive at national level
  - restrictions on neonicotinoid seed treatments.
- At present, no definitive list of PPP under threat from the various policies exists, in part due to uncertainty in the way regulations will be defined and interpreted. This project identified that 87 of the 250 active substances currently approved in the UK could be threatened by the cumulative effects of these policies.
- In practice, there is a sliding scale of threat. It has been assessed that 40 active substances are highly likely to be lost or restricted. This includes 10 insecticides, 12 fungicides, 16 herbicides and 2 molluscicides. The active substances deemed likely to be withdrawn or restricted include important products for UK crop production.
- Loss or restricted use would make control of weeds, disease, and pests in key UK crops far more difficult. Furthermore, as reliance is on fewer PPP, resistance build-up will become more likely.
- Loss of PPP will result in lower overall yields. Predicted yield decreases range from 4-50% in the crops studied, based on the effect of losing PPP classified as ‘high’ likelihood of being restricted or not gaining re-authorisation.
- UK cropping patterns would change, with an increase in spring cropping, fallow and temporary grass. Overall food output from UK farming and horticulture would decline. Although it is assumed that the global market would offset the shortfall, the effect would be to make the UK more reliant on food imports and so reduce self-sufficiency.
- Domestic production of some ‘iconic’ British foods such as frozen peas, apples and fresh carrots would be severely curtailed.
- The structural change in UK crop production would alter farming costs as seed, fertiliser and PPP uses all shift and greater reliance is placed on mechanical and hand weeding.
- A reduction in home-grown cereal output would lead to rising livestock feed costs.
- Modelling all the changes sees UK agriculture’s Gross Value Added (GVA) fall by c. £1.6bn per annum – a drop of 20% on the 5-year average (2009-2013).
- UK farming profit (Total Income from Farming) drops by £1.73bn in monetary terms, which equates to a 36% drop in overall profits. These figures are based on a realistic assessment of the risks of losses of PPP, not a worst-case scenario.

- Declining profitability will cause further structural change. In general, less efficient producers will exit the sector and farming operations will, on average, become fewer and larger.
- The impact of losing key PPP goes wider than agriculture. Farming provides the raw materials for the wider agri-food sector which makes up over 7% of the total UK economy. As a result, the food processing and manufacturing sector would decline over time and potentially lose around £2.5bn of GVA. The impact on the associated workforce would be job losses of 35,000 to 40,000.
- The agricultural supply industry, including wholesalers would be hit hard with a loss of £0.28bn in GVA and job losses of 3,500-4,000.
- The UK's role as a major centre for PPP research and development is threatened by legislative uncertainty. This not only means that better and safer alternatives are not being developed, but it also threatens investment in this high-tech sector of the UK economy.
- As the UK is a relatively wealthy country, purchased imports could make good any shortfall in domestic production. However, food costs are likely to rise for consumers. While not popular with most of the UK population, it would seriously affect up to a fifth of the population who already suffer food poverty.
- There is a moral question of imposing rich-world production standards when some 842 million people globally do not have enough to eat. There is a strong argument that Europe, with its favourable soils and climate, should be optimising output (sustainable intensification).
- Alternative production systems and technologies are often cited as ways of ensuring sufficient food production with less (or no) reliance on PPP. Whilst making useful contributions, these cannot fully replace PPP at the current time.
- The conclusion must be that the current direction of policy in the area of PPP is likely to lead to considerable economic and social losses, with the gains, at best, uncertain or minimal.
- Any policies should be science-led, and the assessment of risks undertaken on a proportionate basis. This will ensure a thriving agricultural sector and safe food for the UK population in future.

CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

The UK agricultural industry faces a threat to its productivity through the loss of key plant protection products. This is a result of legislation resulting in the withdrawal of existing active substances and restrictions of the development of new pesticides and plant protection products.

Crucially, the threat is not from a single source, but from multiple pieces of legislation. A key feature of the report is that it looks at the effect of legislation 'in the round'. Although the economic costs of one policy may be relatively manageable in isolation (and individual cost-benefit analysis may support this), the effect when combined with other overlapping policies is likely to be far more profound.

The interaction of regulatory and commercial pressures is looked at. As the cost of gaining approval for a product increases, then fewer products will have the potential market returns to cover these. These issues are already contributing to a lack of new products in the pipeline for UK and European farmers.

1.2. APPROACH

This report is based on the best available information. Where possible, the basic data will be based on publically-available, referenced, information. There will be a requirement for a number of assumptions to be made in quantifying the impact of the loss of active substances and products. These will be clearly stated and cross-checked to ensure a robust result. Although the research will be comprehensive and detailed, the aim is to summarise it in a number of 'high-level' figures that will provide an overview of the likely effects.

The project has been undertaken primarily as a desk-based research exercise. It has gathered quantitative data about UK agriculture from a number of sources and analysed these to arrive at conclusions. This has been supplemented with interviews with a number of key individuals within the crop protection and farming industries.

1.3. STRUCTURE OF THIS REPORT

The following Chapter provides a brief summary of the legislation that is threatening the continued use of some key plant protection products.

Chapter 3 outlines the active substances that could become unavailable as a result of the policies. In Chapter 4 the effect of these losses on key crops is estimated. Chapter 5 gathers the data for individual crops together to arrive at the effect on the UK farming industry as a whole. This is then extended to look at the wider economic effects in Chapter 6.

Chapter 7 looks at ways the industry might mitigate some of the worst effects of the loss of products and whether there are realistic alternatives. Finally, in Chapter 8, the conclusions bring the various strands of the report together.

1.4. Definitions

Within this report the chemical that provides protection to the plant is referred to as a ‘pesticide’ or alternatively the ‘active substance’. Whilst not used in this report, an alternative term often used is ‘active ingredient’.

A Plant Protection Product (PPP) is the formulation that is used in agriculture or horticulture. It may be made up of one or more active substances. ‘Product’ is used interchangeably with PPP.

‘Pests’ is used to mean all weeds, pests and diseases.

Insect is also used generically to refer to all aphids, moths, flies, midges, and all arthropod pests including mites, centipedes etc.

2. THE LEGISLATION

2.1. BACKGROUND

There are a number of regulatory issues that are coming together to generate a significant threat to many plant protection products (PPP). Much of the legislation originates at European Union (EU) level, but there are additional issues associated with the way in which rules are interpreted and applied in the UK.

The science and regulatory environment can be complex. The following section provides a 'layman's' guide to the issues. It provides a succinct summary of some of the policies impacting on PPP. It does not aim to be fully comprehensive and full references are provided so that further reading is possible for those that require more detail.

The main policies that are addressed are;

- Active Substance Approval – Regulation EC 1107/2009
- Water Framework Directive (WFD) 2000/60 / EC (and related legislation such as the Drinking Water Directive and the Groundwater Directive)
- Conditions of Approval of Neonicotinoids, Regulation 485/2013
- UK-specific implementation and guidelines

2.2. PESTICIDES APPROVAL

2.2.1. History – Directive 91/414/EEC

Before the 1990s, individual Member States were responsible for approving pesticides in their own countries. Directive 91/414/EEC was implemented in 1993 to harmonise the approvals process across the EU. Any active substance had to meet specific criteria on safety and efficacy before it could be placed onto the European market.

Prior to Directive 91/414/EEC there were around 1,000 active substances authorised in at least one Member State[1]. All existing approved substances had to be re-approved under the new Directive. This resulted in around 230 pesticides still having approval in the EU by 2009. The approved active substances were placed on 'Annex I' to 91/414 EEC.

The number of active substances lost under 91/414/EEC looks dramatic – over three-quarters lost. However, most of the substances which did not gain Annex I approval were simply not supported for application (being uneconomic or superseded) rather than being put forward and then being judged unsafe. This legislation had the effect of significantly reducing the active substances on the approved list. Only those where the potential market justified supporting the pesticide through the approvals process remained. Therefore, any loss from this new baseline meant that important substances were now being lost, which was not always the case in the past.

2.2.2. Annex I Products

Active substances judged safe under the criteria of 91/414 EEC were placed on the Annex I list for a period of 10 years. Whilst the EU is responsible for approving active substances, Member States have responsibility for the authorisation of specific PPP containing those substances. Member States can only authorise products containing pesticides listed in Annex I for supply, sale, storage and use.

After the 10 year period, active substances renewals are required at EU level for a further 10-year period. Many commonly used active substances are due to be considered for re-approval in the years through to 2020.

The renewals are grouped into batches. The Annex I Review number 1 (AIR-1) saw seven active substances successfully renewed under Regulation EC 737/2007[2]. At present AIR-2 has 31 active substances under review. Decisions on this batch are due by the end of 2015. Finally, there is an AIR-3 group of 150 active substances that are just starting the re-approvals process. Generally, once an application for re-approval has been made, there is an extension of the expiry date for products containing it whilst the application is processed.

2.2.3. Updated Legislation – Regulation EC 1107/2009

A new 'Thematic Strategy' on The Sustainable Use of Pesticides was adopted by the European Commission on 12th July 2006[3]. This has resulted in two main pieces of EU legislation;

- Regulation 1107/2009 on the Placing of Plant Protection Products on the Market[4]. This replaces Directive 91/414/EEC and came into force in June 2011. It has more stringent requirements for active substance approval (see below). It covers both the approval of new active substances and the renewal of existing substances. AIR-2, AIR-3 and any subsequent re-approvals will be conducted under these new requirements
- Directive 2009/128 on the Sustainable Use of Pesticides[5]. This governs the use of pesticides once they have been approved in the EU

Active substances will not be approved (or re-approved) under 1107/2009 if they are classified as having the following properties;

- Mutagenic
- Carcinogenic or have Reproductive Toxicity (unless the exposure is 'negligible')
- Endocrine Disruptors which cause adverse effects (see below for more details)
- Persistent Organic Pollutants (PoPs)
- Persistent Bio-accumulative and Toxic (PBT)
- Very Persistent / very Bio-accumulative (vPvB)

These are known as the 'cut-off criteria'.

There is a derogation allowing pesticides to be approved for five years in exceptional circumstances, even if they fall within the above criteria, if they are necessary to '*control a serious danger to plant health that cannot be contained within other means*'. Asulam, an important herbicide for bracken control in the uplands, had gained approval for use under this derogation because there are no alterative products.

The following sections look at specific issues arising out of the 1107/2009 legislation.

2.2.4. Risk and Hazard

The key change brought about by the introduction of new legislation (1107/2009) is the move from a risk-based to a hazard-based approvals system.

Under the provisions of 91/414/EEC, even if the properties of a pesticide deemed it to be classified as hazardous (e.g. carcinogenic) the way it was actually used would be looked at. Exposure when correctly used was considered, the risk was assessed and, if not considered unacceptable, the pesticide could be registered for sale. Under the new 1107/2009 rules, any level of exposure to a substance that is deemed as hazardous is considered unacceptable. It is the intrinsic properties of an active substance that are now key.

This is a fundamental change in approach. An equivalent situation might be the banning of coffee because it contains caffeine. Caffeine is a stimulant drug and harmful if taken in a sufficient dosage – it is therefore hazardous. However, as the way it is actually used in products such as tea or coffee provides a very small exposure (dose) it has been consumed by humans for thousands of years with very little or no risk. Paracelsus, a 16th century scientist regarded as the founder of the study of toxicology stated 'dosis facit venenum' *– the dose makes the poison.*

2.2.5. Guidance Documents

Those companies wishing to register an active substance are required to submit a 'dossier' proving that all the necessary risk assessments have been undertaken. This dossier is assessed by a Member State of the EU (acting as 'rapporteur'). The European Food Safety Authority (EFSA) provides technical guidance on how these risk assessments should be undertaken.

The guidance criteria continue to proliferate; there are now 19 guidance documents either in place or in preparation. Examples include the Wild Bird and Mammal Guidance which has significantly increased regulatory costs. The proposed Bee Guidance is estimated by the industry to potentially impact on 95% of all active substances. It would require high investment in new studies which, with current research capacity, would take 24 years to conduct. It can be clearly seen that the way the guidance is implemented raises costs and lengthens timescales for approvals.

The guidance itself is also becoming more conservative with consequent restrictions on rates and timings.

When the guidance criteria are revised, the rules are often applied to pesticides already within the approvals process. This can see active substances lost as, for example, thresholds are changed in the guidance document. This creates an uncertain regulatory environment.

In certain cases, pesticides already approved and on Annex I can lose their approval (or face additional restrictions) if EFSA changes its guidance. This is what happened with three neonicotinoid seed treatments (see Section 2.4).

2.2.6. Candidates for Substitution

Under 1107/2009 some active substances may be approved, but deemed to be 'candidates for substitution'. This means that products containing these pesticides may have their approval removed if a safer alternative is available to control a particular weed, pest or disease problem on a crop. For this to happen, the alternative product must have a significantly lower risk to human health or the environment and there must be historical experience in using the product. Candidates for substitution will only be approved (or re-approved) for a reduced, seven year, period.

The legislation requires a comparative assessment to be undertaken on any ***product*** containing a candidate for substitution. This looks at the specific use or uses the PPP is put to. As product uses vary between Member States, this analysis has to be undertaken at the Member State level. What this means is that an active substance that is a candidate for substitution is unlikely to lose its approval entirely – but the uses to which it can be put may be restricted.

This comparative assessment has the potential to limit the number of products available to control a weed, pest or disease problem on a crop. Removal of a specific major use may lead to the product being withdrawn for commercial reasons and so any use of the product being unavailable. There could be a 'culling' of those deemed more hazardous in favour of a limited number of 'safer' alternatives. A PPP containing a 'candidate for substitution' may be retained if it can be demonstrated that it is required for resistance control, economic reasons, or 'minor uses'. However, this element of Regulation 1107/2009 is relatively new, so it remains to be seen what long-term effect it has on the number of active substances and control mechanisms.

The definitive list of pesticides that are candidates for substitution was due to be published in December 2013. This has not yet been done. The EU Commission contracted the Food Chain Evaluation Consortium (FCEC) to undertake preparatory work on compiling such a list. The FCEC report[6] was submitted in July 2013. Although, this report has not been formally published, it has been made available to Member States' Competent Authorities. It is not a single list, but through combining the multiple lists, studies[7] have calculated that around 100 substances *could* be candidates for substitution.

2.2.7. Endocrine Disruptors

An Endocrine Disruptor (ED) can interfere with an endocrine (hormone) system in animals. The ED chemicals bind with receptors for hormones such as oestrogen and androgen and change how the body functions. The issue is wider than just pesticides, as many other products in the modern world have the potential to be endocrine disruptors – soya milk, plastics, and detergents. The effects are not always negative; HRT and the contraceptive pill work on the endocrine system for example.

The EU has a 'Strategy for Endocrine Disruptors'[8] which was adopted in 1999. Since then, much work has been undertaken in trying to define and list endocrine disruptors. This is still ongoing, with the latest research study[9] being published in January 2012 attempting to set out scientific criteria for the identification of endocrine disruptors.

On 19th February 2013 DG Environment of the EU Commission released a revised proposal for these criteria in a working paper; 'Revised Version of Possible Elements for Criteria for Identification of Endocrine Disruptors'[10].

This would establish a system with two categories of endocrine disruptors. Although not specifically stated, it is assumed that 'Category 1' EDs will not be authorised under Regulation 1107/2009.

At the time of writing, the legislation for defining ED criteria is still under discussion. The EU Commission has recently issued a public consultation on the criteria for identifying EDs[11].

2.2.8. Use and Restrictions

Even when a pesticide is approved at EU level, there may be restrictions placed on products containing it that make its use on farm impractical. An example of this is the product methiocarb. This has been widely used as a slug control product within slug pellets (especially on potatoes). The active substance is still approved, but the EU decided to withdraw approval for its use in slug pellets from mid-September 2014. This is due to the potentially hazardous effect on grain-eating birds that frequent farmland (this was a result of criteria contained in the Birds and Mammals Guidance document). Methiocarb's use in other situations, such as seed treatments, can continue.

2.3. THE WATER FRAMEWORK DIRECTIVE

2.3.1. EU Legislation

The Water Framework Directive (WFD)[12] (2000/60/EC) is EU legislation that requires all rivers, lakes, ground and coastal water to reach good ecological and chemical status. In addition, the Drinking Water Directive (DWD) (1998/83/EC) sets limits on the amount of pesticides and other chemicals that are allowed in drinking water. Finally, the Groundwater Directive (GWD) (2006/118/EC) sets out quality requirements for the protection of groundwater. DWD and GWD are 'daughter directives' of the WFD.

The DWD sets standards at tap of 0.1 microgramme per litre for any one pesticide active substance and 0.5 microgramme per litre for total active substances. To place this in context, this is 0.1 parts per billion, or the equivalent of one paracetamol tablet in an Olympic-sized swimming pool. It is effectively a proxy for zero residues. The standard is applied to all active substances and does not take their toxicity into account. A standard of 0.1 microgramme per litre also applies for groundwater.

In terms of the effect on pesticides availability, the WFD impacts in three main ways.

Firstly, a small number of chemicals that have the biggest impact on water quality are identified at EU-level. The 2008 Priority Substances Directive sets out the list of such chemicals. It has been updated by the 2013 Priority Substances Directive[13], and 45 chemicals are on the current list. Two categories of these are defined. Priority Hazardous Substances (PHS) are deemed to have the greatest threat. The use of these chemicals is to be phased-out. 'Priority Substances' (PS) have a lesser, but still significant, threat and Environmental Quality Standards (EQS) are mandated at EU level. Not all of the chemicals on the Priority Substances lists are pesticides, but examples of pesticides that do appear as Priority Substances are chlorpyrifos, isoproturon, bifenox and cypermethrin.

The EU Commission has also instituted a 'watch list' of chemicals. These are not on the official Priority (Hazardous) Substances list, but are those that are judged to be of possible concern for the future. Methiocarb has been placed on this list. The widely-used herbicide glyphosate was an initial candidate for the watch list but after analysis[14] was found not to be of sufficient concern.

Secondly, at Member State level, chemicals that have certain intrinsic properties and are used widely in that country are identified. In the United Kingdom these are known as 'UK Specific Pollutants'.

Lastly, Article 7 of the WFD requires that the quality of water intended for drinking should not be allowed to deteriorate from a baseline level and thus require additional treatment. Drinking Water Protected Areas (DrWPAs) which supply drinking water have been identified and the aim in these areas is to reduce the need for water treatment to remove a range of pollutants including pesticides. Whilst there is no specific 'list' of substances that come under Article 7, the Environment Agency (EA) has identified those active substances most likely to lead to an issue with Article 7 compliance. Currently, the ten most frequently detected by water company and EA monitoring (in order of frequency of detection) are metaldehyde, MCPA, carbetamide, mecoprop, propyzamide, clopyralid, chlorotoluron, 2-4D, isoproturon and glyphosate. *Isoproturon had been banned in the UK, but has recently been re-approved in a low-dose form for meadow grass control.*

The WFD is implemented in six year 'cycles'. The first cycle ends in 2015, and the second cycle runs from 2015 to 2021. The relevant authorities in the UK (see below) have begun drafting the programme of measures that will apply for the second cycle.

2.3.2. UK Implementation of the WFD

Implementation of the WFD is a devolved matter, so England and Wales, Scotland, and Northern Ireland each have their own regulations. The situation is further complicated by the fact that the WFD is being implemented on the basis of 'River Basin Districts' (RBDs) – simplistically the catchments of major rivers or groups of rivers. A number of UK RBDs cross national boundaries and some in Northern Ireland cross the international boundary with the Republic of Ireland.

River Basin Management Plans have been drawn up for each RBD and these are currently being updated for the next WFD cycle. These are due to be published in December 2015.

DEFRA's updated water quality standards for the 2015 to 2021 cycle, including standards for Specific Pollutants, have recently been published[15]. Of the previous 19 pollutants listed, six have been amended and ten added. Relevant ones in terms of pesticides are carbendazim, chlorothalonil, cypermethrin, diazinon (*although diazinon is not approved for use in the UK*), dimethoate, glyphosate, linuron, mecoprop, methiocarb, pendimethalin and permethrin.

2.3.3. Effect on Pesticides

Pesticides that may cause a risk to WFD aims being met can be dealt with in a number of ways.

At present, the farming and horticultural industry is engaging positively with the issue by taking voluntary measures. These include programmes such as the Voluntary Initiative (see www.voluntaryinitiative.org.uk), Campaign for the Farmed Environment (see www.cfeonline.org.uk) and the Metaldehyde Stewardship Group (see www.getpelletwise.co.uk).

These industry-led programmes are buttressed by schemes that incentivise growers to change their practices to enhance water quality. These include agri-environmental programmes funded by national Governments such as Environmental Stewardship, Glastir, Rural Priorities etc., although these have aims wider than improvements in water quality. Government also funds specific water improvement schemes such as the Catchment Sensitive Farming Scheme in England. Lastly, private sector bodies, mainly water companies, have implemented programmes in specific areas to encourage and in some instances compensate land managers for changing farming systems for the benefit of water. Such ‘payments for ecosystems services’ is an area of current interest to policy makers.

Should voluntary approaches not deliver the required results, then restrictions on the use of active substances may be imposed. This is discussed in more detail below.

In the past, fiscal instruments such as a ‘pesticides tax’ have been considered. This would have the effect of increasing the cost and hence limiting the use of the active substances deemed to be the most polluting. This approach seems unlikely to be adopted in the UK to date because it is perceived to be a blunt instrument and does not consider the way in which a pesticide is used.

Most of the existing PS and PHS have already been withdrawn in the UK. Some Priority Substances do remain authorised however, a notable example being chlorpyrifos. With the revision of the EU lists, some important pesticides have been added. These include bifenox and cypermethrin as PS, and quinoxyfen as a PHS. Any active substance on these lists is in danger of being withdrawn completely from use (in the EU and UK).

For active substances defined as UK Specific Pollutants, or those that may fall foul of the Article 7 rules, restrictions under national legislation can be imposed. This is unlikely to be a complete withdrawal across the UK. Restrictions could be implemented only in catchments and/or DrWPAs where there was an identified problem. Even within a catchment/DrWPA restrictions are more likely to take the form of limits on timings, dose rate or crop use. Such rules could even be imposed at a lower geographic level such as Parish, farm or even field if there was a local water quality problem.

This makes it somewhat difficult to model the possible future effect of the WFD on UK agriculture. The restrictions could be relatively ‘light-touch’ meaning that the majority of users are relatively unaffected, or they could be so severe that continued use of a pesticide is practically impossible. Also, some areas of the UK could face restrictions whilst others would be unaffected. If the affected areas are the only locations where the crops can be grown in the UK (i.e. on specific soil types) these approaches would effectively have the same impact as a total withdrawal. These issues are covered in more detail in the following sections.

The UK potentially has a bigger issue with water quality than many other EU countries due to the large proportion of its land area that is under-drained. This means that any product applied to farmland can move quickly via drains into watercourses before it breaks down in the soil. Surface run-off is also an important consideration though.

Water quality issues led to the loss of the widely-used cereals herbicide isopoturon (IPU) from June 2009. (Note, however, it was not specifically WFD legislation that resulted in the product not being re-registered, instead, the concentrations of IPU in watercourses meant it did not pass the UK's aquatic toxicity risk assessment.) Other active substances that have been lost recently due wholly, or partly, to their effect on water quality or the aquatic environment include atrazine, simazine and trifluralin.

2.4. Neonicotinoid Restrictions

On 1st December 2013 EU-wide restrictions on three neonicotinoids were imposed - clothianidin, imidacloprid and thiamethoxam[16]. The restriction comprises a two-year prohibition of use on the three pesticides as a seed dressing on flowering crops and spring planted cereals. The active substances can continue to be used as a seed dressing on crops such as sugar beet and winter cereals and as a foliar spray.

Neonicotinoids are insecticides derived from naturally-occurring plant compounds (nicotines). They stimulate the nervous system. Every organism will have a different reaction to specific chemicals. The 'No observable effect level' (NOEL) is the maximum dosage that can be taken before the chemical starts to have identifiable effects. The NOEL for neonicotinoids in mammals is far higher than that for insects, so a dose that is harmless to humans and other animals causes paralysis and death in insects.

Neonicotinoids are systemic which means that they are taken up by the plant and transported to all the tissues (leaves, flowers, roots and stems, as well as pollen and nectar). Therefore, if a seed is coated with a neonicotinoid dressing the resulting growing plant is protected from insect attack for 6 to 8 weeks. According to the HGCA[17] over 70% of the UK oilseed rape crop was treated with the three restricted neonicotinoids in 2012.

In the UK, five neonicotinoid insecticides are authorised for use; acetamiprid, clothianidin, imidacloprid, thiacloprid and thiamethoxam. Their main use in the UK has been the treatment of oilseed rape and sugar beet seed, although they are also used on cereals, maize and some horticultural crops.

Various studies have implicated some neonicotinoids in the decline of bee and pollinator populations. It is claimed that currently regulatory practices do not adequately assess the long-term and sub-lethal effects of such pesticides. However, the science is contentious and other studies have found no effect on bees when neonicotinoids are used in normal field situations[18]. Some parties maintain that the EU Commission has not reviewed all of the available data in reaching the conclusion to withdraw clothianidin, imidacloprid and thiamethoxam. A discussion of the science can be found in papers from Imperial College[19] and the Royal Society[20].

2.5. Other Issues

2.5.1. UK Administration

Whilst approvals for ***active substances*** are undertaken at an EU level, ***product*** (PPP) authorisations are conducted at a national level. In the UK the Chemicals Regulation Directorate (CRD) is the competent authority for PPP approval. The CRD is an agency of the Health and Safety Executive and operates on clearly laid-out standards[21]. Any application must be fully supported by data gathered through defined procedures.

As at September 2014, 250 active substances were contained in PPP approved for use in the UK[22]. *Note that this may seem high compared with the EU approved active substances figure outlined in section 2.2.1, but additional active substances have been authorised at EU level since 2009.*

Whilst product authorisation is a Member State activity, the EU has made efforts to harmonise and streamline the process. Europe is divided into three zones (the UK is in the 'central zone'). Member States in each zone can share assessments and mutually recognise each other's authorisations. In theory, this should avoid duplication and make product registration in Europe more efficient – if authorisation is gained in one country, then it would be valid in others in the same zone. However, the system is still relatively new and there is concern over the different interpretations that may be adopted by different Member State regulators. In theory, if one country rejected an application it is still possible to make an application in another Member State. But if the two Member States were in the same zone then the first rejection could well 'colour' any subsequent applications.

Furthermore, Member States can have additional national assessments (such as the UK-specific worker exposure model) which are carried out before an authorisation is granted. This can lead to products being authorised for use in other Member States but not in the UK, placing UK producers at a competitive disadvantage.

The CRD is also responsible for 'extension of authorisation for minor uses' (EAMU) in the UK. Minor uses are crops grown on relatively small areas or very specific uses on major crops. In these circumstances it is not always commercially viable for specific authorisations to be sought (supplying the necessary data under the application rules is an expensive undertaking). Very often, minor uses only have a limited number of products available. The CRD can extend authorisation for products approved on large-scale crops to cover such minor uses. Because the 'toolkit' of pesticides is so small for many of these 'minor crops', the loss of any active substances can have a significant effect.

Many minor crops rely heavily and in some cases solely on the use of EAMUs for plant protection. Often residue data is not available from the manufacturers and data is generated and funded by the growers. There are European Working Groups operating to coordinate trials across the European zones to avoid duplication of effort when generating data to support minor use authorisations. In May 2014 the EU agreed to set up a 'Minor Uses Fund' to try and improve access to pesticides. Farm Ministers have pledged €350,000 per year for the next three years to support the co-operation and co-ordination of research projects to improve the availability of products in this area. The European fund will be matched by Member States. However, the author has been informed that CRD have indicated that they can only contribute 'in-kind' which may not be permissible under the scheme rules.

In many policy areas the UK Government is accused of 'gold plating' EU regulation with over-zealous interpretation and enforcement of European laws. However, with pesticides regulation the CRD is generally regarded as taking a pragmatic, science-based approach to application of regulation and DEFRA also argues the case for science-led policy-making at an EU level. However, the UK is only one of 28 Member States and has limited influence on the EU-level decision-making process.

There are some areas where the industry feels that the interpretation of the rules at a UK level could be more flexible whilst still retaining safety. These cover the extension of products for minor uses (often in 'emergency' situations). The CRD is also perceived to be unwilling to take on risk mitigation measures and can be quite prescriptive in the final level of operational rules imposed. An example would be the use of protective equipment in preventing operator exposure.

CRD currently use a different worker exposure assessment to other Member States (UK POEM). Examples exist where a product is authorised for use in ornamentals crops with a handling interval which is longer than the harvest interval for the same product applied at the same rate in an edible crop – you can eat the crop before you can touch it.

2.5.2. Pesticide Residue Levels

EU Regulation 396/2005 sets harmonised standards for Maximum Residue Levels (MRLs) across the EU. The main issue in regulatory terms is the time that it takes to set MRLs for an active substance. This can delay authorisation and thus prevent access to useful PPP (often products that have already been used elsewhere in the world). It also adds cost to the authorisation process.

An example of where MRL may lead to restrictions is the product chlorpropham (CIPC). This is used as a sprout suppressant in potato storage. It is important particularly in potatoes for processing (frying) where the crop is stored at warmer temperatures. There is currently a stewardship group in place to ensure that MRL are not exceeded (see www.cipccompliant.co.uk/).

A number of retailers have grower protocols which impose additional restrictions on the use of PPP. Even when an active substance or product is authorised a retailer may choose not to buy produce treated with it. This is more common in the horticulture sector than for broadacre arable crops because many horticultural crops are presented to the consumer with minimal processing. As these restrictions are not specifically a regulatory issue they have not been covered in this report

2.5.3. Commercial Considerations

Achieving authorisation (or re-authorisation) for an active substance or product is a costly and time-consuming undertaking. The manufacturers of PPP are commercial organisations and have to provide a return for investors. Some products, even if they are 'safe' under existing rules, will not be put forward for authorisations, as the forecast profits from sales is not high enough to offset the high levels of investment in gaining authorisation. This topic is looked at in more detail in Section 6.3.

3. THREATENED ACTIVE SUBSTANCES

3.1. DATA SOURCES

The availability of a number of key active substances will be threatened by the policies outlined in the previous section. It is not possible to produce a definitive list, as some of the legislation (e.g. on endocrine disruptors) is still to be agreed. This section will set out those ingredients that seem likely to be withdrawn.

The list has been compiled from previous studies outlined below. It has been cross-checked and refined further through discussions with manufacturers, agronomists and academics.

3.1.1. Pesticides Approval Process

The starting point has been the analysis undertaken by the then Pesticides Safety Directorate (now the Chemicals Regulation Directorate) published in December 2008[23]. The list of pesticides contained in Annex 2C is widely regarded as the most likely scenario for losses of pesticides under1107/2009. This was supplemented by a further CRD study[24] published in January 2009 following additional information on Endocrine Disruptors.

With work continuing on the definition of Endocrine Disruptors, a further report for the CRD from WRc [25] used amended criteria to investigate a sample of UK-approved active ingredients (the impact of this was assessed in a follow-up project for the CRD by FERA[26]). The work found that nine substances were 'more risky' to mammalian health under the criteria – these are unlikely to gain authorisation. These have been characterised as having a 'high' likelihood of being lost in the following list.

Another 31 substances were found to be 'less risky', but could be withdrawn depending on the precise criteria used. These have been classed as having a 'medium' likelihood of being lost. The WRc study only looked at around a quarter of the active substances authorised in the UK, so the effects would be wider than shown. Where manufacturers have identified their own active substances as potential EDs, these have also been included. It must be stressed that this list is the authors own estimation, and cannot be regarded as definitive in the absence of final EU criteria.

3.1.2. Water Framework Directive

Any Priority Substances or Priority Hazardous Substances under the WFD are identified from Annex 1 of the EU Proposal for an Amendment to the Water Framework Directive as regards Priority Substances[27].

UK Specific Pollutants are from the document 'Water Framework Directive: Implementation in England and Wales' published in May 2014[28].

The active substances likely to be affected by Article 7 rules are somewhat more uncertain. These have been taken from the ADAS report on 'The Impact of Changing Pesticides Availability on Horticulture' of March 2010[29]. It is supplemented by the Environment Agency's 'WFD Compliance Picture – Pesticides Breakdown'[30]. This chart contains 29 active substances that have been detected in surface water drinking catchments in England. This includes such important pesticides as chlorotoluron, glyphosate and metazachlor for example. However, only five active substances are posing a risk to surface water in more than 20 out of a total of 560 DrWPAs in

England. These are metaldehyde, MCPA, carbetamide, mecoprop and propyzamide. The remaining active substances pose a risk in fewer than 3.5% of DrWPAs (i.e. less than 20 out of 560). For this reason, they have only been identified as having a 'medium' risk of having restrictions imposed. However, metazachlor has been included as having a high likelihood of restrictions despite only appearing in 8 DrWPAs. This is because it is one of the three key oilseed rape herbicides (along with carbetamide and propyzamide) and so there would be substitution issues if restrictions were not placed on all of these. Bentazone has been included as being at a high risk of being lost as there are specific problems with groundwater with this active substance.

3.1.3. Neonicotinoid

The three affected active ingredients are set out in Regulation 485/2013[31].

3.1.4. Other

At present, no losses from other sources have been identified.

3.2. Potential Active Substances Losses

Table 1 below sets out the pesticides that could be potentially lost as a result of current policies. The text below provides more detail on the structure of the list.

It should be noted at the outset that this list draws data from a large number of sources and attempts to present a realistic picture of the situation as at autumn 2014. However, as the previous sections have indicated, the legislation and definitions in many areas are not fixed. The list cannot be fully comprehensive, but aims to provide a firm basis for the agronomic and economic analysis that follows.

3.2.1. List of Active Substances Under Threat – Column 1

The active substances are grouped according to their function (insecticides, herbicides etc.). Those highlighted in blue can also be used as seed treatments. The active substances are presented alphabetically.

3.2.2. Why and Source – Columns 2 & 3

Column 2 ('Why?') sets out the policy or policies that are threatening the product. Where an active ingredient is being threatened by more than one policy, ***only the most serious threat is shown***.

The legislation potentially impacting on active substance availability is shown in Column 3 ('Source'). The asterix '*' denotes an active substance not assessed in the most recent WRc assessment[25] and where the earlier CRD report suggested a possible ban.

In most cases the list has been restricted to active substances used in the UK. However, a handful of substances that are not currently used have been included. These have approval for use in the UK and have often been used historically before superior replacement pesticides became available. They may have uses in the UK if other active substances are restricted. Therefore these substances have been included for completeness.

3.2.3. Likelihood - Column 4

This is a subjective judgement based on a reading of the available literature and discussions with the wider industry. With such high regulatory uncertainty, and definitions still to be set, it is reasonable that different conclusions could be reached.

The labels have been kept deliberately vague to reflect the degree of inherent uncertainty. To provide some guidance on these;

- High – assumed the active substance will be withdrawn in the short-to-medium term. *Although it is difficult to be precise on timings, it can be considered that this is the next 5 to 7 years.* All pesticides listed as having a 'high' likelihood of loss will be included in the economic analysis that follows
- High (by crop) – for example the neonicotinoid ban that only applies to certain crops
- High (catchment) – restrictions in certain geographic areas arising out of the WFD. *'Catchment' in this context also covers DrWPAs.*
- Medium – authorisations could be lost, but there is some uncertainty on this, or the disappearance may be over the longer-term

3.2.4. Area Treated - Column 5

This data comes from the Pesticides Usage Surveys conducted by FERA[32]. It shows the total arable hectares where an active substance was used in cropping year 2011/2012 (i.e. harvest 2012) – either singly, or in a mix. What is shown is 'super developed hectares' – simplistically, this is the area of crop multiplied by the number of applications of an active substance that the area receives. In this context, 'arable' means all the mainstream combinable crops in the UK, plus potatoes and sugar beet. It is designed to demonstrate the relative importance of each active substance listed.

Where the column states 'not listed separately' this means the substance is used in the UK on arable crops, but on small areas so that it is not picked up individually in the FERA survey.

Some of the pesticides are not used on these arable crops, but are very important, either in grassland and forage crops, or in the horticultural sector. Such active substances are identified.

Table 1 – Active Substances Potentially under Threat in the UK

	Insecticides	Why?	Source	Likelihood of Loss	Area Treated 2012
1	abamectin	1107/09 - Endocrine Disruption	WRc 2013	High	used on field veg
2	beta-cyfluthrin	1107/09 - Endocrine Disruption	WRc 2013	Medium	220,057
3	bifenthrin	1107/09 - PBT / vPvB	CRD 2008 2C	High	not listed separately
4	clothianidin	Bee Health - Neonic.	EU Restriction	High (by crop)	313,088
5	chlorpyrifos	WFD - Priority Substance	EU List	High	68,314
6	cypermethrin	WFD - Priority Substances	EU List	High	1,496,610
7	deltamethrin	1107/09 - Endocrine Disruption	CRD 2009*	Medium	not listed separately
8	dimethoate	1107/09 - Endocrine Disruption	CRD 2009*	Medium	not listed separately
9	esfenvalerate	1107/09 - PBT	CRD 2008 2C	High	299,220
10	imidacloprid	Bee Health - Neonic.	EU Restriction	High (by crop)	not listed separately
11	lamda-cyhalothrin	1107/09 - Endocrine Disruption	WRc 2013	Medium	1,460,965
12	permethrin	WFD - UK Specific Pollutant	DEFRA List	High (catchments)	not listed separately
13	spinosad	1107/09 - Endocrine Disruption	WRc 2013	Medium	used on field veg
14	spiromesifen	1107/09 - Endocrine Disruption	WRc 2013	Medium	minor hort use
15	spirotetremat	1107/09 - Endocrine Disruption	WRc 2013	Medium	minor hort use
16	thiacloprid	1107/09 - Endocrine Disruption	CRD 2009*	High	79,925
17	thiamethoxam	Bee Health - Neonic.	EU Restriction	High (by crop)	not listed separately

	Fungicides	Why?	Source	Risk	Area Treated 2012
18	bupirimate	1107/09 - Endocrine Disruption	WRc 2013	Medium	used on fruit crops
19	captan	WFD - Article 7	ADAS 2010	Medium	used on fruit crops
20	carbendazim	1107/09 - Mutagenic	CRD 2008 2C	High	409,967
21	chlorothalonil	WFD - UK Specific Pollutant	DEFRA List	High (catchments)	2,713,241
22	cyproconazole	1107/09 - Endocrine Disruption	CRD 2009*	High	1,326,958
23	difenoconazole	1107/09 - Endocrine Disruption	CRD 2009*	Medium	138,043
24	dinocap	1107/09 - Endocrine Disruption	CRD 2009*	High	small use on fruit crops
25	epoxiconazole	1107/09 - Cut-off Criteria / ED	CRD 2009*	High	4,018,148
26	fenbuconazole	1107/09 - Endocrine Disruption	CRD 2009*	High	used on fruit crops
27	fluazinam	1107/09 - Endocrine Disruption	WRc 2013	High	377,602
28	fluquinconazole	1107/09 - Endocrine Disruption	CRD 2009*	Medium	796
29	folpet	1107/09 - Endocrine Disruption	CRD 2009*	Medium	380,795
30	hymexazol	1107/09 - Endocrine Disruption	WRc 2013	Medium	not used in UK
31	iprodione	1107/09 - Endocrine Disruption	CRD 2009*	High	not listed separately
32	mancozeb	1107/09 - Endocrine Disruption	WRc 2012	High	546,152
33	mandipropamid	1107/09 - Endocrine Disruption	WRc 2013	Medium	240,253
34	maneb	1107/09 - Endocrine Disruption	CRD 2009*	High	not used in UK
35	metconazole	1107/09 - Endocrine Disruption	CRD 2009*	High	959,515
36	metiram	1107/09 - Endocrine Disruption	CRD 2009*	Medium	not used in UK
37	myclobutanil	1107/09 - Endocrine Disruption	CRD 2009*	Medium	used on fruit crops
38	penconazole	1107/09 - Endocrine Disruption	CRD 2009*	Medium	used on fruit crops
39	prochloraz	1107/09 - Endocrine Disruption	WRc 2013	Medium	1,194,913
40	propiconazole	1107/09 - Endocrine Disruption	CRD 2009*	Medium	not listed separately
41	prothioconazole	1107/09 - Endocrine Disruption	WRc 2013	Medium	4,834,559
42	quinoxyfen	1107/09 - vPvB	CRD 2008 2C	High	used on fruit crops
43	silthiofam	1107/09 - Endocrine Disruption	WRc 2013	Medium	192,362
44	tebuconazole	1107/09 - Endocrine Disruption	WRc 2013	Medium	3,092,646
45	tetraconazole	1107/09 - Endocrine Disruption	CRD 2009*	Medium	not used in UK
46	thiophanate-meythl	1107/09 - Endocrine Disruption	WRc 2013	Medium	not listed separately
47	thiram	1107/09 - Endocrine Disruption	WRc 2013	Medium	128,990
48	triademenol	1107/09 - Endocrine Disruption	CRD 2009*	Medium	not listed separately
49	triticonazole	1107/09 - Endocrine Disruption	CRD 2009*	Medium	not listed separately

Herbicides		Why?	Source	Risk	Area Treated 2012
50	2,4-D	WFD - UK Specific Pollutant	DEFRA List	High (catchments)	used on forage crops
51	amitrole	1107/09 - Endocrine Disruption	CRD 2009*	High	used on fruit crops
52	asulam	WFD - Article 7	ADAS 2010	Medium	used on forage crops
53	bentazone	WFD - Article 7 (Groundwater)	EA Compliance	High (catchments)	not listed separately
54	bifenox	WFD - Priority Substance	EU List	High	98,242
55	carbetamide	1107/09 - Endocrine Disruption	EA Compliance	High (catchments)	72,270
56	chlorotolurun	WFD - Article 7	EA Compliance	Medium	290,222
57	chlorpropham	1107/09 - Endocrine Disruption	WRc 2013	Medium	used on field veg
58	clopyralid	WFD - Article 7	EA Compliance	Medium (C'ments)	282,532
59	dimethenamid-P	1107/09 - Endocrine Disruption	WRc 2013	Medium	174,567
60	ethofumesate	1107/09 - Endocrine Disruption	WRc 2013	Medium	120,711
61	fluazifop-p-butyl	1107/09 - Endocrine Disruption	WRc 2013	Medium	130,766
62	flumioxazine	1107/09 - Cut-off Criteria / ED	CRD 2009*	High	not listed separately
63	fluometuron	1107/09 - Endocrine Disruption	CRD 2009*	Medium	not used in UK
64	fluroxypyr	WFD - Article 7	ADAS 2010	Medium	1,037,408
65	glufosinate	1107/09 - Endocrine Disruption	WRc 2013	Medium	not listed separately
66	glyphosate	WFD - UK Spec. Poll'nt *(candidate)*	DEFRA List	Medium (C'ments)	1,620,438
67	ioxynil#	1107/09 - Endocrine Disruption	WRc 2013	High	131,183
68	linuron	1107/09 - Endocrine Disruption	CRD 2009*	High	90,925
69	lenacil	1107/09 - Endocrine Disruption	WRc 2013	Medium	51,417
70	MCPA	WFD - Article 7	EA Compliance	High (catchments)	used on forage crops
71	MCPB	WFD - Article 7	ADAS 2010	Medium	used on forage crops
72	mecoprop	WFD - UK Specific Poll'nt / Art 7	DEFRA List	High (catchments)	708,686
73	metazachlor	WFD - Article 7	EA Compliance	High (catchments)	552,036
74	metribuzin	1107/09 - Endocrine Disruption	WRc 2013	Medium	96,814
75	molinate	1107/09 - Endocrine Disruption	CRD 2009*	High	not used in UK
76	pendimethalin	1107/09 - PBT	CRD 2009*	High	1,333,919
77	picloram	1107/09 - Endocrine Disruption	CRD 2009*	Medium	165,146
78	pinoxaden	1107/09 - Endocrine Disruption	WRc 2013	Medium	409,609
79	propyzamide	WFD - Article 7	EA Compliance	High (catchments)	406,024
80	S-metolachlor	1107/09 - Endocrine Disruption	WRc 2013	High	used on forage crops
81	tepraloxydim	1107/09 - Endocrine Disruption	WRc 2013	Medium	192,809
82	terbuthylazine	1107/09 - Endocrine Disruption	WRc 2013	High	not listed separately
83	tralkoxydim	1107/09 - Endocrine Disruption	CRD 2009*	Medium	not listed separately
84	triflusulfuron	1107/09 - Endocrine Disruption	CRD 2009*	Medium	98,163

Other		Why?	Source	Risk	Area Treated 2012
85	metam sodium	1107/09 - Endocrine Disruption	CRD 2009*	Medium	
86	metaldehyde	WFD - Article 7	EA Compliance	High (catchments)	701,477
87	methiocarb	1107/09 - Bird Safety	EU Restriction	High (by use)	

* not assessed by WRc, earlier CRD report suggested possible ban # unlikely to be supported for Annex I renewal

3.2.5. Candidates for Substitution List

The Candidates for Substitution have been derived from the proposed list drawn up by the Food Chain Evaluation Consortium (FCEC) referred to in section 2.2.6. This has been consolidated to cover only those products authorised in the UK. The PSD assessment of May 2008 listed a larger number of active substances (referenced in the summary impact assessment in Jan 2009[24]) but it is the authors belief that the products shown in the following section are those now more likely to be included.

They have been listed separately as there is considerable uncertainty around the comparative assessment process. Following discussions with industry representatives it has been concluded that, whilst there may be large additional information-provision requirements on manufacturers, this element of policy will not result in many, if any, product losses. This is because resistance issues, minor uses and economics are considered for each crop use at a Member State level.

There may be issues where a Candidate for Substitution is withdrawn for commercial reasons in another Member State where other alternatives which meet the criteria in section 2.2.6 exist. In this case, if the active substance had a major use in the UK or a unique use this would have a significant impact. However, this is not covered in the analysis.

The number listed in Table 2 below is relatively small. This may be surprising when section 2.2.6 indicated up to 100 active substances could be defined as Candidates for Substitution. However, many Candidates for Substitution are also threatened by other policies. These other polices are assumed to pose a greater threat to their availability, so the active substance will have been included in Table 1 above.

Table 2 – Candidates for Substitution Identified as Potential Losses in the UK

Candidates for Substitution					
Insecticides		*Why?*	*Source*	*Risk*	*Area Treated 2012*
i	pirimicarb	Candidate for Substitution	EU List	Low	103,215
Fungicides					
ii	cyprodinil	Candidate for Substitution	EU List	Low	223,736
iii	isopyrazam	Candidate for Substitution	EU List	Low	83,901
Herbicides					
iv	diflufenican	Candidate for Substitution	EU List	Low	1,846,174
v	flufenacet	Candidate for Substitution	EU List	Low	1,596,718
vi	metsulfuron methyl	Candidate for Substitution	EU List	Low	2,058,373
vii	nicosulfuron	Candidate for Substitution	EU List	Low	used on forage crops
viii	tri-allate	Candidate for Substitution	EU List	Low	63,636
Other					
ix	ethoprophos	Candidate for Substitution	EU List	Low	not listed separately
x	fosthiazate	Candidate for Substitution	EU List	Low	not listed separately
xi	oxamyl	Candidate for Substitution	EU List	Low	not listed separately

4. EFFECT OF ACTIVE SUBSTANCE LOSS

4.1. GENERAL

4.1.1. Crops

UK agriculture is incredibly diverse and grows a vast range of crops. Some of these are more important than others in terms of land area covered, value produced, and proportion of domestic food supply. Therefore this report focuses on a number of key crops produced in the UK;

- Winter wheat
- Winter barley
- Winter oats
- Winter oilseed rape
- Field beans
- Peas
- Sugar beet
- Potatoes
- Carrots
- Onions
- Apples

4.1.2. Methodology

For each crop the most important pests are considered. Then, taking into account the likely active substances from Section 3.2 that could be lost, an estimate of effects is outlined. Note that for this analysis, it is ***only*** those active substances that have been deemed to be at a ***'high'*** risk of being lost that have been included in the analysis.

Where multiple products are in danger, the cumulative effects are highlighted.

In this section the main focus will be on the level of yield loss. However, other factors will be noted for inclusion in the later analysis. These include;

- Reduction in crop quality and effects on human and animal health
- Effect on rotations
- Effect on husbandry practices (e.g. greater use of cultivations, spray passes etc.)
- Medium/long term effects such as the build-up of resistance

This information has been gathered from previous reports, but updated and expanded through discussions with academics, agronomists, public bodies and pesticide manufacturers. For confidentiality, names have been withheld.

In particular, the methodology and figures used in two ADAS reports[33] [34] on the effects of the loss of PPP have been used. However, amendments have been made where the active substances listed in Table 1 of this study differ from those considered threatened in the earlier reports.

Some of the land worst-affected by a pest may cease growing that particular crop if control options are restricted. The yield losses shown are those that apply on the remaining cropped area.

4.2. Problem Areas

Following the loss of some PPP, control of key pests will become more difficult. As stated above, this will not only have an effect on yield, but also on crop quality and safety. Table 2 below summarises these effects for the crops under investigation. It is not designed to be fully comprehensive, but highlights the key issues.

It will be seen that, in many cases, these weeds, pests and diseases impact on multiple crops covered in this study. To save repetition, these problem weeds, pests and diseases are discussed in general terms in this section. Sections 4.3 to 4.7 then look at crop-specific factors – concentrating on yield issues.

4.2.1. Summary Table

This table highlights the effect of the loss of PPP on important crops for UK agriculture and horticulture.

Table 3 – Summary of Problem Areas

Crop	*Yield Losses*	*Quality Losses*	*Human/Animal Health Issues*
Winter Wheat	blackgrass, other grass weeds, broad-leaved weeds, septoria, yellow rust, slugs, and aphids	-	fusarium (mycotoxins), ergot
Winter Barley	blackgrass, other grass weeds, broad-leaved weeds, mildew, slugs, and aphids	-	fusarium - limited
Winter Oats	grass-weeds, broad-leaved weeds, mildew, slugs, and insects	-	fusarium - limited
Winter Oilseed Rape	turnip yellow virus, slugs, broad-leaved weeds, grass-weeds, sclerotinia, phoma, volunteer cereals,	cleavers	-
Peas	grass-weeds, broad-leaved weeds, downy mildew, botrytis	fungal diseases (see left) affecting colour and stain, pea moth, potato berries	potato berries
Field Beans	grass-weeds, broad-leaved weeds, chocolate spot	chocolate spot	-
Sugar Beet	volunteer cereals, broad-leaved weeds, grass-weeds, powdery mildew, rust, slugs, beet cyst nematode, leatherjackets and other insects	-	-
Potatoes	blight, potato cyst nematode (PCN), slugs, insects, volunteer cereals, broad-leaved weeds, grass-	PCN, wireworm, slugs, leatherjackets, fungal diseases (rots, canker, scurf etc.)	-

	weeds		
Carrots	broad-leaved weeds, grass-weeds, volunteer potatoes, slugs	carrot fly, cutworm	-
Onions	downy mildew, botrytis, broad-leaved weeds, grass-weeds, volunteer potatoes, slugs	fungal diseases (see left)	-
Apples	broad-leaved weeds, grass-weeds	apple scab, insect damage, moths	-

4.2.2. Grass Weeds

The ADAS Crop report for June 2014[35] found that at the end of May 2014, 58% of the UK wheat area contained black-grass with 22% expected to suffer a moderate yield loss of 5% or more, and 0.5% of the area (around 9,000 Ha) of the crop expected to be destroyed before harvest to reduce blackgrass seed return. Blackgrass is an increasing problem in the UK with it spreading out of its traditional heartlands of south and eastern England further west and north. It is also becoming more prevalent on soil types other than the heavy clay soils with which it has historically been associated.

Its spread has been caused by the increasing area of autumn cropping, and a move to earlier planting (before the end of September). This means more of the blackgrass plants emerge with the autumn cereals crop, rather than beforehand where they can be more easily destroyed. The geographic spread has likely been through the movement of seeds in hay and straw and also on agricultural machinery.

A number of active ingredients used for blackgrass control have already been lost including trifluralin, isoproturon, and chlorotoluron. This has led to a reliance on a smaller group of pesticides to control the weed and resistance has built up as a consequence. According to a recent study[36] herbicide resistant blackgrass is now very widespread and is estimated that some degree of resistance occurs on at least 80% of farms that spray regularly to control the weed.

Yield losses occur due to the blackgrass competing directly with the crop. Data suggests that up to 50% crop losses are possible in untreated cereal crops where blackgrass populations are high. Manufacturers are searching for active substances with alternative modes of action to control resistant blackgrass however regulatory hurdles are making this more difficult. Little or no new chemistry is expected to be developed in the foreseeable future. Non chemical methods have recently been reviewed[37], but whilst they have potential and are being adopted by farmers, they cannot substitute for herbicides completely.

Of the other grass weeds commonly found in arable rotations, the most important are annual meadowgrass, ryegrass, barren brome and wild oats. These compete with the crop directly and also cause contamination of harvested crop (so that it does not meet milling, malting or seed standard). Traditionally, isoproturon (IPU) was a key element in controlling these grass weeds until its authorisation in the UK was revoked (it has now been authorised at low-doses to control meadowgrass). Alternative herbicides exist which currently provide good levels of control. Whilst the resistance issues are not as severe as with blackgrass, resistant ryegrass and wild oats are widespread in England[36]. Any change in the active ingredients that are available will make control more difficult and expensive.

Losses where crops are untreated can be up to 50% for heavy infestations of ryegrass and wild oats, 10% for meadowgrass, and 5-10% for brome.

Historically, couchgrass was a major problem in UK cereal crops. This problem has been controlled almost to the point of irrelevance with the current armoury of crop protection products.

Work, funded by the HGCA[38] has been undertaken to develop strategies for grass weed control in cereals without key active ingredients. This focusses on 'stacking' (applying more than one active ingredient or herbicide product at the same time) and 'sequencing' (when different active ingredients or mixtures of active ingredients are applied in close succession). This is already being practiced on farm.

Whilst grass weeds are more often primarily thought of as a problem in combinable crops, Table 2 above shows that they are also significant in root, vegetable and fruit crops. As with combinable crops, the weeds compete with the crop for water and nutrients and result in restricted growth.

4.2.3. Broadleaved Weeds

This includes cleavers (a particular problem in oilseed rape), mayweed, chickweed, poppies thistles and others of less economic significance. All of these weeds compete with the crop for nutrients, water and light, so their presence in large numbers reduces yield. In some cases, especially with vegetable crops, they can contaminate the saleable crop, resulting in price deductions or rejections.

The presence of broadleaved weeds can create a micro-climate in the growing crop near the soil. This can favour the development of disease.

The most important of these weeds is cleavers, with up to 15% yield loss in untreated crops. The other broadleaved weeds will usually cause losses from 1% to 10%. They can cause higher losses in spring wheat than winter wheat as they compete more vigorously with the growing crop.

Up until now, the herbicides used to control grassweeds in cereals have also provided good control of broadleaved weeds. In some European countries broadleaved weeds that are resistant to Acetolactate Synthase (ALS) inhibiting sulfonylurea herbicides have been found. Populations of ALS-resistant poppy, chickweed and mayweed have now been found in the UK[36]. This is likely to be an increasing problem in future years.

4.2.4. Volunteers

Where high-value crops such as sugar beet, potatoes, carrots and onions are grown this tends to be in a rotation with cereals. To reduce crop competition it is necessary to control 'volunteer' cereals that germinate from seeds shed at harvest. In this context, the cereal is simply a weed – competing for nutrients, water and light against the main crop.

In addition, high-value crops tend to be grown on the 'best' land (fertile, well-drained, good soils, accessible to machinery and processors etc.). The area of such land in the UK is limited, so crops often are grown in the same rotations. This means, for example, that those growing carrots and onions are required to control volunteer potatoes. Another example is the need to control volunteer potatoes in peas (especially vining peas) to prevent potato berries (also known as potato apples) contaminating harvested peas.

4.2.5. Non-Selective Herbicides (Desiccants)

Non selective herbicides control most vegetation to which they are applied. They are widely used to control volunteers and other weeds prior to planting and are also used to desiccate crops prior to harvest. This ensures an even level of crop maturity, reduces moisture content from growing weeds, and makes harvesting easier.

The most commonly used desiccant in the UK is glyphosate. This is a systemic herbicide in that it is absorbed by leaves, and translocated to all plant tissues (including the roots). It is a key part of the crop production process in the crops being looked at in this study. For the purposes of this study it has been assumed that there will be ***no*** additional restrictions placed on its use.

4.2.6. Diseases

All fungal diseases vary from season-to-season depending on climatic and agronomic conditions. A disease that causes significant losses one year, can be relatively innocuous the next.

The key fungal disease in wheat in the UK is septoria tritici. This causes lesions on the leaf which reduce the photosynthetic area and hence yield. According to an HGCA publication[39] losses can be as high as 30-50%, with susceptible varieties seeing average losses of 20% when left untreated. The ADAS study[34] assumes an average of 10% yield loss.

The azole group of fungicides has been the main treatment for septoria. Almost all crops are treated and the HGCA suggests that an average of 2.85 azole treatments per crop is undertaken. The effectiveness of many older azole products has declined as septoria has developed resistance to them. The main azole control options in the UK are now epoxiconazole and prothioconazole.

Alternative control options are chlorothalonil, mancozeb and folpet which are protectant, but provide no curative action. A group of SDHI fungicides including biaxfen, boscalid, fluxapyroxad and isopyrazam also provide control against septoria. However, these have only one site of action, and so the probability of resistance developing if not used in conjunction with the azoles is high.

Other fungal diseases that affect wheat plants are yellow rust, brown rust and mildew. All of these diseases are currently well-controlled with azoles, SDHIs and the strobilurin group of fungicides. For yellow rust, losses in untreated susceptible varieties can be as high as 50%. However, the ADAS report suggests untreated losses of 5% on average. The equivalent figures for brown rust and mildew are 2.5% and 2% respectively.

In barley and oats septoria is not an issue and mildew is more important. Control options for the disease are generally good and predicted PPP losses would only have a minimal effect.

Fusarium fungal infections can produce mycotoxins which can be toxic to humans and animals. Consequentially, there will be problems in achieving safe food where control of mycotoxins is reduced or limited from the loss of products. This issue is greatest in wheat but potentially affects all cereals. Maximum legal limits for the presence of mycotoxins have been set[40] in grain intended for human consumption. The main fungal mycotoxins of concern are deoxynivalenol (DON) and zearalenone. The azole group of fungicides has been effective in controlling the disease, but a large number of these products are at risk as set out in Section 3.2.

Take-all is the key disease infecting the roots of wheat plants. It is the main cause of yield reductions in second and subsequent wheat crops. This can amount to 10-20% depending on soil type and disease pressure. Control of the disease is mainly through seed dressing (silthiofam and fluquinconazole). It is less of a problem in other cereal species.

In oilseed rape the main fungal diseases are phoma leaf spot and light leaf spot. Phoma has historically been more prevalent in south and eastern England whilst light leaf spot was more common in Scotland and northern England. However, the diseases now overlap to a large extent with 90% of the oilseed crop potentially affected by phoma and three-quarters by light leaf spot. Phoma can invade the stem and cause cankers. Untreated the disease can reduce yields by 10%. Light leaf spot causes slightly lower losses (5-10%). The main treatment from both diseases is prothioconazole which should remain available. Additional control is achieved through tebuconazole, fusilazole and metconazole. The latter two are likely to be lost so there will be some effect on yields.

Sclerotinia is the major disease in oilseed rape at flowering. Affected plants can suffer up to 50% yield loss[41] but attacks are very variable from season to season. Prothioconazole is the main active substance used to control the disease. This should remain available, so minimal losses from the disease are assumed in the model. However, if prothioconazole lost its authorisation it would severely compromise control options. Peas, potatoes, carrots and other vegetable crops are all also susceptible to sclerotinia. The fungi alternaria and powdery mildew also infect oilseed rape, but tend to be controlled by the pesticides used for the leaf spots and sclerotinia.

Turnip yellows virus (TuYV) is a major threat in oilseed rape. The disease is spread by the peach potato aphid so control is discussed in the 'Insect Pests' section below. It can decrease yields by up to 30%.

Powdery mildew is a serious disease in sugar beet, peas and onions. In beet, yield losses from the fungus can be as high as 20% if it is untreated. The main active substance used to control the disease in beet is cyproconazole. Both cyproconazole and epoxiconazole which is also used in beet fungicide programmes are both likely to be lost, leaving difenoconazole as the main treatment.

In onions mildew causes leaf loss and the failure of bulbs to mature. Foliar diseases also affect storage ability. All onion crops are affected by the disease with significant losses (over 50% of marketable yield) in untreated crops. The loss of mancozeb would be hugely significant to onion production with chlorothalonil also important. The latter is also important for mildew control in peas (along with metconazole).

Sugar beet is also susceptible to rust, ramularia, and cercospora. The former is the most important of these with yield losses of up to 14% possible. The active substances for mildew (i.e. mainly cyproconazole, plus epoxiconazole) also control these at present, with the same issues around future pesticide availability.

Botrytis is an issue in a number of crops, but most notably in peas and onions. In peas it causes the rotting of stems and pods. This both reduces yield directly and can cause blemishing of the produce reducing its saleability. The effect of these diseases can be variable from year to year (depending on weather conditions and other environmental factors). It is assumed that 10% of the crop will be affected on average each year, but some years the proportion would be much greater. At present, botrytis is effectively controlled in peas by chlorothalonil (in conjunction with cyproconazole and metconazole). All of these products are identified as being highly likely to be lost in Section 3.2. Azoxystrobin, boscalid and pyraclostrobin would remain but control would be less effective. All onion crops are potentially at risk from botrytis (both leaf spot and neck rot). Chlorothalonil is, again, the most important control option although iprodione is also used. Both these active ingredients would be lost and control would be difficult.

In beans, chocolate spot is the most important disease, caused by two fungi from the botrytis family. It is a wet weather disease and causes greatest damage in winter crops although it can also reduce yields and quality in spring beans. Chlorothalonil is a widely used product. If this was lost (or restrictions were placed upon it) then the use of tebuconazole is likely.

Possibly the most 'famous' plant disease is blight in potatoes. This fungal disease was the cause of the Irish potato famine and remains a problem for growers to this day. All potato crops are at risk from blight (more properly known as 'late blight') and will receive multiple fungicide treatments. The disease spreads rapidly causing rotting of the potato leaves and stem. Yield losses of 50% are common in untreated crops, with almost total yield loss possible if the crop is infected early in the season. A range of active substances are used to control the disease. A number of these have a 'high' probability of being withdrawn from use. Although alternatives will remain, the 'toolkit' for blight control will be severely reduced.

For top fruit, the appearance of the product is vital. Consumers and retailers will reject fruit that is blemished or imperfect. Apple scab is a fungal disease that causes lesions on the leaves, buds and fruit. The whole crop can be potentially affected, but the variety Gala is particularly susceptible. Left untreated losses can be as high as 70%, but more usually are around 10%. Treatment programmes are currently successful, but the widely used fungicide fenbuconazole would be lost. Other fungal diseases of apples include mildew, brown rot and fruit rot. These are mostly well-controlled and losses are relatively low.

4.2.7. Slugs

Slugs are a problem in almost all of the crops being studied in this report to a greater or lesser extent (with the exception of apples). An example of this can be seen in the wheat crop. A recent HGCA study[42] found that 22% of the UK wheat area was affected by slugs. The estimated average yield loss across this area was 5%, but in some cases losses can be far greater.

In all crops, slugs cause crop damage by hollowing out seed before crop emergence as well as grazing on cotyledons and small plants.

The three products used to control slugs in UK crops are methiocarb, ferric phosphate and metaldehyde. The EU has withdrawn approvals for the use of methiocarb as a slug pellet after 19th September 2015 due to computer-modelled effects assumed for grain-eating farmland birds. This leaves metaldehyde and ferric phosphate as the slug control options. Biological control of slugs using nematodes is available[43]. However, it is presently not fully reliable and expensive and so is only used on high value crops in controlled environments.

Metaldehyde is found in water sources and its prevalence may increase with the loss of methiocarb. Under the WFD, restrictions may be imposed on its use. The Metaldehyde Stewardship Group[44] was formed in 2009 to develop and disseminate best practice advice for the use of metaldehyde with the aim of reducing metaldehyde movement to water. However, this may not be successful and restrictions on the use of the active substance are considered probable.

The area of a specific crop caught by catchment/DrWPA restrictions is likely to vary. This is covered in more details in the specific crop sections that follow.

4.2.8. Nematodes

Nematodes are a particular issue in the potato crop, but also affect sugar beet and root vegetables. The three key products used to control potato cyst nematodes (PCN) are all assumed to remain available (ethoprophs, fosthiazate, oxamyl). However, their longer-term future is in some doubt as their most recent re-approval was considered marginal under current standards.

Free-living nematodes are a potential threat in potatoes, sugar beet and carrots. In sugar beet they cause ‘docking disorder’, and ‘fanging’ in carrots. Aldicarb was the traditional control option but this lost its approval for use in 2007. However the products benfuracarb, fosthiazate and oxamyl provide effective control and should continue to be available.

4.2.9. Insect Pests

In cereals, insect pests are primarily a problem as vectors of disease. Aphids transmit barley yellow dwarf virus (BYDV), which affects wheat, barley and oats. Early drilling has seen this problem become more widespread as aphids transfer to the newly-planted crop from ploughed-down grasses and volunteer cereals. The aphid population varies by year so the effect of the disease is variable. Early infections can kill patches of plants and yield losses in untreated cereals crops are suggested to be around 2%.

Wheat can also be affected by orange wheat blossom midge (OWBM) and wheat bulb fly. OWBM adults lay eggs inside the emerging wheat ears and after hatching the larvae feed on the developing grain, impacting yield and quality. The larvae of wheat bulb fly attack wheat shoots between January and March, causing the stem or tiller to die and reducing yield. On average, these pests, along with BYDV are assumed to affect around a third of the wheat crop in the average year. Other cereals are subject to attack from leatherjackets, frit flies and gout flies. The yield effect of these is limited however.

In oilseed rape the two key insect pests are cabbage stem flea beetle and aphids – the latter acting as a vector for turnip yellows virus. Adult cabbage stem flea beetles feed on the cotyledons and leaves of oilseed rape from crop emergence. Eggs are laid in the soil over a period of a few weeks. Newly hatched larvae tunnel into the leaf stalks and plant stems between October and early April and can destroy the growing points of the crop, before returning to the soil to pupate.

The peach potato aphid is the main vector of turnip yellows virus (TuYV) in oilseed rape. The virus decreases yield by reducing the number of primary branches, the numbers of seeds per pod and the percentage of oil per seed pod.

Both of these insect pests have historically been controlled by neonicotinoid seed treatments. A study by the HGCA[45] has suggested that the average yield loss from TuYV in untreated crops is 15%, although yield losses of up to 30% can occur. The same study suggested that the average yield losses due to cabbage stem flea beetle are about 1%. However, the study did point out that, in some instances, yield losses may be much higher. In the absence of neonicotinoid seed dressings for autumn 2014 plantings, it is reported[46] that 2.7% of the national winter oilseed rape crop has been completely lost as a result of cabbage stem flea beetle losses. There are also likely to be yield losses on crops that have not completely failed, but the extent of this will only become fully apparent later in the season.

Pollen beetles also affect oilseed rape. The effect on yield is usually relatively modest, but in situations where pest populations are high, losses can be severe without control.

In sugar beet the main pests are leatherjackets, cutworms, aphids, and moths. Of these leatherjackets have the potential to cause the greatest yield loss (up to 15%). However, they are only a problem on a small percentage of the beet crop. Peach potato aphids carry the Beet Mild Yellowing Virus (BMYV) as well as causing direct feeding damage to the plant together with black bean aphids, flea beetles and leaf borers. Caterpillars (such as the silver Y moth) also damage beet plants. There are only a limited number of insecticide sprays available for use on sugar beet and control of these pests is achieved by seed treatments. As a non-flowering plant, it is assumed that neonicotinoid seed treatments will continue to be allowed.

The peach potato aphid causes damage to potatoes through direct feeding damage and by transmission of viruses including potato leaf roll and potato virus Y. All potato crops are potentially at risk, and untreated losses are around 5%.

The main pest in carrots is carrot fly. Through direct feeding, they cause the stunting of young plants, which severely reduces crop value, and may, in severe infestations, render the crop unsellable. Other pests are the willow-carrot aphid, which affects yield by direct feeding damage and transmission of parsnip yellow fleck virus and carrot mottle virus. These viruses stunt root growth and result in high yield losses. Finally cutworms can also affect crop quality. All these pests are well controlled with lambda-cyhalothrin, which should remain available to growers.

Onion pests include bean seed fly and onion thrips. Onion thrips reduce the quality of the onion bulb. Bean seed fly reduces yield.

The apple crop is subject to a large number of insect pests. These include aphids (notably the rosy apple aphid), capsids, apple sawfly and moths (codling, totrix and winter). The effects are variable. Almost all apple crops are susceptible to moth attack; however capsid attack is less frequent. Currently these pests are well controlled, with yield and quality losses relatively modest.

4.2.10. Other

Plant growth Regulators (PGRs) are important in most cereals crops (especially oats). However, the list at Table 1 indicates that no key products are likely to be lost.

As has been mentioned in section 2.5.2, chlorpropham (CIPC) is a key sprout suppressant in potato storage. Residue level issues have led to a stewardship group being set up and it is assumed, for the purposes of this report, that this will be successful in maintaining the availability of this product. If it was withdrawn, the UK processing potato sector (28% of total output in 2012), would find it difficult to continue operating.

4.3. Winter Cereals

4.3.1. Key Issues

For winter cereals the main problem areas are listed (in order of importance) below;

1. Grassweeds – blackgrass, rye-grass, brome and wild oats
2. Fungal Diseases – mainly septoria tritici, but also yellow rust
3. Broadleaved Weeds – cleavers, chickweed, poppies.
4. Slugs
5. Insect Pests – mainly aphids transmitting Barley Yellow Dwarf Virus (BYDV), grain aphids, frit flies, orange wheat blossom midge

4.3.2. Winter Wheat Effects

The tables below summarise the likely effect on a pest-by-pest basis.

It must be recognised that it is not possible to sum all of these losses to arrive at a total yield loss following the withdrawal of key PPPs. It may be possible for a figure of over 100% to be reached – indicating no output at all, which is clearly nonsensical. Even under organic conditions (where no synthetic pesticides are applied), the likely yield loss compared to 'conventional' agriculture is in the order of 50%. The percentages in Table 4 below apply to losses from just one weed, pest or disease. Where multiple pests are present (as in field conditions) the losses will not be cumulative, as the 'top-slice' of production will have already been lost to something else. Therefore, at the bottom of each table is an estimated figure for the yield reduction as a result of the loss of the PPP indicated as 'Likely Losses' in Section 3.2. This is the average yield loss for the entire area of the crop (hence '100%' in the 'Area Affected' column). The overall yield loss percentage will be used in the modelling work in Section 5.

Table 4 – Winter Wheat

Pest	*Area Affected %*	*Yield Loss %*	*Notes*
Blackgrass	50%①	16%	Key loss would be pendimethalin.
Other Grass Weeds	25%	4%	As above. Chlorotoluron, clopyralid and glyphosate availability remains unchanged (i.e. no WFD restrictions).
Septoria	100%②	3%	Most azole products could be lost, but prothioconazole and tebuconazole retained. Chlorothalonil could be restricted due to WFD③.
Take All	80%	0%	No key products lost.
Other Fungal Diseases	68%	2%	Potential loss of carbendazim for fusarium plus loss of azoles.
Broadleaved Weeds	52%	1%	Minor effect from potential loss of 2,4-D, ioxynil and linuron.
Insects	34%	2%	Effect due to potential loss of bifenthrin, chlorpyrifos, cypermethrin, esfenvalerate, and thiacloprid.
Slugs	<1%	3%	Methiocarb will be withdrawn in Sept 2015; likely to be restrictions on metaldehyde④. Ferric phosphate remains available.
Total	***100%***	***12%***	

① based on 2014 blackgrass area of 58%, reduced slightly

② potential – variable between seasons

③ restrictions likely to be limited to a small number of catchments/DrWPAs (see metaldehyde notes below). Therefore effects at UK level minimal.

④ based on Ricardo-AEA report methodology[47]. Priority catchments are Impacted DrWPA and upstream safeguard zones which accounts for 21% of arable land in England. The scaling is tailored to the risk from all pesticides due to the likelihood that the targeted policy options would be implemented at that DrWPA scale. Restrictions placed on 20% of area within those catchments. Therefore around 4% of total arable area affected (20% x 21%). 15% of the wheat crop treated with slug pellets within this area on an annual basis.

4.3.3. Winter Barley Effects

The main areas of concern for winter barley are similar to those for winter wheat. But diseases, crop yield losses and control options are slightly different. Potential losses are summarised in Table 5 below.

Table 5 – Winter Barley

Pest	*Area Affected %*	*Yield Loss %*	*Notes*
Blackgrass	50%	16%	Key loss is pendimethalin.
Other Grass Weeds	25%	4%	As above. Chlorotoluron, clopyralid and glyphosate availability remains unchanged (i.e. no WFD restrictions).
Take All	80%	0%	No key products lost
Fungal Diseases	58%	1%	Quinoxyfen for mildew, carbendazim for fusarium plus loss of azoles
Broadleaved Weeds	52%	1%	Minor effect from loss of 2,4-D, ioxynil and linuron
Slugs	<1%	1%	Methiocarb will be withdrawn in Sept 2015; likely to be restrictions on metaldehyde①. Ferric phosphate remains available.
Insects	21%	1%	Effect due to loss of bifenthrin, cypermethrin, esfenvalerate, thiacloprid and chlorpyrifos
Total	***100%***	***10%***	

① see winter wheat notes above

Although not specifically considered in this report, spring barley is an important crop in the UK, especially in the west and north. With more options for control of grass-weeds, in particular resistant blackgrass through cultivation, the predicted overall yield loss is lower for the spring crop than for winter sowings due to the increased area, in particular in the East and Midlands. A fall of 6% has been included in the model.

4.3.4. Winter Oats Effects

As pendimethalin is not used on oats, the effect of PPP loss on oats is less. Although mecoprop is an important herbicide, it is assumed that restrictions under the WFD would only impact on a very small area of the crop. It is worth noting that, because current control options for weeds such as blackgrass or wild oats are limited, the crop tends not to be grown where these weeds are a problem. Potential losses are summarised in Table 6 below.

Table 6 – Winter Oats

Pest	*Area Affected %*	*Yield Loss %*	*Notes*
Meadow Grass	1%	2%	Loss of mecoprop and flumioxazine①.
Blackgrass	1%	24%	As above.
Other Grass Weeds	1%	11%	As above.
Fungal Diseases	29%	0.5%	Quinoxyfen for mildew, carbendazim for fusarium plus loss of azoles
Broadleaved Weeds	49%	1%	Minor effect from loss of 2,4-D, ioxynil and linuron
Growth Regulators	80%	0%	No key products lost
Aphids	54%	1.5%	Effect due to potential loss of bifenthrin, cypermethrin, esfenvalerate, thiacloprid and chlorpyrifos
Other Insects (inc. slugs)	<1%	1%	As wheat/barley above for slugs.
Total	***100%***	***4%***	

① mecoprop only restricted in certain catchments. EA analysis shows only 27 out of 560 catchments affected; restrictions on a small portion of this area (20% assumed for metaldehyde) means very limited area affected.

Note that there will be declines in other winter cereals too – rye, triticale and cereals mixtures. As these crops traditionally receive lower levels of PPP and have lower yields than wheat and barley, a reduction of 8% in yields is used.

4.4. Other Combinable Crops

4.4.1. Winter Oilseed Rape Effects

For oilseed rape the main problem areas identified are;

1. Turnip Yellows Virus – transmitted by aphids
2. Cabbage stem flea beetle, pollen beetle and aphids
3. Phoma leaf spot, light leaf spot, sclerotinia and other fungal diseases
4. Grassweeds
5. Slugs

A HGCA research project[48] has studied the effects of the neonicotinoid restriction. This suggested a 1% yield loss due to cabbage stem flea beetle. However, practical experience in the autumn of 2014 suggests losses are much higher. A figure of 7% has been assumed pending fuller survey results of the effect of the pest.

Potential losses are summarised in Table 7 below.

Table 7 – Winter Oilseed Rape

Pest	*Area Affected %*	*Yield Loss %*	*Notes*
Turnip Yellows Virus	60%	10%	Loss of neonicotinoid seed treatments. Some control with additional foliar sprays.
Cabbage Stem Flea Beetle	67%	7%	As Turnip Yellows Virus. However, treatment options different.
Phoma Leaf Spot	90%	1%	Loss of metconazole and flusilazole, but prothioconazole retained.
Light Leaf Spot	79%	2%	As above.
Volunteer cereals, grassweeds and broadleaved weeds	4%	24%	Carbetamide, metazachlor, and propyzamide could all face restrictions under WFD①.
Slugs	1.5%	4%	Methiocarb will be withdrawn in Sept 2015; likely to be restrictions on metaldehyde②. Ferric phosphate remains available.
Other Fungal Diseases	62%	0.5%	As above.
Aphids	45%	2.5%	Cypermethrin lost but deltamethrin remains.
Total	***100%***	***18%***	

① based on Ricardo-AEA report methodology. Priority catchments account for 21% of arable land in England; restrictions on 20% of area within those catchments. Therefore around 4% of total arable area affected. All of the oilseed rape crop treated with one or more of these products. Yield loss figure taken from same report.

② same methodology as for wheat. Therefore 4% of total area affected. 50% of the oilseed rape crop treated with slug pellets within this area.

4.4.2. Pea and Bean Effects

For pulses the main problem areas are;

1. Broadleaved weeds
2. Grassweeds
3. Fungal Diseases – powdery mildew and botrytis in peas, plus chocolate spot in beans
4. Volunteer potatoes (peas)

A number of products used in peas and beans such as simazine and trifluralin have already been lost. Potential future losses are summarised in Tables 8 and 9 below.

Table 8 – Peas

Pest	*Area Affected %*	*Yield Loss %*	*Notes*
Broadleaved weeds	75%	15%	Pendimethalin lost, and bentazone restricted by catchment①.
Grassweeds (inc. blackgrass)	30%	3%	As for cereals above, key loss is pendimethalin.
Fungal diseases	10%	20%	Downy mildew and botrytis control affected by loss of chlorothalonil and metconazole.
Potato berries	10%	2%	Loss of pendimethalin makes control of volunteer potatoes more difficult. Restricted yield loss as mechanical control adopted.
Insect pests	80%	0%	No key losses - lambda-cyhalothrin and pirimicarb retained.
Total	***100%***	***15%***	

① based on methodology for slugs and oilseed rape herbicides (see sections above), the area facing bentazone restrictions will be small (likely to be significantly less than 5% of cropped area).

Table 9 – Beans

Pest	*Area Affected %*	*Yield Loss %*	*Notes*
Grassweeds (inc. blackgrass)	50%	4%	As for cereals above. Also bentazone and carbetamide. restricted by catchment①
Broadleaved weeds	60%	12%	Pendimethalin and linuron lost.
Fungal Diseases	25%	20%	Chocolate spot control affected by loss of chlorothalonil and metconazole
Insect pests	80%	0%	No key losses - lambda-cyhalothrin and primicarb retained. Bruchid beetle control retained.
Total	***100%***	***15%***	

① based on methodology for slugs and oilseed rape herbicides, the area facing bentazone restrictions will be small (likely to be significantly less than 5% of cropped area) .

4.5. Root Crops

4.5.1. Sugar Beet

Potential losses for the sugar beet crop are summarised in Table 10 below.

Table 10 – Sugar Beet

Pest	*Area Affected %*	*Yield Loss %*	*Notes*
Fungal Diseases	80%	15%	Cyproconazole lost, but difenoconazole retained. Some control of powdery mildew and rust lost.
Leatherjackets	10%	15%	Some loss of early control with methiocarb, and later with loss of chlorpyriphos
Other pests – cutworms, aphids, moths etc.	10%	5%	Loss of cypermethrin, but continued use of deltamethrin for foliar applications. Clothianidin etc. remain approved as seed treatments.
Volunteer cereals, grassweeds and broadleaved weeds	95%	0%	No key losses of sugar beet herbicides. Ethofumesate, lenacil, metamitron, phenmedipham, triflusulfuron-methyl etc. still available
Slugs	1%	2%	Methiocarb will be withdrawn in Sept 2015; likely to be restrictions on metaldehyde①. Ferric phosphate remains available.
Total	***100%***	***12%***	

① see notes on earlier tables

4.5.2. Potatoes

Potential losses for the potato crop are summarised in Table 11 below.

Table 11 – Potatoes

Pest	*Area Affected %*	*Yield Loss %*	*Notes*
Blight	100%	10%	Loss of chlorothalonil, fluazinam, mancozeb and maneb. Cymoxanil, and cyazofamid retained.
Other pests – aphids, nematodes etc.	80%	2%	Loss of cypermethrin, but continued use of deltamethrin
Slugs	2%	2%	Methiocarb will be withdrawn in Sept 2015; likely to be restrictions on metaldehyde①. Ferric phosphate remains available.
Other Fungal Diseases	60%	0%	Suitable products retained to control rots, canker, scurf etc.
Potato Cyst Nematodes	100%	0%	Actives oxamyl, fosthiazate and ethoprophos all remain available.
Volunteer cereals, grassweeds and broadleaved weeds	95%	1%	Losses of pendimethalin and linuron, but alterative control through bentazone② and metribuzin still available.
Total	***100%***	***12%***	

① see notes on earlier tables

② although may be restricted in a small number of catchments (see peas above).

4.6. Vegetable and Fruit Crops

4.6.1. Carrots

Potential losses for the carrot crop are summarised in Table 12 below.

Table 12 – Carrots

Pest	*Area Affected %*	*Yield Loss %*	*Notes*
Broadleaved weeds	100%	17%	Flumioxazin, linuron and pendimethalin lost.
Grassweeds (inc. meadowgrass)	100%	10%	As above.
Volunteer potatoes	90%	10%	As above.
Slugs	2%	2%	Methiocarb will be withdrawn in Sept 2015; likely to be restrictions on metaldehyde①. Ferric phosphate remains available.
Pests	100%	0%	Cypermethrin lost, but other products such as lambda-cyhalothrin and pirimicarb retained
Fungal Diseases	100%	0%	No key losses – boscalid, pyraclostrobin (and other strobilurins) and tebuconazole remain to control sclerotinia and other diseases
Total	***100%***	***25%***	

① see notes on earlier tables

4.6.2. Onions

Potential onion losses are summarised in Table 13 below.

Table 13 – Onions

Pest	*Area Affected %*	*Yield Loss %*	*Notes*
Downy Mildew	100%	35%	Mancozeb lost, as is chlorothalonil. Although some products remain, control options and efficacy is severely reduced.
Broadleaved weeds	80%	15%	Flumioxazin, linuron and pendimethalin lost. Bentazone①, clopyralid, fluroxypyr, pyridate remain, but control becomes far harder.
Grassweeds (inc. meadowgrass)	100%	12%	As above.
Volunteer potatoes	15%	5%	As above.
Pests	35%	5%	Deltamethrin and lambda-cyhalothrin remain, but resistance issues. Chlorpyrifos lost but spinosad retained. Overall, some loss of control
Other Fungal Diseases	100%	2%	As for downy mildew above. Iprodione lost for botrytis. Tebuconazole remains
Total	***100%***	***50%***	

① although may be restricted in a small number of catchments (see peas above).

4.6.3. Apples

Potential losses are summarised in Table 14 below.

Table 14 – Apples

Pest	Area Affected %	Yield Loss %	Notes
Grassweeds and broadleaved weeds	100%	3%	Ability to maintain weed-free strip is restricted by loss of 2,4-D and mecoprop.
Apple Scab	100%	3%	Fenbuconazole lost but alternative products such as boscalid and pyraclostrobin remain.
Fungal Diseases	75%	1%	As above. Plus loss of mancozeb, but use of tebuconazole retained.
Aphids, Capsids and Flies.	70%	1%	Thiacloprid and chlorpyrifos lost, but alternatives exists so effects minimised
Moths	100%	0%	Suitable products retained such as methoxyfenozide and spinosad.
Total	***100%***	***6%***	

4.7. Other Crops

It should be remembered that there will be effects from the losses of crop protection technology on many, if not all, of the other crops grown in the UK, not specifically covered in the section above.

4.7.1. Minor Crop Usage

'Minor Crop' is perhaps a misleading choice of phrase that has become embedded in usage. It suggests that these crops are relatively unimportant. In fact, horticulture (taken as vegetables, fruit and ornamentals) comprised a third of UK crop output (by value) in the five years 2009-13. However, it is a diverse sector, and the ***area*** of individual crops can be small. As set out in Section 2.5.1, these crops often rely on the extension of authorisation from products approved on 'broadacre' crops.

The section above for carrots and onions provides an insight into the problems (and potential losses) that are faced by all 'minor crops'. There is no reason to believe that carrots and onions are special cases and are going to be harder hit than many other crops.

An example of how government intervention can help deal with the issues around minor crops is the IR-4 Project[49] in the USA which is a public/private partnership working to develop approvals for use in speciality crops. The EU Parliament adopted a 'Strategy for Growth for the Horticultural Sector' in January 2014[50] but, ironically, it is the EU's own approvals process that is restricting the development of the sector.

It should be remembered that minor use does not only cover speciality crops, but also minor diseases in major crops. For example, a novel weed, disease or pest could occur in one of the major crops grown in the UK. *The likelihood of this could well increase due to climate change, and the growing threat from invasive species.* A product may be available to treat the problem, but may not be authorised for use on that crop. Granting an EAMU would allow the product to be used and the weed, pest or disease to be controlled. EAMUs are vital in allowing flexibility to respond to unknown threats.

In many ways, the problems faced by the horticultural sector in terms of lack of specific approvals and limited product choice may be a foretaste of what producers of more ‘mainstream’ crops face if the current direction of policy is maintained.

4.7.2. Grass

Grassland covers two-thirds of the agricultural area in the UK. Rough grazing comprises 28% of UK farmland – either ‘sole-right’ or common land. This receives little, if any, pesticides, although some areas are treated with asulam to control bracken.

Permanent grass makes up 32% of the farmed area, and temporary grass (that in place for less than 5 years), 7%. Within permanent grassland there is a large range in sward quality. At one end of the spectrum is very extensive grazing with fairly low productivity (but hardy) species. This is very similar in nature, output and input use to rough grazing. At the other end of the spectrum some ‘permanent pasture’ can be highly valuable – containing a good mix of clovers and productive grass species. Its agricultural output would often be the equal of many temporary grass leys.

There has been a clear trend in the UK livestock industry over the past decade to maximise production from grazed grass. This has been led by the dairy sector, but is increasingly being embraced by the beef and sheep sectors too. The philosophy is that the cheapest way to feed an animal is to get as much of its feed requirement as possible from grazed forage. This saves costs not only on purchased feed, but also on the costs of mechanically conserving and feeding silage or hay.

To make the system work it is necessary to have high yields of nutritious forage. This has led to a much greater focus on the management of grass than perhaps has been the case in the past. It involves techniques such as paddock or rotational grazing, extended grazing, and grass measurement. As part of this the quality of the sward becomes all-important. Weeds need to be controlled to stop competition with the productive grass species, and to stop the sward becoming unpalatable.

The active substances 2,4-D and MCPA are widely used in grassland for weed control as they are safe to the beneficial clover in the sward. Both of these could have restrictions applied (on a catchment basis) under the WFD. Linuron is also used in grassland products, and is deemed to have a ‘high’ likelihood of being lost.

4.7.3. Soft Fruit

Soft fruit comprises strawberries, raspberries, blackcurrants, currants, gooseberries and various other types of berry. The area taken up by these crops is relatively small – around 9,500 hectares or less than 0.1% of the UK farmed area. However, these crops are economically important. The five year average 2009-2013 saw them comprise around 4.5% of total UK crop output. These crops have also been a great success story for UK farming over the past two decades – especially strawberries (which account for over 60% of the UK soft fruit output by value). The crop has gone from a seasonal luxury only consumed in early summer, to one where UK produce is available from April to October.

The strawberry crop is susceptible to a number of pests and diseases, notably botrytis, mildew, blackspot, strawberry blossom weevil and aphids. Chlorothalonil and iprodione are used in fungal disease control programmes. As set out in Section 3.2 these products may be lost or restricted. This would increase reliance on alternatives such as fenhexamid and tolylfluanid.

Chlorpyrifos is widely used for pest control, and this seems likely to be lost. This being the case, pirimicarb use will increase. It is likely to remain available (although it is a Candidate for Substitution).

4.7.4. Hops

Hops are a vital ingredient in the iconic British product of beer. Whilst the farmgate value of British hops is £9 million, they are used in about half the UK's brewing capacity; with a retail value of £19 billion. The UK hop area has been in long-term decline with the national area dropping below 1,000 hectares. This is a result of competition from cheaper imported hops, and a shift in consumers tastes in beer.

Recently the demand for hops has been increasing rapidly, especially in the USA where the interest in 'craft beers' and the subsequent improved demand for hops have led to there being fears of hop shortages. The recent upturn should provide an opportunity for a resurgence in the UK hops sector, including increased exports. However, growers are reluctant to expand partly because there are too few crop protection options in what is a challenging crop to grow competitively.

Insect pests are a particular problem. The neonicotinoid imidacloprid was widely used as a soil drench but the main target pest, aphids, developed resistance to this active substance (mainly because there were no alternatives with which to build an anti-resistance programme). With this active substance no longer being used a number of novel pests that were previously controlled (such as flea-beetle from oilseed rape) in addition to aphids have now emerged as a severe problem.

The only approved option for British hop growers is to apply a pyrethroid but these have limited effectiveness. Also, they remove natural predators, and this exacerbates problems with major pests like aphid and spider mite, which are difficult to control in their own right. The approval for the last pyrethroid expires this year. The loss of abamectin would be significant as it is the only product to control the two-spotted spider mite in hops.

German and Czech hop growers have access to thiamethoxam which is not approved for hops in the UK. This gives them a significant competitive advantage.

Historically, the the hop industry was subject to regular crop failures (hence the hop warehouses in London). The industry now relies on very few active substances – for example three aphicides and a single acaricide. Were these to be lost the remaining 50 British hop growers could face a situation where crops were completely lost in some years. This would likely result in an end to commercial hop growing in the UK.

4.7.5. Ornamentals

According to DEFRA statistics the production of plants and flowers ('ornamentals') comprised around 12% of the total output of UK crops in the five years 2009 to 2013. It is therefore an important sector within UK agriculture and horticulture, although one often overlooked.

The consumer has a low tolerance for pests and diseases within ornamental crops so pesticides are a vital tool. The widespread use of biological control (see section 7.4) means that chemical pesticides have to be specific and able to be integrated with the biologicals, limiting the choice of product. Two such chemicals under threat are spinosad and abamectin commonly used for spider mites and thrips. These are major pests of ornamentals and for which these products are often the last line of defence. The loss of pirimicarb will limit the choice of a specific aphicide to one active, increasing the risk of resistance.

In the case of ornamentals, the economic loss is less about yield decreases, or even quality reductions. It is in the cost of the alternative methods adopted to protect the crop. These include more regular crop monitoring, increased heating (for protected crops to help prevent disease) and a higher number of pesticide applications (as alternatives are often less effective, as we have seen with the restrictions on imidacloprid).

5. EFFECTS ON UK AGRICULTURE

5.1. METHODOLOGY

To gauge the effect of the loss of the Plant Protection Products (PPP) outlined in Section 3, the outcomes discussed in Section 4 have been fed into a spreadsheet model. This provides a set of outputs – it shows both the monetary loss of the changes, and also changes in yields and cropping. The latter is important when the discussion is broadened to look at the effects beyond the farming sector – in terms of raw materials for the food processing industry and consumers.

The model is based on the aggregate UK farming accounts as compiled by DEFRA. These are published annually in 'Agriculture in the UK'[51]. They are regarded as the definitive guide to the financial performance of the farming industry. From these accounts a measure of profitability for UK agriculture known as Total Income from Farming (or TIFF) is derived. This is the aggregate return to all the entrepreneurs in UK agriculture and horticulture for their management, labour and their own capital in their businesses. Note that the use of the term 'Income' can be confusing – what is essentially being shown is the ***profit*** of the farming industry. The data is collected and produced to EU requirements as part of the UK's statistical reporting to Brussels.

As aggregate accounts, the TIFF data shows total income and costs for each of the main categories in UK farming. For example, income from wheat or milk is shown as one figure; then the cost of fertiliser or labour is also shown. Therefore the data is not produced from gross margins for individual enterprises as the figures for an individual farm would be.

To provide more detailed analysis, the financial data comprised in the TIFF accounts is supplemented in the model by physical data for each crop. This covers areas, yields and prices. These are all reconciled to produce a financial output figure. The source of the physical data is the UK June Agricultural Survey[52], Cereals and Oilseeds Yields Data, and the Basic Horticultural Statistics publication[53].

In all cases, for both financial and physical data, five year averages for the years 2009 to 2013 have been used. This means the most current data is being used in the model. At present the 2013 year is the latest available. However, farming is an inherently volatile industry so the use of a five-year average means that the base figures are not distorted by unusual yearly events – for example weather effects.

From this 'Base' scenario, the estimated effects on crops from the previous section have been applied. This changes planted areas, yields, prices and of course financial returns. UK cropping is fully reconciled following the predicted changes – i.e. if an area of one crop falls due to the loss of PPP, then the area of another crop would rise, or the area of fallow or grass would increase instead.

Further changes have been included in the model. As cropping patterns change, the use of variable inputs such as seeds, fertilisers and pesticides will alter. In addition, production systems will change – for example more cultivations, or a greater number of passes with a sprayer. These effects have been built in to alter the figures in the respective cost categories – machinery costs, fuel, labour etc.

The comparison of the Base scenario with the Post-Loss one assumes all other conditions remain constant. Therefore the analysis is undertaken at today's prices (and premiums) and cost levels. In this way the effect of the loss of PPP can be seen in isolation.

5.2. Main Assumptions

A large number of assumptions are naturally required in the model which are summarised in this section. Inevitably some of the consequences of these are unknown and all estimations will contain a degree of informed guesswork. It would be possible to argue a different outcome for any of the individual assumptions. However, as the model is made up of a large number of calculations any individual figure is not crucial to the overall outcome. Indeed, any errors in one direction, are likely to be cancelled-out by equivalent, but opposite, errors elsewhere.

5.2.1. Yields

All yield changes are from the five-year average 2009 to 2013. In all cases yields decrease due to increased weed, disease and pest pressure on crops. These figures are taken from the tables in Section 4. The 'marketable yield', is dealt with through the average price – set out below;

- Yields of winter wheat decline by 12%, that for winter barley by 10%. Spring barley yields reduce by only 6% as the loss of PPP is less severe in spring crops.
- The oats yield declines by 4%. It is from a lower base, and tends to be a crop which requires lower inputs. 'Other cereals' yields decline by 8%.
- Winter oilseed rape yields fall by 18%.
- Peas have an output drop of 15%, beans by 15%.
- Sugar beet yields decline by 12%.
- Potato yields drop by 12%.
- Carrot yields fall by 25%.
- Onions by 50%.
- Apple yields decline by 6%.

5.2.2. Crop Areas

All changes are from the five-year average 2009 to 2013

- Winter wheat area drops 12% as some land becomes uneconomic to crop with loss of active ingredients.
- Spring wheat area rises as part of shift to spring cropping.
- Winter barley area drops 10% (not as badly affected as wheat).
- Spring barley area rises by 20% as part of shift to spring cropping.
- Oat area rises by 20% as growers look for alternative combinable crops (with low-input characteristics).
- Other cereals (including rye, triticale and mixes) rise by 100% (albeit from a low base) for the same reason.
- Winter oilseed rape area declines by 30%. Spring oilseed rape increases by 100%, but overall rape area drops by 22%.

- The feed pea area increases by 25% as part of the general move to spring cropping. Very few, if any, winter peas are assumed. Both the vining pea industry and combined peas for human consumption disappear completely as it is impossible to produce the quality required, hence they are all imported.
- The combinable bean area increases by 30%, with the selection of spring beans assumed.
- Sugar beet area goes up by 10% to offset a reduction in yield. Sugar beet is bulky, relatively low value per tonne and produced in large quantities in the UK. Therefore, the opportunities for import substitution are more limited. It is assumed that, as the sugar processor has factories to fill, extra area contract will be offered to offset part of the yield loss. Whilst the crop could well be less profitable than at present due to yield reductions, the *comparative* profitability compared with other crops is assumed to be good enough that this additional contract would be taken-up by growers. Whilst the area grown may increase, the assumption is that yield loss will not be fully offset so less sugar will be produced (see below).
- The potato area decreases by 5%. The area does not drop by as much as the yield reduction might suggest, as there are slightly greater barriers to import substitution in the potato sector due to the relatively bulky (and perishable) nature of the crop. Whilst there are currently significant imports from Northern European countries to the UK, it is assumed in the 'post-loss' scenario that growers in the rest of Europe would by facing the same issues with the loss of PPP as UK producers. Therefore imports would have to come a greater distance from outside Europe. This protects the sector to some extent from lower-cost import competition.
- The carrot area falls by 40%.
- Onion plantings (bulb and spring) decline by 50%.
- Although a detailed analysis has not been undertaken on the effects of the loss of products on other vegetables, it seems safe to assume that the effects will be similar to those seen for carrots and onions. All other vegetable areas are assumed to decline by 33% apart from protected vegetables, where cultural control is easier and the area is maintained.
- The apple area declines by 30%.
- In a similar way to vegetables, the trends in other fruit are extrapolated from the changes in apple areas. Thus a decline of 30% is assumed.

Generally, most crop areas decline. This is because it becomes more difficult and more expensive to grow them with the loss of key PPP. Some crops can no longer be grown in certain locations because suitable pesticides are not available to control the prevalent pests. Longer crop rotations also mean a decline in the area of the most widely-grown crops. Finally, where production of a crop is economically marginal, it is likely that it will no longer be grown due to reductions in profitability. Although these area reductions, along with yield changes discussed below, reduce UK output, it is presumed that imports, which are likely to be from outside the EU, will be available to make up the shortfall.

No specific analysis has been undertaken of the effect on the biofuels industry. This is now an important outlet for oilseed rape, sugar beet and wheat produced in the UK. Indeed, if the wider renewable energy sector is looked at then anaerobic digestion is an important driver of the growth in the maize area (plus other crops used as feedstocks). It is assumed that these destinations are simply another outlet for the crops grown in the UK. They will react in the same way to supply, demand, and hence prices as any other market.

5.2.3. Prices

All changes are based on the five-year average 2009 to 2013. Farmgate rather than retail prices are considered.

- In general, all cereals and oilseed rape prices rise by 5%. This is due to a shift from export parity pricing (the prevailing world market price less the cost of transport to the final destination), to import parity (the prevailing world market price plus the cost of transporting the grain to the UK).
- The percentage of wheat sold for milling declines from its historical average of 35% to 30% due to poorer crop quality as a result of the loss of key PPP.
- The swing towards spring barley production (see section above) creates a higher volume of malting grade barley in the market. Although the base price goes up 5%; see above, the malting price declines by 8%. As a result, there is only a small premium remaining for malting grades.
- Most peas grown in the UK now go for human consumption or micronizing. It is assumed that loss of PPP mean that it is harder to meet the quality requirements and more of the crop ‘defaults’ to the base animal feed price. The base price in this market is set by protein in animal feeds. As the UK is already heavily reliant on imports in the sector with an emphasis on soya, so the market dynamics do not alter. Overall, the average pea price falls by 10%.
- For beans, a large proportion of the crop currently goes for human consumption, mainly for export. It is assumed that the loss of products will result in quality issues that end this market (mainly chocolate spot; bruchid beetle control still possible). Therefore average prices are expected to decline by 12%.
- The sugar beet price is assumed to remain relatively unchanged from the price set for the 2015 crop. The processor has a strong commercial incentive to offer a price that encourages enough beet to be grown to fill its factory requirements. It is assumed that a price at this level will achieve that goal.
- The potato price drops by 8%. This does not assume any reduction in the farmgate price for human consumption potatoes, indeed the price may well rise slightly in response to lower output. However, the percentage of grade-outs will rise considerably due to quality issues, so the average price received per tonne of output will fall. The grade-outs are assumed to be sold at a low price as stock feed.
- The average price for carrots and onions is assumed to decline for the same reason as potatoes in response to a higher percentage of grade-outs. The respective price reductions are 15% and 10% respectively, with carrots having higher ‘visual quality’ requirements.
- Other vegetables are assumed to experience a total revenue drop (area, yield and price together) of 33%.
- Apples suffer heavily from the grade-out issue, as consumers have got used to purchasing ‘perfect fruit’ over the past few decades. The average price falls by 20%.

In terms of price effects, an underlying assumption has been made that sufficient volumes of agricultural commodities are available in European or World markets to replace reduced domestic supplies. However, as many of the policies would be implemented at an EU level, the rest of the Single Market would be grappling with a sharp fall in output in the same way as the UK. In some commodities the EU comprises a large portion of global output. An example is wheat where the EU produces around 20% of the world total[54]. Therefore, the effect of falls in EU production would be significant enough to raise the global price higher. This is not factored into the model.

In sectors with higher-value output such as fruit and vegetables, the loss of EU production would have a lesser influence on price. It would make sense for importers to substitute the production of these crops for less valuable ones to supply the newly-available EU market. The price effect might only be marginal.

An earlier report[55] produced for the Crop Protection Association adopted a different approach, with imports from the rest of the world failing to make up the shortfall in production in the UK and EU. This foresaw '*farmgate prices for arable crops, fruit and vegetables would be of the order of 100% higher and the farmgate prices of meat and dairy products would be around 50% higher'*.

5.2.4. Operational Costs

All changes are based on the five-year average 2009 to 2013

- Full inversion cultivation needed on cropping areas previously min-tilled or not tilled. This is to improve weed control (especially against blackgrass). It is assumed that this will be relevant to 25% of winter cropping area. Some spring area is now also likely to need fuller cultivations but this is accounted for in the figure.
- Assumes an average of two and a half extra spray passes on all cropped land – this is because many of the remaining PPP are less persistent, or less effective than those products being lost. Hence the need for a greater number of applications. An example of this is the loss of neonicotinoid seed treatments, where foliar sprays now have to be applied in the autumn.
- Four passes of additional tractor hoeing on vegetable land.
- Hand weeding once on all vegetable land.
- The cost of these operations are based on average farmers' costs from the 2015 John Nix Pocketbook[56]

5.2.5. Other Costs

All cost changes are based on the five-year average aggregate costs, 2009 to 2013

- Seed costs drop in proportion to lower cropped areas – with extra fallow and extra temporary grass area. *It is possible that if demand drops seed houses may increase their costs of seed per unit to allow for continued returns. This is not factored-in the model.*
- Fertiliser costs also drop for a similar reason. Spring cropping land, and extra temporary grass is assumed to get two-thirds of the application of winter combinable crops. Fallow receives nothing.
- The change in the cost of pesticides is complex. Despite the loss of key active ingredients the spend on cropped hectares is likely to rise as more expensive and possibly a greater number of products are applied. *An example of this is the loss of linuron for weed control in potatoes. The alternative control options are all more expensive*. The cost on winter combinable crops and fruit and veg is expected to rise by 15%. The shift to spring cropping will reduce applications in these circumstances – as with fertiliser, rates of two-thirds the winter cropping cost will be used. No products used on fallow or additional temporary grass.

- Feed prices for livestock farmers will rise as the internal UK cereals prices rise. As animal feed is made up of protein (soya) and other ingredients as well as cereals, the full 5% change is unlikely. A 2.5% uplift has been included.

There are other cost changes that could be made, for example lower crop storage costs due to lower output. Furthermore, although the grass area has risen, no additional livestock output has been included. It is assumed that grazing livestock would become more extensive. The list of adjustments is potentially endless. This model has attempted to capture the main ones.

5.3. RESULTS

5.3.1. Summary of Results

The results of the models are presented in the following two tables. The 'Base' figures are the averages for 2009 to 2013. The 'Post-Loss' figures are the situation once the most likely scenario for the loss of PPP has been applied.

Table 15 – Summary Financial Effects

£m	Base		Post-Loss
Income			
Wheat	1 956		1 499
Barley	825		816
Other Cereals	105		139
Oilseed Rape	797		522
Beans and Combining Peas	117		119
Sugar Beet	238		184
Potatoes	738		567
Other Crops	735		840
Carrots	120		46
Onions	104		23
Other Vegetables	1 003		668
Apples	112		59
Other Fruit	474		333
Ornamental Crops	1 014		1 014
All Livestock Output	12 389		12 389
Other Farming Income	2 008		2 008
Total Income	***22 734***		***21 225***
Costs (Intermediate Consumption')			
Seed	696		680
Fertilisers	1 423		1 384
Crop Protection Products	815		854
Energy (includes Fuel)	1 318		1 342
Animal Feed	4 545		4 658
Machinery Expenses	872		890
All Other 'Intermediate Consumption'	5 021		5 021
Total Intermediate Consumption	***14 689***		***14 830***
Gross Value Added (Mkt Prices)	**8 045**		**6 395**
Other Costs			
Depreciation	3 731		3 773
Subsidies (less Taxes)	- 3 338		- 3 338
Wages	2 290		2 327
Rent and Interest	579		589
Total Other Costs	***3 261***		***3 350***
Total Income From Farming ('Profit')	**4 784**		**3 045**
Change			- 1 739
% Change			-36%

The drop in Gross Value Added equates to a fall of £1.65bn or around 20%. The figures for Total Income from Farming are clearly shown in the table, with over a third of the profit of the farming and horticultural industry being lost. This could well be an understatement as some sectors (e.g. ornamentals) have not been included in the analysis.

Some crop categories show income rises. This is because the ***area*** of the crop is rising – offsetting any yield drops. This is a result of changes in cropping patterns brought about by the loss of certain PPP, which are illustrated in Table 16 below.

Table 16 – Summary Cropping Changes

'000 Ha	Base		Post-Loss		% change
Combinable Crops					
All Wheat	1 858		1 681		-10%
Winter Barley	368		331		-10%
Spring Barley	682		819		20%
All Barley	***1 050***		***1 150***		9%
All Oats	132		159		20%
All Other Cereals	27		54		100%
Total Cereals	***3 067***		***3 043***		-1%
Winter Oilseed Rape	638		447		-30%
Spring Oilseed Rape	39		78		100%
All OSR	***678***		***525***		-22%
Other Oilseeds	36		65		82%
Combining Peas	33		42		25%
Field Beans	138		180		30%
Total Combinables	***3 952***		***3 855***		-2%
Other Arable					
Maize	169		225		33%
Sugar Beet	116		128		10%
Other Crops	109		130		19%
Fallow Land	196		250		27%
Total Other Arable	***591***		***733***		24%
Vegetables, Fruit and Flowers					
Potatoes	143		136		-5%
Vining / Processing Peas	42		0		-100%
Carrots	11		7		-40%
Onions	11		5		-50%
Other Vegetables	59		39		-34%
Apples	9		6		-30%
Other Fruit	20		18		-13%
Ornamental Crops	12		10		-16%
Total Horticulture	***307***		***221***		-28%
Grass and Other Land					
Temporary Grass	1 300		1 350		4%
Permanent Pasture	5 854		5 850		0%
Outdoor Pigs	9		9		0%
Rough Grazing	5 132		5 127		0%
Woodland and non-Agric.	1 174		1 173		0%
Total Grass and Other	***13 467***		***13 509***		0%
Total Farmed Area	**18 317**		**18 317**		0%

The overall farmed area remains the same. It can be seen that, overall, winter cropping drops at the expense of spring crops. The area of fallow rises as some land is taken out of production. This will be either the least productive land that is no longer economic to crop, or land taken out of production rotationally to control weeds. The area of temporary grass also rises as this 'crop' is included more regularly in arable rotations to assist with weed control.

5.3.2. Further Consequences

These changes in the financial status and structure of the farming sector will have consequences that are not fully covered in the model. Lower output and profitability is likely to accelerate a restructuring of the farming sector. Farms that are financially weaker or less efficient are likely to cease production with their land taken over by 'better' business. Thus, the long-term trend towards fewer, but larger farming enterprises in UK agriculture could well increase. Whether this is a good or bad thing is debatable. It may result in a more streamlined sector, but there may be social consequences in certain areas with the loss of traditional 'family farms'. Obviously for any individual farm that is rendered uneconomic by the changes, the effects are massive, and usually traumatic. It is also arguable that larger, 'leaner' business might be less willing to spend on landscape maintenance or biodiversity enhancement.

In certain sectors the demand for labour might actually rise. This is especially true in the horticultural sector, where hand-weeding or additional labour for grading may be required. However, the past few years have illustrated the difficulty the horticultural sector has in attracting the indigenous UK population to undertake this kind of work, which tends to be hard and often relatively low paid. Even in the recent recession, when unemployment was high, the sector was forced to rely heavily on migrant labour to undertake many of these tasks.

The analysis in this report has assumed that this situation is unlikely to change. It would be difficult for growers to pay higher wages to attract more workers, as they are under economic pressure from imported produce with fewer restrictions on pesticides use. Therefore, it has been assumed that a lower area of horticultural crops would be grown, partly as a result of there not being the labour to satisfy the new labour-intensive production systems.

Overall, it is likely that employment in agriculture will fall as a result of the loss of PPP.

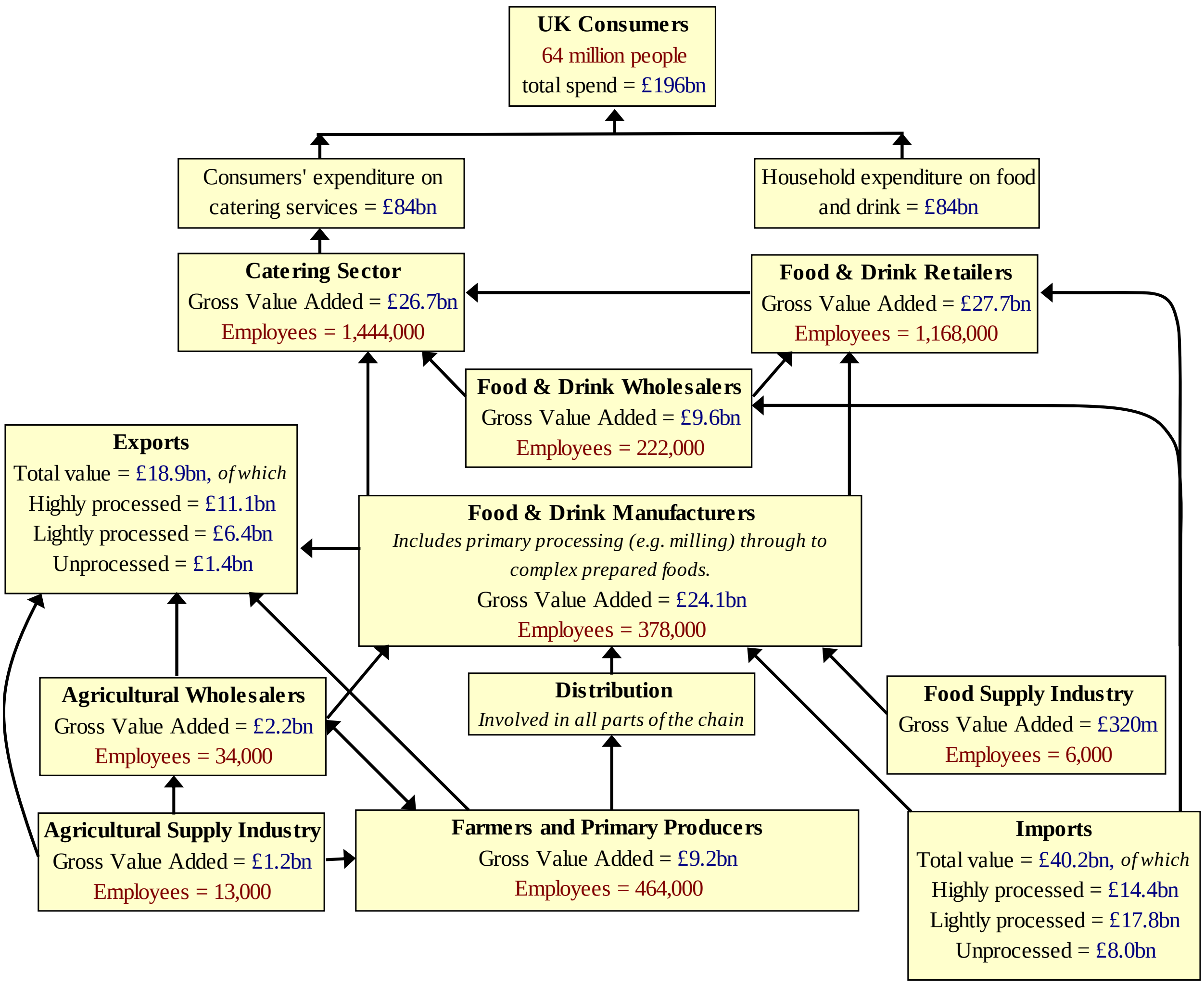
6. WIDER ECONOMIC EFFECTS

6.1. THE FOOD CHAIN AND CONSUMERS

6.1.1. The UK Food Chain

The farming industry is just one element of the far larger food and drink sector. In 2012, for which the latest full figures are available[57], the 'agri-food' sector contributed £97 billion to the UK economy which is just over 7% of the economic activity of the nation. The entire sector employs over 3.5 million people, around 13% of total employment in 2013. Figure 1 below shows the contribution of the various sectors of the UK food chain.

Figure 1 – The UK Food Chain, 2013 (Source: DEFRA)



The financial figures in the chart are based on Gross Value-Added (GVA). GVA is a measure used in national income calculations. It is the output of an industry, less the value of 'intermediate inputs'. These are inputs purchased from other sectors of the economy. GVA does not include the cost of depreciation, wages, interest and rents. It can therefore be seen as the return on all labour and capital invested in an industry. In 2013 the GVA of agriculture was £9.2bn, whilst profit (TIFF) was £5.5bn.

6.1.2. Likely Changes

Section 5 discussed the physical and financial implications to the agricultural industry from the loss of PPP. The wider economic effects can be calculated from the information contained on the flowchart in the previous section.

The starting point is that it is assumed that the UK population will not consume any less food and will continue to consume it in the same way i.e. the balance between food consumed inside and outside the home will remain broadly constant. (This balance may well change if food became more expensive – the recent recession saw a decline in eating-out due to economic pressures.) With the same amount of food being consumed, the effect on retailers and caterers is likely to be negligible. Food wholesalers will also be largely unaffected as they would amend their supply chains to source more imported products at the expense of home-produced food.

The key sectors affected would be Food and Drink Manufacturers, Agricultural Wholesalers and the Agricultural Supply Industry. In addition the Distribution sector, which links all these together, would also see losses.

Taking these in turn, the effect on Food and Drink Manufacturers would have the largest economic effect. It can be seen that the GVA of this sector is between two and three times larger than farming, thus any changes will have a more significant impact.

Food processors and manufacturers tend to base themselves near to their supply of raw materials. This is because the unprocessed product for example wheat, milk, etc. tends to be bulky, whilst the processed product such as bread and cheese is less so. As a result, transport costs are minimised. Traceability and provenance are also reasons why manufacturers like to be close to and have a relationship with their primary suppliers. Often, in marketing and branding terms, having the raw material sourced from a specific location is part of the appeal (e.g. Scotch Whisky). In some cases, these geographical links are enforced legally through the EU's system of labelling food products. These are Protected Designation of Origin (PDO), Protected Geographical Indication (PGI), and Traditional Specialities Guaranteed (TSG).

Looking at the effect of the loss of PPP from the model, the following output drops are forecast for the commodities under investigation;

Table 17 – Drop in Raw Material Output

'000 tonnes	Base		Post-Loss		% change
All Cereals	20 721		18 124		-13%
Oilseed Rape	2 319		1 474		-36%
Carrots	702		316		-55%
Onions	366		92		-75%
Apples	224		148		-34%

It is unlikely that food manufacturing will decline by a similar percentage to the fall in raw material availability. This is because;

- The loss of PPP mainly affects crop production. The effect on livestock production would be less marked (although feed prices would rise). As much food manufacturing (at least half) is involved with the processing of livestock products, the loss of PPP would be minimal on this sector.
- Food processors and manufacturers have a considerable amount of 'sunk costs' in their current plants and factories. Although they favour domestic sourcing, it is likely that they would import raw materials to keep these facilities operating at economic throughputs. Therefore, it is unlikely that there would be an

immediate ‘offshoring’ of a large element of UK food production. Instead, when new investment was being made, it would be far more likely to be made outside of the UK and probably the EU. Therefore, there would be a gradual decline over a period of time in the manufacturing sector.

- Although the raw material losses are higher in the fresh produce sector, the amount of processing tends to be less.

For all these reasons it is considered that, in the medium term (once ‘offshoring had taken place), the loss of GVA in the food and drink manufacturing sector could be in the region of 10%. This would equate to an economic loss of £2.5bn. If the workforce showed the same level of change, this would see job losses of between 35,000 to 40,000. There would be knock-on effects on the Food Supply Industry (machinery and equipment for Food Manufacturers and Processors), but this is difficult to quantify.

As a group, Agricultural Wholesalers both sell products (inputs) to farms and also buy and trade their produce. This dual role exposes them to reductions in the size of the primary agricultural industry. In terms of inputs, the model demonstrates that, although values of seeds, fertiliser, plant protection products and fuel will fall, the drop is not dramatic. Taken together, the declines average about 5%. It may appear that these falls are offset by the increase in animal feed sales. However, as price rises have been driven by raw material price increases, the returns to Wholesalers will not increase.

More dramatic changes will result from the output side. The Wholesalers are involved in the trading of combinable crops. More specialist crops such as potatoes, roots and fruit have dedicated, more direct, supply chains. The livestock sector also tends to have supply chains separate from Wholesalers. This means that grain trading is the primary ‘upstream’ activity of these companies. It can be seen from Table 17 above that volumes of grain available from UK farms drops considerably with the loss of PPP, by somewhere in the region of 15-20%.

It is assumed that two-thirds of Wholesaler business is in input supply. Of this figure, half is in the livestock sector which is relatively unaffected by the loss of PPP. The remaining third of business is from trading grain and other outputs.

Working through the figures, it results in an estimated loss of GVA for the Agricultural Wholesaling sector of £0.18bn. This equates to an 8% drop in economic output. Again, assuming that the effects on employment would be proportional to the drop in business activity, the effect could be to see job losses of just around 2,700.

In this analysis, the Agricultural Supply Industry is defined as manufacturers of products for use in agriculture. This includes machinery, equipment, fertilisers and pesticides. It has been demonstrated that the total amount of agricultural activity in the UK will only drop slightly as a result of the loss of PPP. Indeed with more cultivations, the demand for farm equipment and machinery may actually increase.

Many of these Supply Industry businesses are international and export a significant proportion of their UK production. This would still occur after PPP loss and increased exports may be able to offset reductions in the domestic market. However, as discussed in section 5.2.3, it is likely that other EU countries would be experiencing many of the same effects. Therefore, unless they had access to markets further afield, the effect on demand for their products may well be noticeable. If an 8% overall reduction is assumed, that would suggest a loss in GVA of £0.1bn. The effect on employment would be the loss of over 1,000 jobs.

Perhaps of greater importance in this sector is the effect that policy is having on investment and research and development in new PPP. This is covered in more detail in section 6.3.

Finally, it should be remembered that the ‘lost’ output from UK agriculture illustrated in Table 17 is assumed to be replaced by greater imports. The UK already runs a substantial trade deficit in foodstuffs as is shown by the data in Figure 1 – exports of £18.9bn, imports of £40.2bn. The UK balance of payments would worsen following any loss of key PPP. At the revised prices used in the model, the cost of additional imports would worsen balance of payments by almost £1.0bn (£960m). This assumes the replacement products are purchased in their most basic form. If they are processed outside the UK, then the change would be higher.

6.1.3. Consumer Availability and Choice

It has been a general presumption within the modelling that any loss of UK output will be replaced by imports from less restricted production regions around the world. The UK consumer is relatively wealthy in global terms, so could ‘outbid’ other buyers for the food we demand. Whilst this is fine for the UK, it does not help food availability in other parts of the world.

It has already been covered that the costs of some raw materials will rise from export parity to import parity prices. This is mainly grain, which forms a relatively small element of the cost of final retail food prices (the wheat costs is less than 10% of the shop price of the typical loaf). It would also be present in the other products that have to be imported instead of being home grown – there would be additional transport costs, the cost of securing supplies (beating other buyers), and any market effects from lower overall global production.

With most UK consumers spending a relatively small proportion of their income on food, any small price rise may not have a large impact on the majority. But it should not be forgotten that even in the UK there are those on low incomes who struggle to secure enough nutritious food. Research funded by Tesco published in 2013[58] found that 18% of the population had suffered some sort of food poverty in the previous 12 months. Any price rises would disproportionally affect this group. An argument could be made that policy and standards imposed by an ‘elite’ are adversely affecting the poorest.

It cannot be assumed that the imports that substitute for lower domestic consumption will be of the same standard. Retailers have minimum quality protocols, but as the horsemeat scandal showed, particularly in processed products or where there are long and complex supply chains full traceability cannot always be guaranteed.

Some production would inevitably be exported to parts of the world with lax regulatory and inspection regimes, and so the temptation and ability to ‘cut corners’ on quality would be high.

In any event, the produce may well be grown using PPPs that are perfectly legal in the country of production, but which are not authorised in the UK. Food production will have been exported with no improvement in safety.

There are also more subjective issues. With greater imports, the ability to buy home-grown, local or even seasonal produce will diminish. There is already a lack of understanding in the UK population about where and how their food is produced. If more of it is simply shipped-in on a boat then the large ‘disconnect’ between the majority of food consumers and food production could become even greater.

6.1.4. Resilience of the UK Food Chain

The concept of food security is much-debated. In many cases it is conflated with self-sufficiency - i.e. if we produce what we consume on these islands, then our food security is ensured. In a modern, open trading economy this perhaps does not make much sense. It is no more vital that the UK has high self-sufficiency in food than, for example, the Isle of Wight does.

However, in an uncertain world, with sophisticated but delicate supply chains there are pinch-points that could threaten food security. Some of these were highlighted in a DEFRA report[59] on food security. This highlights that having a diversity of supplies makes the UK's food security greater – if there is a crop failure or disease outbreak it is relatively easy to switch to alternative sources.

However, the complexity of modern supply chains causes its own problems in terms of resilience. Over 90% of the UK's food imports come by ship. It is therefore crucial that shipping lanes remain open. Whilst any major disruption to seaborne trade seems unlikely, the handling of imports comes through only a small number of UK ports. A recent study[60] shows that 50% of food imports come through just six ports (Channel Tunnel, Dover, Felixstowe, Southampton, Thames/Medway, and Humber). Any disruption through natural or man-made disaster to these would severely constrain the UK's ability to import in the short-term.

There is then the internal logistics of food supply. Many of these ports are located in the south of England and disruption to the transport infrastructure would result in the food not being able to reach consumers. This is not just an issue with imports however. The rise of just-in-time logistics means that there is less resilience built into the system. The whole food supply, manufacture and distribution is also very energy-dependent, and any disruption to energy and fuel supplies could have severe effects on availability.

Having home grown food does not solve all these problems. But it does create a more diverse food supply infrastructure, and results in sources of food being spread around the countryside.

***Table 18 – Changes in Availability of Key Foodstuffs** (Source: DEFRA – Agriculture in the UK)*

'000 tonnes	Current UK Consumption	Current UK Production	Current Self-Sufficiency	Revised UK Production	Additional Imports	Revised Self-Sufficiency
Commodity						
Wheat	13 910	13 894	100%	11 062	2 832	80%
Barley	5 201	5 981	115%	6 006	- 24	115%
Oilseed Rape	1 994	2 319	116%	1 474	845	74%
Sugar	2 055	1 211	59%	1 174	37	57%
Potatoes	7 149	5 832	82%	4 876	956	68%
Apples	670	224	33%	148	77	22%
Carrots	729	702	96%	316	386	43%
Onions	729	366	50%	92	275	13%

6.1.5. Competitiveness

It has been referred to in other sections of this report, but it is worth highlighting the competitive effects of policies on PPPs on UK and EU farming. If effective, and cost-effective, products are not approved or restricted at the UK or European level, whilst being allowed in other parts of the world, then this places domestic production at a considerable disadvantage. Other regions will be able to produce food at a lower cost of production and will gain market share at the expense of domestic production.

This makes little sense if it only serves to export production to the least-regulated and least-cost parts of the world. An example of this is the ban on sow stalls unilaterally imposed in the UK in 1999. It was not until 2013 that the rest of the EU followed and implemented the same sort of restrictions. In that time the UK had lost around half of its breeding pig herd.

The crop protection sector recognises that a 'race to the bottom' in terms of lowering standards to reduce costs is not in the best long-term interest of anyone. However, there is a strong argument that Europe and the UK should not get too far ahead of the global mainstream and undermine its own production base

6.2. ENVIRONMENTAL EFFECTS

6.2.1. UK Countryside and Biodiversity

The use of PPPs has been widely blamed for a loss of biodiversity in the UK (for an example, see this[61] report). However, other scientific studies[62] have shown there is a more nuanced situation with many other factors contributing to changes in biodiversity.

The agricultural and horticultural industries have become far more aware of the environment over the past quarter century. Programmes such as agri-environment schemes, the Voluntary Initiative (VI), and LEAF (Linking Environment and Farming) have demonstrated that modern farming can co-exist successfully. Indeed, it can be argued that having 'intensive' agriculture leaves more room for the environment elsewhere.

It should be acknowledged that the farming and agro-chemical industries have moved on since the 1950's and 1960's, with better science and greater environmental and social awareness which has affected product development and use. There is also an appreciation of the importance of comprehensive regulatory controls. But those controls need to be proportionate, properly applied through risk assessment, based on clear guidelines and underpinned by robust scientific evidence.

It is also recognised that science progresses, and additional knowledge and techniques have changed and continue to change the regulations to protect the environment and biodiversity. Again, this needs to be based on sound science and not political considerations. In addition, a careful weighing of the costs and benefits of any additional regulation should be undertaken. There is a strong perception that the regulators see their task as to 'regulate' – i.e. there is a strong built-in bias to be risk-adverse, and continually add additional 'safeguards'. However, regulation does not exist in a vacuum. Any loss of an approved active substance will involve a trade-off between possible environmental benefits and potential losses in agricultural output. This should be considered more fully, especially in the context of the global need for food outlined in the following section.

Like all technologies, additional research and development of PPP should result in 'better' products. This does not necessarily mean more effective control of pests; it could equally involve a product with similar control to present PPP, but with a 'lighter touch' on the wider environment. This makes the case for ongoing research and development to produce new PPP.

The results of the modelling work shown in Section 5.3 show a shift to more spring cropping. This is likely to increase biodiversity, and could be seen as a benefit of the loss of certain PPPs. However, this is a trend that is already underway for a variety of reasons – whilst policy towards PPPs may accelerate it, it is not key to its development. It is important to recognise that spring cropping is not feasible in all situations particularly on certain soil types and that PPP are still needed for productive spring cropping.

6.2.2. UK's Global Responsibility

Previous sections have already covered the issue of exporting production of food to countries with lower standards than Europe or the UK. Whilst these producers may receive a short-term economic gain in terms of greater sales, the long-term environmental effects are unlikely to be beneficial. With greater food demand from Europe, there may be increased pressure in other parts of the world to turn land over to agriculture. Looking at the global environment 'in the round' any gains in Europe from current policy on PPPs would be more than offset by environmental losses elsewhere.

Within the conclusions of DEFRA's Green Food Project[63] it was stated that there is a '*moral obligation to do what we can both domestically and through our influence on other countries to help address the critical long term food security issue, as well as the more pressing issue of hunger in some parts of the world*'. The FAO calculates that in 2013 there were 842 million people in the world who did not have enough to eat[64]. Whilst this number has fallen by 17% percent since 1990, the world still has some way to go to remove hunger.

With this background, it seems perverse that the UK and Europe is not using its natural resources, particularly good soils and favourable climate, to the maximum advantage. By producing food in a sub-optimal way, it is actually asking the rest of the planet to take on more of the burden of feeding a hungry population.

At points of lower production/higher price, EU consumer demand for food will impact on poorer countries where we out-bid locals for supplies of food. Destruction of the biofuel industry also removes an incentive for farmers to produce enough to buffer low output years – if not produced, grain stocks cannot be diverted for biofuel processing and into other markets. Over-regulation of futures markets risks exaggerated volatility in both production levels and prices where price discovery becomes inefficient and farmers respond to misleading signals.

6.3. Effect on Research and Science Base

6.3.1. Introduction

Discussions with those in the agro-chemical sector have made it clear that the current regulatory environment for the authorisation for PPP is stifling future innovation. This is borne out by a recent study[65] on research and development (R&D) carried-out for the European Crop Protection Association (ECPA). This is in direct contrast to the aspirations contained in the UK Government's Agri-tech strategy[66] which states;

'*We want the UK to become a world leader in agricultural technology, innovation and sustainability; exploit opportunities to develop and adopt new and existing technologies, products and services to increase productivity; and contribute to global food security and international development*'.

This section looks at some of the trends in plant protection research and the factors that are driving them.

6.3.2. Declining R & D Base

Evidence collated on a worldwide basis since 1950[65]**,** indicates a pattern of decline in the number of new active substance introductions since 1997. Of greater concern however is the fact that there has been a significant fall in the number of new active substances in development from 70 in 2000 to just 28 in 2012.

The share of investment in global crop protection for products used in Europe has fallen from 33.3% in the 1980s to only 7.7% in the 2005-2014 period[65]. European farmers can no longer draw on the same amount of new technology to drive agricultural production as their competitors in other parts of the world. Whilst Europe was benefitting from new agrochemical introductions at a rate of 4.1 and 4.0 per annum in the 1980s and 1990s, this rate is predicted to fall significantly to 1.2 per annum between 2005 and 2015[65].

The greatest regional market expansion in value terms over the past 5 and 10 year periods has occurred in the developing markets of Asia and Latin America. In Europe the market for conventional chemical plant protection products is split into three distinct areas, the mature EU-15 markets, the developing new members of the EU-12 and the non-EU European countries, which include the relatively mature Swiss and Norwegian markets and most importantly the rapidly developing markets in Russia, the Ukraine and other Eastern European countries. It is this third category, the Rest of Europe which has experienced the greatest growth in Europe. The EU-15 market has been characterised by relatively low rates of growth.

6.3.3. Causes of the Decline

A number of inter-related factors which have caused the decline in R&D investment in Europe, and hence the UK, are outlined in the previous section. Of these, the cost of gaining approvals is the most important.

The most recent data on the average cost of bringing a new active substance to market indicates that there has been a significant increase between 1995 and 2005 of 68.4%[67] Of particular note from these figures however, is that whilst research costs have risen by 18.0%, a staggering 117.9% of the rise relates to development costs (studies required to achieve registration). It is now estimated that it takes on average 10 years and costs £170 million to bring a new active to market[68].

This increase in time and costs is largely due to the quantity of evidence that must be supplied in terms of studies to support an application. This is a direct result of a more risk-averse regulatory environment. Some of the cost is for very little gain in terms of safety. An example of this is the Candidates for Substitution legislation. This is likely to create a large amount of research work through comparative studies, but with minimal or no improvement in safety or environmental outcomes. In many cases, the modelling work and risk assessments are not representative of real-world situations in which the products will be used.

Paradoxically, the improvement in science has contributed to the mushrooming cost of approvals. Better scientific knowledge and equipment creates more and better data. It provides more issues to look at and causes concerns to be raised.

All these problems apply not just to the approvals and registration of new active substances. They also apply to the re-registration of existing pesticides. In a lot of cases, the investment spent on securing a re-registration is many times the original cost of getting the pesticide approved.

As well as cost and time, the uncertainty of the regulatory environment is another key reason why investment in research and development has dropped. The introduction of new policies at EU level has created a particularly unstable policy framework over the past few years. This may settle-down in future with some certainty returning, but this is perhaps unlikely in the foreseeable future;

- Rules and definitions are still to be written in many areas - (e.g. Endocrine Disruptors). EU legislators are way behind their own deadlines in terms of providing detailed rules.
- The Guidance that sets out what evidence is required to be presented for the approvals process is changing / being written / re-written. Often this happens whilst a pesticide is within the approvals process - changing the 'rules of the game' whilst it is underway
- There can be 'political' decisions made outside of the normal regulatory framework – the restrictions on neonicotinoids are an example of this

The final point is an important one. The crop protection industry feels that this was not science based policy-making and that due process was not followed. It has 'spooked' companies within the sector as, if it can happen with this class of insecticides, it could potentially happen with other active substance. This only adds to the uncertainty in gaining and keeping approval for pesticides. At a practical farm-level, such ad-hoc decision-making means there is no time to develop alternative strategies and certainly not enough time to develop new PPP to replace those that are banned or restricted.

Given the timescales, costs and uncertainty now involved in the regulatory system, it is not surprising that many companies are no longer willing to progress new active substances through to development or to invest in Europe. A very strong business case has to be made to pursue registration. If there is any uncertainty over whether a pesticide will gain an approval it is simply 'strangled at birth'.

As registration costs rise, the commercial calculations change. To make a return on the huge investment needed the PPP needs to have a large market potential. This means world-wide products, not just those targeted at the UK or even just Western Europe. In addition, the product must have uses on the major global crops. This means there is very little product development for more minor crops and, even if a product is developed for minor crops, it may not be submitted for authorisation in Member States where the market is considered too small. The main focus for R&D is cereals, followed by maize then oilseed rape and soya. From an R&D perspective, the EU-15 market is seen as low-growth and this limits its attraction as a focus for R&D investment and new active substance development.

Another trend contributing to the decrease in European R&D is the lack of GM technology. Analysis clearly indicates that R&D investment in the seeds and traits industry is growing at a faster rate than for agrochemicals, a trend that has been evident since 2010[65]. This situation draws investment away from Europe, as this part of the world still severely restricts this technology. It is not only the R&D investment that goes into breeding, but additional investment is also made in the chemical protection required to support GM seeds. This means that research goes into creating PPP that are unlikely to be suitable for use in Europe.

With the EU singled out as the region with the most severely regulated pesticide registration system in the world, R&D companies looking to maximise their chances of successful registration and commercial return for new innovative products now invariably focus their investment outside Europe.

6.3.4. Market Structure

The high costs and uncertainty built into the EU approvals process creates a high barrier to entry to the sector. Worldwide, the number of companies involved in the research of new active substances has halved from 35 in 1995 to 18 in 2012[65]. In Europe specifically, the number of companies involved has fallen from 8 to 4 during this time. This trend has clearly affected levels of competition in the new product area and the diversity of products that have been developed. In the past small start-up companies have often been responsible for technology development, however as the associated costs and risks have escalated this source of innovation is far less common.

The cost of the approvals process is also discouraging 'generic' manufacturers. This means there is less completion in marketplace, even for those active substances that come off-patent.

7. MITIGATION STRATEGIES

7.1. BACKGROUND

It is unrealistic to expect an industry as dynamic as farming to accept the potential level of change outlined in Section 5 without responding to it, and trying to minimise the effects.

Other production systems such as organic farming are often cited as a realistic alternative to the caricature of ‘industrial’ agriculture. This section will look at such alternative approaches and assess if they offer a viable solution.

7.2. ORGANIC FARMING

7.2.1. Organic Principles

The concept of organic farming embraces philosophies and assumptions that are well beyond the simple label of ‘chemical free’. The aim is to create a ‘sustainable’ farming system based on the minimum use of external inputs.

Techniques include wide rotations; the use of organic matter to provide humus enriched soils; the use of only water-insoluble fertilisers; cultivations and mechanical weed control; exclusion of synthetic fertilisers, chemicals, growth regulators, and routine antibiotic applications. The use of genetically modified organisms is also prohibited. Ecological balance and the preservation of soil structure and micro-organisms are fundamental to the system. Such farming needs a high degree of management skill and may be best suited to those already operating low-intensity systems.

Due to the restrictions placed on farming practices, yields are usually lower under organic systems. To offset this, premium prices are required for organic produce. To achieve the price premiums required to make organic production viable there may be a greater need to successfully market the produce than under ‘conventional’ systems. Furthermore, larger acreages are required for cropping to offset the impact of lower yields, which in turn has an effect on the uncropped areas available for wildlife.

Despite the commonly held belief that low yielding organic agricultural systems are more environmentally beneficial and sustainable than high yielding farming systems, the reality is not always true. Many professional researchers and scientists suggest that these claims are as yet unproven and require more research. Indeed one leading organic researcher admitted that in organic farming ‘there is very little science’ and that ‘this gives rise to a great deal of illogicality and confusion particularly in some areas of production’.[69]

7.2.2. Organic Production

UK cereal farmers have significantly increased production over the past 65 years from a cereals area that has been in decline since the 1980s. DEFRA figures indicate that the average farm now produces three times more per hectare than in 1945. While better management techniques, improved plant varieties and fertiliser applications have had a significant part to play, the use of synthetic pesticides has both enabled and protected these gains.

Crop yields are significantly lower within an organic farming system where synthetic chemicals are not used. Research in Germany[70] has shown that overall, crop yields would roughly halve without their use. This conclusion is supported by other studies, both modelling and on farm studies, which routinely found organic wheat yields to be about 50% of conventional wheat yields.

More recently, ADAS (2008) suggests that an absence of chemicals would see a reduction in wheat yields, and implicitly cereal yields in general, in excess of 60%. It found that this reduction would result more or less equally from the loss of synthetic herbicides and fungicides. It concluded that the effectiveness of herbicides in controlling weeds would only partly be offset by increased ploughing and labour costs per hectare. Furthermore, the loss of synthetic fungicides would end modern cereals farming in the UK and by implication Europe. The ADAS study went on to highlight similar yield losses for all arable crops, vegetables, fruits and grasses.

These findings prompt the question as to whether the area of land used for cropping could be increased to make up the shortfall in organic yield, or whether customers would look to import from elsewhere. In the UK, there is little scope to increase the cropping area. Currently the UK cereals area is around 3 million hectares compared to around 4 million 25 years ago. In the intervening years much of the 'surplus' land has been lost to development and it is by no means certain that land currently in other crops would be made available. This pattern of lower output is likely to be similar in Europe and other parts of the world, where demand for cereals would also outstrip supply. On a global scale, whilst yield loss in some areas could be more readily offset by bringing more land into production, even in parts of the world less constrained than Europe greater awareness about the associated costs to biodiversity and natural resources is becoming more influential.

In reality, every type of agriculture has an impact on the environment. The perception that organic farming per se is better for the environment because it relies on natural processes does not always hold true. Natural processes are variable and outside the grower's control[71]. This can cause problems, for example the natural breakdown of mineral nitrogen can occur at the wrong time for the plants, increasing the chances of nitrate leaching[72]

Furthermore, on organic farms where most of the weed control is undertaken mechanically, this can exacerbate the problems of soil compaction, the disruption of soil structure and soil erosion whilst at the same time increasing fossil fuel consumption and global warming. An integrated approach in contrast can combine herbicide use with no till (or min till) practices to reduce soil disruption, increasing soil porosity and water holding capacity.

The use of soluble mineral salts prohibited by organic regulations is another contentious issue. The minerals removed from the land as food must balance those put back by other means. Organic farmers typically rely on legume nitrogen fixation, rain water or mineral recycling. The few detailed accounts that are available suggest slow but accumulating mineral deficits particularly of potassium and phosphate on organic farmland[73].

7.2.3. Can Organic Farming Feed the World?

There is clear evidence to suggest that organic agriculture is politically favoured as an environmentally benign alternative to the use of chemicals. However, there is also a significant body of professional opinion that believes widespread organic farming on a global scale is simply not a viable option at this time. In particular, Pacanoski[74] is of the opinion that whilst organic farming may satisfy the whim of the rich American and European consumer, its extension to the developing world would be a disaster. He reinforces this belief by quoting the Indian biotechnologist CS Prakash who observes that ‘the only thing sustainable about organic farming in the developing world is that it sustains poverty’.

The Food and Agriculture Organisation (FAO) of the UN predicts that there will be 9 billion people in the world by 2050 and that a population of this magnitude will require a 70% increase in food production to survive. Whilst increasing the land area used for production might seem the most logical response to a problem of this scale, there are a number of reasons why this suggestion is not a realistic option by itself and would be particularly difficult for organic farming alone to achieve.

According to Paarlberg[75] synthetic fertilisers currently supply around 40% of all nitrogen used by crops grown on a global scale. Given the current levels of attention to climate change, the replacement of these artificial sources with animal manures requiring an increase in the global cattle herd from around 1 billion to 7 billion, would be an environmental disaster. Furthermore, with rising land scarcity and wage rates in much of Asia, the likelihood of diverting already pressured farmland to more extensive green regimes is minimal.

One further factor to consider is that the reliability of harvest in organic farming systems is less certain than in those that use a full range of technologies. Therefore, additional average production could be required in order to provide a ‘buffer’ against crop failures and preserve food security.

The Soil Association[76] sees things differently however, believing that organic and other agro-ecological farming systems can help the world feed itself, that they are best suited to the needs of the poorest people and they have the potential to reverse environmental degradation. It does however qualify this by acknowledging that a change in farming systems in isolation is not the answer, highlighting the need for different eating habits, less food wastage and alternative feeding regimes for livestock.

Smaje[77] concludes that there is probably still a case for a bit of both; organic and conventional rather than just either/or. He believes the agricultural industry is not currently in a position to abandon synthetically fixed nitrogen and mined phosphates any time soon, and feels it makes sense to use all the technological means at our disposal to optimise the efficiency. Nevertheless, he does support some of the views held by the Soil Association in believing there is a case globally to rethink in the longer term the way we recycle nutrients, respond to the demand for meat, manage our waste, structure our labour markets and allocate global resources.

In summary therefore, it is evident that organic farming practices in the UK are unable to satisfy the levels of demand for agricultural produce on their own. The yields associated with organic production are insufficient to match demand, there is an increasing reluctance to pay premium prices and there is a finite supply of available land to extend cropping acreages. Furthermore, there are three important additional considerations which reinforce the situation further. Firstly, the effect of lower yields will be compounded by the fact that in the absence of modern inputs to control pests and diseases, more land will need to be left fallow or sown to grasses and legumes. Similarly, for those crops that make it into storage, the absence of synthetic chemicals to ensure cheap, efficient protection will contribute to further reductions in yield as a result of post-harvest losses. And finally, many farms in developed countries would find it impossible to recruit the cheap, willing labour they would need to control weeds economically in the absence of chemical inputs.

7.3. Precision Farming and Integrated Pest Management

Increasing concerns about the sustainability, environmental impacts and health effects of intensive farming have led to an increased demand for the development of alternative farming systems such as precision farming and integrated pest management (also called integrated farm management). Precision farming is the integration of information, utilising computer technology, GIS and GPS devices and remote sensing to match inputs with actual yields across different parts of both fields and individual farms. Estimates suggest that in the region of 60% of the UK farmland is farmed using precision technology. Whilst the numbers of farmers using these systems is thought to be low by comparison as a result of restrictive economies of scale, it is likely that more will be looking to use it in future as the costs of the technology come down.

Integrated Pest Management (IPM) is a whole farm approach to management that aims to help farming systems adapt to, eliminate or reduce the negative impacts of production on the environment whilst maintaining the economic viability of the farming enterprise. More specifically IPM seeks to minimise the use of pesticides and fertilisers through better targeting and integration with cultural control of weeds, pests and diseases[78]. The development of IPM is encouraged under the EU’s Sustainable Use Directive – a summary can be found in a recent note from the NFU[79].

For many farmers IPM is a logical development of their current conventional farming systems, combining the best of traditional methods with appropriate modern technology. This practice was conceived as being a dynamic concept rather than a prescriptive process, enabling it to adapt to new technology and changing market pressures and consumer demands. It is important to stress however that the concept was conceived as one of ‘integration’ and not one that sought to exclude conventional crop protection products entirely.

While IPM techniques are generally considered to have more beneficial than adverse effects on sustainable farming practice, there are nevertheless some areas of conflict. In particular, the mechanical and physical techniques aimed at reducing pesticide use. A number of these techniques involve an increased use of energy and other resources and, in the case of physical barriers, may create other problems such as additional waste or adverse effects on biodiversity and the landscape.

IPM techniques associated with soil management tend to be associated with more positive benefits for energy consumption and efficiency. Examples include fertility building crops, managing weeds through rotation, careful field drainage management and fertiliser applications. However, although the application of manures provides a valuable source of plant nutrients and can often be a direct replacement for inorganic fertilisers, manures can also be a source of environmental pollution and a high negative score for climate change.

It is evident that IPM works best when there is an appropriate balance between cultural and chemical control and there is merit in pursuing these opportunities in future.

Most recently, a study published in Nature[80] commented that yields should only be viewed as part of a set of economic, social and environmental factors that should be considered when evaluating the benefits of different farming systems. Foley adds that ‘by combining organic and conventional practices in a way that maximises food production and social good while minimising adverse environmental impact, we can create a truly sustainable food system’.

7.4. BIO-PESTICIDES

Biopesticides are PPP derived from such natural materials as animals, plants, and bacteria. Three main types are seen in the EU. ***Microbial pesticides*** have a micro-organism (e.g., a bacterium, fungus, virus or protozoan) as the active substance. ***Botanical pesticides*** are naturally occurring substances that have plant protection properties. Examples are plant derived products such as garlic extract or vegetable. Finally, there are ***Semio-chemicals*** such as insect pheromones.

Examples of microbial pesticides used in the UK are *Bacillus thuringiensis* which is a bacteria which causes disease in many insects, *Bacillus subtilis* a bacteria used to control grey mould in fruit, and the fungus *Coniothyrium mintans* to control sclerotinia in oilseed rape.

These products have a number of advantages. They are usually fully bio-degradable with no metabolites resulting as is the case with 'synthetic' pesticides. There is usually no withdrawal period after the use of biopesticides. Their mode of action is often very restricted – only attacking a very specific pest. This means they are targeted and do not affect other parts of the environment.

A number of drawbacks have been suggested for biopesticides. They are perceived to be more costly than synthetic PPP (although this is not necessarily the case). The products tend to be slower acting. This means they are more suited to preventative applications, than immediate treatment of an outbreak. A sufficient density of the control product must be maintained over a period of time for the biopesticide to take effect. Sometimes this can be problematical due to all the climatic and biological factors in play in field situations. Multiple applications may be required rather than one or two applications of synthetic PPPs.

In general, it might be considered that the use of these products requires a 'mindset' change. They are more about controlling pest populations below levels that are injurious to the crop, rather than the removal of pests. There is a greater degree of management required than with conventional pesticides. This is due to the need for multiple applications, and the requirement to use the product before the pest becomes established. This partly explains their greater take-up in the specialist cropping sector where the areas of crop are less, the value higher and the management more intensive. There is also an issue (as set out in Section 4.7.1) that there are often limited synthetic pesticides available for 'minor crops'. Therefore *any* PPP is welcomed. Broadacre cropping currently has a variety of control options, although these are decreasing as this report has demonstrated. Therefore the growers have, until now, continued to use the 'simpler' synthetic PPP.

Biopesticides look to have a positive part to play in plant protection in the future. Indeed many of the major agro-chemical companies have made investments in this sector in recent years. However, like IPM, they are likely to be complementary to synthetic pesticides, rather than a straight replacement.

Perhaps the most important point however, is that they are still 'pesticides'. Biopesticides are subject to the same EU approvals process as synthetic active substances. This means that getting a biopesticide product onto the market is subject to all the same issues of cost, delays and regulatory uncertainty as any other PPP. Therefore biopesticides do not provide an alternative option to 'bypass' the current policy environment.

7.5. Future Developments

Advances continue to be made with agricultural information technology, with more farm equipment being fitted with smart sensors. These are capable of reading everything from plant health and water needs in the crop to organic matter and nitrogen levels in the soil. Furthermore, in future drones will be more commonly used to identify crop health across fields. Farmers now have the opportunity to improve the timing, placement and management of key inputs during the growing season. Previously, such 'precision farming' technology had tended to focus on nutrients, especially, nitrogen requirements. However, increasing use is being made of variable rate spray applications. This has the potential to significantly reduce the quantity of pesticides being applied, as they will only be placed where they are useful. However, even if the quantities are reduced, this technology still needs effective and useful pesticides to be successful. Therefore, such technology is not a solution to the problem of losses of key PPP.

Robotics engineering is a new area of study which is destined to take off in precision farming as technology seeks to reduce labour inputs and the potential for human error. An increasing number of 'farmbots' are being developed to remotely check crops for growth, moisture and signs of disease. This year the UK government has allocated funding of £70 million to go towards the commercialisation of new agricultural technologies including robots. It is suggested that the logical endpoint of this technology will be autonomous robots that will 'rove' a field and detect weeds in the crop on an individual basis. The weeds could be controlled by spraying micro quantities of pesticides on the specific plant. Again, though, this still requires approved pesticides. Alternative methods such as lasers to 'burn off' the growing point to the weed plant have been suggested. Although this offers a 'pesticide free' alternative, it only seems a feasible option with weeds, and still leaves the problem of diseases and insects.

Other technology may have a role to play in this. There are biopesticides (see above) which are perhaps more suited to disease and insect control rather than weeds. In addition, techniques such as using suction to remove insects from horticultural crops have been used. In the specialist sector, the protection of crops under plastic (polytunnels) enables a micro-climate to be created and this has greatly assisted the control of pests. It seems unlikely that these technologies could be employed cost-effectively at large scale on the 'broadacre' crops grown across much of the UK however.

In general, whilst new technology offers some exciting opportunities, it is not currently developed enough to replace PPP. Even when the technology improves, and costs reduce, it seems unlikely to offer the complete answer. Like biopesticides, IPM, and even organic farming techniques, it is likely to provide one element of a holistic approach to plant protection, in which synthetic PPP continue to play an important part. It will enable PPP to be used far more effectively, but it will not be a replacement for PPP.

8. CONCLUSIONS AND RECOMMENDATIONS

The main conclusions of this study are summarised below. For ease of reference, they have been grouped under sub-headings.

8.1. Potential Losses

The current EU policy regime for Plant Protection Products (PPP) risks severely damaging UK (and by extension EU) agriculture by removing or limiting the use of key active substances. By drawing on various sources, this project has identified that the continued use of 87 (out of a current UK-approved total of around 250) active substances could be threatened by the cumulative effects of these policies.

In practice there is a sliding scale of threat. In an uncertain policy environment, gauging this is not easy. However, it has been assessed (through widespread consultations with the industry) that 40 active substances are likely to be lost or restricted in their use. Of that number, 10 are insecticides, 12 fungicides, 16 herbicides and 2 molluscicides.

8.2. Effect on Crop Production

The active substances deemed likely to be withdrawn or restricted are important in UK crop production. Control of weeds, disease, and pests in key crops grown in the UK would become far more difficult.

Whilst, there may be alternative pesticides to replace those likely to be lost, very often they will be less cost effective. In addition, the loss of any key active substance reduces the number of ‘modes of action’ against a specific pest. This means ineffective control, and resistance build-up is more likely. By limiting the control options, some pesticides and products will be used more widely. This could lead to increasing residues of these alternatives being found in the environment or in food and then they, in turn, could face restrictions.

For the key combinable crops grown in the UK (wheat, barley, oats, oilseed rape, peas and beans), the control of grass weeds (particularly blackgrass), is a vital issue. Broadleaved weeds are currently less of a problem, but could emerge as a major threat in the future. The impact of fungal diseases in cereals would also be far greater with the loss of threatened PPP.

In higher-value crops in the fruit and vegetable sector, insects and nematodes are important pests. These pests can affect both crop yields and quality, the latter jeopardising the chances of a crop being accepted by the retailer and consumer.

The area of crops such as apples, carrots and onions is relatively small compared to the ‘broadacre’ crops like wheat and barley. Although fruit and vegetable production has a high value per hectare, its sales potential makes it uneconomic for PPP to be developed specifically for these crops. As a result these crops tend to rely heavily on ‘extension of authorisation for minor use’ (EAMU) approvals. This is where a product approved on a major crop is also allowed to be used on more specialist cropping. Obviously, if the overall approval is not maintained due to changing policy or economic reasons, then the minor use on the horticultural crop is lost too.

The likely loss of PPP will lead to lower overall yields in the crops studied. Yield decreases are in the range of 4-50%, depending on crop. This is based on the effect of losing those PPP classified as 'high' risk of being restricted or not gaining re-approval.

8.3. Impact on the Farming Industry

There are changes in market prices following the loss of some key PPP – largely due to reduced output. In many cases these price changes are relatively small as it is assumed that the global market would be able to offset the shortfall resulting from lower UK output. However, it must be remembered that many of these policies are set at EU level, and thus the rest of Europe would be experiencing the same effects. In areas where the EU is a key producer (for example cereals), the market changes as a result of losing key PPP are likely be large enough to cause effects at a global level.

The loss of PPP changes cropping patterns in the UK. Generally, most crop areas decline. This is because it becomes more difficult and more expensive to grow them with the loss of key PPP. Greater crop rotation also means a decline in area of the largest crops. However, spring cropping increases and the area of fallow and temporary grass rises. Lastly, where production of a crop is economically marginal, it is likely that it will no longer be grown due to reductions in profitability.

This change in the structure of UK crop production is accompanied by changes in farming costs. The use of seed, fertiliser and PPP all change. In addition, the loss of some PPP means that greater reliance is placed on mechanical and hand weeding. The rise in cereal values also has an effect on the cost of animal feed for the livestock sector.

Modelling all these changes sees the Gross Value Added (GVA) of UK agriculture fall by about £1.6bn per annum. This represents a drop of 20% on the 5-year average 2009 to 2013.

UK farming profit (Total Income from Farming) drops by £1.74bn in monetary terms, but this is a higher proportion of the overall profit – a 36% drop from current levels. This decline in profitability will cause further structural readjustment in the farming industry. In general, less efficient producers will exit the sector. Farming operations will, on average, become fewer and larger.

It should be noted that the economic assessments undertaken in this report aim to be based on the most likely scenario. They are not 'worst-case' estimates.

8.4. Wider Economic and Social Effects

The impact of the loss of key PPP goes wider than just agriculture and horticulture. Farming provides the raw materials for the wider agri-food sector which makes up over 7% of the total UK economy. As a result, the Food Processing and Manufacturing sector would decline over time and would potentially lose an estimated £2.5bn of its GVA. The associated workforce would see job losses of between 35,000 and 40,000.

The other sectors hit hard would be Agricultural Wholesalers and the Agricultural Supply Industry. Together, the loss of GVA in these sectors would total £0.28bn with the potential loss of 3,500 to 4,000 full time jobs.

The UK is a major centre for research and development for PPP. The present EU policy environment is uncertain and generally unfavourable for the development of new PPP. Not only does this mean that more effective and environmentally benign alternatives are not being developed, but it also results in investment in this high-tech sector of the economy coming under threat.

Consumers in the UK will not go hungry as a consequence of the loss of some PPP. Being a relatively wealthy country, purchased imports could make up any shortfall in domestic production. However, the cost of food for consumers is likely to rise marginally. This may not have a great impact on the majority of the UK population, but would be serious for up to a fifth of the population that is already struggling with food poverty.

The make-up of UK food would change if the quantity of imported produce increases. In some cases, this imported produce would be grown using lower standards than those acceptable in the UK. Therefore, a net loss in terms of quality and possibly safety would result ('horsegate' provides an example of this). In addition, there would be the potential export of part of the food supply infrastructure. There are also more qualitative issues. With greater imports, the 'disconnect' between the majority of food consumers, and knowledge of where their food comes from and how it is grown, could become even greater.

In a globalised economy the concept of food self-sufficiency can seem archaic. However, in an uncertain world, with sophisticated but delicate supply chains, there are pinch-points that could threaten food security. These might include sea routes, ports, transport infrastructure and fuel supplies. Having a certain proportion of domestically-produced food can lessen some of these risks.

The increase in exports means some environmental issues are simply exported. This will often be to parts of the world with far less regulation and enforcement than the UK or Europe. The 'losses' in environmental terms in these countries are likely to be far greater than the (marginal or non-existent) gains in Europe. There is also the moral question of imposing rich-world production standards on other countries when there are 842 million people globally without enough to eat. There is a strong argument that Europe should be optimising its output (sustainable intensification) from its favourable soils and climate in response to this global challenge.

8.5. ALTERNATIVES

An argument is often put forward that alternative production systems not reliant on PPP can provide enough food. Of these, the most recognised is organic production, which attempts to operate without 'artificial' chemicals. Whilst various studies have found that organic systems could 'feed the world' these tend to rely on two large assumptions. The first is that consumers in the western world change their diets substantially to eat far less meat and dairy products, and those in the developing world do not adopt 'western' diets wholesale. The second assumption is that the global food storage, transport and distribution system is re-ordered to vastly reduce waste and create a 'fairer' allocation of the available food. Whilst, theoretically, both of these changes are possible, neither actually looks likely to happen. Again, there is a moral dilemma associated with the imposition of a certain 'worldview' on those who might wish to decide for themselves what and how they eat.

The concept of Integrated Pest Management (IPM) aims to minimise the use of PPP. As the name suggests however, it is a method by which PPP are used in conjunction with other techniques. Without the underpinning of effective PPP the whole structure falls down. New technologies may provide answers to certain crop pests (mainly weeds), but these are, as yet, not sufficiently developed for commercial use. Effective PPP will remain a vital component of a 'rounded' approach to plant protection.

8.6. OVERALL

The overall conclusion must be that the current direction of policy in the area of PPP is likely to lead to considerable economic and social loss with the gains, at best, uncertain or minimal.

Any policies should be science-led, and the assessment of risk has to be undertaken on a proportionate basis. A less precautionary approach with more realistic assessment of risks (rather than hazards) is essential if the UK wants to continue to benefit from having a thriving agricultural and horticultural sector, which protects the environment and provides a safe, affordable and sufficient supply of food for UK consumers.

APPENDIX I – REFERENCES

[1] PIP (Anon): Summary of EU Pesticides Regulations. (updated 2011). See http://pip.coleacp.org/en/pip/18110-pip-summary-eu-pesticide-regulations *(Accessed August 2014).*

[2] Europa (Anon): Commission Regulation EC No 737/2007 of June 2007 Laying down the procedure for the renewal of the inclusion of a first group of active substances in Annex I to Council Directive 91/414/EEC and establishing the list of those substances. Brussels (2007). See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:169:0010:0018:EN:PDF *(accessed August 2014)*

[3] Europa (Anon): Communication from the Commission of 12 July 2012 entitled "A thematic strategy on the sustainable use of pesticides" (COM (2006) 372 final – not published in the Official Journal). Brussels (2006). See http://europa.eu/legislation_summaries/other/l28178_en.htm *(accessed August 2014)* and European Commission (Anon): EU Policy for a Sustainable Use of Pesticides – The Story Behind the Strategy. Brussels (2007). See http://ec.europa.eu/environment/archives/ppps/pdf/pesticides_en.pdf (Accessed August 2014).

[4] EU (Anon): Official Journal of the European Union. Regulation (EC) No 1107/2009 of the European Parliament and of the Council of 21 October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC. Strasbourg. Brussels (2009). See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:309:0001:0050:EN:PDF *(accessed August 2014).*

[5] EU (Anon): Official Journal of the European Union. Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for Community action to achieve the sustainable use of pesticides. Brussels (2009). See - http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:309:0071:0086:en:PDF

[6] See - FCEC (Food Chain Evaluation Consortium): Ad-hoc study to support the initial establishment of the list of candidates for substitution as required in Article 80(7) of Regulation (EC) No 1107/2009. 2013. Framework Contract for evaluation and evaluation related services - Lot 3: Food Chain, Final report submitted to the European Commission, 09.07.2013. Available online to Member State authorities.

[7] Faust et al. Environmental Sciences Europe 26:11: Comparative assessment of plant protection products: how many cases will regulatory authorities have to answer? (2014). See - http://www.enveurope.com/content/pdf/s12302-014-0011-8.pdf *(accessed August 2014).*

[8] European Commission: An overview of the establishment by the European Commission of a legislative-based strategy for endocrine disruptors. Brussels (2014). See http://ec.europa.eu/environment/chemicals/endocrine/strategy/index_en.htm *(accessed August 2014).*

[9] Kortenkamp A, Martin O, Faust M, Evans R, McKinlay R, Orton F, Rosivatz E A Report for the European Commission – State of the Art Assessment of Endocrine Disruptors. Brussels (2011): See http://ec.europa.eu/environment/chemicals/endocrine/pdf/sota_edc_final_report.pdf *(accessed August 2014).*

[10] European Commission Directorate-General Environment (2013): ED-AD-HOC-6/2013/02.

[11] EU Consultation on the Definition of Endocrine Disruptors. Brussels (2014). See - http://ec.europa.eu/dgs/health_consumer/dgs_consultations/food/consultation_20150116_endocrine-disruptors_en.htm *(accessed October2014).*

[12] EU Directive to establish a framework for community action in the field of water policy. Brussels (2000). See http://eur-lex.europa.eu/legal-content/EN/ALL/;ELX_SESSIONID=gs67TLrR4HwjLz3G72VTnbn7hmBPq5l52Jyppt1TQb1td9JrbVWn!246607505?uri=CELEX:32000L0060 *(accessed August 2014).*

[13] European Commission (Anon): Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC as regards priority substances in the field of water policy. Brussels (2013). See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:226:0001:0017:EN:PDF *(accessed August 2014).*

[14] Raquel N. Carvalho, Lidia Ceriani, Alessio Ippolito and Teresa Lettieri, Development of the 1st Watch List under the Environmental Quality Standards Directive, JRC, Brussels, (2014).

[15] DEFRA (Anon): Water Framework Directive implementation in England and Wales: new and updated standards to protect the water environment. London (2014). See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/307788/river-basin-planning-standards.pdf *(accessed August 2014).*

[16] Commission Regulation 485/2013 restricting neonicotinoid seed treatments. See - http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:139:0012:0026:EN:PDF *(accessed August 2014).*

[17] AHDB (Anon): Neonicotinoids: key messages - a summary of the key implications of insecticide restrictions for growers of oilseed rape and cereal crops. Kenilworth (2014). See

http://www.hgca.com/media/11527/Neonicotinoids%20%E2%80%93%20key%20messages%20August.pdf *(accessed August 2014).*

[18] DEFRA (Anon), An assessment of key evidence about Neonicotinoids. London (undated) - https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/221052/pb13937-neonicotinoid-bees-20130326.pdf *(accessed August 2014).*

[19] Walters K, Outlooks on Pest Management: Review of data on the effects of neonicotinoid on pollinators. Sunningdale (2013). DEFRA (Anon): An Assessment of Key Evidence about Neonicotinoids. London (undated). See http://pesticidetruths.com/wp-content/uploads/2012/01/Reference-PCP-Bees-2013-08-00-Data-Data-Everywhere-But-We-Don%E2%80%99t-Know-What-To-Think-Walters.pdf

[20] H. Charles, J. Godfray, Tjeerd Blacquière, Linda M. Field, Rosemary S. Hails, Gillian Petrokofsky, Simon G. Potts, Nigel E. Raine, Adam J. Vanbergen, Angela R. McLean. A Restatement of the Natural Science Evidence Base Concerning Neonicotinoid Insecticides and Insect Pollinators. Proceedings of the Royal Society. London (2014). See http://rspb.royalsocietypublishing.org/content/281/1786/20140558.abstract

[21] HSE (Anon): Registering a Pesticide. Bootle (undated). See http://www.pesticides.gov.uk/guidance/industries/pesticides/topics/pesticide-approvals/pesticides-registration/registering-a-pesticide.htm

[22] Based on the PSD Database showing Product expiry dates, sorted to remove ‘amateur’ products and those actives using biological and straight chemical control – see http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/P/product_dates_05_09_14.xlsx

[23] Pesticides Safety Directorate (Anon): An assessment of the impact on crop protection in the UK of the ‘cut-off criteria’ and substitution provisions in the proposed regulation of the European Parliament and of the Council concerning the placing of plant protection products on the market. York (2008). See http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/R/Revised_Impact_Report_1_Dec_2008(final).pdf *(accessed August 2014).*

[24] EU (Anon): Proposal for a regulation of the European Parliament and of the Council concerning the placing of plant protection products on the market – Summary Impact Assessment. (COM(2013) 0620. Brussels (2014). See http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/O/Outcomes_paper_-_summary_impact_assessment_(Jan_09).pdf *(accessed August 2014).*

[25] WRc for DEFRA (Anon): Extended impact assessment study of the human health and environment criteria for endocrine disrupting substances proposed by HSE, – PS2812. London (2012). See http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18083

[26] HSE (Anon): Regulation (EC) No 1107/2009: progress on endocrine disruptors and candidates for submission. Bootle (2014). See - http://www.pesticides.gov.uk/guidance/industries/pesticides/News/Collected-Updates/Information-Updates-2014/January/Regulation+_EC_No_1107_2009-progress_on_endocrine_disrupters_and_candidates_for+substitution

[27] European Commission – Environment (Anon): An overview of links to the legal/preparatory acts, study reports and other supporting background documents relevant to the development of the legislation on priority substances under the Water Framework Directive. Brussels (2014). See http://ec.europa.eu/environment/water/water-dangersub/lib_pri_substances.htm#prop_2011_docs

[28] DEFRA (Anon): Water Directive implementation in England and Wales – new and updated standards to protect the water environment. London (2014). See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/307788/river-basin-planning-standards.pdf

[29] DEFRA (Anon): Impact of changing pesticide availability on horticulture and an assessment of all impacts and priorities on a range of arable, horticultural and forage crops. - IF01100. London (2010). See - http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17126

[30] Environment Agency (Anon): WFD Compliance Picture – Pesticides Breakdown. *Unpublished.*

[31] EU (Anon): Official Journal of the European Union. Commission implementing regulation (EU) No 485/2013 of 24 May 2013 amending Implementing Regulation (EU) No 540/2011, as regards the conditions of approval of the active substances clothianidin, thiamethoxam and imidacloprid, and prohibiting the use and sale of seeds treated with plant protection products containing those active substances. Brussels (2013). See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:139:0012:0026:EN:PDF

[32] Food & Environment Research Agency (Anon): Pesticide Usage Survey. York (undated). See http://www.fera.defra.gov.uk/landUseSustainability/surveys/

[33] Clarke JH, Wynn SC, Twining SE, Berry P, Cook S, Ellis E and Gladders P, HGCA Research Review 70: Pesticide Availability for Cereals and Oilseeds Following Revision of Directive 91/414/EEC; Effects of Losses and New Research Priorities. Kenilworth (2009). See - http://archive.hgca.com/document.aspx?fn=load&media_id=5195&publicationId=5850
[34] ADAS (Anon): Impact of Changing Pesticide Availability on Horticulture. Wolverhampton (2010). See - http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17126
[35] HGCA (Anon): ADAS Arable Crop Report :June 2014. Kenilworth (2014). See http://www.hgca.com/markets/market-news/2014/june/27/adas-arable-crop-report-june-2014.aspx
[36] S R Moss, R Marshall, R Hull and R Alarcon-Reverte: Current status of herbicide-resistant weeds in the United Kingdom. Aspects of Applied Biology 106 (2011)
[37] Lutman P J W, Moss S R, Welham S J, Cook S, A review of the effects of crop agronomy on the management of Alopecurus myosuroides. Weed Research (2012)
[38] Stobary RM and Ballingall M, HGCA Project Report No 509: New strategies to maintain autumn grass-weed control in cereals and oilseed rape. Kenilworth (2011). See http://www.hgca.com/media/197879/pr509-summary.pdf
[39] HGCA (Anon): Topic Sheet 113 /Spring 2012 Septoria tritici in winter wheat. Kenilworth (2012). See http://www.hgca.com/media/178045/ts113_septoria_tritici_in_winter_wheat.pdf
[40] HGCA (Anon): Guidelines to minimise risk of *Fusarium* mycotoxins in cereals. Kenilworth (2010). See http://adlib.everysite.co.uk/resources/000/245/487/2010_FusariumGuide.pdf
[41] HGCA (Anon). Oilseed Rape Guide. Kenilworth (2014). See http://www.hgca.com/media/493856/g55-oilseed-rape-guide-updated-september-2014.pdf
[42] Nicholls CJ HGCA Research Review No 79: Implications of not controlling slugs in oilseed rape and wheat in the UK. Kenilworth (2014). See http://www.hgca.com/media/364367/rr79.pdf
[43] AHDB (Anon) Information Sheet 02 Autumn: Integrated slug control – latest information and action points prepared in conjunction with the Potato Council. Kenilworth (2013). See http://www.hgca.com/media/246568/ahdb-is02slug_control_-_ahdb_is2_aut_2013_20139115815.pdf
[44] Metaldehyde Stewardship Group (Anon): Get Pelletwise – Guidance and best practice for the use of metadehyde slug pellets. (2014). See http://www.getpelletwise.co.uk/
[45] Nicholls CJ HGCA Research Review No 77: Implications of the restriction on the neonicotinoids: imidacloprid, clothianidin and thiamethoxam on crop protection in oilseeds and cereals in the UK. Kenilworth (2013). See http://publicationsarchive.hgca.com/publications/documents/RR77.pdf
[46] Wynn S, Ellis S and Alves L. Cabbage stem flea beetle snapshot assessment – incidence and severity at end September 2014. ADAS for HGCA. See http://www.hgca.com/media/507048/cabbage-stem-flea-beetle-report.pdf?utm_medium=email&utm_campaign=CSFB%20press%20release&utm_content=CSFB%20press%20release+CID_748ddec7bea5e9e65b9dc16f5dc5ef7d&utm_source=Campaign%20monitor%20emails&utm_term=Cabbage%20stem%20flea%20beetle%20snapshot%20assessment%20%20incidence%20and%20severity%20at%20end%20September%202014
[47] Ricardo-AEA (Anon), Appraisal of Policy Options to Manage pesticides
[48] Nicholls CJ HGCA Research Review No 77: Implications of the restriction on the neonicotinoids: imidacloprid, clothianidin and thiamethoxam on crop protection in oilseeds and cereals in the UK. Kenilworth (2013). See http://archive.hgca.com/document.aspx?fn=load&media_id=8858&publicationId=9309
[49] See http://ir4.rutgers.edu/
[50] See http://www.europarl.europa.eu/sides/getDoc.do?type=TA&reference=P7-TA-2014-0205&language=EN&ring=A7-2014-0048
[51] DEFRA (Anon): Annual statistics about agriculture in the UK for 2011, 2012 and 2013.London (updated 2014. See https://www.gov.uk/government/collections/agriculture-in-the-united-kingdom
[52] DEFRA (Anon): Statistical Data Set – Structure of the agricultural industry in England and the UK at June. London (updated 2014). See https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june
[53] DEFRA (Anon) National Statistics – Basic Horticultural Statistics 2013 on the area, yield, production, trade and valuation of the main fruit and vegetable crops grown in the UK. London (updated 2013). See https://www.gov.uk/government/publications/basic-horticultural-statistics
[54] International Grains Council – Monthly Market Report.
[55] Rickard S CPA Report: The Value of Crop Protection. Peterborough. (2010). See http://www.cropprotection.org.uk/media/1903/cpa_the_value_of_crop_protection_rickard_report.pdf

[56] Redman G John Nix Pocketbook 45[TH] Edition 2015. Melton Mowbray (2014). See http://www.thepocketbook.biz/
[57] DEFRA (Anon). Agriculture in the UK, 2013.
[58] Tesco PLC (Anon): News Release – One in five parents struggling to feed their children. Cheshunt (2013). See http://www.tescoplc.com/index.asp?pageid=17&newsid=790
[59] DEFRA (Anon): UK Food Security Assessment: Our approach: London (2009). See http://archive.defra.gov.uk/foodfarm/food/pdf/food-assess-approach-0908.pdf
[60] DEFRA (Anon) Science and Research Project: Resilience of the food supply to port disruption – FO0108. London (undated). See http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17782
[61] Isenring R, Pesticide Action Network Europe: Pesticides and the loss of biodiversity – How intensive pesticide use affects wildlife populations and species diversity. London (2010). See http://www.pan-europe.info/Resources/Briefings/Pesticides_and_the_loss_of_biodiversity.pdf
[62] HSE (Anon): The Impact of Herbicides on Weed Abundance & Biodiversity – Executive Summary and Conclusions. Bootle (undated). See http://www.pesticides.gov.uk/guidance/industries/pesticides/topics/publications/research-reports/the-impact-of-herbicides-on-weed-abundance-biodiversity
[63] DEFRA (Anon): Policy Paper - Green Food Project Conclusions (jointly developed and owned by the Green Food Project Steering Group). London (2012). See https://www.gov.uk/government/publications/green-food-project-conclusions
[64] Food and Agriculture Organisation of the United Nations (Anon): The State of Food Insecurity in the World (SOFI) 2014. Rome (2014). See http://www.fao.org/publications/sofi/en/
[65] Philips McDougal: R&D Trends for Chemical Crop Protection Products and the Position of the European Market – A Consultancy Study Undertaken for ECPA. Pathhead. (2013).
[66] DEFRA, DBIS and DID Policy Paper (Anon): See UK Agricultural Technologies Strategy – an outline of the way government and industry will build on the strengths of the UK sector. London (updated 2013). See - https://www.gov.uk/government/publications/uk-agricultural-technologies-strategy
[67] Phillips McDougal: A Consultancy Study for Crop Life America and ECPA. Pathhead. (2010).
[68] Crop Protection Association - Challenges to Crop Protection (undated).
[69] House of Lords Select Committee on European Communities: 16[th] Report Organic Farming and the European Union. HL93 ISBN 0 10 409399 4. London (1999).
[70] Oerke E: Crop Losses to Pests. Bonn (2006)
[71] Kidd M, Lewis E: Organic Foods – Consumer Concerns (Submission to the House of Commons Agriculture Committee Enquiry into Organic Farming). London (1999).
[72] Myers RJK, Van Norordwijk M, Vityakon P for ASB: Synchrony of Nutrient Release and Plant Demand: Plant Litter Quality, Soil Environment and Farm Management Options. Wallingford (1997).
[73] Nolte C, Werner W: Biol. Agric. Horticult.10 235- 254. (1994).
[74] Pacanoski Z: The Myth of Organic Agriculture. Skopje (2009).
[75] Paarlberg R Food Politics: What Everyone Needs to Know. New York (2010).
[76] Soil Association: Feeding the Future - How Organic Farming Can Help Feed the World. Bristol (undated).
[77] Smaje C: Can Organic Farming Feed the World? Statistics Views 21-5-2013 (2013).
[78] Boatman ND, Parry HR, Bishop JD, Cuthbertson AGS: Impacts of Agricultural Change on Farmland Biodiversity in the UK. (2007).
[79] See http://www.nfuonline.com/assets/20830
[80] Seufert V, Ramankutty N, Foley JA: Comparing the Yields of Organic and Conventional Agriculture – Nature. (2012).

Report produced by:
THE ANDERSONS CENTRE
Old Bell House
2 Nottingham Street
Melton Mowbray
Leicestershire
LE13 1NW

Contact:
RICHARD KING
Office: 01664 503 200
Direct: 01664 503 208
E-mail: rking@theandersonscentre.co.uk