EUROPEAN PARLIAMENT

Technology options for feeding 10 billion people

Interactions between climate change & agriculture and between biodiversity & agriculture

Summary

Science and Technology Options Assessment

STOA

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Abstract of the study

There will be rising global demand for food and energy from the land over the coming decades resulting from population growth and economic development. This will coincide with the need to adapt agriculture to increasing climate-related threats (which will probably outweigh opportunities in Europe), whilst decreasing the impact of agricultural emissions on climate change. At the same time, biodiversity losses due to intensive agricultural practices and abandonment of biodiversity-rich farming are expected to continue.

The long-term sustainability of farming is being undermined by trends such as soil degradation, declines in pollinators, the loss of natural biological control of pests and diseases, and the loss of plant and animal genetic diversity. Substantial changes in agricultural systems are required in Europe to ensure rapid reductions in agricultural emissions of greenhouse gases, as well as effective adaptation to climate change and strengthened biodiversity conservation.

This report describes a range of practices and developments in agriculture that could sustainably increase agricultural productivity whilst contributing to climate change mitigation and adaptation, and providing biodiversity benefits. Policy could play a larger role in supporting innovation and development in the full range of agricultural systems in Europe and in the use of certain wastes and residues for energy purposes.

The report provides a set of recommended options for incentivising beneficial actions, constraining unsustainable practices, and promoting innovative options whilst ensuring environmental safeguards for new technologies that might have unwanted negative impacts on biodiversity.

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1 INTRODUCTION

There is an increasing need for the 'sustainable intensification' [1] of agriculture to ensure food security in light of the anticipated global population of 10 billion people by the end of the century. The focus of this study is to examine the interrelationship between agriculture, climate change and biodiversity, and address the potential for a range of innovative options for a more sustainable, resilient and efficient agriculture in the EU, with fewer negative impacts on climate change, biodiversity and ecosystem services[2].

The two key drivers affecting overall **demand** for food and agriculture are population size and economic growth. Much of Europe has experienced considerable economic growth, until recently, which has had a major impact on consumption, and consequently major impacts on the environment. The Food and Agriculture Organisation (FAO) has estimated that the global demand for food will rise by approximately 70 per cent over the next 40 years to feed a rising world population with changing dietary trends. As societies have become more affluent they tend to consume more processed foods and livestock products (meat and dairy), and have become more wasteful, creating an increased demand for agricultural land. This increasing global food demand will be met through a combination of bringing non-agricultural land into production and by increasing yields. Although it is expected that the majority of this increased demand will arise and be met outside the EU, particularly in Africa, some increase in production is likely within the EU, particularly in relation to cereals in Eastern Europe.

Yields in the main productive areas of Western Europe are already high and the environmental impacts of production are considerable, and in some situations unsustainable, with serious concerns about the state of biodiversity, as well as water and soil resources. Although there may be some potential to increase crop yields in the EU, the extent of the increases that are likely to be **sustainable** are limited, and likely to depend on new technological developments and their wider use. Therefore substantial changes in European agricultural systems will be required in order to reduce the existing environmental impact and increase crop production, in addition to dealing with new pressures such as those associated with climate change.

These serious challenges facing global food systems means that there is an urgent need to take **action** on the problems of climate change, environmental degradation and resource depletion at the same time as addressing food security. As agriculture operates within a global market the central challenge will be increasing agricultural productivity in ways that avoid and reverse the negative environmental impacts of current farming systems. Changes in technologies and land management practices that lead to the more sustainable production of food will be a central element of strategies for reducing pressure on land resources in Europe and in those countries from which the EU imports products. The rationale for this study, therefore, is to gain a greater understanding of the *potential options for a more sustainable resilient and efficient agriculture in the EU, with fewer negative impacts on climate change, biodiversity and ecosystem services.*

[1] *Sustainable intensification:* producing more from the same area of land while reducing negative environmental impacts and increasing contributions to natural capital and the flow of environmental services

[2] *Ecosystem services*: the direct and indirect contributions of ecosystems to human wellbeing; categorised in four main types: provisioning services (eg food, water, fuel); regulating services (eg flood and disease control); supporting/habitat services (eg nutrient cycling, pollination, soil formation); and cultural services (eg recreation, cultural, spiritual and aesthetic values).

2 CLIMATE CHANGE AND AGRICULTURE

2.1 The impacts of climate change on European agriculture

Climatic changes present many challenges for increasing European agricultural production, with the future impacts of climate change likely to be **complex** and difficult to predict. More frequent extreme weather events, pest and disease attacks, as well as climate variability and higher overall temperatures, all have the potential to outweigh the positive impacts that increased CO_2 density and warming may have on some crop yields (EEA, 2012).

Box 1: Climate change effects on climate and agriculture

- Directly changing the conditions for crop growth
- Changing the availability of water
- Altering the frequency and severity of extreme weather events
- Affecting soils and soil processes
- Changing the conditions for the spread of pests and diseases
- Changing the risk of fire
- Altering patterns of energy use

The combination of increased temperature and changing patterns of rainfall are likely to increase the demand for irrigation water needed for crop growth, due to reduced and changing patterns of rainfall. It may be difficult to sustain adequate supplies of irrigation water to meet this additional demand, particularly in southern and south-eastern Europe. Furthermore, in southern Europe crop growth may suffer as a result of increased temperatures, whereas in northern Europe crop growth may benefit as the growing season may be extended and potential growth rates increased. However, some of these benefits may be offset by the predicted increase in the frequency of extreme weather events, such as flooding, which may make crop yields more unpredictable. Temperature change is predicted to lead to a northward shift of areas suitable for certain crops, but this may not translate to an overall increase in productivity. The other major impacts that can be predicted at the moment are that of altering complex soil interactions, and of pests and diseases. It is likely that climate change will provide new opportunities for their spread, with the risk of damage occurring more frequently and in new areas.

Climate change is likely to provide European agriculture with both threats and opportunities. Substantial **changes** are likely to be needed to adapt European agriculture to the challenges presented by climate change, further complicating the already challenging task of achieving sustainable intensification.

2.2 The impact of European agriculture on climate change

Agriculture is an important net source of greenhouse gases in the atmosphere. Major sources of greenhouse gas emissions include carbon dioxide from the loss of carbon from arable soils, methane from livestock and manure, and nitrous oxide from the use of manure, fertiliser and external inputs to soils. The emissions of methane and nitrous oxide are particularly significant as these make a much greater per unit contribution to global warming than carbon dioxide. Cropland soils in particular act as a net source of emissions, for example through oxidation of soil carbon following soil erosion or tillage. N_2O emissions are attributed to the cultivation of organic soils and the mineralisation of soil organic matter as a result of land use conversion and drainage (European Commission, 2009).

Box 2: Greenhouse gas emissions

Greenhouse gas emissions from agriculture account for 9.8% of all EU emissions (not counting emissions from land use, land use change and forestry) (EEA, 2012). Croplands in the EU-27 emit about 70 million tonnes of CO_2 equivalent per year. Agriculture accounts for a substantial share of the total emissions of nitrous oxide and methane.

Conversely, the conversion of cropland to grassland can reduce net emissions by locking up increased amounts of carbon dioxide as organic carbon in the soil. Existing grasslands and peat soils also contain large reservoirs of stored carbon that need to be properly managed so that they do not release their stores. Afforestation of agricultural land can also lock up carbon, both in the soil and in the trees themselves. CO_2 emissions from agriculture can additionally result from the use of fossil fuels for agricultural machinery, transport, heating and drying, and from upstream activities including the production of fertilisers and pesticides, and the production and maintenance of machinery.

Box 3: **Impact of cultivation and drainage on peat soils**

Around 16 per cent of Europe's peatland, and up to 70 per cent of peatland in some Member States, is currently used for agricultural purposes and drained, including the vast majority of peat in Northern and Western Europe. Nitrous oxide is released from cultivated peat soils for decades after its drainage. In 2007, EU-27 emissions from cropland on peat soils amounted to 37.5 million tonnes CO2-eq, corresponding to 88 per cent of total emissions from cropland. (European Commission, 2009; Gobin et al, 2011; Schils et al, 2008).

The vulnerability of agriculture to climate change illustrates the need for agriculture to play a part in the global effort to reduce greenhouse gas emissions. There is considerable **potential for agriculture to reduce its net emissions**, but some of the changes that this would require may conflict with the goal of increasing agricultural production.

2.3 How can European agriculture both contribute to climate change mitigation and adapt to climate change?

There are many actions available for addressing climate change mitigation and adaptation within the agricultural sector, a large number of which can be carried out at farm level. However, many of these require collective action from a number of stakeholders. Mitigation measures aim to address the reduction of CO_2, CH_4 and N_2O emissions - from land use and soils, by sequestering carbon and preventing its release; from machinery use and energy use on farms; from indirect sources such as the production of fertilisers; from the storage, processing and application of manure; from soils and drainage; and from livestock management. Different types of management that can bring co-benefits for climate change mitigation and adaptation are available for:

- The livestock related sectors, including changes in livestock management and grazing land and pasture management;
- Cropland management;
- Land use change and other land based measures;
- Energy efficiency and renewable energy use on farms and in rural areas
- Sustainable water use and improved water efficiency for example in irrigation;
- Other key actions for adaptation; and
- Cross-cutting actions

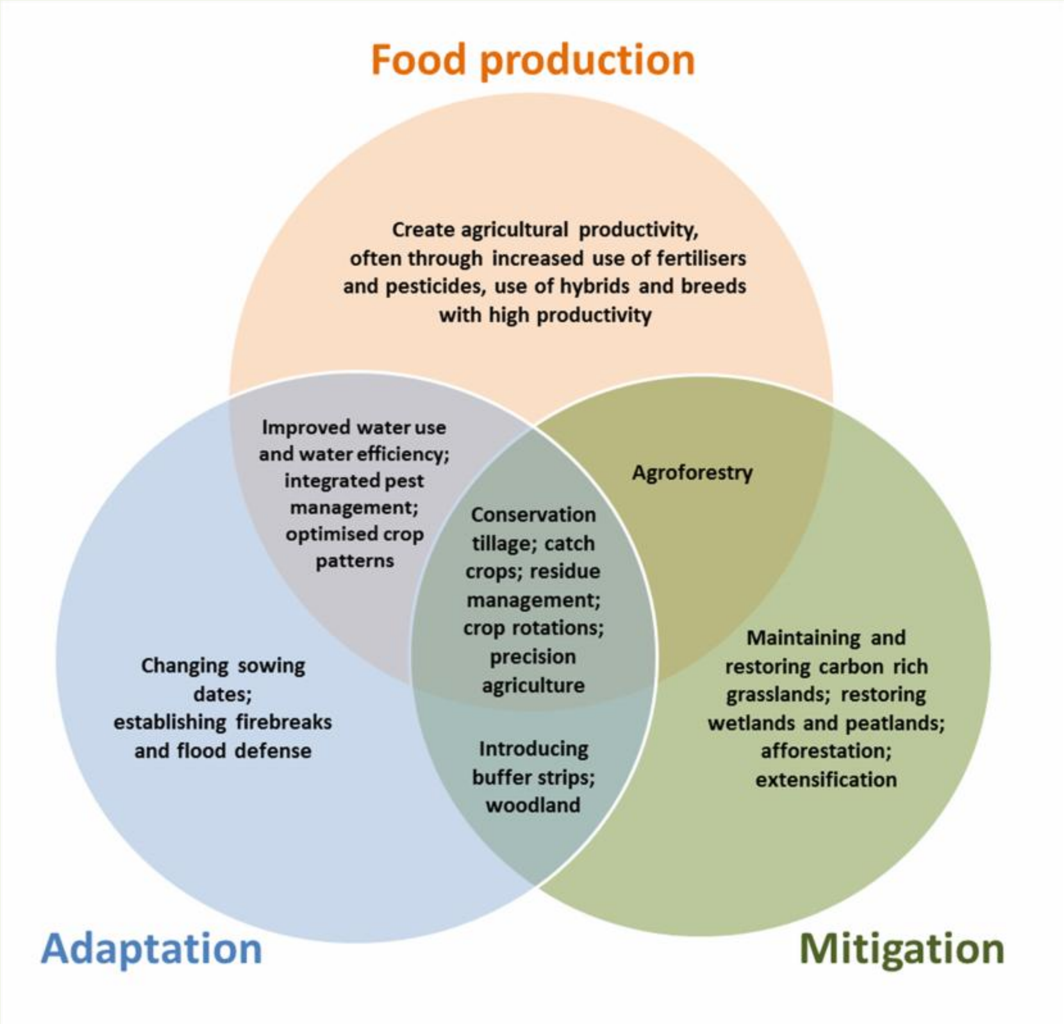
Some of the most important forms of crop management to support and adopt on a larger scale include diversification of crop rotations; planting catch crops, more winter cover, more green manure and less fallow; under-sowing and adding nitrogen-fixing crops to rotations; more intercropping; reducing tillage; more crop residue management in-field; effective restrictions on agricultural activities on slopes; reducing or optimising fertiliser and pesticide use; and precision agriculture.

At the same time, actions can be devised to address adaptation in the use of soil, water and inputs and in livestock management. It will also be necessary to minimise the future impact that climate change will have on biodiversity and to respond to the changes resulting from mitigation approaches. Appropriate adaptive actions have the potential to strengthen the resilience of farms and agro-ecosystems as well as reducing vulnerability. At the farm level, three main types of adaptation measure can be distinguished (OECD, 2010):

- Those that reduce the vulnerability of affected agro-ecosystems and agricultural soils;
- Those that reduce the exposure of a farming system to the effects of climate change such as drought, heavy rainfall, and storms by hazard management; and
- Those that increase resilience, both in ecosystems by conserving resources and the resilience of the farming population to enable them to overcome the losses that do occur.

It is predicted that European agriculture has the potential to reduce non-CO_2 emissions (including from livestock systems and the use of fertiliser) by 42 to 49 per cent by 2050 compared to 1990 (European Commission, 2011). Sixty-four separate **actions have been identified** which could help agriculture respond to this challenge. Some of these would contribute to both climate change mitigation and adaptation whilst increasing productivity in the long-term, whilst some are essential for climate change mitigation or adaptation but may reduce productivity slightly or to a greater degree. This is illustrated in the figure below:

Box 4: Potential synergies and trade-offs between climate change adaptation, mitigation and food production (modified graphic based on Campbell et al. 2011)



A strategy for meeting the central challenge of sustainable intensification is to focus first on those actions that lie within the intersection of all three circles in this diagram – mitigating negative environmental impacts, allowing adaptation, and increasing food production. Such steps are likely to be beneficial wherever they are deployed and, because they have food production benefits, farmers may undertake them for purely economic reasons. Unfortunately, it is unlikely that these actions alone will be sufficient to meet the full scale of the challenge. Further actions will be required to manage the resultant trade-offs that will be introduced. The evidence gathered for this report suggests that this will require:

- A holistic approach
- Advice and support to farmers
- Coordinated and targeted action at a landscape scale
- Cooperation and collaboration
- More focussed research and development
- The active involvement of government at all levels

3 BIODIVERSITY AND AGRICULTURE

3.1 Biodiversity in EU agricultural ecosystems

Biodiversity and agricultural systems in Europe are closely interrelated. Firstly, agriculture is ultimately **dependent on the ecosystem processes** that support plant production, such as the maintenance of soils, pollination, and the regulation of pests and diseases, and these processes rely on biodiversity. Secondly, the majority of habitats existing in Europe are the result of thousands of years of human activities, which has created many semi-natural habitats dependent on traditional, extensive agricultural practices for their existence. However, agriculture since the 1950s has seen a change to the predominance of highly modified and simplified agricultural habitats and landscapes over much of the lowlands of the EU, resulting in the loss of semi-natural farmland habitats, and leading to further significant falls in diversity and loss of specialist agricultural species over much of Europe (Poláková et al 2011).

Box 5: Biodiversity decline

Since 1980 common farmland bird populations in Europe have shown a substantial **51% decline**, grassland butterfly populations have declined by almost 50% across Europe since 1990, and there has been significant decline of wild bees and their forage plants.

As a result, the farming systems of the highest biodiversity importance are the remaining traditional low-intensity farming systems that maintain semi-natural habitats - High Nature Value Farming systems (HNV) - which still cover around a third of the EU agricultural area (Oppermann et al 2012). The most serious threat to agricultural biodiversity in most of the EU is the continued **loss and degradation of semi-natural habitats** dependent on farming - the EU has lost 2.4 per cent of semi-natural farmland since 1990 - because of partial or complete abandonment of agricultural management as a result of their low economic viability and social and agronomic change (EEA 2010). Many semi-natural habitats and their associated species are of European conservation importance and therefore the subject of conservation measures under the **EU Habitats and Birds Directives**.

3.2 The impacts of farming practices on biodiversity

Farming practices associated with more intensive and specialised farming can have **significant impacts on habitats and biodiversity**, both in and outside of farming systems. Some farming practices, such as conventional tillage, pesticide use, drainage and irrigation, and the use of artificial fertilisers, nearly always result in less biodiversity, whereas others can have differing effects depending on ecosystem type and intensity, for example optimal levels of grazing can help maintain habitats, but over and under-grazing can be damaging. High levels of fertiliser use, ploughing of grassland, and soil erosion from over-grazing have led to increases in water pollution.

Box 6: Agricultural changes that result in loss of biodiversity on farmland

- Declines in mixed farming systems
- The removal of farmland habitat features
- Drainage of grasslands
- Ploughing and reseeding
- Intensive grazing
- Early mowing of grass for silage
- The use of avermectins and other drugs against parasites of livestock
- Switches from spring-sown crops to winter-sown crops
- Ploughing and other tillage operations
- Irrigation

Box 7: Biodiversity footprint outside the EU

The EU has a substantial impact on agriculture-related biodiversity outside the EU, largely resulting from imports from non-EU countries which supply around 70% of its animal feed needs. Soybean cultivation in Brazil and Argentina has resulted in the conversion of semi-natural habitats high in biodiversity, and has caused indirect deforestation through the displacement of livestock farming into forest. The net embodied deforestation associated with EU-27 imports of crop and livestock products between 1990 and 2008 was calculated at 7.4 million ha, equivalent to 4 per cent of the EU's forest area (EC 2013).

Intensive fertiliser application decreases weed diversity, and has a strong negative impact on **plant diversity** in field margins. On grassland, it reduces the types of plants typical of natural and semi-natural habitats, turning the grassland into **dense species poor grassland** with fewer insects and other invertebrates, less food for farmland birds, and sometimes less soil organic matter and soil biodiversity. Nitrogen emissions into water and air from fertilisers are now considered to be one of the most important causes of biodiversity loss, both terrestrial and aquatic.

Pesticides also have significant impacts on species in freshwater habitats; amphibians, the most threatened and rapidly declining vertebrate group in Europe, are particularly vulnerable to pesticide toxicity. Evidence strongly suggests that the use of broad-spectrum pesticides[3] has been a key factor in the **decline of non-crop plants, invertebrate groups and birds** in arable farmland habitats across much of Europe. A particular concern is the impacts of insecticides on bees and other pollinators. Four systemic insecticides[4] have now been restricted for two years to only non-flowering crops, greenhouse crops, and winter cereals because of concern about their impact on honey bees and bumblebees.

[3] Broad spectrum pesticides are pesticides that kill or affect many different species, not just the pest(s) they are meant to kill

[4] The neonicotinoid pesticides imidachloprid, chlothianidin, thiamethoxam and the phenylpyrazole pesticide fipronil

Two new agricultural techniques that may have a big influence on EU agriculture in the future are feedstocks for advanced generation biofuels and GM crops. Their possible impacts are described in Chapter 5.

3.3 Why do biodiversity losses in agricultural systems matter?

Biodiversity loss may threaten the long-term sustainability of farming in some areas as a result of the degradation of the ecosystem services on which farming depends, including soil processes, natural pest control, and pollination.

Soils are highly complex systems with a very high level of biodiversity, most of which is unknown. Soil life supports agricultural production by decomposing plant residues and driving nutrient cycling, and by helping to stabilise soil structure, degrade pollutants, and regulate soil pests and diseases. But a recent expert review indicates that **soil biodiversity** is potentially under high pressure in nearly a quarter of the EU (Gardi et al 2013). Much of this is due to the serious decline of soil organic matter on most of Europe's arable land.

There is also evidence that the **natural biological control** of pests, diseases and weeds across Europe's arable farmland is compromised because of insecticide use and the lack of refuge habitat and floral resources to sustain invertebrate populations (Geiger et al 2010).

Box 8: Pests, diseases and weeds and their natural enemies

A diversity of pests, diseases and weeds present challenges to agricultural production in Europe, and can destroy yields if not controlled. For example, stemborers, a pest of **maize,** weaken plants, reducing grain quality, and encouraging fungal infections. **Diseases** can be caused by fungi, viruses, bacteria, and/or other pathogens, and can be transmitted by water, wind, soil, plant material, insects, or other animals. It is predicted that climate change and climate variability will increase pest and disease losses in agriculture, especially in Southern Europe.

Weeds present management challenges in almost all crops, and can result in significant crop losses. In each crop a few persistent weed species cause most of the problems, and integrated weed management systems actually aim to increase weed diversity so that dominant weeds are suppressed. Some common pasture weeds are poisonous to livestock.

Luckily, most native pests, pathogens and weeds are eaten, parasitized, and infected by a wide range of predators, parasitoids, parasites and pathogens, including bacteria and viruses, insects, other invertebrates, amphibians, reptiles, birds and mammals. These are collectively known as '**natural enemies**' and their service to pest control is referred to as **natural biological control**. In ecologically intact communities, natural enemies can keep pest populations at a low level. In crop monocultures, pest populations can increase faster than their natural enemies, unless the natural enemies are able to survive on alternative food or hosts in or near the field and then move onto the crop quickly enough to keep the pest population under control. Natural enemies need refuge habitats and alternative prey on weeds and in field margins; particularly important are nectar and pollen-rich flowers as alternative or supplementary food.

Pollination by animals is essential or important to the production of many crops. Domestic honeybees are important pollinators wherever there are beekeepers, but just as important are the wild pollinators, including wild bees, flies, butterflies and moths. However, pollinators are in decline in the

EU, as described in Chapter 6. This chapter also describes the situation of another key part of agricultural biodiversity in the EU - **plant and animal genetic resources** for food and agriuclture.

Arresting and reversing losses of biodiversity and ecosystem services in EU agricultural habitats, and in habitats affected by agricultural activities, is essential if the EU is to meet the nature conservation targets of the Biodiversity Strategy 2020 and of the Convention on Biological Diversity.

3.4 What can be done to maintain and increase biodiversity on farmland in the EU?

There is a wide range of farming practices and actions that have been shown to increase biodiversity at the farm scale and field scale in Europe. Many of these beneficial practices are supported under agri-environment schemes[5] in Member States' Rural Development Programmes. Biodiversity-friendly farming practices include:

- Protecting and maintaining semi-natural agricultural habitats such as grasslands, and farmland features that provide habitats such as wide hedges, dry stone walls and terraces, ditches and ponds
- Creating and managing field margins, crop rotations, fallow patches and fields, and crop stubbles so that they provide breeding habitat and food (eg flowers and seeds) for wildlife
- Reducing and targeting the use of fertilisers, pesticides, and irrigation so that they have fewer negative impacts on wildlife

An example is the provision of field margins and buffer strips. Buffer strips protect water courses from pesticide run-off and spray drift, can reduce soil erosion and improve water retention, and if managed for biodiversity can increase plant diversity and food resources for pollinators, other insects and birds, maintaining bird and pollinator populations. Additionally buffer strips can reduce susceptibility to pests and diseases through maintaining natural biological control and reducing greenhouse gas emissions from the reduced use of fertilisers and pesticides, if natural biological control is enhanced, while the plants with the margins can store carbon.

Research clearly shows that agri-environment schemes benefit species richness and abundance on both arable and grassland across Europe (Bátary et al 2010), but are not currently sufficient to reverse the declines in Europe's farmland biodiversity, due to poor scope and being insufficiently targeted (Merckx et al 2009). Agri-environment programmes need to be better targeted to the nature of the landscapes of the regions where they are implemented and the type of species groups that should be benefiting in order to reap significant biodiversity benefits.

The spatial scale over which agricultural biodiversity is delivered needs to be increased significantly and the efficiency and effectiveness of measures improved to ensure that biodiversity thrives in the wider countryside as well as in protected areas (Poláková et al, 2011). For example, a study estimated that Germany would need active management actions over at least 15 per cent of its utilised agricultural area in order to reverse the decline of farmland species and secure valuable habitats in farmed areas. This wouldinvolve restoring and maintaining semi-natural landscapes, extensifying 10 per cent of intensive grassland, and allocating 7 per cent of arable and grassland to farmland features (Hampicke, 2010).

[5] Agri-environment schemes are support payments that are intended to encourage farmers to adopt more environmentally-friendly and sustainable farming practices, including the conservation of biodiversity, landscapes and other natural resources

4 FOCUS ON CROPPING SYSTEMS: GM AND BIOFUEL FEEDSTOCKS

Two technology innovations that may have a big impact on European agricultural production in future, including its footprint in the rest of the world, are crops for biofuel production and genetically modified crops. There is some evidence for estimating the current and possible future impacts of these cropping systems and options for mitigating negative impacts, but there is also significant uncertainty associated with predicting the impacts.

4.1 POSSIBLE IMPACTS OF GM CROPS ON BIODIVERSITY IN THE EU

4.1.1 GM crops in the EU

Genetically modified organisms (GMOs) are animal or plant varieties that contain one or more genes inserted into their genome using breeding technology, enabling the insertion of genes with desirable traits from completely unrelated species. GM crops may be designed to offer agronomic, economic, nutritional, or environmental benefits. However, there are also potential environmental risks. In Europe only two GM crops are currently authorised for cultivation – insect-resistant Bt maize (MON810) and starch-modified Amflora potatoes. These crops are only grown on relatively small areas. New GM traits, genes and crops that have been developed in small-scale tests, but have yet to be cleared for commercial use, include crop varieties which provide different nutritional or industrial qualities, such as easier conversion to biofuel, or increased tolerance to environmental stresses such as freezing, drought or salinity. However, it seems unlikely, due to lack of consensus between EU Member States, that current applications for new GM crops will be authorised in the EU in the next decade.

4.1.2 What might be the future impact of GM crops on biodiversity in Europe?

It is not possible to make any generalised statements about the consequences for biodiversity as GMOs cover a very broad spectrum, with characteristics and possible impacts that vary greatly. The evidence for benefits to biodiversity from the current EU-relevant GM crops such as reduced use of certain broad spectrum insecticides and greater up-take of zero-tillage arable systems, comes mainly from North and South America, and may be different in the EU situation. There is also evidence that some current GM crops are having adverse effects on biodiversity, including hybridization with wild relatives, resistance development in pests and weeds, and loss of biodiversity from more intensive cultivation practices. Evidence from the US and other parts of the world can inform risk appraisal and analysis in Europe, but each GM variety must be evaluated in the specific local conditions of European cropping systems (EFSA 2010). A number of EU governments have chosen to adopt the precautionary principle, militating against the use of GMOs, with eight Member States implementing national bans on GM crop cultivation citing concerns about impacts on biodiversity.

In most of the EU, commercial planting of GMOs has been on a very small scale to date. If GM cultivation were to expand in scale in Europe it would be likely to involve a broader range of new generation GM traits than are currently grown in comparable regions, for which the evidence base is still very limited. It is therefore **difficult to forecast the balance of hazards and benefits to biodiversity** from a larger scale use of GMOs in Europe.

Box 9: Possible pathways of gene flow from GM crops in Europe in the future

One of the key environmental risks of GM crops is the risk that gene flow into feral crop populations or crop wild relatives leads to either problems with invasive plants or the loss of valued wild genetic diversity. It is known that gene flow from many of the crops grown in Europe is already affecting their crop wild relatives. If GM oilseed rape were widely grown in the EU it would be likely to result in feral GM oilseed rape populations and crop-wild hybrids, but it is not clear if this would result in harm to biodiversity, because impacts would vary with the GM trait and may only be noticeable after a number of years. Gene flow from wheat, sugar beet, grass and tree species is also likely.

In the longer term, if it were to be established that GMO based cropping systems were both stable in the longer term and able to sustain a higher level of yield than conventional crops without adverse environmental impacts, then there would be the prospect that the pressure to expand the agricultural land area can be constrained and more **land could be available for biodiversity conservation**. At present, however, it is unclear whether GMO based arable systems in Europe could perform such a role and it would be premature to conclude that a gain for biodiversity could be made this way. Key biodiversity considerations would include the likelihood and consequences of hybridisation and the risk of invasive feral populations[6] with stress tolerance traits.

4.2 IMPACTS OF BIOFUEL FEEDSTOCKS ON BIODIVERSITY

4.2.1 The biofuel market within the EU

Biofuel	Feedstocks
Bioethanol	EU: wheat, sugar beet or maize Non-EU: sugar cane, maize Advanced biofuel: Tall-growing grasses (eg *Miscanthus*, Canary Grass, Switch grass); short rotation coppice (eg willow, poplar); and crop residues (eg straw)
Biodiesel	EU: oilseed rape, sunflower, waste products (eg used cooking oil and tallow) Non-EU: soya, jatropha and palm oil

The key driver behind EU biofuel use is the Renewable Energy Directive's (RED) target to increase the share of renewable energy in the transport sector to 10% in each Member State by 2020. At present liquid biofuel is the primary option for meeting the target, ie bioethanol and biodiesel made from the processing of plant material or waste food products.

Box 10: Total EU biofuel consumption

Total EU biofuel consumption in 2010 amounted to close to 13 million tonnes of oil equivalent (Mtoe); i.e. 4.27% of total transport energy.

The current EU biofuels market is dominated by **conventional biofuels** produced from food and feed crops. Rapeseed oil dominates the biodiesel market, amounting to almost half of all consumption,

[6] *Feral population*: a population of crop plants that is self-propagating outside the crop field itself (ie in field margins, roadsides, waste land)

while sugar beet, wheat, maize and sugar cane dominate the ethanol market. In recent times **advanced** or "second generation" biofuels have emerged; although they have not yet been used commercially for this purpose, they are generally expected to be economically feasible by 2020.

4.2.2 Biodiversity impacts of biofuel consumption

Box 11: International impacts

Palm oil plantations in South-East Asia are often cited as a critical driver of forest and biodiversity loss. An estimated 27% of oil palm concessions **displace peatland rainforest** in Malaysia, and 56% in Indonesia occurred at the expense of the highly biodiverse lowland evergreen tropical forest (Campbell and Doswald 2009). In Brazil, bioethanol production is one of the main economic drivers for the expansion of sugar cane, which is **encroaching into the Brazilian Cerrado**, the world's most biodiverse savannah.

The demand for food and feed crops for the production of conventional biofuels for EU consumption will lead to significant additional land requirements. A major concern related to the consumption of biofuels is the conversion of natural or semi-natural ecosystems, either for production of biofuel feedstock themselves (i.e. direct land use change) or for production of other crops that have been displaced by biofuels, (i.e. indirect land use change). Extra land could come from the **conversion of semi-natural areas**, from agricultural land already in production (through displacing existing forms of production), or through the utilisation of marginal or degraded land.

One estimate predicts a loss of 3-8 per cent of semi-natural vegetation in the EU by 2020 compared to 2000, as a consequence of the displacement of grasslands and arable farming (Hellmann & Verburg 2010. However, it is thought that 50 per cent of biofuel production will occur outside the EU. Globally, the conversion of natural or semi-natural land to agriculture remains one of the most significant pressures on biodiversity worldwide and is increasing – it is estimated that the EU's biofuels target could lead to a global increase in cropland of 1.73 to 1.87 million ha (Laborde 2011). Estimates vary depending on different modelling approaches, in particular with regards to the use of biofuel co-products[7] and yield developments. What is certain, however, is that **indirect land use changes** from EU biofuel demand are a real and tangible problem, affecting global biodiversity, food prices, access to land, and other social and environmental impacts.

Advanced biofuel feedstocks such as willow coppice or *Miscanthus* grass could have benefits for biodiversity compared to arable crops. However, it is too early to judge the overall biodiversity impacts of commercial scale production of advanced biofuel feed crops, as much will depend on which habitats are being replaced, the management, and the scale and location of planting. Furthermore, studies on biodiversity impacts have not yet looked at the **cumulative impacts** of large developments and regional concentrations of energy crop mono-cultures that will be necessary to supply large power plants.

4.2.3 Policy for more sustainable biofuels

EU sustainability criteria for biofuels were introduced as part of the **EU Renewable Energy Directive** with the objective of preventing the conversion of biodiversity-rich habitats and high-carbon storage areas to cropland to grow biofuel feedstocks. Although the criteria are very important as a first step in mitigating the impact of the biofuel industry, these regulations **do not mitigate** against indirect land use change risks. Indirect impacts, resulting from a chain of displacement effects, are not monitored let alone regulated at present as part of the Directive's sustainability scheme, and are believed to be a

[7] such as oilseed cake from biodiesel production and dried distillers grain from bioethanol production

considerable risk. It is likely that the sustainability criteria in the Directive will have little or no effect on global agricultural systems due to **displacement** of food and animal feed crops to areas important for biodiversity and/or carbon storage, and the biofuel sector outside Europe. To be effective, the policy would need to target a wider range of agricultural commodities and a more comprehensive group of countries.

A conceptually, if not politically straightforward solution would be the **phasing out of volume targets** for conventional biofuels in the EU. While volume targets have been successful in bringing about a significant scaling up of first generation biofuel production, they turn out to be inflexible in light of the need to respond to evidence based challenges such as ILUC and all its associated effects. Therefore, such targets should be replaced by emission reduction targets for fuel suppliers and increasingly stringent vehicle CO2 standards in the longer term.

5 FOCUS ON PLANT GENETIC RESOURCES AND ON POLLINATORS

Two vital components of the biodiversity that underpins sustainable agriculture are pollinators – both honeybees and wild pollinators – and plant genetic resources for food and agriculture. Both of these are under threat in Europe for many reasons, as described below.

5.1 PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE IN EUROPE

5.1.1 The importance of plant genetic resources

The genetic diversity within crops and related species plays an important role in agriculture's ability to adapt to a changing climate, resist new pests and pathogens, and provide high yielding varieties under different conditions. However, the continuing erosion or extinction of plant genetic diversity reduces options for plant breeding, and the options of future generations to use diverse crops, to adapt to climate change and to ensure sufficient and nutritious food for all. FAO warns that the world's food security is threatened by our failure to conserve crop genetic diversity and crop wild relatives, estimating that three-quarters of crop diversity has been lost globally since 1900 (FAO 2010).

Plant genetic resources for food and agriculture (PGRFA) encompass a wide range of different crops and wild plants, including modern crop cultivars, breeding lines and genetic stocks, obsolete cultivars, ecotypes, landraces and crop wild relatives, as well as weedy races and primitive forms of crops.

5.1.2 Conservation and use of plant genetic resources

It is vital that EU and at the Member State level policies recognise the current threat facing European PGRFA and the crucial contribution that policy will make in tackling the challenges associated with sustainable intensification of food production. Diversity of plant genetic resources should be recognised as a necessity, with a higher priority given to ensuring their conservation. Although Europe has approximately 500 gene banks maintaining 2 million *ex situ*[8] accessions, they do not effectively conserve the range of diversity required by contemporary plant breeders, at least 11.5 per cent of European crop wild relatives are threatened (Bilz et al 2011), there is no estimate of what percentage of traditional farmer-bred crop landraces[9] are conserved, and there is no sustainable *in situ*[10] or on-farm conservation of crop-related biodiversity in Europe (Maxted et al 2012). Therefore there is a need to ensure policies are in place to support their **enhanced conservation and use**.

The second Global Plan of Action of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) lays out agreed priority plans and actions to protect the diversity of genetic resources and to ensure the sustainable creation of improved varieties from plant breeding. The current challenges to the conservation and use of PGRFA and the needs of future generations demand an **integrated, multifaceted approach** that builds on the initiatives of all stakeholders concerned and is based on increased cooperation and mutual learning.

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[8] *ex situ* conservation means the conservation of components of biological diversity outside their natural habitats, for example in gene banks or botanical gardens

[9] Land races are unique crop varieties that have adapted to local conditions through a process of farmer selection

[10] *In situ* conservation means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticates or cultivated species, in the surroundings where they have developed their distinctive properties

5.2 HONEYBEES, POLLINATORS AND POLLINATION IN EUROPE

5.2.1 The importance of pollinators

Pollinators ensure the reproduction and fruit set of many crops and wild plants by transporting pollen from one flower to another, ensuring crop yields and the transfer of genes within and among populations of plant species, maintaining genetic diversity. In Europe, more than 150 crop species and 80 per cent of European wild plant species are directly influenced by insect pollination for **fruit and seed set**, including a variety of fruits and vegetables, industrial crops, seeds and nuts, herbs and forage crops. Bees are the primary pollinators for most crops requiring animal pollination, including domestic honey bees and wild species such as stingless bees, bumblebees and solitary bees.

An abnormal decline of both honeybees and wild bees has been observed worldwide for several decades. There is scientific evidence that the loss of pollinators in Europe is having an economic impact on food production and an ecological impact on wild plant species. Additionally, our **dependency on both honeybees and wild pollinators** for a nutritionally diverse and balanced food supply is high, suggesting that pollinator decline may thus lead to future human nutritional imbalances and deficiencies.

5.2.2 The factors affecting bee/pollinator populations in the EU

Current knowledge suggests the cause of decline is due to **multiple factors**, with the frequency, severity and rapidity of bee colony mortality varying depending on the conditions. Key pressures and **drivers of colony decline** identified with substantial scientific evidence include: pests and pathogens, specifically *Varroa destructor* (which in combination with diseases is a major driver of winter colony mortality across Europe); agricultural practices, including pesticide use, increased fragmentation and habitat loss, decline in pollen quality, and lack of nutrient sources, diversity and quality due to intensification of grassland and arable land; and poor beekeeping practice, including the lack of honey-bee genetic diversity (AFSSA 2008, European Parliament 2011). The causes of wild bee declines are less investigated, but expected to be similar.

Box 12: Economic importance of pollinators

It has been calculated that pollinators have an impact on the yield of 35 per cent of Europe's food production (by weight), and the **economic value of food production** from animal-pollinated crops is estimated at €15 billion per year (European Parliament, 2011).

Many of these factors are linked or interact, adding to the complexity of understanding the exact causes of bee decline. For example, evidence on neonicotinoids pesticides seem to show that such products do not necessarily have significant impacts alone, but reduce the resistance to pests, making both factors in combination a significant threat to bees (eg Alaux et al 2010). The effects of **interactions** could be almost as important as those of each driver in isolation.

Monitoring and reporting, and finding causes and solutions, is difficult because the beekeeper sector is very fragmented, and most beekeepers are non-professional. However, monitoring systems are now being implemented in most Member States, and significant new research programmes are underway.

5.2.3 What is needed to reverse pollinator decline in Europe

Honeybee decline is caused by the interaction of many factors, which means a **range of measures** are needed, **requiring concerted actions** by public authorities, beekeepers, farmers, the pharmaceutical industry, and researchers. Whilst recognising that multiple factors require action, two **specific actions** are (1) local breeding for Varroa resistance, necessary as current control methods for Varroasis are failing due to resistance and their significant costs, and (2) increasing flower resources for pollinators in agricultural landscapes. Pollen and nectar resources in agricultural landscapes have declined significantly, the primary factor limiting wild pollinator populations. Agri-environment measures could encourage farmers to protect semi-natural habitat patches in farmland and create field margins rich in flowers for bees on a larger scale.

6 RECOMMENDATIONS

The interrelated challenges of climate change and biodiversity loss lead to the conclusion that if agricultural production is to be increased through intensification then **it must be achieved sustainably**, taking into account climate and biodiversity needs in the EU and elsewhere. The term 'sustainable intensification' has been coined to describe this twin challenge of increasing the productivity of agricultural land to produce more food and more environmental services in the face of a changing climate. Substantial changes in agricultural systems are required in Europe in order to **reduce the existing environmental deficit** as well as deal with new pressures, such as those associated with climate change. Changes in consumption patterns (particularly decreases in meat consumption) and a greater effort over time to reduce food wastage are also necessary. EU policies, including the CAP and the European Innovation Partnership (EIP) on agricultural productivity and sustainability, have key roles to play in increasing the scope, pace and effectiveness of actions. Such actions should include **incentives** for climate resilient and biodiversity-friendly farmland management, the effective use of **policy instruments** including regulations to avoid unsustainable practices and protect important ecosystems and their biodiversity, and funding to stimulate **research and adoption of innovative management options**.

The following are **recommended priority options** for sustainably increasing agricultural productivity whilst supporting key actions to facilitate agriculture-related climate change adaptation and mitigation and biodiversity conservation. These are based on a review of the implications of the interrelationships between climate change and agriculture, and between agriculture and biodiversity, and take into account the potential for using a range of innovative options to increase agricultural productivity on a sustainable basis.

1. Options that provide appropriate incentives for climate resilient and biodiversity-friendly farm management

Promote actions that have benefits for climate change adaptation and mitigation and avoid significant biodiversity damage, and are also economically beneficial for farmers in the EU

- Integrate a stronger climate dimension into the CAP both from 2014 and in future rounds , including rural development programmes. Farmers need encouragement to identify and take appropriate actions to **use water, soil, energy and waste resources more efficiently**.
- Well-designed, targeted and monitored **agri-environment schemes**, as well as other incentive measures, can provide benefits for biodiversity and climate change adaptation. Improved crop rotations, integrated weed and pest management, intercropping, better nutrient management, conservation tillage, unfarmed flower-rich buffer strips, and reduced livestock densities are all examples.

Public funding should help **overcome barriers to action** by farmers, implementing climate change mitigation and adaptation measures, through modest support to upfront investment costs and start-up costs where needed, particularly in the livestock sector where there are fewer direct productivity benefits. Many of the actions needed are more beneficial if they are planned and targeted at a **scale larger than the individual farm**. The Rural Development Regulation contains supporting measures that can help encourage and pay for the necessary planning and targeting of long-term actions at a landscape scale by funding local partnerships, facilitators and advisory services.

Strengthen the protection and management of semi-natural agricultural habitats and the economic viability of the farming systems that maintain them

- This requires a combination of **increased support and enhanced investment** in traditional management alongside the development of new approaches and adaptation to changing socio-economic conditions.
- Support and advice needs to be targeted to **farming systems that maintain and restore Natura 2000[11] habitats and species**, both within Natura 2000 sites and outside, especially where they buffer or connect Natura 2000 sites.
- Effective climate change mitigation and biodiversity conservation will require some limited areas to be **taken out of highly productive use**, such asthe rewetting of peatlands and the extensification of grassland.

Member States can use the Common Agricultural Policy framework to develop measures that **assist High Nature Value farming** by supporting the appropriate management of valuable semi-natural habitats on farmland and by less direct measures that add value to HNV farm produce to improve economic and social sustainability, reducing abandonment. Actions to restore and recreate semi--natural farming systems must be supported by policy measures that **recognise the substantial ecosystem services** they provide, by more explicitly linking public support to the provision of ecosystem services, through ecosystem assessments, strategic multifunctional land use planning and management, payment for ecosystem services schemes and improved monitoring.

2. Options that constrain unsustainable practices in Europe

Ensure compliance with the Nitrates Directive and other EU legislation that reduces environmental burdens

- Better **management of the nitrogen cycle** on farmland would bring substantial benefits for biodiversity, reduce GHG emissions, and improve water quality. This requires more consistent and rigorous action across the EU for balanced fertiliser use[12] , improved crop and manure management; low-protein animal feeding; and improved manure storage. Yields can be maintained while reducing pollution loads.

Push for ambitious pesticide reduction targets and full implementation of integrated pest management

- Member States are currently failing to set ambitious **pesticide reduction** targets under the Sustainable Use of Pesticides Directive. However, under the new CAP framework, Farm Advisory Services are obliged to provide farmers with advice on integrated pest management, through which substantial biodiversity benefits could be gained.

Use CAP cross-compliance[13] requirements to ensure protection and management of farmland elements that benefit biodiversity and climate change adaptation

- Ensure that Member States use the greater flexibility to set GAEC requirements in the new CAP cross-compliance regime so as to enhance protection and management of permanent grassland, riparian buffer strips, and farmland features, as well as water and nitrogen use efficiency.

3. Promote innovative options for a productive climate resilient agriculture that benefits biodiversity whilst ensuring environmental safeguards for new technologies

[11] Natura 2000 is a framework of EU nature conservation legislation (including the Birds and Habitats Directives) that protects important habitats and species including an EU-wide network of protected areas

[12] ie fertiliser use that does not lower crop yields but that decreases nitrogen losses to less than 50 mg NO^3-l^{-1}

[13] Cross-compliance is a set of standards that defines good agricultural and environmental practices on EU farmland

Ensure that innovation investment targets areas of greatest potential and knowledge gaps, combining yield improvement with sustainability objectives

- Existing streams of yield advance need to be better integrated with **innovative practices that reduce the damaging environmental effects** of high yielding agriculture. The European Innovation Partnership for Agricultural Productivity and Sustainability provides an opportunity to energise and channel more resources into this priority. Research should also focus on more extensive systems, including research on methods to increase yields in organic farming systems.
- Develop **production systems** that provide the greatest co-benefits for food production, climate change mitigation and adaptation, improved resource efficiency, and biodiversity conservation such as precision farming, paludiculture[14] on rewetted peatlands, and some forms of agroforestry.
- Targeted creation of **green infrastructure** to restore connectivity and ecosystem services in agricultural landscapes.

Environmental safeguards, research and evaluation of the possible negative impacts of new technologies

- There is considerable scope for the production of advanced biofuels from wastes and residues in Europe but a new policy framework will be required to utilise this. Appropriate environmental safeguards will be necessary to prevent **harmful indirect effects**, such as those related to the displacement of straw and other crop residues that are needed to retain soil carbon in fields..

- New **biologically novel crops**, produced through both genetic modification and new plant breeding techniques, should be carefully assessed to determine potential environmental and agronomic impacts. A wide range of new generation traits and crops will be available for use in the near future. These crops can be beneficial or detrimental to biodiversity depending on their traits and management.

Ensure Europe's genetic resources for food and agriculture (PGRFA) are better used and conserved

- Systematically foster plant genetic resource diversity in each link of the plant breeding cycle. Give greater prominence in the Horizon 2020 programme to **research on plant genetic resources** for a more biodiverse crop base better adapted to climate change.
- Establish a European network of *in situ* **genetic reserves** for crop wild relatives and on-farm conservation sites for landraces, supported by a European action plan for crop wild relative conservation.
- Establish a more coordinated European Genebank Integrated System that provides crop breeders with greater actual or predictive characterisation and evaluation of conserved plant genetic resources, and more available online information linked with better mutual cooperation between gene banks.

Provide increased direct funding for research on tackling the multiple factors causing honeybee losses and wild pollinator decline

- **Public funding** is urgently required to address the multiple factors causing European honeybee losses, and the loss of wild pollinator populations. The fact that no one factor seems to be the cause of bee decline should not be used as a reason for inaction.
- An **integrated response** with concerted actions by public authorities, beekeepers, farmers, the agrochemical industry, and researchers is needed.

[14] Sustainable agricultural productin on peatland that has undergone rewetting

- Specific **priority actions** include: increasing knowledge of the risks posed by neonicotinoids and other systemic pesticides; measures to increase breeding for *Varroa* resistance and improve availability of better treatment methods; and actions that increase flower resources for pollinators in agricultural landscapes.

4. Options to reduce the negative external impacts of European agriculture and biofuel imports

Intensify the EU's efforts to reduce its global environmental footprint over time in relation to food, feed and bioenergy, encouraging consumer demand for environmentally sustainable food

- The EU has an important role in intergovernmental initiatives to **develop global environmental principles** and agreements for food, fibre and energy production, while encouraging effective voluntary and private environmental certification schemes and products.
- In the case of biofuels action is required to address the indirect impacts of biofuel related land use change, alongside appropriate sustainability standards for feedstocks. Promoting advanced biofuels from wastes and residues, accompanied by environmental safeguards to prevent harmful indirect effects, would help overcome the negative impacts of the EU's overreliance on conventional biofuels.
- Promote **domestic animal feed production** that bring benefits for biodiversity and adaptation to climate change, such as legume crop systems that do not require high levels of pesticide use, as well as to avoid the environmental costs associated with feed imports.

Land sparing versus land sharing strategies and further investigation so that the trade-offs for biodiversity and agricultural production at a global as well as EU level are better understood and policies adjusted accordingly.

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