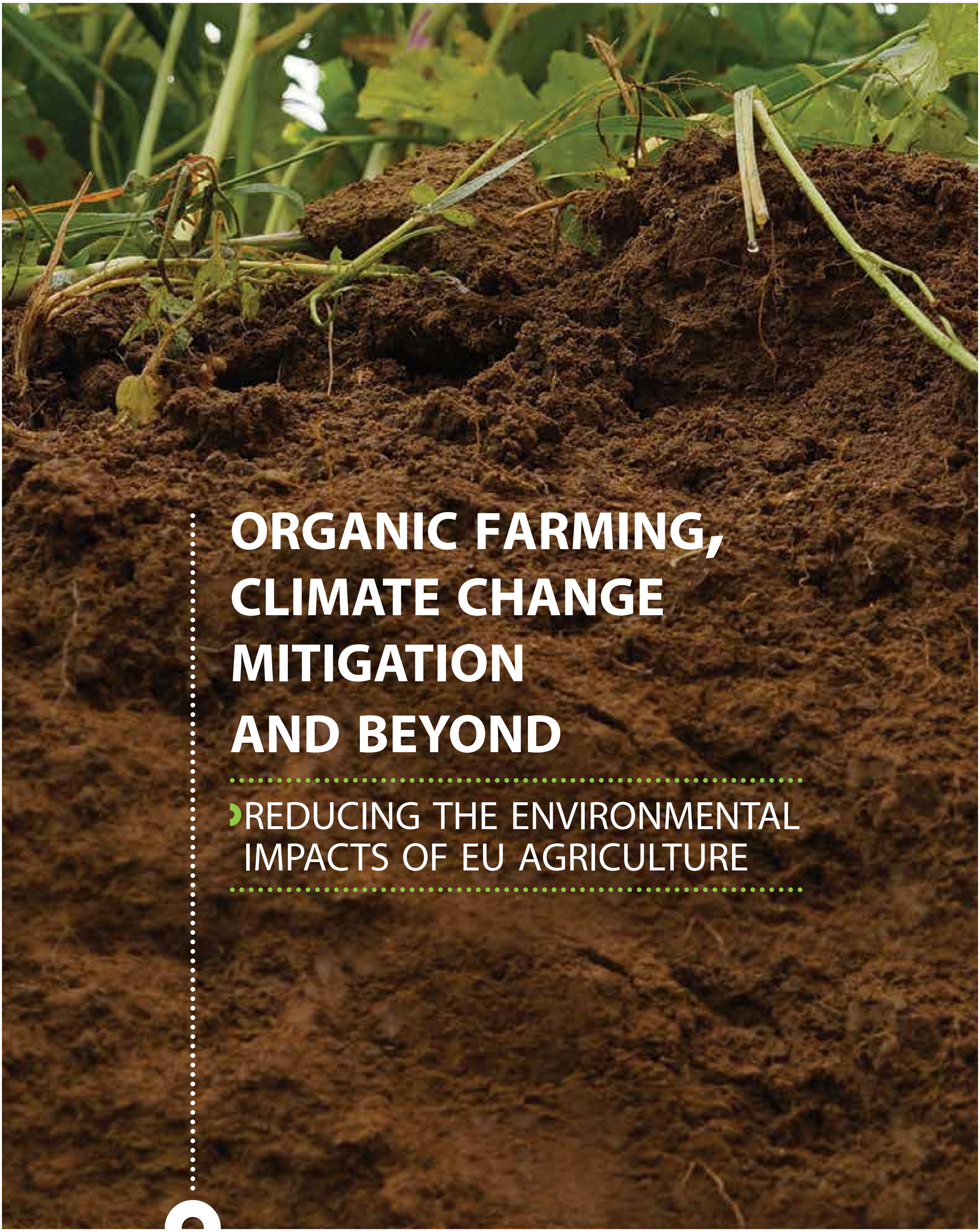

ORGANIC FARMING, CLIMATE CHANGE MITIGATION AND BEYOND

REDUCING THE ENVIRONMENTAL IMPACTS OF EU AGRICULTURE

IFOAM EU GROUP

MAKING EUROPE MORE ORGANIC

FiBL

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ABBREVIATIONS:

CAP - Common Agricultural Policy
CC- Climate change
CH_4 - Methane
CO_2 - Carbon dioxide
COP - Conference of the Parties
ESD - Effort Sharing Decision
ESR - Effort Sharing Regulation
EU - European Union
EU-ETS - EU Emissions Trading System
FAO - Food and Agriculture Organization of the United Nations
GHG - Greenhouse gas
$GtCO_2$-eq - Gigatonnes of carbon dioxide equivalent
IA - Impact Assessment
INDC - Intended Nationally Determined Contributions
LULUCF - Land use, land use change and forestry
$MTCO_2$-eq - Megatonnes of carbon dioxide equivalent
N - Nitrogen
N_2O - Nitrous oxide
NAMA - Nationally Appropriate Mitigation Actions
NI - Nitrification Inhibitors
SDG - Sustainable Development Goals
UNFCCC - United Nations Framework Convention on Climate Change

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FOREWORD

Climate change is one of the biggest challenges of our time. Agriculture's role is twofold: it is a sector that contributes to climate change, yet it is also one of the first sectors to suffer from climate change, as do the people whose livelihoods depend on it. The impact of agricultural practices, food wastage, and diets must all be taken into account if we are to understand how food and farming can positively contribute to climate change mitigation and adaptation, while simultaneously ensuring food security. The issue about what is produced to meet human needs, what is produced for intermediate production purposes (e.g. livestock feed) and what is wasted between the field and the kitchen must all be part of the discussion.

To provide healthy food in a sustainable way, we need to transform the food & farming system and transition to agriculture and food production that can adapt to unavoidable climate change whilst preserving our natural heritage such as biodiversity, sustaining the quality of our soils, improving the livelihood of farmers, protecting the health and welfare of farmed animals and ensuring that the food produced promotes health and is of high quality.

Organic farming offers a system that can reduce environmental impacts compared to conventional farming. Climate change mitigation is not (and should not be) the primary objective of organic farming, but increased conversion to organic agriculture can contribute to the reduction of greenhouse gas emissions, while also bringing important benefits, such as improved system resilience to the effects of climate change, maintaining or improving biodiversity on farmland, conserving soil fertility, reducing eutrophication and water pollution, and improving food security and farmers' sovereignty.

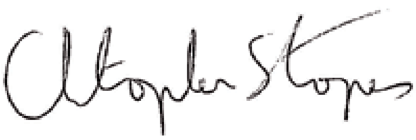
At European policy level, several pieces of legislation drive the European Union's contribution to the reduction of greenhouse gas (GHG) emissions. The Effort Sharing Regulation, and the Land Use, Land Use Change and Forestry (LULUCF) Regulation are two of the pillars of the European Union's climate change and energy policy package for 2030. Both regulations are currently discussed in the co-decision process between the European Parliament and Council.

IFOAM EU believes that agriculture has potential to mitigate greenhouse gas emissions and should do its fair share in the overall EU effort to reduce emissions. While a certain level of flexibility, allowing offset through LULUCF, is justified for a few countries with a high share of their GHG emissions in the agriculture sector, this flexibility should remain limited, and the agriculture sector should not be left off the hook altogether. Too high a level of flexibility would fail to incentivise action on climate change in the agriculture sector, and would also fail to trigger a transition to more sustainable farming systems and climate-friendly agricultural practices. The EU ambition for 2030 should be in line with its international commitment under the Paris Agreement.

The Common Agriculture Policy (CAP) also has a crucial role to play in helping farmers adapt their practices to face environmental challenges, and the European Commission will present proposals by the end of the year on how it should reformed. IFOAM EU firmly believes that the principle of "public money for public goods" should be at the heart of the next reform, and that farmers who take good care of the environmental services provided by our ecosystems should be rewarded. In no case should the need to reduce our GHG emissions be a pretext to further industrialise European agriculture.

Climate change mitigation should not be addressed in isolation of the need to deliver many other changes – adaptation to climate change, protection of animal health and welfare, reduction of the environmental impacts of agriculture and better quality, healthier diet. In this report, which has been produced by IFOAM EU and the internationally renowned institution FiBL, we aim to provide a comprehensive discussion of these varied, yet interlinked issues.

Enjoy the read!



Christopher Stopes,

IFOAM EU President

EXECUTIVE SUMMARY

Sustainably feeding the growing world population and preventing dangerous climate change are two of the major challenges facing society today. While there is a growing understanding of the complexity of the links between these challenges and of the global degradation of the environment, the contribution of food and farming to climate change mitigation is all too often looked at from the single perspective of greenhouse gas (GHG) emissions per hectare or kilogram of product. This narrow view fails to account for the vast array of ways that food and farming contribute to climate change, as well as the destructive effects of industrial agriculture on soils, biodiversity and the natural resources on which we depend for food production.

The impact of agriculture practices, food wastage, and diets must all be evaluated if we are to understand how food and farming can positively contribute to climate change mitigation and adaptation, while simultaneously providing food security. The issue about what is produced to meet human needs, what is produced for intermediate production purposes (e.g. livestock feed) and what is wasted between the field and the kitchen, needs to be part of the discussion. To provide healthy food in a sustainable way, we need to transform the food & farming system and transition to agriculture and food production that can adapt to unavoidable climate change, preserve our natural heritage such as biodiversity, sustains the quality of our soils, and improve the livelihood of farmers.

This report aims to provide a comprehensive discussion of these varied, yet interlinked, issues.

FOOD AND FARMING'S CONTRIBUTION TO CLIMATE CHANGE

According to official accounting, agriculture is responsible for about 10% of greenhouse gas emissions in the EU-28 plus Iceland. Most of this 10% share of emissions is generated by methane from enteric fermentation (flatulence and belching from cattle and sheep), and nitrous oxide emissions from fertiliser use and manure management. What is not accounted for in this percentage are the indirect emissions of the EU agricultural sector, namely emissions from feed production in third countries, from fertilisers' production and from transport. Furthermore, emissions from land use and land use change, and from soil carbon losses due to soil management are also relevant, but neither are included in these percentages of direct emissions from agriculture. Consequently, the contribution of farming to EU greenhouse gas emissions is higher than that given in the official accounting.

In more detail, soil carbon loss from existing cropland and grassland, from managed drained peatlands and from conversion of other land use to cropland, together in the EU lead to emissions of 2-3% of total EU GHG emissions (roughly equivalent to 25% of agriculture emissions). Existing forests and land conversion to forest, on the other hand, represent a significant sink in the magnitude of about 10% of total emissions (and roughly equivalent to 100% of EU agriculture emissions). Emissions from deforestation embodied in imported goods, primarily concentrate feed, equal to an amount of 3-5% of total EU emissions.

The production of mineral fertilisers is another important contributor, amounting to 1.75% of total EU emissions.

For a better picture of the impact agriculture and the whole food system, all activities needed to keep the current agro-industrial system running should be taken into account. Unfortunately, it is almost impossible to calculate the emissions generated by fossil fuel use and irrigation on farms, as well as through the processing, import, transport and sale of food, as these areas are currently not accounted for separately.

Taken together, one third to half of global greenhouse gas emissions could be linked to food production, processing, transport, distribution and consumption.

In addition to being a significant contributor to GHG emissions, agriculture is also among the first sectors to suffer from the impact of climate change: many farmers, especially smallholders and those predominantly in the South, have already been affected from harvests being destroyed or damaged by the changing climatic conditions; extreme weather events, heat waves and droughts will be increasingly frequent in the future, and will also impact farmers in the EU. At the same time, agricultural production is the basis of the global food supply for the world´s citizens. Thus, it is important to scrutinise how agriculture can help reduce GHG emissions, as well as how it may best prepare for the unavoidable negative impacts of climate change, while still ensuring food security. The improvement can only come through changes in the whole food production and consumption system.

Organic agriculture empowers farmers by helping them design agronomic systems that are more resilient towards the impacts of climate change, by enabling them to reduce dependence on external inputs, and by promoting the development – rather than the degradation – of the natural resources on which we depend for food production. As there is already more than enough food produced, we need to improve distribution, reduce food waste, promote sustainable diets and reduce consumption of animal products. Organic agriculture contributes through its holistic approach to sustainable food systems working towards healthy farms, healthy people and a healthy planet.

KEY AREAS WHERE EMISSIONS CAN BE REDUCED

ANIMAL PRODUCT CONSUMPTION AND ENTERIC FERMENTATION

The methane emitted by cattle and sheep, generated during digestion – enteric fermentation – accounts for 40% of agricultural greenhouse gas emissions in the EU-28 plus Iceland, roughly 4% of all emissions in the EU.

With this share of emissions, it is the first place to look for GHG reductions in the agriculture sector.

There are solutions on both the production and consumption ends, however changing consumption patterns would have the most immediate effect. A shift in diet – meaning consumption of less animal products, particularly those from cattle and sheep (ruminants) – would clearly lead to corresponding reductions in emissions from EU-based production as well as imported products. A recent study finds that EU's overall climate target cannot be met without a reduction of 50% in animal products from ruminants. The study takes into account many potential technological solutions for reducing emissions linked to productivity, feed additives, manure management and other areas. This demonstrates that a sustainable, climate-friendly food system cannot be achieved without a change in diet, and without encouraging plant-based protein sources as a substitute for animal-based proteins.

A shift in diet would also have an impact on the emissions generated by arable land used for concentrate feed production and, where relevant, deforestation that is clearing forests to make even more space for such production. This aspect is mainly linked to pig and poultry production, which relies most on such concentrate feed. The climate benefits would be significant and real – but due to the accounting rules, they would not show up in the EU balance, as they largely relate to imported feed.

On the production side, organic agriculture offers farmers a number of practices that help decrease emissions from raising cattle and sheep. Based on the rules of organic production, agricultural land can only sustain a limited number of animals, since there are clear rules on how many head of livestock are allowed per hectare. If the whole agricultural land was converted to organic, then automatically the number of animals would be reduced. Furthermore, grassland based animal production perfectly fits the organic production systems. Albeit emissions calculated per kilogramme of product may be higher, the overall size of production and corresponding emissions would be lower. This would allow to utilize grasslands that cannot be used for food production otherwise, thus sparing on concentrate feed and related arable land use. However, as mentioned before, it is crucial that there is a change in consumption behaviour so that a reduction in the production of animal products does not result in leakage, i.e. the replacement of EU production with imports.

Organic farming contributes in different ways to reducing the impacts of animal production:

- Grazing is the natural behaviour of sheep and cattle. Organic rules require that animals be kept outside and allowed to graze as much as possible. Furthermore, increasing concentrate shares in feeding rations, and the corresponding intensity increases in animal production, go along with increased risks to animal welfare and health and adversely impacts the longevity of the animals.

- If stocking rates are adapted to the grassland type and situation, as promoted by organic, higher soil carbon sequestration in the areas where the feed for the organic farms is sourced and the generally reduced production level compensates for the difference generated by the greater enteric fermentation

generally linked to higher roughage shares in diets. Furthermore, only ruminants are able to turn grasslands that cannot be used for arable crops into food for humans.

- The EU organic regulation already requires that 60% of the feed for ruminants should come from the farm or from the same region and many private organic standards are even more demanding. Feed should therefore not be imported from abroad, which reduces the emissions generated by transportation and reduces the deforestation carried out on other continents to clear land for the production of animal feed to be exported to Europe.

- Organic promotes diets that are healthy for people, animals and the environment. In terms of animal husbandry, the organic system of production leads to a reduction in the levels of production – as less is produced per unit of land area, for example – while simultaneously improving the quality of the meat and milk. Importantly, organic also provides more sustainable livelihoods for farmers. Certified organic farmers can sell their products for higher prices, while benefiting from lower input costs. Despite having fewer animals, this results in higher net incomes compared to conventional farming and increases the economic resilience of farms.

FERTILISATION

Nitrogen is a key nutrient required for fertile soils. Yet its use and manufacture are linked to high levels of emissions all along their life cycles.

Nitrous oxide emissions from managed soils account for almost 40% of agricultural emissions in the EU, corresponding to 4% of total emissions. These emissions are generated by the application of nitrogen fertilisers to farmland and the ensuing chemical processes, regardless of the source of the nitrogen: mineral synthetic nitrogen or organic nitrogen sourced from legumes, manure, crop residues, mulch and compost. In addition, emissions from the production of mineral nitrogen fertilisers amount to about 1.75% of total EU emissions.

As there is a direct correlation between nitrous oxide emissions and the amount of nitrogen fertilizer applied, reducing nitrogen application rates is the most effective measure to reduce emissions. Generally, agricultural land in the EU is over-fertilised, and given the high nitrogen surplus on EU soils, there is considerable potential for reducing application of nitrogen. Organic agriculture is a role model for such low nitrogen input systems. Organic farming methods focus on establishing closed nutrient cycles, minimising losses via runoff, volatilization and emissions and do not allow for the use of synthetic nitrogen fertilisers. Nitrogen levels on organic farms therefore tend to be lower per hectare than on conventional farms. Even if yields may drop, in combination with reduced feed production (e.g. much less forage maize) and less animals, this can contribute to a sustainable climate friendly production system that delivers enough food.

If all agriculture in the EU were to abandon mineral nitrogen fertilisers altogether, the emissions linked to their production would be eliminated, resulting in the avoidance of emissions of around 18% of agricultural emissions. It would also have the potential to reduce nitrous oxide emissions by about 10% of total agricultural emissions when accounting for the use of alternative, organic nitrogen sources from legumes.

MANURE MANAGEMENT

With 15% of agricultural GHG emissions and about 1.5% of total EU emissions, methane and nitrous oxide emissions from manure management make up the third largest agricultural emissions category. The key factor in reducing such emissions lies in how the manure is handled because the amount of methane emitted is highly dependent on the anaerobic conditions and temperature in the manure management systems. Better storage and treatment of manure can significantly reduce greenhouse gas emissions of both nitrous oxide and methane by 50% and 70%, respectively.

Manure composting is often used in organic agriculture, and in biodynamic agriculture in particular. This technique alone can reduce nitrous oxide by 50% and methane emissions by 70%, although it does have the potential to increase ammonia emissions and thus may result in 50-120% higher indirect nitrous oxide emissions. Yet, the indirect emissions from the application of manure compost can be much lower than those from normal manure. Given the trade-offs over the entire life-cycle from production to application, manure compost has the potential to reduce emissions from manure management.

A reduction in animal numbers as discussed above would of course also result in correspondingly reduced manure volumes and emissions from their storage and management.

SOIL CARBON SEQUESTRATION AND SOIL FERTILITY

Forests, and to a lesser extent grassland, in the EU, currently sequester the equivalent of about 10% of total EU GHG emissions. As a result, measures that retain and enhance carbon sequestration, also in arable land, are often promoted as very useful means to achieve the overall emission reduction targets of the EU and the long-term goals set out in the Paris agreement.

Soil organic carbon stocks have been shown to be significantly higher on organic farms. Complete conversion to organic agriculture in the EU by 2030 could theoretically offer compensation for almost 20% of the cumulative agricultural emissions through the additional soil carbon sequestration generated by organic farm management.

Organic agriculture has a strong focus on enhancing and maintaining soil-fertility and quality and a number of organic core practices support this, which also has considerable climate change adaptation benefits. Some of the agriculture practices favoured by organic and that protect and enhance soil carbon sequestration are:

- Use of organic fertilisers such as compost and manure
- Optimisation of crop rotations with legumes and the planting of cover crops
- Use of improved and locally adapted crop varieties
- Protection of existing grasslands from conversion to cropland

However, soil carbon sequestration is difficult to measure, reversible and not permanent. It therefore cannot be considered to be a real mitigation tool. Rather, it may allow for the offsetting of emissions (reducing the increase of greenhouse gas concentration in the atmosphere, without actually decreasing emissions) up until the point when soils become carbon saturated, thus gaining some time for the implementation of true emission reductions. Sequestration rates level off as a new equilibrium state in the soils or forests is reached and they become saturated. The sequestration potential will therefore decline in the future because of the saturation dynamics of biological and soil carbon sequestration. Furthermore, sequestration is not permanent: the carbon sequestered can be lost to the atmosphere again at a later point in time if there is a change in land use or management, for example.

On the other hand, in addition to providing a mitigating effect, the stock of organic carbon in soil maintains soil productivity, structure and soil life. These important ecosystem functions improve plant health, water holding and retention capacity, resistance to droughts and other extreme weather events, and contribute to the maintenance and development of yields. In this way, ensuring sufficient soil organic matter (i.e. carbon) can significantly help agriculture adapt to the harmful effects of climate change on production.

FOOD WASTE

In the EU, emissions related to food waste along the whole value chain correspond to about 10% of GHG emissions. One third of the food produced globally goes to waste. Unlike the other areas where the production of food will inherently generate at least some emissions, waste has no productive value and can theoretically be reduced to zero. Practically speaking, however, achieving zero waste is unlikely and not even desirable, as some waste will remain due to economic and technical reasons and because the resilience of the system will be bigger with some redundancy in supply that then goes as waste if not needed. But the current levels of waste are unsustainable and can be reduced drastically with a corresponding potential to reduce emissions along the value chain.

Organic farming is about cultivating natural resources in a coherent way that takes the different elements and their impact on each other into account; it aims to benefit the environment, the people farming and the people eating the food produced, as well as animals. In other words, it is a system-based approach that works with and is inspired by natural production cycles. Organic matter and legume crops are used to fertilise the soil, which in turn nourishes crops, the waste of which can be composted and again used to fertilise the soil along with animal manures. This holistic approach means that organic farms tend to (re)use materials, waste less and are less intensive, given that external inputs are much lower.

THE MULTIPLE BENEFITS OF ORGANIC FARMING

Organic agriculture can help reduce GHG emissions within the agricultural sector of the European Union and beyond. However, the sustainability of agriculture and food systems requires much more than just climate change mitigation. Organic farming practices deliver solutions for a wide range of sustainability challenges, such as biodiversity, climate change adaptation, eutrophication and socio-economic benefits. This is particularly relevant as, over the past decades, agriculture in the EU has been associated with biodiversity loss, water pollution, soil erosion, decreasing landscape quality and food safety concerns.

BENEFITS OF ORGANIC FARMING FOR ADAPTATION TO CLIMATE CHANGE

The adverse effects of climate change, such as heat waves, droughts, heavy precipitation and other extreme weather events, will unavoidably increase in the future. With average winter temperatures set to rise, there will be increased climate variability and risks to production in general. Likewise, pest and disease pressure will increase. Agricultural systems must adapt to these adverse impacts in order to ensure resilient food production. Organic farms often sustain higher species diversity and cultivate locally adapted varieties. This enhances the resilience of agro-ecosystems against adverse climate conditions, such as extreme weather events. Studies indicate that organic systems out-produce conventional under extreme drought conditions, that there is 15-20% greater movement of water through soils down to the groundwater level, and therefore higher groundwater recharge in organic systems. Water capture and retention capacity in organically managed soils is up to 100% higher than in conventional soils. To summarize, organic farming systems are more resilient to changing weather conditions, such as extreme droughts and extreme rainfall.

INCREASED BIODIVERSITY AND RESISTANCE TO DISEASE AND PESTS

Organic farms sustain 30% more biodiversity than conventional farms, as demonstrated by a meta-analysis of 94 studies from the past 30 years. The most distinct differences in biodiversity were seen in landscapes containing a higher proportion of arable crops, and plant biodiversity benefited the most from organic farming practices. As well as the farm management practices, the landscape, climate, crop types and species also play a major role in the effects of organic farming on biodiversity. Studies found that the numbers, density and abundance of species was significantly higher in and around fields on organic farms. In particular, the biodiversity of plant species was 70-100% higher, and weed abundance 75-150% higher than on conventional farms. Overall organic farming has positive benefits for wildlife at both farm level, and on a larger scale aggregated across several farms and other areas in a landscape.

The argument that since organic farming tends to produce lower yields, larger agricultural areas are required, overlooks the fact that agricultural production in Europe is often too intensive and outstrips the carrying capacity of local environmental resources. Organic farming is a viable option to reduce agricultural intensity while at the same time fulfilling biodiversity protection goals. Farmland biodiversity also provides many ecosystem services that in turn are important for agricultural production itself, such as pollination, pest control and nutrient cycling. Large-scale studies of European agricultural landscapes have shown that it is vital to maintain a large proportion of semi-natural habitats in order to sustain high species diversity in agricultural landscapes.

Studies also show that organically grown crops have a higher resistance to pests and diseases, thanks to greater soil microbial biomass and improved soil quality, slower growth of the plants in organic systems (which allows the plant to develop its own chemical defences to prevent damage by pests and diseases), and enhanced biodiversity in organic systems, which leads to enhanced diversity of natural enemies (such as predatory birds and invertebrates). Together these prevent or diminish pest and disease pressures. Organic agriculture also bans the use of genetically modified organisms (GMOs). It encourages on-farm agrobiodiversity, both through the diversity of plant varieties cultivated, and through increased genetic diversity within plant populations.

CONSERVATION OF SOILS

Organic agriculture has a strong focus on enhancing and maintaining the fertility and quality of soils, and a number of its core practices support that goal (e.g. cover crops, mulching, intercropping…). Studies have identified a greater abundance of soil microorganisms in organically managed soils, along with more carbon and nitrogen transformation through biological activity than in conventionally managed soils, and on average, soil organic carbon sequestration is higher in organic than conventional agriculture. Living soils, in turn, provide a good basis for coping with climate uncertainties, such as heavy rains or droughts, while the good soil structure of organically managed soils reduces the risk of water logging and soil erosion.

REDUCTION OF EUTROPHICATION AND WATER POLLUTION

Studies show that much higher rates of nitrate leaching occur in conventional farming systems than organic, and that the former are associated with higher levels of pollution. This is in part due to the lower nitrogen application rates in organic farming systems and the correspondingly better plant uptake, which curbs the rate of nitrogen leaching, and to the greater amount of soil organic carbon.

Groundwater pollution and eutrophication are also influenced by loss of phosphorus through erosion and runoff. A meta-analysis identified reduced phosphorus losses in organic farming systems, and there is enough evidence to support the idea that lower phosphorus fertilizer inputs in organic systems reduce the phosphorus leaching into water bodies and thus helps to reduce further eutrophication. In addition, trials have shown that organic farming reduces surface runoff and increases water infiltration capacity, thereby reducing soil erosion and preventing flooding of agricultural fields. This in turn helps increase yields and plants adapt to climate change impacts. Finally, organic farming does not allow synthetic pesticides that also run off into water bodies with a polluting effect and toxicity for to aquatic life.

BENEFITS FOR HUMAN HEALTH

Human health also potentially benefits from an increase in organic production in the EU. A meta-analysis concluded that organic food differs from conventional in the concentration of antioxidants, pesticide residues and cadmium. In conventional crops, pesticide residues occur four times more frequently than in organic crops. In addition to the human health benefits from the reduced use of agrochemicals, organic farming can also help to reduce the air pollution associated with farming practices. Organic farming reduces soil erosion and emissions of particulate matter, oxides of nitrogen, carbon and sulphur, as well as volatile organic compounds and pathogens, which all have adverse effects on human health, being a cause of respiratory diseases, allergies and other problems.

PROFITABILITY

Finally, from an economic point of view, certified organic farmers can sell their products for higher prices, while often incurring lower input costs. This results in higher net incomes compared to conventional farming, increasing the economic resilience of farmers. Moreover, while conventional farmers are often highly dependent on products supplied by agrochemical producers, for which they are obliged to pay set prices, organic farmers have greater sovereignty, with more control over their production processes and the associated costs.

SUMMARISING REMARKS

When the focus is on efficiency and emissions per kg product, a number of conventional approaches deliver better performance. However, these pursue just a single goal, whereas organic agriculture is about a wealth of multiple benefits that often fit together in a web of trade-offs and synergies. The low per-kg emissions for meat and milk produced in intensive high-concentrate feed systems often go hand-in-hand with higher environmental impacts per area, including nitrogen and phosphorous excesses. This in turn has adverse effects on biodiversity, water quality and other environmental features.

Animal health and welfare are low in high intensity systems based on a large proportion of concentrate feed. On the other hand, many grassland areas are unsuitable for crop production and can only be used for human nutrition through grass-fed ruminant production. When considering the entire food system, the combination of organic livestock production with lower total production volumes produces good results in terms of most environmental indicators. The need to ensure "food security" should not be used as an excuse to continue business as usual and to further industrialise European agriculture. It is important to promote solutions that contribute to mitigation, but also to adaptation, and to improvements of biodiversity, water quality, soil health, animal welfare, and farmers' profitability. It is crucial to avoid trade-offs and to take into account all the environmental "co-benefits" of alternative farming systems.

Overall, organic agriculture is a role model for sustainable agricultural production that shows the necessary direction of travel, it offers opportunities for sustainable practices also

viable for conventional production. It is crucial to take a food systems view, not only focusing on mitigation in agricultural production, but also on consumption patterns, as well as optimal resource use. Thus, organic agriculture, combined with reduced concentrate feed and animal products, and reduced food wastage provides an optimal sustainable and climate friendly agricultural production and food system.

AGRICULTURE IN THE EU EFFORT SHARING AND LULUCF REGULATIONS

On the basis of the conclusions adopted by the European Council in October 2014, which set an overall target of 40% reduction on 1990 levels by 2030, the European Commission developed new proposals for the EU climate and energy package for 2030. This package consists of three pillars:

- The Emissions Trading System (ETS), which covers emissions for the energy sector, with a target of 43% reduction compared to 2005 levels
- The Effort Sharing Regulation (ESR), which covers national emissions from transport, buildings, waste and non-CO_2 emissions from agriculture (methane and nitrous oxide), with an average target of 30% emissions reduction compared to 2005 levels
- The land use, land use change and forestry (LULUCF) proposal, which covers CO_2 emissions and removals from forest management, afforestation, reforestation, deforestation, cropland and grazing land

The Commission presented the ESR and LULUCF proposals on 20 July 2016. Given that LULUCF is a carbon sink in the EU, mainly due to the way forest management emissions and removals are calculated, the Commission assessed different options for integrating the LULUCF emissions and removals into the EU climate and energy framework 2030. After an intense debate with strong concerns voiced over the environmental integrity of the climate package, the European Commission eventually decided to maintain a separate LULUCF pillar, but with a certain level of flexibility allowing Member States to benefit from removals in the LULUCF sector to comply with their ESR target.

This flexibility mechanism proposed by the Commission would allow Member States to use potential credits from LULUCF to reach their ESR target, under certain conditions. A "no debit" rule would apply, meaning that Member States must maintain their LULUCF accounts without debits at the end of the compliance period and that only Member States whose LULUCF sector absorbs more carbon than it releases would be allowed to generate credits. Such credits could only be generated from the management of cropland and grazing land, or from deforestation/afforestation (forest management is excluded). Moreover, the total amount of flexibility that could be used is capped at 280 $MtCO_2$ for the period 2021-2030 for the whole EU.

These proposals are now passing through the co-decision process and should be adopted in 2017.

HOW MUCH SHOULD THE SECTOR REDUCE EMISSIONS?

Agricultural non-CO_2 emissions in 2005 amounted to 446 $MtCO_2$ for the EU-28. Under a business as usual scenario (no further policy action), very low reductions are projected for the agriculture sector, of just 2.1% by 2020, and around 2.4% by 2030. According to the impact assessment and to the models used by the Commission, on average at EU level, little or no further action to reduce emissions is expected of the agriculture sector beyond those already due from the policies in place. With 280Mt flexibility, the agriculture sector would only have to reduce its emissions by around 7% in 2030 compared to 2005. The picture is however different for those individual Member States which have both a higher than average effort to make to meet their ESR target, and a high proportion of their emissions in the agriculture sector. The flexibility mechanism was designed explicitly by the Commission to avoid any impact on the level of production, especially in the livestock sector, or on prices.

All emissions from the agriculture sector should be addressed together (CO_2 and non-CO_2) and the inclusion in the accounting of carbon sequestration in cropland and grassland should be welcomed. Allowing Member States to generate credits with soil carbon sequestration could drive the necessary actions to improve the status of European soils, which will also deliver positive side-effects for adaptation and productivity.

But the level of flexibility granted by the Commission proposal (280 Mt) is very high and will not sufficiently incentivise mitigation action in the agriculture sector. The EU's agriculture sector should have a higher level of ambition emissions reduction. This would drive investments and the development of a long-term roadmap for mitigation and adaptation, and affect other environmental impacts of agriculture. A broader set of mitigation options should also be considered, on both the supply side and the demand side. It is important to address agricultural production and food consumption together. With an all-encompassing food systems view it would be possible also to address any carbon leakage related to changing production volumes triggered by some mitigation measures.

The CAP provides a range of measures that can be used to support the uptake of climate mitigation actions. But many aspects of the current CAP lack any real ambition for a change to more sustainable agricultural practices. as spending on the CAP takes up about 40% of the entire EU budget, mainstreaming climate-friendly practices will require a fundamentally new approach to the CAP. Instead of allocating money primarily for individual actions, payments to farms must be holistic and targeted at those farmers whose approaches inherently promote the environmental and socio-economic sustainability of their own farms, and of their regions and local citizens. Prioritising public money for farm system approaches fostering public goods would enable farmers to make sound decisions on all aspects of sustainability for their entire farm enterprise, and in collaboration with other farmers, while at the same time meeting societal expectations.

RECOMMENDATIONS

The European Union and Member States should:

Adopt a systemic approach to reduce GHG emissions from food production and to transition towards sustainable food systems

A systemic approach is essential to reducing GHG emissions linked to food production and consumption in the EU, to help the agriculture sector adapt to climate change while not endangering food security, and to achieve sustainable development goals, in particular on the restoration of ecosystems services. A silos approach or a sole focus on mitigation risks leading to further industrialisation of European agriculture, loss of farmers' livelihoods and environmental trade-offs.

A linear increase of the share of organic farming on EU agriculture land from 6% to 50% from 2016 to 2030 would reduce or compensate cumulative GHG emissions from agriculture from 2016 to 2030 by 7.5-8.5% through increased soil carbon sequestration (-5.5%) and reduced nitrogen fertilizer application rates (between -2 and -3%). It would also lead to a reduction of emissions linked to the production of mineral fertilizers, equivalent to 4-5% of agriculture-related emissions. It would also bring important benefits, such as improved system resilience to the effects of climate change, maintaining or improving biodiversity on farmland, conserving soil fertility, reducing eutrophication and water pollution, and improving food security and farmers' sovereignty.

Furthermore, increased use of European pastures and reduced reliance on imported feed would significantly reduce emissions linked to feed production and associated land use change in the countries where this feed is produced. However, these benefits might come at the cost of reduced agricultural yields, meaning that more land would be needed to produce the same amount of agricultural goods. Therefore, an increased share of organic farming and grassland-based animal production must go hand-in-hand with changes in food consumption patterns, including a shift towards more plant-protein based diets and a reduction in food wastage. The issue about what is produced to meet human needs, what is produced for intermediate production purposes (e.g. livestock feed) and what is wasted between the field and the kitchen, must all be part of the discussion.

Support sustainable grazing on well-managed grasslands

When adopting a whole food-systems view, a combination of organic agriculture and grassland-based livestock production with reduced total production volumes fares well according to most environmental indicators and leads to lower GHG emissions, mainly via the reduction in total emission volumes from reduced animal numbers and reduced nitrogen application rates. Grassland based production with adequate stocking-rates should therefore be supported for ruminants, and concentrate feed imports should be minimized, which would also contribute to the reduction of nitrogen levels. A number of measures linked to stocking rates could help to orientate livestock production towards sustainable grazing on well-managed grasslands. A reduction of EU production has to go hand in hand with a reduction in consumption to ensure net positive effects on sustainability and to avoid leakage due to replacing reduced domestic production by imports.

Reduce emissions from fertilized soils

A general reduction in nitrogen inputs would reduce nitrous oxide emissions from fertilized soils, but also eutrophication, and would have beneficial effects on biodiversity. The Nitrates Directive has been effective but EU climate action should specifically support further action to reduce nitrogen inputs on agricultural land. Specific incentives are needed to achieve ambitious reduction goals for the nitrogen surplus across the EU, with corresponding reductions in GHG emissions. A tax on nitrogen could be established that would apply if the nitrogen-balance deviates beyond a certain threshold, for example beyond a 10% positive deviation. A tax on nitrogen surplus would need to be designed in such a way that it would adequately address nitrogen flows and their disposal from monogastric production units. Organic agriculture is a production system that has a significant potential in this regards, as nitrogen levels per hectare tend to be lower than in non-organic systems.

Adapt indicators and measures of success

Measuring outputs and impacts of farming through single criteria, as is typically the case (e.g. yields of specific crops, GHG emissions per kilogramme of product) disregard negative externalities and tend to favour “efficiency” approaches, large-scale industrial monocultures and industrial livestock systems, which can achieve high yields through the intensive use of inputs such as manufactured nitrogen fertiliser and concentrate feed. Diversified systems are by definition geared towards producing diverse outputs, whilst delivering a range of environmental and social benefits on and off the farm, with reduced negative externalities and reduced dependency on external inputs (e.g. fossil-fuels).

For an encompassing sustainability assessment of food production systems, it is crucial to complement efficiency measures with more systemic aspects that make it possible to address overall production levels, overall environmental impacts, i.e. "sufficiency" measures, as well as the role certain resources play in a food systems context, i.e. the "consistency" of resource use.

Moreover, for effective reduction of GHG emissions from agriculture production, fluxes occurring outside the agricultural sector need to be taken into account, such as the emissions linked to the production of mineral fertilizers. For livestock production, emissions from land use and land use change linked to concentrate feed production or conversion of forest to pasture or arable crop production should be accounted for and included in life cycle analyses.

Consider a broader set of mitigation measures, also targeting the demand side

Instead of an intensive export-based model, the EU should promote the production of quality meat and animal products, keeping in mind that the livestock sector is essential to the nutrient cycle and to optimize the use of grasslands. When addressing mitigation in agriculture, the EU and national governments should also explicitly engage in a discussion on the role of consumption and food waste. Measures should be taken to raise consumers' awareness on the benefits of a sustainable diet, in which the share of meat, fish, fruits, vegetables, bread, fat, sugar and salt all have their fair share based on common sense and pleasure. Such changes in consumption are important to ensure that a switch to organic agriculture and grassland-based animal production with lower production levels does not lead to increased imports and leakage effects with regard to emissions and land-use change, if the diet and consumption remain unchanged, whilst production is reduced.

Maintain ambition in the Effort Sharing Regulation and LULUCF proposal

The EU agriculture sector should have a higher level of ambition for emissions reductions, which could drive investments and the development of a long-term roadmap to 2050 for mitigation and adaptation, and other environmental impacts of agriculture. A certain level of flexibility for agriculture may be justified for Member States with a high share of emissions in the agriculture sector, but the high level of flexibility currently granted by the Commission proposal implies that very little mitigation (of the order of 6-7% for the EU) is expected from agriculture for the EU as a whole. This level of flexibility was proposed explicitly by the Commission to avoid any impact on the level of production, especially in the livestock sector, and on prices.

Accounting for soil carbon sequestration in cropland and grassland is relevant and coherent with a more systemic approach, and can drive necessary action to improve the status of European soils, which will also deliver positive side-effects for adaptation and productivity. Flexibility should however be limited to soil carbon sequestration, landscape elements (e.g.

hedgerows, single trees) and agroforestry, and exclude pure forestry offset. Mitigation measures in the LULUCF section should not endanger biodiversity and be consistent with the EU Biodiversity objectives. Carbon sequestration in the land use sector has a crucial role to play to meet the long-term objective of the Paris agreement, but it is not permanent and reversible, and thus needs constant protection, and its potential is limited in time, as further sequestration stops when soils reach a new equilibrium.

Engage in a food transition towards agroecology

The EU should engage in a food systems transition, equivalent to the energy transition, and move agriculture towards agroecological approaches such as organic farming and agroforestry. Just as the industrial, mechanized systems of monoculture that transformed post-war global agriculture could only be installed with massive public investments and the concerted efforts of all the relevant segments of society, so too will the next transformation of agriculture require a similar concerted effort for its success – an effort that involves science, research and technology combined with effective policies and economic incentives.

Mainstream environment and climate-friendly farming systems under the CAP

A new CAP, aligned to the UN's 2030 Agenda for Sustainable Development and focusing on incentivising and rewarding the tangible, environmental and societal outputs of farming, would help to keep farmers in business, while providing high-quality food and contributing to the EU's goals for rural viability, climate change and the environment. To this end, successive reforms should move the CAP towards a new model of farm payments based on agroecological outcomes. Mainstreaming public money for public goods would require policymakers to make fundamental changes to the current CAP by introducing a flagship payment model for stimulating environmental and socio-economic services delivered at the farm level. This new payment model would include efforts by farmers to mitigate and adapt to climate change, but also provide other public good benefits related to biodiversity, soil and water quality, social capital and rural viability.

Establish a research flagship programme for the transition of Europe's food systems

Many lock-in factors prevent the dominant food system to change. Policies from the local to the global level need to be re-designed and better integrated, new farming systems based on ecological approaches are needed, new supply chains need to be established, whilst innovation systems, including extension and education, need to adapt. Only a properly funded EU flagship research programme with sufficient budget will be able to make significant advances in the transition of Europe's food systems.

1. INTRODUCTION

To avoid dangerous climate change, the Paris Agreement[1] aims to limit the increase in the global average temperature to well below 2 °C, and it supports efforts to restrict the increase to 1.5 °C above pre-industrial levels (Article 2). To achieve this, the international community aims to reach the peak in global greenhouse gas (GHG) emissions "as soon as possible" and to undertake rapid reductions thereafter. In this way it wants to achieve "a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty." (Article 4).

Agriculture is both a significant contributor to GHG emissions and one of the first sectors to suffer from the impacts of climate change. Many farmers have already seen their harvests destroyed or damaged by the changing climatic conditions. Extreme weather events, heat waves and droughts will become increasingly frequent in the future. At the same time, agricultural production underpins the global food supply for the world´s citizens. It is therefore indispensable to assess how the agricultural sector can help reduce GHG emissions, as well as how it can best prepare for the unavoidable negative impacts of climate change, while still assuring food security (FAO, 2016).

Furthermore, climate change is only one aspect of the global environmental crisis. Biodiversity is disappearing at an unprecedented rate. Industrial agriculture is recognised as one of the main causes of biodiversity loss, but it also creates water shortages and soil erosion, which can in turn result in lost fertility and declining yields. The use of synthetic pesticides has negative impacts on flora and fauna, but also on human health, while the excessive use of nitrogen affects the nitrogen cycle. This has dire consequences such as less robust crops, the eutrophication of water bodies, increased GHG emissions and biodiversity losses.

Food security and climate-change adaptation and mitigation cannot be addressed separately, and action on these fronts should obviously avoid any further disruption of ecosystem services or loss of biodiversity. In the context of global climate change mitigation policies and interventions, the European Union has committed itself to reducing its GHG emissions by 20% by 2020, and by 40% by 2030. All sectors are expected to contribute to this effort. This report focuses on the role agriculture plays in the EU's emissions and the mitigation of those emissions. In particular, it looks at the potential contribution organic agriculture can make to the achievement of the EU's mitigation goals.

The discussion surrounding climate change mitigation in agriculture today is generally dominated by efficiency approaches, i.e. measures intended to reduce emissions that do not have a negative effect on production levels, thereby achieving reduced emissions per kilogram of product. However, it is important to go beyond mere efficiency assessments and to adopt an approach that addresses the whole food system. This includes the role of consumption and changing diets (e.g. by exploiting the potential to reduce food waste or animal products in people's diets), and the optimized roles played by resources like grasslands in a sustainable and climate-friendly food system. Furthermore, climate change mitigation and adaptation are only two of the many aspects that need to be considered to achieve a sustainable agriculture. Others include animal health and animal welfare, altered nitrogen and phosphorous cycles, biodiversity, soil fertility, and socio-economic aspects such as farm income and profitability. Only by embedding the analysis in this broader context of sustainability is it possible to investigate the full potential of different production systems, such as organic agriculture, to contribute to climate change mitigation.

2. UNDERSTANDING AGRICULTURE'S SHARE OF GREENHOUSE GAS EMISSIONS AND WHERE THEY COME FROM

2.1 AGRICULTURE'S CURRENT SHARE OF GREENHOUSE GAS EMISSIONS AND PROJECTIONS

Agriculture, forestry and land use change together account for about one fifth (21.5%) of global GHG emissions. In 2014, they accounted for 10.6 gigatonnes (Gt) of carbon dioxide equivalents[2]. Agriculture alone is directly responsible for 5.1 $GtCO_2$-eq, which is about 10% of total global GHG emissions (Danila et al., 2016).

While the EU's agricultural GHG emissions have decreased continuously since the early 1990s (see Figure 1), only a modest further fall is expected up to 2030. Meanwhile, the relative importance of agricultural emissions is expected to rise significantly, with their share of the overall total tripling by 2050 (see Figure 2).

The past reduction is mainly associated with a general decline in the number of animals, especially cattle, observed over this period (FAOSTAT, 2016), as well as reduced levels of nitrogen use and improved farming practices and manure management in particular (Eurostat, 2016b). In 2014, the sector still emitted about 436 $MtCO_2$-eq (see Figure 1), which accounted for about 10% of the total GHG emissions of the EU-28 plus Iceland. (Danila et al., 2016).

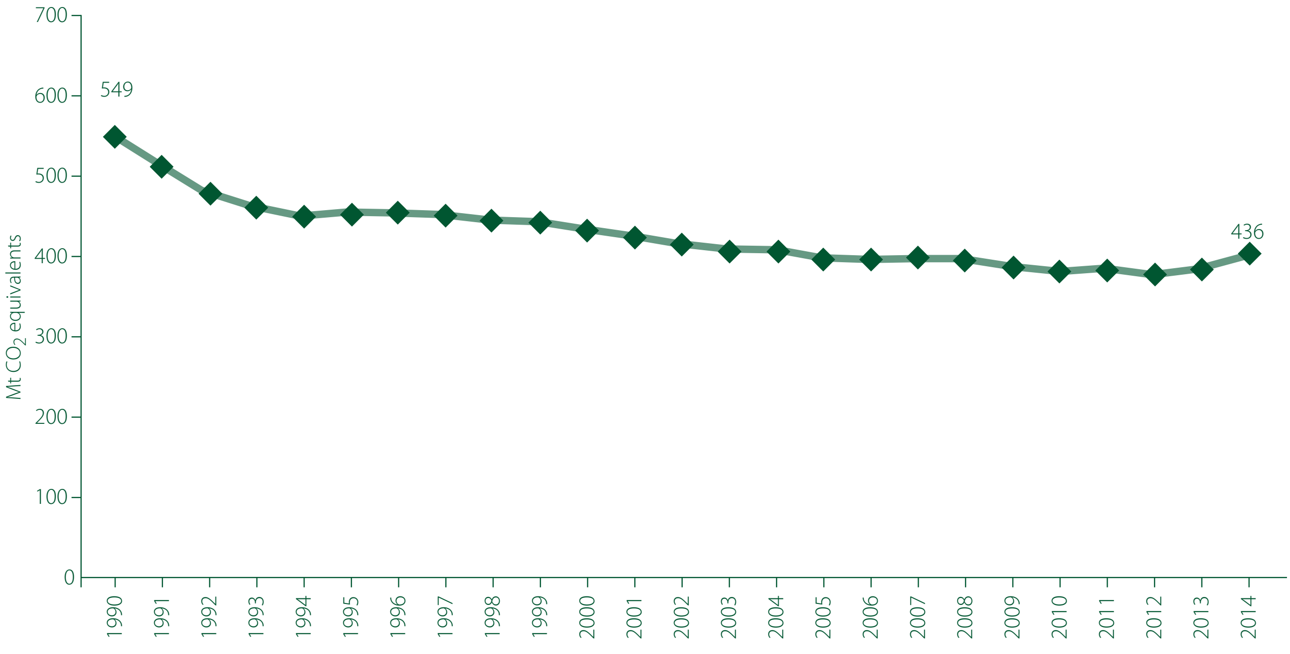
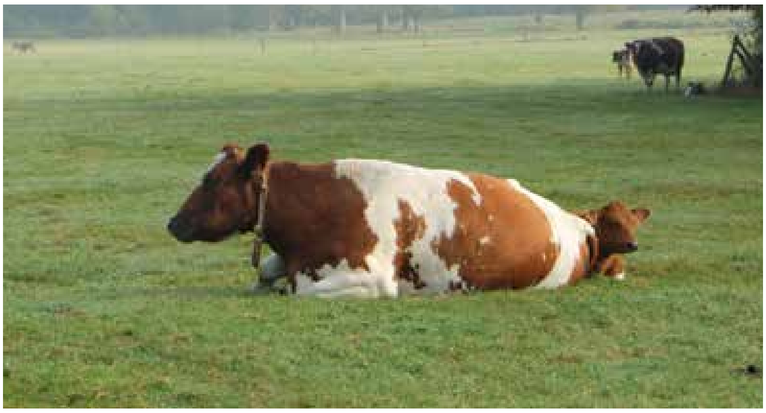


Figure 1: GHG emissions from the agricultural sector in the EU-28 plus Iceland, 1990-2014

Source: Danila et al., 2016, page 436



The Commission's impact assessment[3] of the land use, land use change and forestry (LULUCF) proposal notes that "continuing the trend of steady emission reductions from agriculture may be challenging" and that "in most Member States the reduction path slowed down significantly between 2001 and 2012. For some countries, much of the low cost mitigation potential in agriculture for non-CO_2 emissions has already been utilized."

In the future, the European Commission expects that, if no further action is taken, agricultural emissions will decline by just 2.1% by 2020, and 2.4% by 2030 (against 2005 levels). This is far below the overall 10% and 30% reduction ranges that are required for all non-energy intensive sectors under EU legislation (see chapter 6) (European Commission, 2016e).

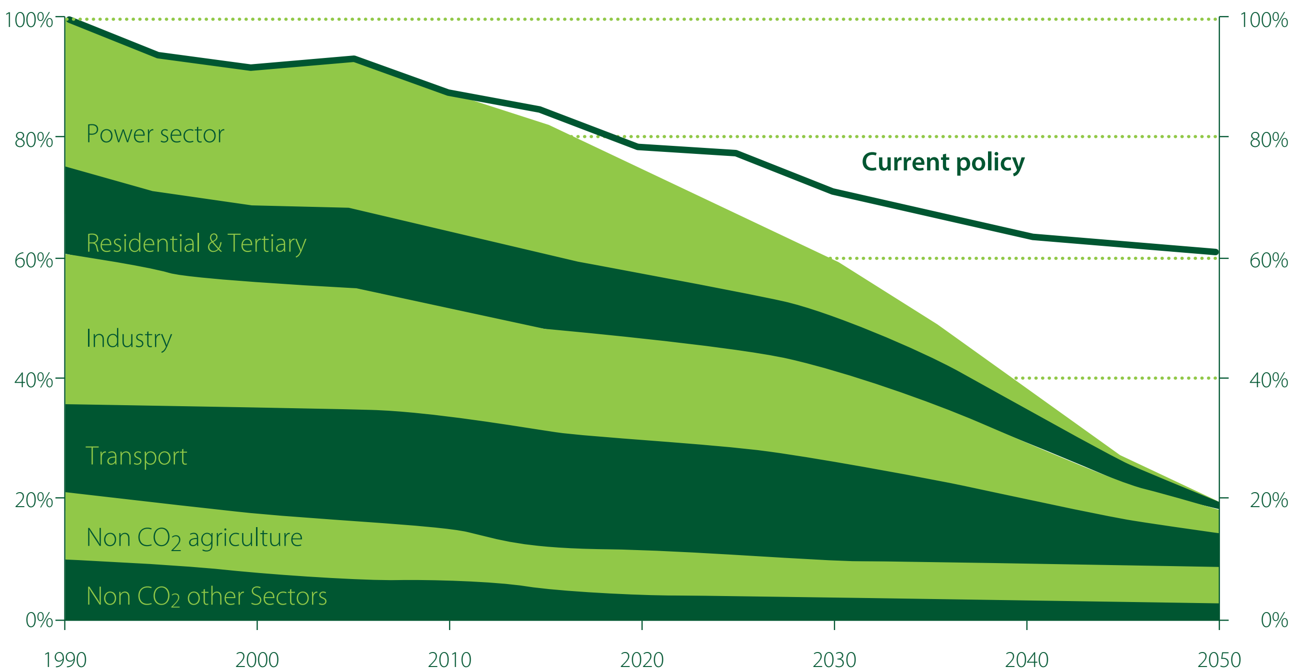


Figure 2: State of the art and best practice for climate action in the agriculture and forestry sectors

Source: European Commission, Presentation at the Workshop "Agriculture and LULUCF in 2030 EU Climate and Energy Framework", Brussels, 15 September 2015

2.2 SOURCES OF DIRECT EMISSIONS FROM AGRICULTURE

2.2.1 METHANE EMISSIONS FROM ENTERIC FERMENTATION

Most agricultural emissions are non-CO_2 emissions (see Figure 4). Methane emissions linked to enteric fermentation in ruminants (belching and flatulence) and nitrous oxide emissions from mineral and organic fertilizers applied to managed soils form the largest share of GHG emissions from the agricultural sector, both globally and in the EU (Bellarby et al., 2008, Danila et al., 2016).

Enteric fermentation in cattle and sheep accounts for 41% of GHG emission from agriculture in the EU-28 plus Iceland – roughly four percent of total GHG emissions. Methane emissions from enteric fermentation are by-products of ruminant digestion[4]. Ruminants (cattle, sheep, goats) have a special intestinal tract that allows them to digest roughage feed. It is therefore difficult to reduce emissions from enteric fermentation without interfering with this natural digestive processes. Roughage feed such as grass and forage legumes are relatively more difficult to digest than concentrate feeds, such as grains and grain legumes, and generally lead to higher emissions. But the digestibility of different roughage can vary considerably, and methane emissions from enteric fermentation depend on feed type and quality. Rye grass, for example, tends to result in lower emissions than maize stover or straw from cereals.

Clearly, livestock numbers drive the overall emissions from enteric fermentation, so the recent downward trend in the numbers of cattle and sheep in the EU (see Figure 3) contributed to reducing the related emissions.

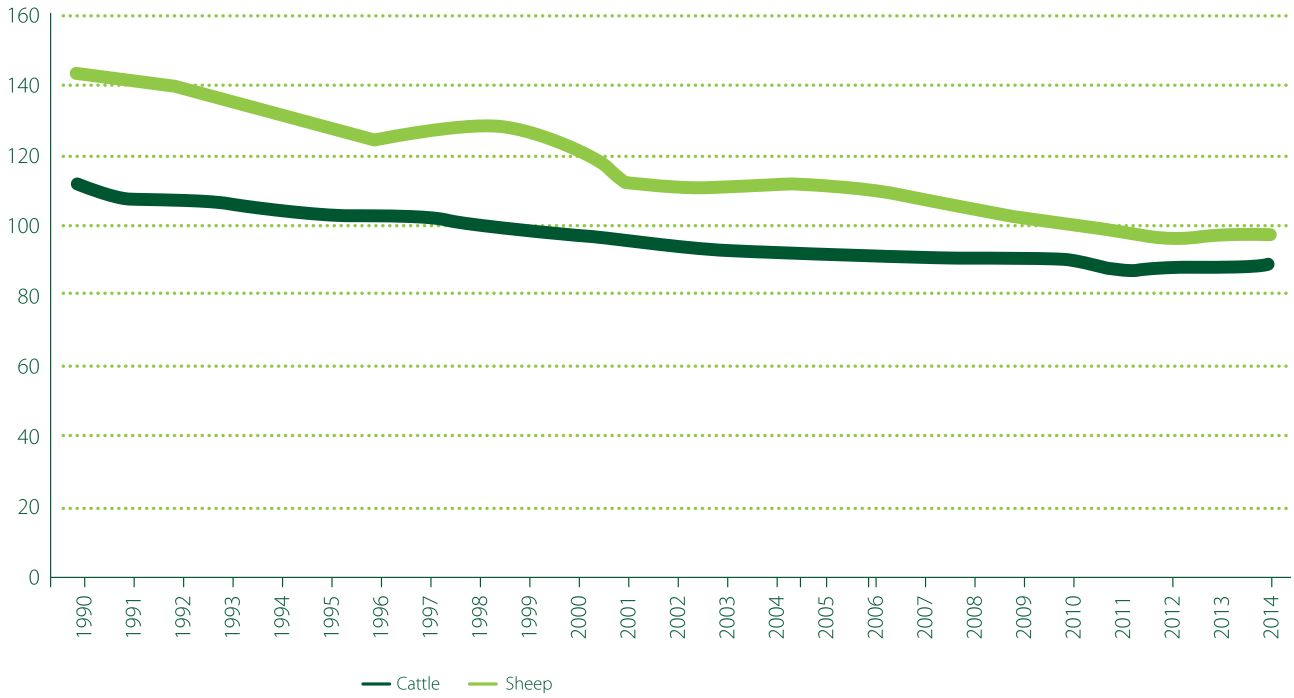
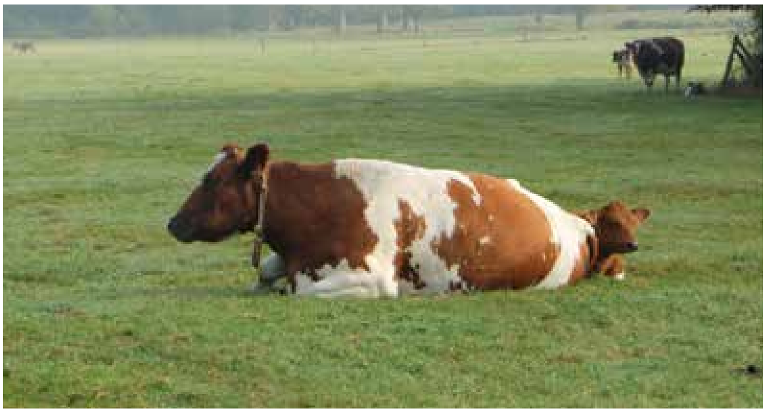


Figure 3: Numbers of cattle and sheep in the EU, 1990-2014

Source: Food and Agriculture Organization of the United Nations, Statistics Division, 2016



2.2.2 NITROUS OXIDE FROM FERTILIZED LAND

Direct and indirect[5] nitrous oxide emissions from managed soils account for 38% of agricultural emissions, and a similar four percent share of total emissions. Direct nitrous oxide emissions from managed soils stem from microbial nitrification and denitrification processes in soils, as well as a range of other soil processes on reactive nitrogen applied in mineral and organic fertilizers or sourced of crop residues and soil organic matter decay. Indirect nitrous oxide emissions derive from further reactions of nitrate, ammonium and oxides of nitrogen due to volatilization and deposition of the latter two, and due to nitrogen runoff and leakage of the former. These emissions arise from all fertilizer types, be they synthetic, mineral-based nitrogen fertilizers or organic fertilizers, i.e. nitrogen sourced from manure or crop residues, mulch and compost. This means that the use of nitrogen fixed biologically in leguminous biomass also causes nitrous oxide emissions when applied to the soils as mulch or compost (although the nitrogen fixing process itself does not lead to emissions). As a rule of thumb, there is a linear relationship between the N_2O emissions occurring and the amount of nitrogen applied (Danila et al., 2016).

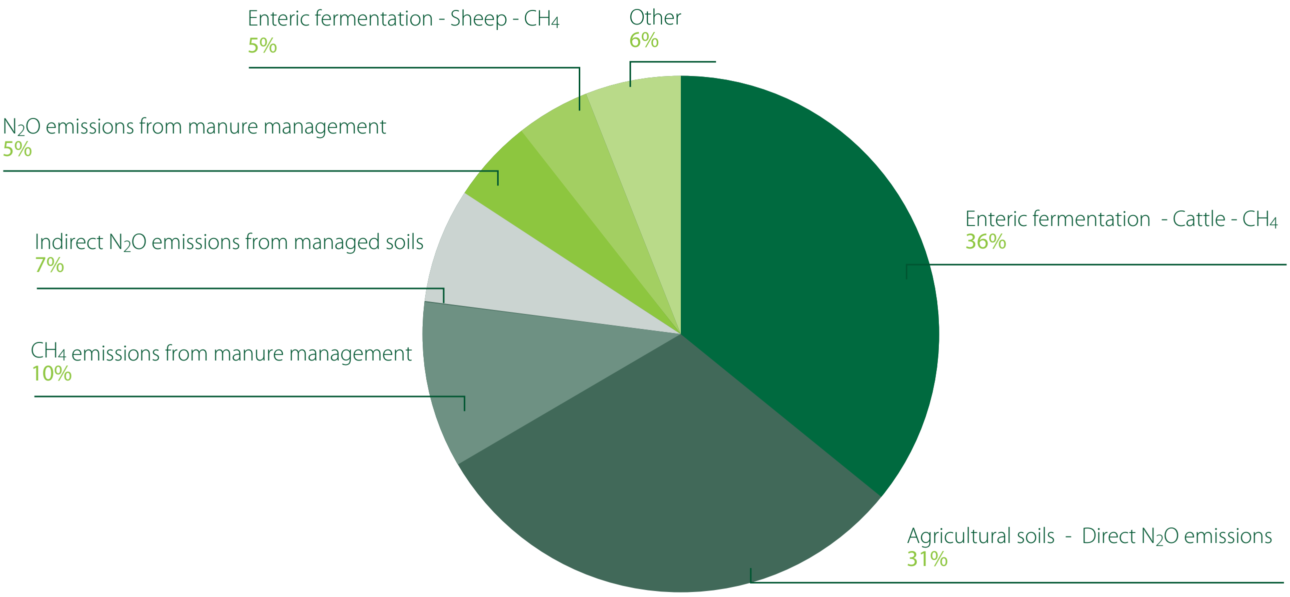


Figure 4: Agricultural GHG emissions breakdown for the EU, 2014

Source: Danila et al., 2016, page 437

2.2.3 MANURE-LINKED EMISSIONS

The third-largest agricultural emissions category comprises methane and nitrous oxide emissions from manure management. This accounts for 15% of agricultural GHG emissions and about 1.5% of total EU-28 plus Iceland GHG emissions (Danila et al., 2016). These methane emissions depend strongly on the anaerobic conditions and on the temperatures in the manure management systems.

2.2.4 OTHER SOURCES OF EMISSIONS

The remaining agricultural GHG emissions from the EU-28 plus Iceland mainly stem from the open burning of biomass residues on agricultural fields and from rice cultivation, each of which accounts for just a small fraction of a percent (Danila et al., 2016, Eurostat, 2016b).

2.2.5 DISTRIBUTION ACROSS THE EU

The biggest emitters in absolute numbers are France and Germany, with 19% and 15% respectively of the EU-28's total agricultural emissions in 2012. The UK follows with 11%, then Spain, Poland and Italy with about eight percent each. (Eurostat, 2016b).

The overall pattern of emissions in the EU largely reflects the data from the individual Member States, although land area and the relative importance of different agricultural subsectors at the national level clearly influence the detailed figures, as shown in Table 1.

The agricultural area and the animal population in each Member State strongly determine its share of the EU-28's total agricultural emissions. The contribution of CH_4 and N_2O emissions relative to a country's overall agricultural emissions reflect the importance of meat and milk production compared to arable crops in that country.

Germany, for example, has a large agricultural area and it contributes a large share of the total agricultural emissions of the EU. Its nitrous oxide emissions are larger than its methane emissions, which reflects the fact that the livestock sector does not dominate. The share of agricultural emissions in its total emissions is well below 10%, indicating that other sectors are more significant than agriculture.

For Ireland, on the other hand, about 30% of its total GHG emissions come from the agricultural sector, most of which consists of methane emissions. This reflects the importance of the livestock industry to its economy.

Ireland's 30% figure represents the highest agricultural proportion of total emissions of any EU country. The country with the smallest agricultural share is Malta, with 2.5% (Eurostat, 2016b).

Most of the above-mentioned emissions are direct emissions, monitored and accounted as part of the EU's Effort Sharing Decision (ESD). The ESD also covers emissions from the transport and building sectors, but excludes the industrial emissions covered by the European Emissions Trading System (ETS). Combined, the ETS and ESD policies aim to reduce GHG emissions by 20% by 2020. For more information about relevant EU policies, please refer to chapter 6. On average these direct non-CO_2 emissions from agriculture represent 18% of the emissions covered by the ESD. The differing shares of non-CO_2 agricultural emissions within the ESD in the different Member States are shown in Figure 5.

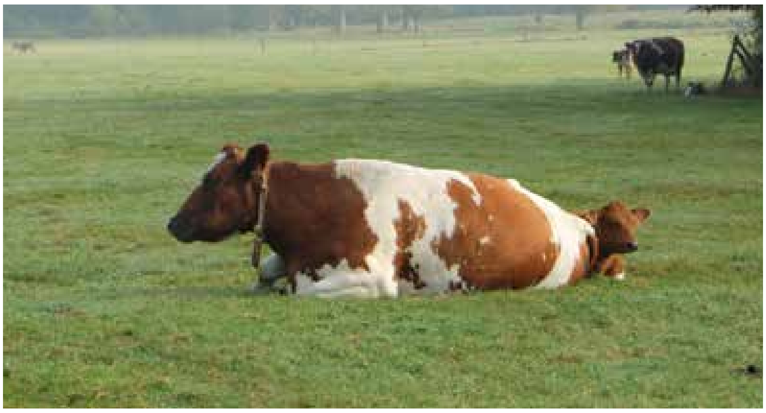


Table 1: EU Member States' GHG emissions in million tonnes CO_2-equivalent for the year 2012 (in $MTCO_2$-eq)

	Total greenhouse gas emissions (1)	Emissions from agriculture (2)		
		Methane (CH_4) emissions	Nitrous oxide (N_2O) emissions	Methane and nitrous oxide emissions
EU-28	4,548.4	198.8	271.9	470.6
Belgium	116.5	5.0	4.3	9.3
Bulgaria	61.3	1.9	4.6	6.5
Czech Republic	131.5	2.5	5.6	8.1
Denmark	51.6	4.2	5.4	9.6
Germany	939.1	25.8	43.7	69.5
Estonia	19.2	0.5	0.9	1.3
Ireland	58.5	11.0	6.9	18.0
Greece	111.0	3.7	5.4	9.1
Spain	340.8	17.9	19.8	37.7
France	490.3	38.4	50.8	89.3
Croatia	26.4	1.0	2.4	3.4
Italy	461.2	15.3	20.1	35.4
Cyprus	9.3	0.3	0.5	0.8
Latvia	11.0	0.8	1.6	2.4
Lithuania	21.6	1.7	3.4	5.1
Luxemburg	11.8	0.3	0.3	0.7
Hungary	62.0	2.8	5.9	8.7
Malta	3.1	0.1	0.0	0.1
Netherlands	191.7	9.2	6.7	15.9
Austria	80.1	3.5	4.0	7.5
Poland	399.3	11.5	25.2	36.7
Portugal	68.9	4.0	3.3	7.2
Romania	118.8	8.7	9.5	18.2
Slovenia	18.9	1.0	0.8	1.9
Slovakia	43.1	1.0	2.2	3.3
Finland	61.0	1.8	3.9	5.7
Sweden	57.6	2.9	4.8	7.6
United Kingdom	582.9	22.1	29.7	51.8
Iceland	4.5	0.3	0.4	0.7
Liechtenstein	0.2	0.0	0.0	0.0
Norway	52.8	2.2	2.3	4.5
Switzerland	51.5	3.1	2.4	5.5
Turkey	439.9	21.4	10.9	32.3

(1) Excluding Land Use, Land Use Change and Forestry (LULUCF) net removals
(2) Emissions from agricultural transport and energy use are excluded, as these sectors are not defined as part of the agriculture sector by the current IPCC reporting guidelines

Source: European Environment Agency and Eurostat

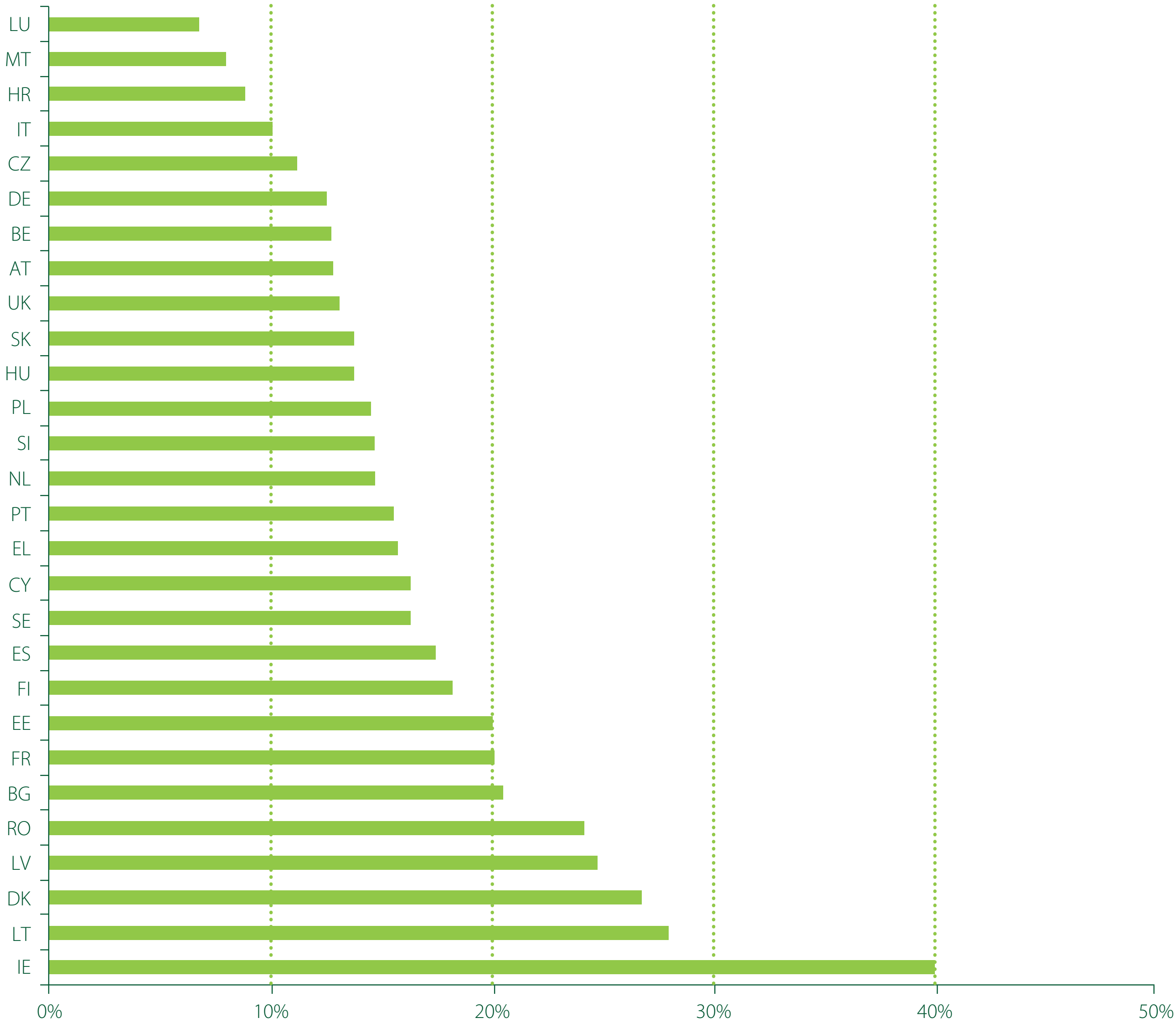
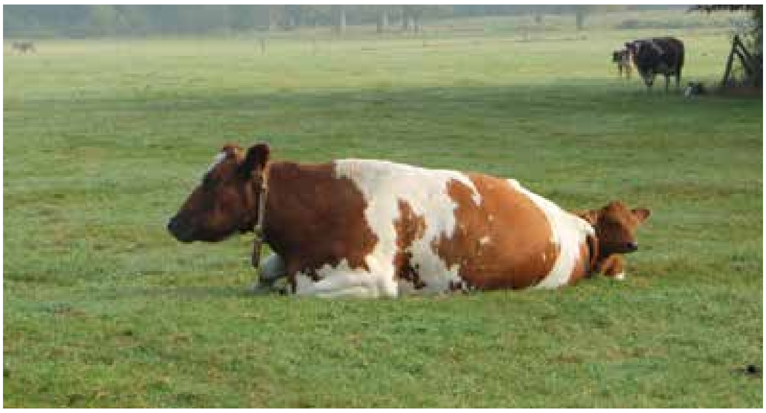


Figure 5: Varying shares of agricultural non-CO_2 in the emissions covered by the ESD (i.e. in the total of the sectors not covered by the EU-ETS), 2008-2012

Source: European Commission 2016



2.3 BEYOND THE FARM: EMISSIONS FROM SYNTHETIC FERTILIZER PRODUCTION, FOOD WASTAGE, LAND USE CHANGE AND OTHER MISSING PIECES OF THE PUZZLE

While enteric fermentation, fertilizer use and manure management account for a large part of agriculture-related emissions (10-12% of total emissions), they are only part of the story. To get a better idea of the impacts that agriculture and the entire food system have, we also need to consider the emissions from production of synthetic fertilizers and plant protection products, as well as the fossil fuel used in farming operations. Likewise important are soil carbon losses from cropland, grassland management and the conversion of land to agricultural use[6], and emissions from food processing, the retail sector and food waste and loss (Bellarby et al., 2008). However, even accounting for these aspects, the picture remains incomplete because the emissions generated from imported food and feed are not included in the national GHG inventories, as these apply to national system boundaries.

Table 2 provides indicative global and EU figures for these "indirect" yet inherently related aspects of our food systems (more details are provided in the subsequent sections).

2.3.1 EMISSIONS FROM LAND USE CHANGE ABROAD: THE IMPACT OF DEFORESTATION FOR ANIMAL PRODUCTION

Land conversion from forest or grassland to agricultural land (pastures and cropland) is estimated to create 6-17% of global GHG emissions. A large part of this is related to the clearing of forests to grow soybeans and other crops for animal feed, as well as to create grasslands for beef production (Bellarby et al., 2008). Here, what is relevant to the EU agriculture is the "embodied" deforestation and related GHG emissions generated by food and feed products imported to the EU. According to Cuypers et al. (2013), over the period 1990-2008 for which data is available, this amounted to an area of around half a million hectares per year. Such deforestation entails annual GHG emissions of 160-230 MtCO_2-eq[7] and corresponds to about 35-50% of the EU's agricultural emissions. The land use, land use change and forestry sector in the EU is addressed in section 2.3.2.

Table 2: Indicative figures from "indirect" inherently related aspects of our food systems, for the EU-28 and globally

Units: Mt CO_2e	EU	Global
Total land use change to agricultural land	Cropland 45 Grassland -24 (negative, as this is mainly conversion from croplands to grasslands)	3,000 - 9,000
Land use (soil carbon loss/gain)	Cropland 25 Grassland 33 Organic soils 15	
Deforestation embodied in imports	160-230	
Mineral fertilizer production	80	410
Energy use for irrigation	n.a.	370
On farm machinery use	n.a.	160
Production of plant protection chemicals	n.a.	70
Food wastage (emissions along the whole value chain, including production and disposal)	500	3,300
Total direct agricultural emissions	450	5,100

Source: Bellarby et al. 2008; Danila et al. 2016; Cuypers et al. 2013; FAO 2013a; Monier et al. 2011

2.3.2 EMISSIONS FROM LAND USE, LAND USE CHANGE AND FORESTRY (LULUCF) IN THE EU

LULUCF emissions and removals play a key role in the ongoing debate surrounding the EU's GHG emissions mitigation measures and the potential for flexibility between different sectors. In 2014, the net effect of land use change in the EU was estimated to provide a sink for about 310 $MtCO_2$ (EEA, 2016). Existing forested land represents 386 $MtCO_2$, while the conversion of land to forest in 2014 added another 53 $MtCO_2$-eq, bringing the total contribution of forests as a sink to about 440 $MtCO_2$-eq. Existing cropland was a source of 25 $MtCO_2$-eq in 2014, due to soil carbon loss. The distribution of this factor among the EU Member States is uneven, with Germany, Finland, Denmark and the UK reporting almost 80% of these emissions, while Romania, Belgium, Hungary and Spain report croplands as carbon sinks. This is mainly driven by the IPCC methodologies rather than by direct measurements, since a decline in land use intensity on croplands tends to translate into increased soil carbon sequestration. Soil carbon losses through the conversion of land for crops amounted to 45 $MtCO_2$-eq in 2014. France, Germany and the UK are the biggest emitters in this category. Growing crops therefore leads to emissions of 70 $MtCO_2$, from soil carbon losses on existing cropland (25 $MtCO_2$-eq) and from the conversion of other land to cropland (45 $MtCO_2$-eq).

Existing grasslands are a net source of emissions across the EU, and were responsible for about 33 $MtCO_2$-eq in 2014, although some countries, such as the UK, report significant sequestration in grasslands. On the other hand, the conversion of cropland to grassland resulted in the sequestration of an additional 24 $MtCO_2$-eq, as in many countries this involved the conversion of croplands rather than forests. The biggest sinks in this category are reported in France, Italy, UK, Bulgaria and Lithuania. Overall, grasslands contributed net emissions of nine $MtCO_2$-eq in the LULUC category in 2014. The use of wetlands resulted in about 15 $MtCO_2$-eq emissions due to the oxidation of the drained peat and organic soils. The biggest emitters in this respect are Poland, Germany, Finland and Ireland, which together accounted for more than 85% of such emissions. Finally, the conversion to settlements in 2014 resulted in losses of about 47 $MtCO_2$-eq (EEA, 2016).

2.3.3 EMISSIONS FROM THE PRODUCTION OF MINERAL NITROGEN FERTILIZERS, FOSSIL FUEL USE, AND FOOD WASTE

In the EU-28 plus Iceland, emissions from the production of mineral nitrogen fertilizers amount to about 1.75% of total emissions, or around 18% of agricultural emissions[8]. Data on the fossil fuel used in farming operations and irrigation is not readily available, as it is combined with the figures for forestry and fisheries in the EU Greenhouse Gas Inventory (common reporting format, CRF, category 1.A.4.c). Nor are any data separately available on the emissions from food processing, transport and retailing in the EU.

Emissions from food wastage are also very high, and they are largely unnecessary, and could be significantly reduced. Here we take into account the emissions from wasted food linked to agricultural production, dumping and burning[9], as well as emissions generated along the entire value chain, including consumption (cooking, etc.). To avoid double-counting the emissions from production, only the emissions caused along the value chain and by food dumping must be accounted for in addition. Those equate to about 23% of global agricultural emissions[10] (FAO, 2013a).

Emissions linked to food wastage also play an important role in the EU. About 90 million tonnes of agricultural production were wasted in 2008 (180 kg per capita and year; 40% each at household and manufacturing level). That year, the shares varied between the different commodity groups (Monier et al., 2011, FAO, 2013a), but added up to around 3.5% of total EU-27 emissions[11]. Monier et al. (2011) do not address waste incurred during agricultural production or post-harvest handling and storage, which account for almost 50% of total food wastage in the EU (FAO, 2013a). Without these factors, the FAO (2013a) reports wastage of about 120 million tonnes, somewhat higher than Monier et al. (2011), while including them brings the amount of primary production wasted in the EU to 240 million tonnes – almost 10% of its total GHG emissions. In short, if all the stages of the value chain and all sources of emissions are included, food wastage accounts for almost 10% of the EU's GHG emissions[12]– about the same as its total direct emissions through agricultural production.

3. HOW CAN AGRICULTURAL GREENHOUSE GAS EMISSIONS BE MITIGATED?

Many agricultural emissions are due to biological processes and cannot be avoided by changing food production processes. In this, agriculture is fundamentally different from the energy sector, for example, where emissions from fossil fuels can be avoided by switching to renewable energy without changing the quantity or type of energy supplied. Nevertheless, the greatest potential for mitigating agricultural emissions lies in reducing the amount of land cultivated for feed and animal production. This would require people to change their diets and show a greater acceptance of plant-based protein instead of animal-based protein (see section 3.7). At the same time, however, it is also possible to mitigate agricultural emissions through a range of measures on the production side.

A number of mitigation measures are shown in Table 8 in the appendix, including an estimate of the costs and potential benefits involved, where such figures are available. Examples of mitigation measures can be found in Smith et al., 2014, Muller and Aubert, 2014, Bryngelsson et al., 2016, Smith et al., 2008, which look at the global level. A number of studies, such as Pérez Domínguez et al., 2016, RICARDO-AEA, 2016, specifically focus on the EU and also consider the abatement costs and technical feasibility. In general, the biggest potentials for mitigation derive from practices to reduce the use of nitrogen fertilizers and to reduce emissions from fertilized soils, from measures to reduce enteric fermentation and improve the management and application of manure, and from practices that help increase carbon sequestration in soil. Finally, in terms of land use, it would be a significant step to rewet drained peatsoils, to avoid converting land from forests to cropland and grassland, or from grasslands to croplands, thereby avoiding the related emissions from biomass and soil carbon losses.

Another area for potentially significant emissions reductions is the production and use of mineral fertilizers. This is discussed in section 4.2, where we specifically address the potential of organic agriculture for this. The production of agrochemicals for plant protection and the use of fossil fuels in farm operations (machinery and irrigation) also offer reduction potential, but this is much lower than with the other measures (Bellarby et al., 2008, Wollenberg et al., 2016). We do not discuss it in any further detail.

3.1 NITROGEN

Reductions in nitrogen applications can be achieved by avoiding over-fertilization and by implementing precision farming techniques that meet plants' nutrient needs with optimal timing, application type and quantities. The EU in particular seems to see great potential in directly reducing the nitrous oxide emissions caused by nitrogen fertilization by applying nitrification inhibitors (NI) that slow the rate at which nitrate is formed in fertilized soils. This would improve the efficiency with which crops take up nitrogen and reduce the amount of N_2O emissions that occur in this process (RICARDO-AEA, 2016)[13]. The reduction rates range from 25% to 65% of emissions prior to NI application. This represents a huge potential for an absolute reduction in emissions, given the extent of N_2O emissions from fertilized soils as a share of total agricultural GHG emissions (38%). However, NIs are agrochemicals and there could be a risk of developing tolerant populations, or they might have negative effects on non-target soil organisms. Until now, no clear evidence has been available about whether or not NIs have long-term negative effects on non-target soil organisms or undesirable impacts on nitrifying organisms in soils. Studies into these questions should ideally focus on soils with a long history of NI application, enabling an investigation of the potential long-term effects (Ruser and Schulz, 2015). Therefore, any widespread application of NIs to agricultural soils in the EU should only be allowed when peer-reviewed research indicates that NI use is environmentally safe and has a real mitigation potential.

3.2 COMBINING ANIMAL WELFARE, FEED AND OTHER MEASURES TO REDUCE ENTERIC FERMENTATION

Enteric fermentation emissions can be addressed through a number of approaches. Roughage feed[14] generally results in more methane emissions from enteric fermentation than concentrate feed. Research into feed composition suggests that it is the higher digestibility of concentrate feed that results in lower methane emissions. The degree of digestibility depends on the components of the concentrate, with starch-rich concentrate feeds (e.g. based on wheat, barley or maize) reducing methane production more effectively than fibrous concentrates (e.g. based on beet pulp) (Martin et al., 2010). In general, increasing the share of more easily digestible proteins in the feed helps to reduce methane emissions, whereas higher fibre and protein contents, which are more difficult to digest, increase methane emissions (Shibata and Terada, 2010).

However, different types of roughage result in different emission levels. "High-quality" roughage, measured in terms of its energy and protein content as well as the digestibility of the fibrous part, can perform as well as concentrate-based diets. Klevenhusen et al. (2011) found that pure ryegrass rations produced similar emission levels from enteric fermentation as maize or barley-based diets in which grains and meal were combined with straw and stover. This is because such a diet contains energy and protein content in equal parts, and the lower-fibre barley straw and maize stover is relatively digestible compared to ryegrass. Moreover, since roughage is a more natural diet for ruminants, this approach would be preferable for animal welfare reasons.

Reductions in emissions from enteric fermentation can also be achieved by a range of feed additives such as tannin, fatty acids or etheric oils. Recent studies show some potential for emission reductions of 15-25% compared to feed without such additives (Grainger et al., 2011, Durmic et al., 2014). However, there is still too little practical experience of this and it remains unclear how great the potential would be from wider application. Feed additives could have a major influence on enteric microbiota, with unclear impacts on the animals, especially over the long term. In all, many animal health- and performance-related issues remain uncertain.

Furthermore, reducing emissions from enteric fermentation might lead to higher emissions from manure and manure management. Here too, more research is needed. As with nitrification inhibitors, the widespread application of the approach requires caution and more research results are needed before any substantial promotion of these additives is attempted.

Other measures to reduce emissions include genetic selection, improved herd health and productivity (Martin et al., 2010, Knapp et al., 2014). Genetic selection is a long-term endeavour with uncertain outcomes regarding methane emissions. Less intensive production practices with lower annual yields result in better animal health and greater longevity, with a higher number of lactation periods. This means the unproductive period of the animals' lives is shorter in relation to their productive adult lives. Whichever system brings the best results in terms of emissions per kilogram of milk depends on the relationship between yields, rearing phase and the number of lactations. This shows that other, more systemic approaches have some potential for mitigation as well. Enteric fermentation emissions per kilogram of milk, for example, are calculated based on the unproductive rearing period and the number of lactations. Increasing the number of lactations and therefore total output reduces the emissions per kilogram of milk. Similarly, switching to dual-purpose breeds that can produce both milk and meat without being optimized for one form of output or the other can reduce emissions per kilogram of output, as these animals do not produce only milk or meat, but both together. This allocates the enteric fermentation emissions over a larger output quantity, reducing emissions per unit of output.

3.3 MANURE MANAGEMENT

Measures to reduce emissions from manure management are mainly intended to establish aerobic conditions, reducing the anaerobic generation of methane, or to use closed storage in which the methane is captured and flared or used as biogas. This can be achieved, for example, by:

- Optimizing the structure and management of manure heaps (turning and aeration)
- Separating solids from slurry and adding substances that reduce methane and nitrous oxide formation
- Storing manure in closed tanks or beneath solid covers
- Managing manure in biogas digesters, so as to capture the methane emitted and use it for biogas production

However, biogas production is too often associated with the significant cultivation of energy crops (e.g. maize). Emissions from indirect land use change for the cultivation of such crops can negate the gains from some of the reduction expected from biogas production. Biogas production should therefore only exploit waste and residues[15].

Feed composition also matters. More intensive protein-based feeding means more N_2O from urine and excrements (Meier et al., 2015).

3.4 SOIL CARBON SEQUESTRATION

Enhancing CO_2 storage in agricultural soils and forestry is also relevant, but soil carbon sequestration is difficult to measure. It is also reversible and non-permanent, and therefore should not be considered a mitigation tool like genuine emission

reductions. The forests and agricultural land in the EU currently sequester a net amount of carbon that is equivalent to seven percent of total GHG emissions from the EU-28 plus Iceland. This sink effect is mainly due to forest management and is expected to decline in the future. Measures that protect or enhance carbon sequestration are therefore often promoted as essential to reach the overall emissions reduction targets of the EU and the long-term goal set out in the Paris agreement. Such measures include the use of organic fertilizers and optimised crop rotations involving legumes, as well as efforts to prevent existing grasslands being converted to cropland, or to prevent the drainage of wetlands and peat bogs with high organic matter content for agricultural use, or to restore such wet soils that have previously been drained and used for agriculture.

As well as using positive sequestration potential, it is important to avoid losing the carbon already stored in soils, especially in grasslands (Smith et al., 2014). This also favours grassland-based livestock systems, if the stocking rates are adapted to the grassland type and situation. For example, in their comparison of organic and conventional reference farms in Germany, Hülsbergen and Rahmann (2015) found that the overall emissions per kilogram of milk were similar, despite the fact that the organic farms fed their cows a significantly higher proportion of roughage, producing higher enteric fermentation emissions. They showed that the organic farms compensate for the higher emissions by avoiding losses of soil carbon through land use change and by sequestering more carbon in the soils from which they sourced their feed. In general, modelling studies on the soil carbon sequestration potential, referred to by the European Commission (2016e), estimate that soil carbon sequestration could amount to about 10-40 $MtCO_2$-eq/year till 2050 – i.e. it could compensate as much as 10% of the EU's agriculture emissions, but uncertainties are very high.

However, using carbon sequestration to achieve emission reduction goals is controversial, since it does not reduce emissions but merely offsets them. As such, it only helps to gain time as it slows down the rate of increase of GHG concentration in the atmosphere, but does not change emission levels per se in the way genuine reduction measures do. Furthermore, sequestration is not a permanent solution as the sequestered carbon can be lost to the atmosphere again later in the event of land use or management changes. Lastly, sequestration rates level off when a new equilibrium in soil carbon levels is reached[16].

In any case, the LULUCF sector needs improved governance and further development. If it is to be included, even in part, in future EU climate policies to meet the 2030 targets under the ESR (European Union, 2016, European Commission, 2016e) it will require an adequate accounting regime. Under the current EU legal framework (up to 2020), LULUCF emissions are reported but not accounted for in either the Effort Sharing Decision or the Emissions Trading Scheme (European Commission, 2016b, European Commission, 2016f). This might change for the period 2020 to 2030, as the European Commission has proposed[17] that, in certain circumstances ("no debit" rule), the Member States could count reductions achieved through afforestation, cropland and grassland in calculating their progress towards their targets under the Effort Sharing Regulation (see chapter 6).

3.5 LAND USE, LAND USE CHANGE AND FORESTRY EMISSIONS FROM IMPORTED FEED

Land use and land use change (LULUC) emissions associated with feed production can be quite high but are usually not taken into account in most life cycle analyses. Emissions and removals from LULUC, according to the United Nations Framework Convention on Climate Change (UNFCCC) accounting logic, are reported separately from the economic activities driving the processes behind, although the overwhelming part of land use changes are driven by agricultural or forestry activities. A recent exception is the analysis by Weiss and Leip (2012), who reported detailed product-based net emissions for the main livestock products (meat, milk and eggs) at the national level for the EU-27, with a cradle-to-gate life-cycle assessment. The analysis includes LULUC emissions. The authors found that the total GHG fluxes from European livestock production range from 623 to 852 $MtCO_2$-eq. Of this, 182–238 $MtCO_2$-eq (28–29%) come from beef production, 184–240 $MtCO_2$-eq (28–30%) from cows' milk production and 153–226 $MtCO_2$-eq (25–27%) from pork production. According to the authors, and based on IPCC classifications, 38–52% of total net emissions are created in the agricultural sector and 17–24% in the energy and industrial sectors (feed processing and transport, pesticide use, on-farm energy use). 12–16% are related to land use (CO_2 fluxes from the cultivation of drained peatlands and the reduction in carbon sequestration compared to natural grassland) and 9–33% to land use change, mainly due to feed imports. These results suggest that "for effective reduction of GHG emissions from livestock production, fluxes occurring outside the agricultural sector need to be taken into account", and that the use of pastures should be preferred over dependency of imported feed products.

3.6 REDUCING FOOD WASTAGE

Reducing the volume of food that is wasted, thereby also reducing the necessary production levels, would be a very effective way to reduce emissions by eliminating superfluous emissions that arise along the value chain of the wasted products. However, this would again necessitate changes in behaviour along the whole value chain, for example altering the requirement that fruits and vegetables conform to standard shapes and sizes for efficient processing and packaging.

Where the complete avoidance of waste is not possible, other options include making unused food available to charities, using it as animal feed, using it in optimised composting processes to make organic fertilizers, or in bio-digesters to produce methane as a biogas and organic fertilizers. The Food and Agriculture Organization of the United Nations (FAO) has presented a number of mitigation options and their reduction potentials (FAO, 2013b). Some authors judge the reduction of food wastage as having just marginal potential to support GHG emission reductions in the EU (Bryngelsson et al., 2016). This is because they only look at wastage at the retail and consumption levels, and they do not take into account emissions from waste dumps or from waste treatment and processing. Accounting for this raises their reduction potential from 1-3% of the emissions from the baseline, to 5-6%, or even 10% if including the end-of-pipe emissions[18]. Hiç et al. (2016) have somewhat higher estimates, but they also under-estimate the potential, as they neglect end-of-pipe emissions and do not include embodied feed production emissions in livestock products. Bellarby et al. (2013) cover all these elements, but they also have somewhat lower wastage shares than the FAO (2013a), and they only address the livestock sector.

3.7 REDUCING MEAT PRODUCTION AND CONSUMPTION

Consumption and behavioural change can have a large impact. Simply reducing the amount of animal products in the diets of EU citizens would lead to a decline in animal numbers, ruminants in particular, and would clearly bring a corresponding reduction in emissions, both from EU-based production and from imported products.

Technically, the EU could reduce its emissions by reducing its animal population. However, this could prompt the substitution of domestic production with imported goods that are produced abroad. This might be economically interesting for countries outside the EU, and it would improve the environmental situation regarding several indicators such as nitrogen and phosphorus surplus in the EU. However, it would result in a potentially significant leakage of emissions to the new production areas. Leakage means that the reduced production would be substituted by increased production outside the EU. The corresponding increase in emissions there would, at least in part, offset the domestic emission reductions.

Therefore, there is a need to strengthen measures on the demand side considerably, and to discuss their potential benefits explicitly. At present, these are rather neglected in the discussions of mitigation measures for agriculture. This is reflected, for instance, in a number of recent studies (European Commission, 2016e, RICARDO-AEA, 2016, Pérez Domínguez et al., 2016). The European Commission (2016e), for example, relies on modelling studies that conclude that with a 20% reduction of non-CO_2 emissions from agriculture "the impacts on production would be significant and substantial emission leakage could occur" (LULUCF Impact Assessment, see Chapter 6). However, this just reflects the fact that these studies were conducted in the assumption that no reduction would occur in the demand for, or consumption of animal products. The wish to avoid any impacts on agricultural production is the main reason why the Commission proposes a flexibility mechanism between the ESR targets and the LULUCF sector[19]. Nevertheless, if we are to establish a sustainable, climate-friendly food system we cannot persist with the assumption that demand and consumption should not drop, and need to discuss related reductions in production.

Looking at the bigger picture, it is therefore clear that any strategies and policies for climate change mitigation in agriculture should address the whole food system (including consumption as well as production), including the need for fundamental changes within that system beyond the specific attempts at mitigation through agricultural production.

A recent modelling study of agricultural GHG emissions in the EU and how to reach the EU reduction targets by Bryngelsson et al. (2016) illustrates this. They find that without a reduction of 50% in ruminant meat consumed, the EU cannot meet its required climate target. Their calculations already include the different technological changes possible within animal productivity, feed additives, manure management and other (see Figure 6). Even under an optimistic technological scenario (right bars of the graph), compared to more moderate changes (left bars in the graph), emissions would be too high to reach

the EU climate targets without changing animal product consumption levels.

Mitigation potential also occurs all along the value chain between production and consumption – i.e. storage, processing distribution and retailing – which mostly relates to the avoidance of food wastage and to reduced energy use.

However, the greatest leverage occurs in the total volume of agricultural production needed to feed a population, as the non-production of an agricultural commodity comes with a 100% reduction in related emissions. This explains the strong emphasis on reduction in animal products and related animal feed, and in wastage at the consumer level, rather than on other aspects of the value chain.

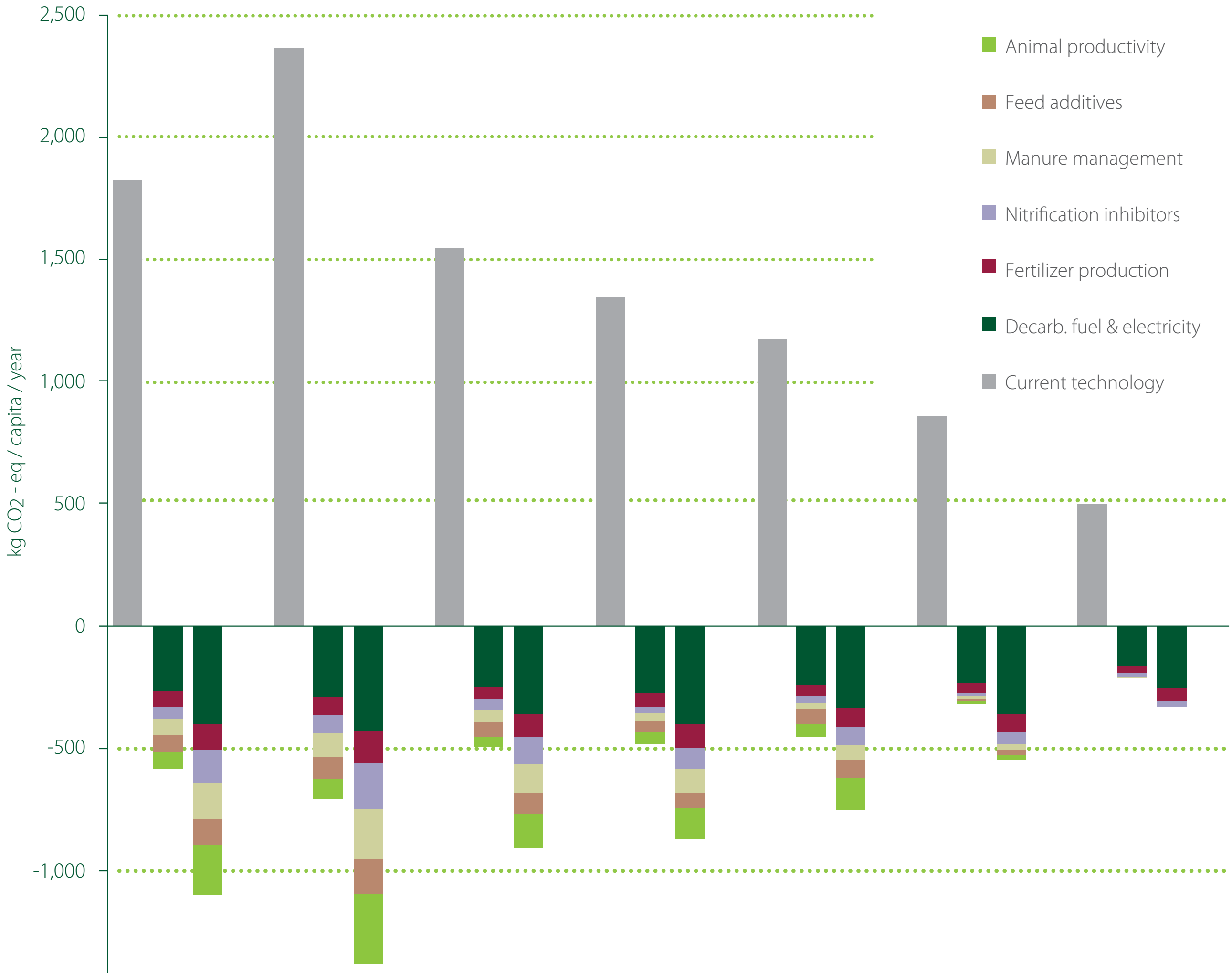


Figure 6: Current diet-based emissions (grey bar), emission reductions with moderate technological advances (middle bar) or with optimistic technological advances (right bar), for different diets in the European Union, such as the average situation, vegetarian, vegan or reduced meat. The effects of different measures are indicated separately by means of the colour coding.

Source: Bryngelsson, Wirsenius et al., 2016, page 162

4. THE POTENTIAL OF ORGANIC FARMING TO CONTRIBUTE TO CLIMATE CHANGE MITIGATION

WHAT IS ORGANIC AGRICULTURE?

IFOAM definition

Organic agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved.

4 IFOAM principles

Organic farming is based on four core principles:

Health: Organic agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible.

Ecology: Organic agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them.

Fairness: Organic agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities.

Care: Organic agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

Organic agriculture is largely rooted in agroecological approaches, both in principles and actual practices. Many organic and some innovative conventional farmers in Europe have embraced agroecological principles for the design and management of their farms. There are different schools of thought but, in short, agroecology can be defined as the use of ecological principles for the design and management of sustainable agricultural/food systems. It relies on the application of five basic principles: recycling, efficiency, diversity, regulation and synergies (Tittonell, 2014). In 2015, IFOAM EU published a report on the crucial role of agroecology in transforming the agri-food system and ensuring food security (Hilbeck and Oehen, 2015). Interest in organic farming amongst farmers has increased steadily in the EU since the mid-1980s as the farming community sees the move to organics as an attractive sustainable business opportunity. The latest Eurostat figures show organic production accounting for 6.2% of the EU's total farmland area in 2015, covering more than 11 million hectares. At the end of same year, the EU has 271,500 organic producers – an increase of 5.4% compared to 2014 (Eurostat 2016).

Demand for organic food in EU continues to increase year-on-year. Compared whole EU food and drink sector, the EU organic food market has developed significantly over the last decade. Organic retail sales doubled from 11.1 billion euro in 2005 to 24 billion euro by 2014 with a growth of rate of 7.4% on previous year (Stolze, in Meredith and Willer, 2016).

This section addresses the potential of organic agriculture to contribute to climate change mitigation. Many of the mitigation measures in agriculture discussed in the previous section (cf. Table 8 in the Appendix) are key practices in organic agriculture and have been well established in organic systems for decades (these include lower nitrogen fertilization levels, a focus on soil organic carbon and the use of legumes in crop rotations). Other measures are not at all suited to organic agriculture, as they conflict with the underlying principles (e.g. nitrification inhibitors). Here, we will discuss the main emission categories as identified above, in relation to the key options and practices for organic agriculture. This will indicate measures that fit particularly well with organic production systems and are therefore likely to be implemented in a conversion to organic agriculture. We also point out what measures are especially problematic for organic agriculture. Most of these measures are not compulsory in the sense that they are not described in the EU's organic regulations, but they are standard practice for those switching to organic agriculture. Theoretically, the measures could all be implemented in conventional agriculture as well. Overall, organic agriculture has considerable potential to contribute to climate change mitigation, as is shown in Table 5 towards the end of this section, which synthesizes the discussion in sections 4.1-4.5.

MEASURING THE PERFORMANCE OF AGRICULTURAL PRODUCTION SYSTEMS

The key point about measuring performance and mitigation potential was expressed by Tittonell (2014), who said that "what causes global warming is the total net emission of CO_2 and related gases per area, irrespective of the yields obtained. Calculating emissions or any other environmental impact per unit of produce, as often done through the methods of environmental accounting, is thus misleading. This exacerbates the sensitivity of environmental assessments to the definition of system boundaries."

When discussing climate change mitigation in agriculture, the primary metric usually used is emissions per kilogramme (kg) of output, rather than emissions per hectare (ha). This assumes an unquestioned demand for agricultural products that should be met with the lowest possible GHG emissions. With such an approach, conventional agriculture usually performs better as the yield gap between organic and conventional production (Seufert et al., 2012) often leaves the former at a disadvantage, despite the fact that its emissions per ha tend to be lower. This is a limited view which does not allow a proper assessment of mitigation potentials across whole food systems (Niggli et al. (2009), IPES-Food (2016), Tittonell (2014)). It is important to adopt a more systemic view, since the emissions per kg of product are just one way – and not necessarily the most important way – of measuring emissions and emission reductions in agriculture.

A paper by Seufert et al. (2012) concluded that the average yield gap between conventional and organic agriculture systems across crop types and locations amounted to about 20% (Seufert et al., 2012). According to Pablo Tittonell, "a new publication that reanalysed the same data using more sophisticated statistical techniques to account for co-variances indicates that yield gaps between both systems are narrower when similar amounts of nitrogen are applied in both systems (9%), or when entire rotations were considered (7%) (Ponisio et al., 2015)"[20]. Tittonell also notes that, "considering long-term series rather than point measurements is important when comparing yields in both systems," as long-term yield stability and resilience are two important aspects to consider when comparing the merits of agricultural systems, especially in light of the need to adapt to climate change.

On the question of whether to benchmark GHG emissions per land area or per product quantity, Niggli et al. (2009) point out that "environmental concerns – such as nitrate losses into groundwater or biodiversity loss through over-fertilization and overgrazing – are the main rationale behind organic agriculture standards on stocking density, limiting livestock to two units per ha in most productive areas. Animal welfare is another reason, because lower stocking densities offer free movement to animals. Therefore, the very purpose of the organic paradigm is producing less livestock while increasing the share of crops for human consumption. In this respect, per area benchmarking of GHG emissions is more appropriate than per product quantity for farming system comparisons, especially in the context of climate change and livestock production" (Niggli et al., 2009).

IPES-Food (2016) highlight the role of the choice of measures and indicators as a "conceptual barrier around the way questions are framed and one of the key mechanisms locking industrial agriculture in place, regardless of its outcomes." They point out that "research funding, development programming and political support for agriculture is often decided on the basis of specific performance indicators. Which indicators are used is therefore crucial. The performance of agriculture is often measured in terms of total yields of specific crops, productivity per worker, and total factor productivity (total outputs relative to total land and labour inputs)", which favours highly specialized and increasingly large-scale farms, but […] "the analysis of different agricultural systems' viability is generally carried out based on simplistic cost-benefit analysis, which does not incorporate ecological, social and cultural variables, and does not take into account the complexity of systems." (IPES-Food, 2016).

All these points show how important it is to complement efficiency measures with more systemic aspects that make it possible to address overall production levels, as well as the role certain resources play in a food systems context. The overall level of production and the resulting environmental impact are crucial. Reductions in wastage or in the consumption of animal products each offer considerable leverage for mitigation at this level. To complement "efficiency", such approaches can be listed under the heading of "sufficiency". Furthermore, optimal use of resources is crucial. Grasslands that can only be used to produce food from ruminants are important feed sources, although the emissions from enteric fermentation tend to be higher than for animals fed on concentrates. Such approaches of optimal resource use in a systemic context complement "efficiency" under the heading of "consistency". These systemic aspects are explored in more detail in section 5, while the more technical farm and field-level mitigation options for organic agriculture are addressed in the following sections.

4.1 EMISSIONS FROM LIVESTOCK AND MANURE MANAGEMENT

This covers emissions from enteric fermentation in ruminants and from manure management for all animals.

4.1.1 ENTERIC FERMENTATION

Feed additives are not yet sufficiently well developed as a technology for practical application, and many of them are unlikely to be considered compatible with organic standards.

Feed composition clearly has an impact on enteric fermentation. The substitution of roughage feed by concentrates generally tends to reduce emissions from enteric fermentation. A higher proportion of concentrates in feed rations is also necessary to increase animals' productivity for high milk yields of 10,000 litres or more, and for fast-growing meat animals that reach their slaughter weight at between 9-12 months. However, forage quality and fibre digestibility play a key role and well-designed roughage-based feeding rations can act in a way similar to concentrate-based feed, as was shown by Klevenhusen et al. (2011), among others. A study, carried out by the Thünen Institute for the German organic farmers' association Bioland, compared 40 organic farms with 40 conventional farms in Germany, including a wide range of farm types. The analysis of the dairy farms in Table 3 shows that product related emissions reach similar levels, with organic emissions being lower, albeit not significantly (see Table 3).

Changing feed composition towards a higher share of concentrate feed is against the spirit of organic agriculture. The EU organic regulation already demands that 60% of the feed for ruminants should come from the farm or from the same region. The BioSuisse standard in Switzerland goes even further and has an upper limit of 10% on the use of concentrate feed. Feed should therefore primarily come from the farm or the farm region and should not be imported from abroad. Furthermore, increasing the proportion of concentrate in animals' feed, thereby also raising the intensity of production, poses a correspondingly higher risk to animal health and welfare and has an adverse impact on the animals' longevity. Several authors also point out that some of the dietary changes may even pose risks to human health (Martin et al., 2010, Sejian et al., 2011). Recent findings show that milk and meat derived from a roughage-based diet contain significantly more omega-3 fatty acids and less cadmium, saturated fatty acids and pesticide residues, and bring corresponding health benefits (Średnicka-Tober et al., 2016a, Średnicka-Tober et al., 2016b). Finally, the GHG balance of feed containing more concentrate is influenced by the characteristics of its production. When addressing ruminant feed, it is important to use wider systemic boundaries and to include all emissions related to feed production, namely the emissions from arable land for concentrate feed production and, if relevant, also from land use change that took place to provide areas for concentrate feed production.

There are many reasons why increasing the use of feed concentrate as a means of directly reducing enteric fermentation emissions is undesirable for organic production. These include the health and nutritional aspects described above, as well as the role of grassland and feed farming as a competitor to food production on arable land in sustainable food systems, as has already been mentioned above and will be discussed in section 5. Organic farming therefore needs other measures to help reduce emissions from enteric fermentation.

Specific practices can be used to increase the longevity and the number of lactation periods of dairy animals, which reduces the emissions per kilogram of milk. As emissions per kilogram are calculated according to the animals' entire lifetime – including the unproductive rearing phase – the longer a cow stays within the herd, the lower the associated methane emissions on the farm (O'Mara, 2004). Importantly, by increasing the average number of lactations per animal during its lifetime from 2.5 to 5, methane from enteric fermentation decreases by around 13%. Another approach is to adopt dual-purpose breeds of cattle that provide both milk and meat. As two end-products are obtained from each animal, the emissions per kilogram of each product can be significantly reduced (Muller and Aubert, 2014).

These two measures – increased lifespan and the use of dual-purpose breeds – are particularly well suited to organic production systems, which are generally less intensive and focus more on animal health and welfare.

If changing diets and consumer behaviour expand the scope for substitution by including chicken and pork as well as beef, then per kg emissions are further reduced as these mono-gastric animals emit considerably less per kg product (Tilman and Clark, 2014). However, as was pointed out in the insert on measurement above and is discussed again in section 5, focusing on emissions per unit of product provides a very limited picture. For a holistic assessment of mitigation options through food production we must look at the entire food system, including consumption.

Table 3: Product-related GHG emissions from dairy production systems (gCO_2-eq/kg milk). (n.s. = not significant)

	Organic				Conventional				Significance
	Mean value	Minimum	Maximum	Standard deviation	Mean value	Minimum	Maximum	Standard deviation	
Total emissions	**983**	**835**	**1,397**	**149**	**1,047**	**911**	**1,248**	**88**	n.s.
GHG from energy use	165	133	218	25	191	165	219	16	
GHG from feed production	127	3	301	70	269	177	385	53	
N_2O	192	156	263	30	189	140	247	31	n.s.
Soil carbon changes	-65	-210	38	63	37	-76	122	49	
Indirect land use change (LUC from imported feed)	0	0	0	0	43	5	112	36	
Enteric fermentation	547	473	706	71	453	392	574	48	
Manure management	144	97	237	36	134	61	185	36	n.s.

Source: Hülsbergen H-J, Rahmann G (eds.) (2015) Klimawirkungen und Nachhaltigkeit ökologischer und konventioneller Betriebssysteme – Untersuchungen in einem Netzwerk von Pilotbetrieben: Forschungsergebnisse 2013-2014

4.1.2 MANURE MANAGEMENT

The storage and treatment of manure can have a very significant effect on GHG emissions. Liquid manure generates greater emissions, and the accumulation of manure in liquid form occurs more often in intensive than in organic livestock systems, as in the latter more bedding material is usually mixed in with the manure. Improved manure stock structure and management can reduce nitrous oxide and methane emissions by 50% and 70%, respectively. A technique often used in organic agriculture, and in biodynamic agriculture in particular, is manure composting. This can result in similar reductions, with about 50% less nitrous oxide and 70% less methane (Pardo et al., 2015).

When emissions derived from the application of this compost are measured, they can be somewhat lower than for normal manure. On the other hand, manure composting can increase ammonia emissions leading to 50-120% higher indirect nitrous oxide emissions (Pardo et al., 2015). However, viewed across the whole life-cycle from production to application, composting manure has the potential to reduce the emissions associated with manure management. It must be emphasized, that these results are derived from only a small number of studies, so further GHG measurements are needed to fully appreciate the climate relevance of composting.

Another option, which seems promising, is the small-scale production of biogas from manure, with the slurry used as fertilizer on the fields. Attention must be paid to avoid a competition between food and biogas with, for instance, energy crops specifically grown for use as a biogas substrate (e.g. maize in Germany). Furthermore, the use of biogas slurry as a fertilizer on fields does not always meet with acceptance, and may even be excluded by certain regulations. Guidelines have been developed for the best ways of producing biogas on organic farms[21], and the discussion continues (Gerlach et al., 2013).

4.2 EMISSIONS DUE TO MINERAL NITROGEN AND SYNTHETIC FERTILIZERS

There is a direct correlation between the nitrous oxide (N_2O emissions generated by nitrogen fertilizer applications and the amount of nitrogen (N) applied. In this respect, reducing nitrogen applications is the most effective way of achieving emission reductions. Agricultural land in the EU is usually over-fertilized so there is a general potential to reduce the rates of application. On organic farms, nitrogen levels per hectare tend to be lower than on conventional farms due to the ban on mineral nitrogen fertilizers, the focus on closed nutrient cycles and the efforts to minimize losses through runoff, volatilization and emissions. Livestock densities also tend to be better adapted to the resources available on the farm itself, then is the case with conventional farms. Correspondingly, nitrous oxide emissions tend to be lower on a per hectare basis.

Due to the yield gap between organic and conventional agriculture, nitrogen emissions per kilogram tend to be higher in organic than conventional agriculture. Tuomisto et al. (2012), for example, report about 30% lower median nitrous oxide emissions per area in organic systems, while the impact per unit of product was 8% higher than in conventional farming systems. This refers to direct nitrous oxide emissions from fertilized soils, but the picture is similar for indirect emissions stemming from volatilization and runoff, mainly as ammonia. Here, Tuomisto et al. (2012) report 18% lower ammonia emissions per ha, but 11% higher emissions per kg product. However, Meier et al. (2015) identified inconsistencies in the nitrogen balances in most of these studies, concluding that the life-cycle assessment (LCA) models underlying them do not adequately capture nitrogen dynamics in organic systems and may overestimate emissions on a per kg product basis. Part of the nitrogen flows are overestimated in the common LCA models, which are not adequately adapted for the specific characteristics of organic fertilizers and organic production systems. Correcting for this, they also found that the per kg product emissions are not necessarily higher in organic systems.

The most recent study of soil-borne emissions in organic and conventional systems, based on experimental system comparisons, reports a similar pattern (Skinner et al., 2014). They find that the higher emissions per kg product in organic agriculture would vanish if the yield gap drops below 17%, which is not very far from the yield gaps reported in recent all-encompassing meta-studies by Seufert et al. (2012) and


others (cf. footnote 28). Skinner et al. (2014) also report a significantly higher methane uptake in organically managed soils, but it is only a small effect and data is scarce. Focusing on Mediterranean climates, Aguilera et al. (2013b) find nitrous oxide emission reductions of up to almost 30% in organic production systems on a per ha basis, but they do not report on emissions per yield.

Reducing nitrogen applications has additional benefits if it is achieved through the reduction of mineral fertilizers, as this results in a corresponding reduction of emissions from fertilizer production. Referring to the numbers from the previous section, abandoning the use of mineral nitrogen fertilizers altogether in the EU – as would be the case with full conversion to organic agriculture – would result in an 18% reduction in total agricultural emissions in the EU (not accounting for the yield reductions that could arise from this, cf. below). In terms of the EU GHG inventories and targets, such reductions would be accounted for under industry, which also includes fertilizer production.

With such a reduction in mineral fertilizer use, total nitrogen input levels would fall. Given that mineral fertilizers account for 45% of total N inputs to agriculture in the EU (Eurostat, 2016a), this has the potential to reduce soil-borne N_2O emissions by 45% as well – i.e. about 20% of total agricultural emissions. As this might not be possible without adding alternative sources of nitrogen (increased legume cropping), for an indicative illustration, we may only assume a reduction of half this amount after the additional N-fixation in legumes – i.e. about 10% of total agricultural emissions.

The development of organic farming therefore offers good potential for reducing overall nitrogen levels in agriculture. Furthermore, there are indications that mineral fertilizer applications adversely affect soil organic carbon levels (IFOAM EU, 2015b).

4.3 GREATER SOIL CARBON SEQUESTRATION IN ORGANIC FARMING

Organic agriculture is associated with higher carbon sequestration as many organic practices help to improve soil quality and carbon sequestration. The most common organic practices that increase soil organic carbon are the use of organic fertilizers (such as the composted waste products from livestock husbandry), crop rotation involving legumes and the planting of cover crops (Bellarby et al., 2008, Gattinger et al., 2012, Muller et al., 2011).

A meta-analysis by Gattinger et al. (2012) indicates that significant differences exist between organic and conventional farms, in terms of their soil organic carbon stocks and sequestration rates. The authors emphasize that the main changes in soil organic carbon result from commonly applied practices in organic agriculture, such as improved crop varieties, extended crop rotations and the application of organic fertilizers like composted waste from livestock husbandry. The meta-analysis shows that soil organic carbon stocks in the upper 20 centimetres of soil are significantly higher in organic systems than under non-organic management practices (by 2.5-4.5 tonnes of carbon per hectare). The analysis also shows a mean difference in annual carbon sequestration ranging from 0.9 to 2.4 tCO_2-eq per hectare (net sequestration in the top soil), or from -0.35 to 2.35 tCO_2-eq per hectare for closed systems where no biomass is imported from outside. In another meta-analysis, Tuomisto et al. (2012) compared the environmental implications of organic farming in the European Union and showed that soil organic matter content was 7% higher on organic than on conventional farms. One of the main reasons for this is that organic matter inputs (manure or compost) were on average 65% higher.

Table 4: Benchmark values in conventional farming for crop-specific changes in soil organic carbon stocks expressed in CO_2-equivalents (t CO_2-eq/ha/yr)

t CO_2 - eq / ha / y Loss (-) or Gain (+)		
Crop	**Lower range**	**Upper range**
Sugar beet	-2.8	-4.8
Potatoes	-2.8	-3.7
Maize (silage)	-2.1	-2.9
Cereal crops, oleiferous crops	-1.0	-1.5
Grain legumes	+0.6	+0.9
Alfalfa grass / Clover grass	+2.2	+2.9
Stubble crops	+0.3	+0.4
Interrow crops	+0.7	+1.0

Source: Muller et al., 2011, page 24, based on VDLUFA, 2004

How much carbon the soil is able to sequester depends mainly on the quantity of organic matter applied, although the type of organic matter also seems to play a role[22]. Gains in soil organic carbon sequestration are highest for compost, with raw manure adding over a tonne of carbon less per ha and year (Aguilera et al., 2013a). Furthermore, certain crops have a bigger impact than others, with legume crops clearly adding more to the soil organic carbon stocks (see Table 4). Besides the supply of organic matter and the planting of legume crops, which are both key features of organic farming, crop rotation as commonly practised on organic farms can also increase soil organic carbon stocks by about 0.8 tCO_2-eq/ha per year, compared to monoculture practices (Muller et al., 2011, based on West and Post, 2002, and Smith et al., 2008).

Soil organic carbon stock is important not only because it has the potential to sequester large amounts of carbon, but also because it maintains soil productivity, structure and soil life. These important soil attributes improve plant health, water holding and retention capacity, resistance against droughts and other extreme weather events, and contribute to the maintenance and development of yields (Lorenz and Lal, 2016, Muller et al., 2011).

In many EU countries, soil carbon levels are actually declining in arable and horticultural farmland. Intensive agriculture is linked to ongoing soil degradation, soil carbon losses and a possibility of declining future yields. A study and review of a 50-year US agricultural trial found that the use of synthetic nitrogen fertilizer resulted in an average loss of around 10,000 kg of soil carbon per hectare and the loss of all crop residues. The higher the application of synthetic nitrogen fertilizer, the greater the amount of soil carbon lost as CO_2 (Khan et al., 2007, Mulvaney et al., 2009).

Applying the sequestration rate in closed systems referred to above, Gattinger et al. (2012) show that converting from conventional to organic agriculture on the available arable land in the EU would lead to the sequestration or reduced loss of 110 MtCO_2-eq per year, which would offset around 25% of the EU's total agricultural emissions. However, the process of sequestration is not unlimited. After a few decades, soils would be in equilibrium and the annual rate of sequestration would decrease, eventually reaching zero in about 30-40 years. Thus, we can derive an indication of the cumulative sequestration potential as follows. We assume that the soil carbon sequestration rate drops linearly to half its value over 15 years, after the conversion from conventional to organic agriculture. We also assume a more or less constant level of EU agricultural emissions of about 465 MtCO_2-eq for a baseline projection without further conversion to organic agriculture until 2030, as forecast by Van Doorn et al. (2012). Under these assumptions, the cumulative soil carbon sequestration potential until 2030, derived from an immediate conversion to 100% organic agriculture, corresponds to about 18% of the cumulative agricultural emissions in the EU up to 2030, against the baseline without conversion to organic agriculture.

These estimates for the mitigation potential of soil carbon sequestration under conversion to organic agriculture can be compared to the estimates of the mitigation potential from carbon sequestration in general. This is derived by applying a range of different agricultural practices in conventional agriculture, rather than focusing on the conversion to organic agriculture. It is presented, for example, by the European Commission (2016e). Earlier similar assessments of the general sequestration potential judged the theoretical potential to be quite high, at up to 200 MtCO_2-eq per year, if applied to all agricultural land in the EU (including arable land and grasslands)[23]. However, this has been contested as unrealistic, with the effectiveness of some measures called into question (e.g. no-till and reduced tillage). Moreover, other factors such as water availability can further restrict this potential. More recent studies – based on more detailed models of soil carbon dynamics and addressing economic constraints – report lower numbers ranging from 10-40 MtCO_2-eq/year (Lugato et al. (2014), Frank et al. (2015) cf. European Union (2016). Thus, the soil carbon sequestration potential of arable land can be realised through a combination of practices (mainly optimised crop rotations, organic amendments, partly improved tillage),

which can be applied in both conventional and organic contexts but are well established and implemented in organic agriculture.

In organic systems, due to weed pressure it is harder to realise the sequestration potential of reduced tillage – if such potential exists at all. Research on this is ongoing and results so far show no clear trend regarding the suitability of this management approach in organic systems (Mäder and Berner, 2012). In conventional agriculture, crop rotations and reduced tillage or no-till approaches are most relevant, while the optimal use of organic amendments is less common.

Organic agriculture represents a production system in which optimized crop rotations and organic fertilizers, such as compost and manure, and the use of mulches are combined optimally. Recent research comparing conventional and organic production systems at 80 reference farms in Germany has shown the optimal nature of organic farms with regard to soil carbon sequestration. Although emissions from enteric fermentation are higher per kg product on organic farms, due to the greater proportion of roughage fed to the animals, this is compensated by the increased soil organic carbon sequestration, both on the land used for feed production and in the avoidance of land use change emissions (Hülsbergen and Rahmann, 2015). Due to the mitigation effect of soil carbon sequestration, conventional and organic dairy farms show similar overall emission levels (cf. section 4.1.1).

4.4 OTHER ASPECTS OF CROP AND LIVESTOCK PRODUCTION

Enteric fermentation, manure management, nitrous oxide emissions from fertilized soils and emissions from mineral fertilizer production comprise the most important emission categories. However, there might also be openings for reductions in other areas. In the EU-28 plus Iceland, the major opportunities occur in the production of plant protection chemicals and the use of energy.

Global emissions from the production of plant protection agrochemicals are equal to about a tenth of the emissions from mineral fertilizer production (Bellarby et al., 2008), but these are uncertain estimates. Such emissions are avoided in organic agriculture, since the use of these products is banned. However, some replacement treatments are allowed in organic production, and the production emissions related to these must be accounted for as well, which somewhat lowers the reduction potential from banning pesticides.

On-farm energy use mainly involves heated greenhouses, farm machinery and irrigation, as considerable amounts of energy are required for pumping water. Emissions from heated greenhouses (with non-heated renewable energy) generally do not occur in organic agriculture, as many labels prohibit them (e.g. Demeter or Naturland). Emissions from machinery and irrigation are not necessarily lower in organic farming, although the improved soil fertility, higher water holding capacity and water use efficiency could mean the irrigation needs and corresponding energy use are lower.

Besides on-farm energy use, transport energy is also relevant. Some organic labels include regulations on transportation of agricultural products. The Swiss private organic label "Knospe", for example, excludes unnecessary transportation of agricultural products by air, thereby saving further CO_2 emissions.

As a rule, organic agriculture performs better than conventional agriculture regarding energy use, measured both per hectare and per product (Reganold and Wachter, 2016, Meier et al., 2015). The meta-analysis of Tuomisto et al. (2012) similarly states that median energy use per product unit in organic systems is about 20% lower than for conventional farming practices, and the review by (Scialabba and Muller-Lindenlauf, 2010) found that organic agriculture consumes around 15% less energy than conventional agriculture, per unit produced. These differences arise mainly because the production and transportation of inorganic fertilizers require large energy inputs, which are not needed in organic farming since they are prohibited. Consequently, the GHG emissions associated with the production and use of inorganic fertilizers are also absent from the organic farming system (see above). In integrated agricultural farming, for example, Deike et al. (2008) found that about 37% of the total energy inputs consisted of the fossil fuel consumption entailed by mineral fertilizer production and application. On the other hand, Gomiero et al. (2008) highlight the fact that the differing energy inputs for organic and conventional production largely depend on the products being considered, and the results do not always indicate a clear trend. They showed, for example, that organic agriculture consumes between 9.5% (apples) and 69% (milk) less energy than conventional farming. Other studies of the meta-analysis indicate a 7% to 29% higher energy consumption for organic potato production, compared to conventional farming (Gomiero et al., 2008). Here again, the newer and more detailed analysis of Meier et al. (2015) gives a somewhat clearer picture. The energy use per unit of product is lower for livestock products and arable crops, while it is mixed for fruits and vegetables.

4.5 SUMMARISING REMARKS

Organic agriculture has significant potential to help mitigate climate change. Based on the figures in the assessment above, by 2030 soil carbon sequestration and the avoidance of mineral fertilizers in organic agriculture could reduce or offset emissions equivalent to about 35% of total agricultural emissions in the baseline projections, for which the emissions are now forecast to stay at around 465 $MtCO_2$-eq per year till 2030[24].

This assessment assumes an immediate conversion to 100% organic agriculture. Assuming a 50% conversion of EU arable land to organic production (i.e. an additional 44 percentage points to the current 6%), this would result in the mitigation of about 17% of the EU's cumulative agriculture emissions up to 2030. Given that such conversion would not happen within one year, we may assume a linear increase to this 50% share in 2030, which produces a cumulative mitigation effect of about 8-9% for the whole period to 2030, based on soil carbon sequestration (contributing about 5.5%)[25] and reduced mineral fertilizer production (contributing 4-5%).

Such a conversion would entail a corresponding reduction of nitrogen inputs on the fields, and therefore bring additional emission reductions due to the reduced amount of N_2O emitted by fertilized soils. As soil-borne N_2O is about 40% of total agricultural emissions and mineral N is about 45% of total N applied in the EU, a linear increase in conversions to organic agriculture to 50% by 2030 would result in additional cumulative reductions of about 4-5% of EU agricultural emissions. In this calculation, we assume that the reduction in mineral fertilizer use when converting to 50% organic agriculture would not be compensated by additional N inputs[26]. This is however unrealistic, given the higher share of legume cultivation in organic agriculture. Nevertheless, overall N levels would decline, and a realistic lower estimate of the cumulative reduction in emissions due to a 50% conversion would be 12-14%, derived from increased soil organic matter and reduced production and application of mineral N fertilizer up to 2030. These figures are presented in Table 5.

We stress the caveat that yield levels would probably fall to some extent with such a change, thus necessitating a reduction in exports or a corresponding change in consumer behaviour, be it a reduction in food wastage or the lower consumption of animal products.

Table 5: Summary of the potential CC mitigation effects of organic agriculture, based on a scenario of linear increase towards 50% organic agriculture in the EU-28 plus Iceland by 2030. Percentages are in relation to the EU-28 plus Iceland future agricultural BAU emissions till 2030 as projected in van Doorn et al. (2012) or, similarly, in relation to the somewhat lower emissions in the baseline 2005 (Danila et al., 2016); Differences in percentages reduction potential if related to one or the other of these two base values is negligible given the uncertainties of these numbers, at less than 0.7%.

Scenario: Linear increase to 50% organic agriculture from 2016 to 2030	Cumulative emission reductions up to 2030, in % (equivalent to average reductions per year in this period, %)	Emission reductions in 2030 after having reached the conversion to 50% organic agriculture	Annual emission reductions beyond 2030, assuming a constant 50% share of organic agriculture
Emission sources/sinks			
Increased soil organic carbon	5.5%	18% (assuming that each area converted to organic agriculture loses 1/15 of half the sequestration potential each year until 2030 - i.e. an area converted in 2016 reaches 50% of the sequestration a potential in 2030)	18% in 2030 to 0% in 2060, assuming that the sequestration rate drops to 0 over 30 years (areas converted in 2016 reach 0% in 2045 already)
Reduced production of mineral N fertilizers	4-5%	9%	9%
Reduced application of mineral N fertilizers (assuming some compensation by increased legume shares)	2-3%	5% (assuming that about half the reduction from reduced mineral N fertilizer application is compensated by legumes)	5% (assuming that about half the reduction from reduced mineral N fertilizer application is compensated by legumes)
Total	12-14%	32%	32% (2030) 14% (2060)

Source: Own calculations based on the discussion and references presented in section 4

In 2030, if organic agriculture has achieved a 50% share of total production, the lower mineral N levels would result in 9% lower production emissions and N_2O emissions from fertilizer application would fall by 10%, though this would be counteracted in part by the increased cultivation of legumes. Soil carbon sequestration would continue to occur, but at a decreasing rate. Altogether, this would offset about 32-34% of agricultural emissions in the year 2030, or about 12-14% of cumulative emissions till 2030[27], assuming that these developments were accompanied by behavioural changes to reduce food wastage and the consumption of animal products, thereby compensating for the likelihood of lower yields from organic production.

SOME OBSERVATIONS

While they are core features of organic farming, many of the practices that help reduce emissions or increase carbon sequestration in organic agriculture could well be used in conventional agriculture too. This is evident, for example, in the list of general mitigation practices for agriculture presented by the IPCC (Smith et al., 2007) (see also Table 8 in the Appendix). This is important, as it demonstrates the potential of organic practices for climate change mitigation in agriculture in general. It shows that organic agriculture can serve as a best practice example and blueprint to increase the sustainability of agriculture in general.

When assessing the potential emission reductions from conversion to organic agriculture, it is important to adopt a systemic perspective. Such a conversion avoids mineral fertilizer production, but, as mentioned, it also results in an average 20% decline in yields (Seufert et al., 2012)[28]. Without a change in overall demand, this would effectively offset the emission reductions as the missing produce would have to be produced on additional domestic cropland or imported from abroad. Furthermore, organic agriculture entails a larger share of legumes in crop rotations, which will also be reflected in human diets, unless legumes are mainly grown for animal feed. The conversion to organic agriculture therefore has a considerable potential to reduce GHG emissions from agriculture, if it is combined with dietary changes that lead to a reduction in food wastage and lower consumption of animal products (Schader et al., 2015, Muller et al., 2016). To complete the picture, an analysis of organic agriculture must be complemented by an assessment of the sufficiency and consistency of entire food systems, focusing on the total production level and optimal resource use across the whole system. Such an all-encompassing food-system approach shows how organic agriculture can play a significant role in sustainable food systems that ensure food security while contributing to climate change mitigation. We should also keep in mind that, as discussed in section 5, organic farming systems are more resilient to changing weather conditions and often significantly outperform conventional systems in conditions of extreme drought.

We would stress the importance of the entire-food-systems perspective, in particular in contrast to common life-cycle analyses that focus on (eco-)efficiency and per-unit product emissions. We reiterate the point that efforts to reduce GHG emissions in agriculture should do more than just address agricultural production and assess the relative performance of organic and conventional approaches, for example, on a per-unit basis. Livestock feed should be analysed systemically, as the role of grassland can support different arguments than GHG emission levels per kg product. The yield gap plays a significant role in system comparisons based on emissions per kg, but it is less important if the reduction of food wastage becomes an option, i.e. the reduction of total agricultural output. Such a measure on food system rather than farm level considerably reduces the importance of the yield gap as the total emissions of an overall smaller production system can still be lower, even if emissions per unit of produce are higher. The reduction of animal products in human diets can be assessed along similar lines, in particular if it is achieved through a reduction in concentrate feed and focuses on grassland-based ruminant production and monogastrics (e.g. pigs) being fed by-products from food processing and crop residues. Such a system would also result in lower demand for agricultural products (as it would largely avoid the need to use arable land for feed crops), and in turn reduce the pressure to close the yield gap.

Clearly, reducing the yield gap and increasing organic yields would reduce emissions still further, but in a systemic view the yield gap relates to "efficiency", which is only one criterion for assessing sustainable food system – in other words, the relative resource-use or impact per kg product. At least as important as this are the total consumption levels, as reducing these clearly also reduces emissions (whether because of the reduced wastage, or the reduced animal feed production and correspondingly lower quantities of animal products). This relates to "sufficiency". Finally, the role various resources play in the food system is similarly important. Grassland, for example, can only be used in the production of food for humans by keeping ruminants. It might therefore make sense to focus on grassland-based ruminant production while reducing the amount of concentrate feed fed to them, although this could increase emissions per kg product. This relates to "consistency", which addresses the question of the roles different resources play in the context of a sustainable food system. As such, it helps to indicate viable paths towards increased sustainability.

5. BEYOND CLIMATE CHANGE MITIGATION: THE MULTIPLE BENEFITS OF ORGANIC FARMING

As we have shown above, organic agriculture can help reduce GHG emissions within the agricultural sector of the European Union and beyond. However, the sustainability of agriculture and food systems requires much more than just climate change mitigation. Organic farming practices deliver solutions for a wide range of sustainability challenges, such as biodiversity, climate change adaptation, eutrophication and socio-economic benefits (Meier et al., 2015, Reganold and Wachter, 2016). This is particularly relevant as, over the past decades, agriculture in the EU has been associated with biodiversity loss, water pollution, soil erosion, decreasing landscape quality and food safety concerns (Hole et al., 2005). As the following sections will make clear, the diverse benefits of organic agriculture not only contribute to better environmental conditions, but also help to reduce environmental damage and the costs to taxpayers, and to improve human health and the profitability of farmers themselves. This in turn reduces the environmental burden of agriculture on the planet.

5.1 BIODIVERSITY

Organic farms sustain 30% more biodiversity than conventional farms, as demonstrated by a meta-analysis of 94 studies from the past 30 years (Tuck et al., 2014). The most distinct differences in biodiversity were seen in landscapes containing a higher proportion of arable crops, and plant biodiversity benefited the most from organic farming practices.

As well as the farm management practices, the landscape, climate, crop types and species also play a major role in the effects of organic farming on biodiversity (Hole et al., 2005, Gabriel et al., 2010). Fuller et al. (2005), for example, analysed some of the practices that enhance biodiversity on organic farms in the United Kingdom. They found that field boundary management (e.g. the use of hedges), crop sowing time, crop rotations and the combination of livestock and crops were different in organic farms, compared to conventional systems. Organic famers sowed their crops later and included fallows in the crop rotations. Some of them also included livestock that grazed the grassland. Moreover, the organic farmers in the study cut their boundary hedges less frequently, so the hedges became higher and broader, thereby providing a more valuable habitat for a number of species. While the density and abundance of some species is influenced to a great extent by the management practices of the farm, other species are unaffected by the difference between organic and conventional management practices. The extent to which organic systems increase biodiversity also depends on different species' colonization traits – in other words, how easily plants that have been strongly affected by the use of agrochemicals and fertilizers can re-colonize areas following changes in agrichemical inputs (Fuller et al., 2005). Nevertheless, this study found that the numbers, density and abundance of species were significantly higher in and around fields on organic farms. In particular, the biodiversity of plant species was 70-100% higher, and weed abundance 75-150% higher than on conventional farms.

In a similar study that sampled species diversity on comparable pairs of organic and conventional farms (Gabriel et al., 2010), organic farming had positive benefits for wildlife at both farm level, and on a larger scale aggregated across several farms and other areas in a landscape. A clear difference was found among species groups, with most showing higher species richness on organic than on conventional farms. At the same time, the study found that the positive effects on biodiversity were not as strong as previously understood from studies that did not contrast paired farms within specific landscapes (i.e. an organic and a conventional farm located in comparable production contexts and of comparable farm type). This is probably explained by the fact that the organic farms might have been situated in a landscape context with a lower share of semi-natural habitats, and were therefore not fully comparable to the conventional farms (Gabriel et al., 2009, Gabriel et al., 2010). Overall, these studies show that organic farming has the potential to increase biodiversity within agricultural landscapes if a substantial area within that landscape is farmed organically.

5.1.1 BALANCING AGRICULTURAL PRODUCTION AND BIODIVERSITY CONSERVATION

Although organic agriculture can contribute to increasing biodiversity and may also help to reverse or at least halt the decline of species within the European Union and abroad (Tuck et al., 2014), some people argue that organic

farming tends to produce lower yields, which means larger agricultural areas are required to produce the same quantities as conventional agriculture, and that this, in turn, can have negative consequences for biodiversity (Lorenz and Lal, 2016). However, this overlooks the fact that agricultural production in Europe is often too intensive and outstrips the carrying capacity of local environmental resources. This is reflected, for example, in the large-scale exceeding of critical nitrogen loads (Westhoek et al., 2014). Agricultural intensity must be lowered on a large scale if we are to fulfil our biodiversity protection goals. Organic farming would be a viable option to achieve this. Moreover, it is doubtful that more food could be produced by sparing land for agricultural production and biodiversity conservation, as substantial areas of land would have to be excluded from human use. Such semi-natural or natural areas would also need to be interconnected in order to conserve populations.

In addition, land sparing would lead to a loss of farmland biodiversity which contributes significantly to global biodiversity as roughly 40% of the earth's terrestrial surface is occupied by agriculture (Foley et al., 2011). Farmland biodiversity also provides many ecosystem services that in turn are important for agricultural production itself, such as pollination, pest control and nutrient cycling. Large-scale studies within European agricultural landscapes have shown that it is vital to maintain a large proportion of semi-natural habitats in order to sustain high species diversity in agricultural landscapes (Billeter et al., 2008). In their meta-analysis of 76 studies, Hole et al. (2005) found that organic farms provide a more beneficial ratio between crop and non-crop habitats than conventional farms. Again, provided that a substantial proportion of an agricultural landscape is farmed organically, organic farming would be a promising means of conserving farmland biodiversity beyond the field level, while maintaining important ecosystem services.

5.1.2 INCREASED BIODIVERSITY AND RESISTANCE TO DISEASE AND PESTS

Despite the benefits of a high level of farmland biodiversity described above, it is sometimes argued that increased biodiversity in farmland is associated with increased pest and disease pressure and corresponding yield losses. However, Azadi et al. (2011) point out that organically grown crops have a higher resistance to pests and diseases. Important reasons for this include:

- Greater soil microbial biomass and improved soil quality
- Slower growth of the plants in organic systems, which allows the plant to develop its own chemical defences to prevent damage by pests and diseases
- Enhanced biodiversity in organic systems, which leads to enhanced diversity of natural enemies (such as predatory birds and invertebrates) that prevent or diminish pest and disease pressures (Azadi et al., 2011).

5.1.3 NO GENETICALLY MODIFIED ORGANISMS

Another positive impact of organic agriculture in terms of maintaining biodiversity derives from the ban on genetically modified organisms (GMOs). The loss of cultivar diversity is already advanced in modern agriculture due to the use of hybrid seeds. This could be further exacerbated by the widespread adoption of genetically modified plants, as only few crop varieties are used in their development. Low genetic diversity of crops conflicts with the need to maintain genetic resources for current and future generations. As a study in the USA has shown, insect-resistant GM plants that produce toxins derived from Bacillus thuringiensis (Bt) can help reduce the quantity of insecticides sprayed (Benbrook, 2012), at least in the short term, as long as the insect populations do not build resistance against the Bt. But increased use of pesticides sets in as insect populations build resistance over time. In the USA, overall pesticide use increased by 7% between 1996 and 2011 due to the use of herbicide-resistant GM corn, soybeans and cotton (Benbrook, 2012).

The widespread use of glyphosate-tolerant GM crops has led to a substantial increase in glyphosate applications. Today glyphosate-tolerant crops account for about 56% of global glyphosate use (Benbrook, 2016). As glyphosate is the most widely applied pesticide worldwide, ecological and human health impacts are very likely, even though they are still controversially discussed by academics and policymakers. In particular, it seems to have a negative effect on the diversity of wild plant species in agricultural landscapes, which leads to plant biodiversity loss and the loss of all associated animal species (Brooks et al., 2003, Bohan et al., 2005). A recent study also revealed a significant reduction in earthworm activity due to glyphosate applications, with corresponding negative impacts on soil structure and fertility (Gaupp-Berghausen et al., 2015). Meanwhile, however, weed resistance to glyphosate has become a significant problem, leading to the application of higher doses of glyphosate and to the associated use of other herbicides.

In contrast to this, organic farming encourages on-farm agrobiodiversity, both through the diversity of plant varieties cultivated, and through increased genetic diversity within plant populations.

5.2 CONSERVATION OF SOILS

Fertile, healthy soils are a key resource for long-term agricultural production. Organic agriculture has a strong focus on enhancing and maintaining the fertility and quality of soils, and a number of its core practices support that goal. Practices such as cover crops, mulching and intercropping protect soils against erosion from both run-off water and wind. Organic fertilizers and optimised crop rotations help the accumulation of soil organic matter (Gattinger et al., 2012), which in turn improves soil characteristics, such as its water infiltration and holding capacities (Zeiger and Fohrer, 2009, Lorenz and Lal, 2016). In a comprehensive global literature review of 75 studies, Lori et al. (submitted) have identified a greater abundance of soil microorganisms in organically managed soils, along with more carbon and nitrogen transformation activities than in conventionally managed soils. This means that, on average, soil organic carbon sequestration tends to be higher in organic than conventional agriculture. Moreover, the higher organic matter shapes the soil as a habitat for soil life. A living soil, in turn, provides a good basis for coping with climate uncertainties, such as heavy rains or droughts, while the good soil structure of organically managed soils reduces the risk of water logging and soil erosion (Lorenz and Lal, 2016).

5.3 REDUCTION OF EUTROPHICATION AND WATER POLLUTION

Nitrogen fertilizers and associated nitrate leaching are a major cause of eutrophication and water pollution. The Nitrate Directive (EC 1991) and Drinking Water Directive (EC 1980) set a maximum permissible concentration for nitrate of 50 mg/l in surface freshwater or in groundwater. Several studies indicate that this maximum value is often exceeded in areas dominated by conventional farming, but less often near organic farms (Kolbe, 2009, Kolbe, 2004, Mondelaers et al., 2009). Studies show that much higher rates of nitrate leaching occur in conventional farming systems than organic, and that the former are associated with higher levels of pollution. This is in part due to the lower nitrogen application rates in organic farming systems and the correspondingly better plant uptake, which curbs the rate of nitrogen leaching. Another factor is the greater amount of soil organic carbon, which results in a correspondingly higher nitrogen holding capacity in the topsoil of organic farmland.

Another element that influences groundwater pollution and eutrophication is phosphorus, and its loss through erosion and runoff. In a meta-analysis, Mondelaers et al. (2009) identified a tendency towards reduced phosphorus losses in organic farming systems. Although the available studies were somewhat limited and the differences were not very significant, there is enough evidence to support the idea that lower phosphorus fertilizer inputs in organic systems reduce the phosphorus leaching into water bodies and thus helps to reduce further eutrophication (Mondelaers et al., 2009).

In addition to the reduced nitrogen and phosphorus fertilizer applications in organic systems, experimental trials have shown that organic farming reduces surface runoff and increases water infiltration capacity, thereby reducing soil erosion and preventing flooding of agricultural fields (Zeiger and Fohrer, 2009, Lorenz and Lal, 2016). This in turn helps increase yields and helps plants adapt to negative climate change impacts, such as water-related extreme weather events (Muller et al., 2011).

Finally, organic farming does not allow synthetic pesticides that also run off into water bodies with a polluting effect and toxicity for water animals. The ban on such products therefore prevents these negative impacts.

5.4 CLIMATE CHANGE ADAPTATION

We will increasingly face unavoidable adverse effects of climate change, such as heat waves, droughts, heavy precipitation and other extreme weather events. With average winter temperatures set to rise, there will be increased climate variability and risks to production in general. Likewise, pest and disease pressure will increase. Agriculture systems must adapt to the adverse impacts in order to ensure resilient food production.

Organic farms often sustain higher species diversity and cultivate locally adapted varieties. This enhances the resilience of agro-ecosystems against adverse climate conditions, such as extreme weather events. Promoting a resilient and diverse agricultural system makes it easier to compensate for economic losses due to the changing climate, and it reduces the economic risks to the farmer and the threat to food security (Scialabba and Muller-Lindenlauf, 2010, Muller, 2009, Muller et al., 2013).

A 22-year trial in the USA compared a conventional farming system with two different organic production systems, one animal-based and one legume-based. The trial was located in Kutztown, Pennsylvania, which has a similar climate to some regions of the EU, including Eastern Europe. In the drier years (with rainfall below 350 mm per year), average corn yields were significantly higher in the two organic systems (28-32% higher) than in the conventional system. In the years with normal rainfall, no significant decrease in yield was identified for the organic system. Under extreme drought conditions (below 224 mm rainfall during the growing season), the animal-based organic system produced significantly higher corn yields than the other two systems, and in such conditions soybean cultivation was higher in both organic systems: 1,440-1,800 kg per hectare, compared to 900 kg per hectare in the conventional system (Pimentel et al., 2005). Other studies even indicate that organic systems out-produce conventional by 70-90% under extreme drought conditions (Gomiero et al., 2011).

Furthermore, 15-20% greater movement of water through soils down to the groundwater level was shown in organic systems, with runoff reduced accordingly (Pimentel et al., 2005). Therefore, the groundwater recharge was higher in the organic systems. Pimentel et al. (2005) estimated that around 816,000 litres per hectare of water can be held by the soil organic matter in organic systems, which reduces the production losses associated with droughts. In addition to the higher soil organic matter content, another reason why organic fields can hold more water is the greater number of earthworms present in organic soil. These increase the percolation of water into the soil by creating holes which also reduce water runoff (Pimentel et al., 2005). Water capture and retention capacity in organically managed soils is up to 100% higher than in conventional soils (Gomiero et al., 2011). In drought situations this could mean less need to irrigate. In some regions of the EU it would therefore help mitigate the potential water scarcity arising both from the shortage itself, and the competing demands for water, for example, from the electricity sector (e.g. in France, demand for water to cool nuclear power plants was very high during heat waves in 2003).

To summarize, organic farming systems are more resilient to changing weather conditions, such as extreme droughts and extreme rainfall (Fließbach et al., 2007).

5.5 HUMAN HEALTH

Human health would also benefit from an increase in organic production in the EU. One of the most comprehensive meta-analyses carried out to date, including 343 peer-reviewed publications (of which approximately 70% were studies carried out in Europe), indicates that organic food differs from conventional in the concentration of antioxidants, pesticide residues and cadmium (Cd) (Barański et al., 2014).

Of particular interest are the concentration of antioxidants in agricultural products, because these are associated with positive impacts on human health, including protection against chronic diseases, certain cancer types, such as prostate cancer, and neurodegenerative diseases. Concentrations of antioxidants are 20-70% higher in organic crops. In conventional crops, pesticide residues occurred four times more frequently than in organic crops. The differences in pesticide contamination mainly result from the fact that organic agriculture prohibits the use of synthetically produced chemical crop protection.

Finally, the occurrence of toxic metals is considerably higher in conventional than organic products, the concentration of cadmium for instance being twice as high. Cadmium is one of the very few toxic metals that accumulates in the human body and it is associated with severe health impacts. As such, the lower incidence of such substances in organic products can increase food safety and provide strong benefits to the health of farmers and of European citizens (Barański et al., 2014).

There is evidence that the differences in antioxidant and cadmium content derives from the specific characteristics of the organic production systems that reject the use of some chemical fertilizers, such as mineral nitrogen, potassium chloride and superphosphate.

In addition to the human health benefits from the reduced use of agrochemicals, organic farming can also help to reduce the air pollution associated with farming practices. Organic farming reduces soil erosion and emissions of particulate matter, oxides of nitrogen, carbon and sulphur, as well as volatile organic compounds and pathogens. These substances have adverse implications for human health, being a cause of respiratory diseases, allergies and other problems (Lorenz and Lal, 2016).

5.6 PROFITABILITY AND INSTITUTIONAL ASPECTS

We should highlight the fact that there is ample potential in organic agriculture to provide farmers with a livelihood, as the economic performance is often on par with, or better than conventional production (Reganold and Wachter, 2016, Crowder and Reganold, 2015). Certified organic farmers can sell their products for higher prices, while often incurring lower input costs. This results in higher net incomes compared to conventional farming, increasing the economic resilience of farmers.

Moreover, while conventional farmers are often highly dependent on products supplied by agrochemical producers, for which they are obliged to pay set prices, organic farmers have greater sovereignty, with more control over their production processes and the associated costs. In organic production systems individual farmers are better able to develop production methods themselves, and to communicate their needs for market development (Kilcher, 2007). Lastly, thanks to their lower energy consumption organic farmers are also less exposed to rising energy prices (Scialabba and Muller-Lindenlauf, 2010).

5.7 SUMMARISING REMARKS

Table 8 in the Appendix collates the findings from the previous sections. This can be used to illustrate the challenges of climate change mitigation in sustainable agriculture. When the focus is on efficiency and emissions per kg product, a number of conventional approaches deliver better performance. However, these pursue just a single goal, whereas organic agriculture is about a wealth of multiple benefits that often fit together in a web of trade-offs and synergies; it is about finding an ideal balance among these different benefits. We can illustrate this by comparing different aspects of efficiency-oriented, low-emission ruminant production with consistency-based approaches that focus on optimal grassland utilization.

Firstly, the low per-kg emissions for meat and milk produced in intensive high-concentrate feed systems often go hand-in-hand with higher environmental impacts per area, including nitrogen and phosphorous excesses. This in turn has adverse effects on biodiversity, water quality and other environmental features. How to balance the different impacts against each other is an additional challenge, but the most important thing is clearly to show the impacts in all the relevant areas. One aspect of intensive livestock production systems with large feed inputs is the high level of local nitrogen excretion in the form of manure. Since animal numbers in such systems tend to be much larger than the sustainable populations based on the available grassland or domestic feed-crop supplies, the nitrogen excretion is unrelated to the area of available agricultural land and its disposal therefore results in over-fertilization. In this case, nitrogen inputs cannot be reduced by adjusting the nitrogen application rates per hectare directly, but rather by reducing animal numbers in relation to available agricultural land area.

Secondly, many grassland areas are unsuitable for crop production and can only be used for human nutrition through the keeping of ruminants. Grass-fed ruminant production is therefore the ideal use of these resources and reduces pressure on cropland. Feeding a concentrate-based diet to ruminants and monogastric animals ignores this resource, but necessitates instead the use of other areas for feed production, which could in principle be used for food crops.

Thirdly, animal health and welfare suffer in high intensity systems based on a large proportion of concentrate feed, and low amounts of roughage.

Finally, when considering the entire food system, the combination of organic livestock production with lower total production volumes produces good results in terms of most environmental indicators. Reduced animal numbers lead to lower GHG emissions. While it would be possible to combine low total production volumes and the greater use of concentrate feed, thereby lowering GHG emissions relative to population density, none of the other benefits mentioned above would be gained.

Such is the role of organic livestock production in the context of climate change mitigation. We must emphasize again that these assessments are necessarily more complex than simply evaluating the emission levels per kg product. In order to achieve truly sustainable food systems, it is essential to adopt a whole-system perspective – one that includes consumption patterns and the optimal use of available resources (such as grasslands) as well as assessing efficiency in terms of the GHG emissions per kg product.

6. HOW THE EU CAN HELP IMPROVE AGRICULTURE PRACTICES AND SIMULTANEOUSLY WORK TOWARDS ITS CLIMATE CHANGE GOALS

6.1 GLOBAL POLICY CONTEXT

In 2015, two global policy developments stood out, which are highly relevant for agriculture. Firstly, the Sustainable Development Goals (SDGs) were agreed, which seek to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture (Goal 2) by 2030 (UN, 2016). Secondly, the UNFCCC Paris Agreement was adopted at COP 21, entering into force a year later on 4 November 2016. The Paris Agreement sets out the international pathway to combating climate change and accelerating the transition to a low carbon future. The overarching goal is to hold the global average temperature increase to a maximum of 2°C above pre-industrial levels by 2100, and to pursue efforts to limit temperature increase by 1.5 °C. To achieve this, the signatory countries should prepare "intended nationally determined contributions" (INDCs) that describe the efforts to be taken by the countries to reduce their GHG emissions by 2030 and beyond (UNFCCC, 2016). The INDCs include mitigation plans to further reduce GHG emissions, as well as adaptation measures that prepare for inevitable climate change impacts (FAO, 2016).

The European Union has developed a roadmap to make the European economy more climate-friendly and less energy-intensive by 2050. This roadmap proposes collective emissions cuts compared to 1990 levels of 40% by 2030 (implemented under the future 2030 climate and energy legal framework, currently being discussed by EU institutions), of 60% by 2040, and 80% by 2050. These reductions should be achieved by domestic emission cuts and not by relying on international emissions certificates from reduction activities outside the EU (European Commission, 2016b). The roadmap covers all economic sectors, including agriculture. The European Council conclusions from October 2014 endorsed a 40% reduction by 2030, but they also mention the "lower mitigation potential from agriculture" and the need "to ensure food security".

It should be noted that, according to some scenarios, meeting the 1.5°C limit would require much greater GHG reductions by 2030, and even negative emissions already by 2050 (Climate Analytics, 2016).

6.2 THE EU CLIMATE AND ENERGY LEGAL FRAMEWORK FOR 2020

The current legal framework, adopted in 2008, sets an overall goal for 2020 of a 20% GHG reduction (compared to 1990). It is supported by several mechanisms. The two main pillars of the system are: the EU Emissions Trading System and the Effort Sharing Decision.

The EU Emissions Trading System (EU ETS), which regulates power stations and industrial plants with heavy energy consumption, as well as air transport within the EU (plus Iceland, Liechtenstein and Norway), thereby covering about 45% of EU GHG emissions. This sets binding caps for the participating installations, and aims to reduce emissions by 21% on the 2005 level (5% for aviation), by 2020. Set up in 2005, the EU ETS is the world's first and biggest international emissions trading system, accounting for over three-quarters of international carbon trading. It is currently in its third trading period, which runs from 2013-2020 (European Commission, 2016).

The Effort Sharing Decision (ESD) regulates the emissions of the sectors that do not participate in the EU ETS, and it excludes emissions and removals from LULUCF. The ESD mainly relates to emissions in the transport, buildings, agriculture, small-scale industry and waste sectors, which accounted for more than 55% of total EU GHG emissions in 2013. The ESD does not set specific emission targets for these individual sectors, but leaves it to the Member States to decide where and how to achieve the necessary reductions. The ESD establishes national reduction targets for Member States according to their relative wealth, measured by per capita GDP in 2005. These add up to a collective reduction of 10% on 2005 levels by 2020, although the individual national goals vary from a 20% reduction for the richer countries to a 20% increase for the least wealthy Member States (European Commission, 2016).

In terms of agriculture, only non-CO_2 emissions fall within the ambition of the ESD. That means methane and nitrous oxide, which make up 18% of all the emissions covered by the ESD

(CO_2 emissions from agriculture are accounted for in LULUCF). The ESD does not set specific targets for the individual sectors. However, assuming that all sectors reduced their emissions by 10%, this would mean that, by 2020, agriculture might emit no more than about 400 $MtCO_2$-eq (van Doorn, Lesschen et al., 2012). Theoretically, therefore, reductions of about 40 $MtCO_2$-eq should be achieved in the agriculture sector at EU level in the coming years.

6.3 COMPLEMENTARY LEGISLATION TO REDUCE EMISSIONS

The 20% GHG reduction objective is complemented by two further objectives and corresponding legislation for the 20% use of renewable energy and a 20% increase in energy efficiency by 2020. However, other pieces of legislation are particularly relevant for agriculture. These include the Nitrates Directive and the regulations on CO_2 emissions due to land use, land use change and forestry (LULUCF).

The Nitrates Directive (Council Directive 91/676/EEC) regulates animal manure management (application, storage, limits and prohibitions of applications) in order to avoid water pollution caused by nitrate leaching from agricultural practices. The overarching goal of this directive is to restrict nitrate concentrations in groundwater to a maximum of 50 mg NO_3-l^{-1} by suggesting good farming practices under Annex II B, which can be implemented. These include the use of crop rotation systems, the maintenance of vegetation cover during rainy periods, the establishment of fertilizer plans and the prevention of nitrogen leaching by irrigation systems (European Commission, 1991).

LULUCF covers carbon emissions that result from the management of soils, forests and agricultural lands, or the carbon sequestered in those carbon pools. Some management practices, such as afforestation, rewetting of organic soils or the conversion of arable land to permanent grassland lead to carbon sequestration and the building up of sinks, while other practices, such draining peat land, felling forests or ploughing grassland lead to carbon emissions (European Commission, 2016). A list of measures to reduce carbon losses through LULUCF is included in Decision No 529/2013/EU of the European Parliament and the Council from 21 May 2013, Annex IV (European Council, 2013). However, LULUCF emissions and reductions are currently not accounted for in the EU reduction goals for 2020. Rather, the focus is on establishing and testing robust and effective accounting for these emissions and reductions (European Council, 2013).

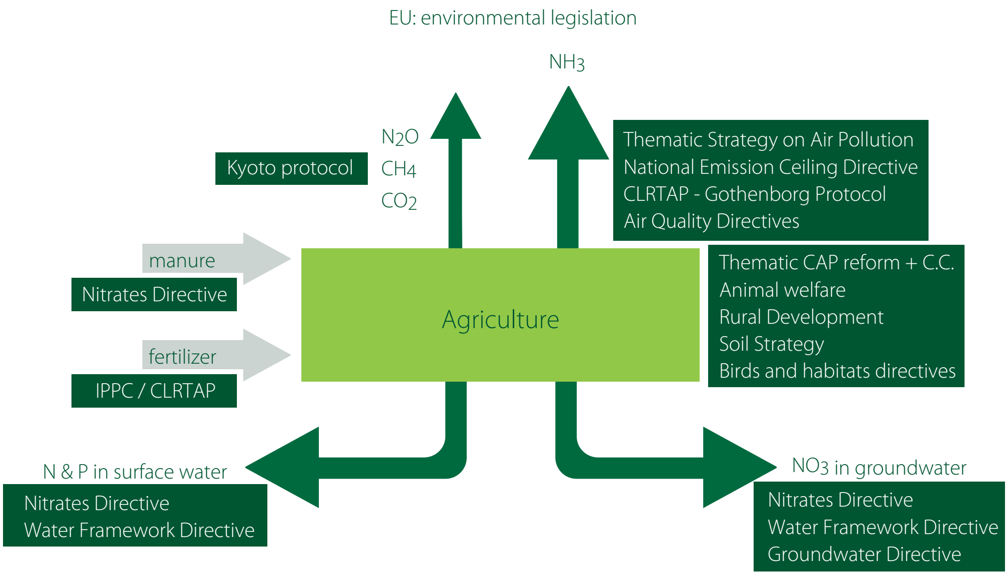


Figure 7: Active environmental legislation and policies that target the agricultural sector across the EU-27 Convention on Long-Range Trans-boundary Air Pollution (CLRTAP)

Source: Van Doorn et al., 2012, page 10

The EU has initiated several policy interventions to reduce GHG emissions specifically from the agricultural sector, as shown in Figure 7. Most Member States have policies of this kind that contribute to the reduction of GHG emissions, although they are not primarily targeted at GHG reductions. Instead, these polices address air quality or nitrogen levels, or they relate to the CAP. Reductions in GHG emission are often a side benefit. This is particularly true of N_2O emissions as many of the policies serve to reduce nitrogen inputs. Mitigation of non-CO_2 GHGs from agriculture is not specifically regulated in most Member States. However, processes have been launched towards establishing such regulations. Some countries have (voluntary) agreements on reducing agricultural GHG emissions. Examples include the "Schoon en Zuinig" covenant (the Netherlands), the Green Growth Agreement (Denmark), the Comprehensive Rural Environmental Protection Scheme on sustainable farming (Ireland) and the government-industry partnership (United Kingdom) (van Doorn, Lesschen et al., 2012).

Under the Effort Sharing Decision, Member States have a lot of room for manoeuvre to decide how they will meet their national GHG reduction target, and which economic sectors will contribute the most to this effort. But a number of EU policies in the health, environment or agriculture sectors can already contribute to emissions reductions. However, at a time when the agriculture sector is in crisis in many Member States, discussions on GHG reductions have proven extremely sensitive. In recent negotiations about the National Emissions Ceilings (NEC) Directive – part of the air quality package for 2030 – after intense lobbying both the Council and the European Parliament decided to exempt "enteric fermentation" from cattle from the CH_4 ceiling proposed by the Commission.

6.4 THE NEW EU CLIMATE AND ENERGY PACKAGE FOR 2030

On the basis of the conclusions adopted by the European Council in October 2014, which set an overall target of 40% reduction on 1990 levels by 2030, the European Commission developed new proposals for the EU climate and energy package for 2030. This package consists of three pillars:

- The Emissions Trading System (ETS)[29], which covers emissions for the energy sector and energy intensive industries, with a target of 43% reduction compared to 2005 levels
- The Effort Sharing Regulation (ESR)[30], which covers national emissions from transport, buildings, waste and non-CO_2 emissions from agriculture (methane and nitrous oxide) i.e. the sectors not covered under the ETS, with an average target of 30% emissions reduction compared to 2005 levels
- The land use, land use change and forestry (LULUCF)[31] proposal, which covers CO_2 emissions and removals from forest management, afforestation, reforestation, deforestation, cropland and grazing land.

The Effort Sharing Regulation (ESR) will replace the Effort Sharing Decision (ESD) after 2020. The main new addition, compared to the current EU Climate and Energy package 2020, is that emissions from LULUCF will be accounted for at European level from 2020 onwards.

As in the current ESD, Member States will pursue different targets under the ESR, varying from a reduction of 40% to 0%. This is mainly based on each country's per capita GDP and is intended to be fair, while taking into account cost-effectiveness[32]. Annual emissions levels for the period 2021-2030 are calculated based on a linear trajectory starting with the average emissions for 2016-2018, based on the most recently reviewed GHG emissions data. The Commission will conduct annual evaluations in the Member States to identify any need for corrective actions in the ESR, as well as a compliance check every five years assessing each of the preceding years over that period. The two compliance checks would take place in 2027 and 2032. For the LULUCF pillar, there would be regular compliance checks by the Commission and the European Environmental Agency.

The Commission presented the ESR and LULUCF proposals on 20 July 2016, accompanied by two impact assessments. Given that LULUCF is a carbon sink in the EU, mainly due to the way forest management emissions and removals are calculated, the Commission assessed three different options for integrating the LULUCF emissions and removals into the EU climate and energy framework 2030:

a) A separate LULUCF pillar with its own target. In this option, the LULUCF emissions and removals would be kept separate from the sectors covered by the ESR

b) The creation of a new pillar to include emissions from both agriculture and land use (AFOLU). Here, agricultural methane and nitrous oxide emissions would be merged with the LULUCF emissions and removals. According to research commissioned by Fern and IFOAM EU and carried out by the Öko Institut[33], depending on how the forest management reference level would be set, LULUCF negative emissions might appear to offset up to 98% of agriculture emissions. This means that if this option had been chosen, agriculture emissions would be "hidden" behind the LULUCF removals.

c) A merger of the ESR with LULUCF as a single pillar. This would have a negative impact on the overall target because LULUCF credits would be used to offset agricultural and other emissions under the ESR.

After an intense debate with strong concerns voiced over the environmental integrity of the climate package, the European Commission eventually decided to maintain a separate LULUCF pillar, but with a certain level of flexibility allowing Member States to benefit from removals in the LULUCF sector to comply with their ESR target.

This flexibility mechanism proposed by the Commission would allow Member States to use potential credits from LULUCF to reach their ESR target, under certain conditions. A "no debit" rule would apply, meaning that Member States must maintain their LULUCF accounts without debits at the end of the compliance period and that only Member States whose LULUCF sector absorbs more carbon than it releases would be allowed to generate credits. Such credits could only be generated from the management of cropland and grazing land, or from deforestation/afforestation (forest management is excluded). Moreover, the total amount of flexibility that could be used is capped at 280 $MtCO_2$ for the period 2021-2030 for the whole EU.

These proposals are now passing through the co-decision process and should be adopted in 2017.

6.5 BY HOW MUCH SHOULD THE AGRICULTURE SECTOR REDUCE ITS EMISSIONS?

In the sectors covered by the ESD (ESR for the 2020-2030 period), the range of emission reductions expected for 2030 (30%) represent a more significant effort compared to the current period up to 2020 (10%).

According to the Commission's Impact Assessment (IA) accompanying the LULUCF proposal[34], "on the basis of current policies, GHG emissions are not expected to decrease sufficiently to reach the EU's 2030 target of 30% GHG domestic reductions under the ESD. In the EU Reference Scenario 2016, reflecting current trends and policies, emissions covered by the ESD are projected to decrease by around 16% in 2020 and achieve 24% reduction in 2030 compared to 2005. This reflects full implementation of existing legally binding targets as well as adopted policies. This leaves a gap of 6 percentage points to the 30% reduction in 2030, requiring cumulatively still around 1 billion tonne additional reductions in the period 2021-2030."

In 2005, agricultural non-CO_2 emissions amounted to 446 $MtCO_2$ for the EU-28. Under a business-as-usual scenario (no further policy action), very low reductions are projected for the agriculture sector, of just 2.1% by 2020, and around 2.4% by 2030, compared to the overall 10% and 30% reduction required for all sectors under the ESD/ESR, compared to 2005.

A previous IA performed in 2014 had concluded that, for the EU to meet a 40% reduction target by 2030, the agriculture sector would need to reduce emissions by 28%[35]. In contrast, according to the updated EU 2016 Reference scenario quoted in the ESR Impact Assessment[36], energy efficiency (a 27% non-binding target) is expected to deliver a large part of the GHG emissions reduction in the ESD/ESR sectors. This must be "complemented by cost-effective reductions in non-CO_2 emissions – mostly in agriculture." However, with a greater effort to improve energy efficiency (a 30% target instead of 27%), "no reductions in non-CO_2 sectors such as agriculture beyond Reference take place." According to the models used by the Commission, therefore, little or no further action to reduce emissions is expected of the agriculture sector beyond those already due from the policies in place. This relates to the average situation at EU level.

However, the picture is very different for those individual Member States which have both a higher than average effort to make to meet their ESR target, and a high proportion of their emissions in the agriculture sector. According to Professor Alan Matthews, in countries like Denmark, France, Ireland and the Netherlands, "agricultural mitigation will have to play a central role if the 2030 ESR targets are to be met through domestic action alone[37]."

6.6 ESTIMATIONS OF COSTS AND IMPACTS ON PRODUCTION

According to the Commission, since "limited opportunities for further reduction of non-CO_2 emissions exist in the agricultural sector" and "the cost-efficient mitigation potential of agriculture is apparently lower than for other sectors," there

is a need to examine the "availability of cost-efficient CO_2 mitigation in the LULUCF sector, also on agricultural land." Also, "other sectors such as buildings, transport, and waste would have to deliver relatively higher emission reductions to compensate for lower mitigation in agriculture."

The Commission bases this assessment on the EcAMPA 2 study[38] undertaken by the EU Joint Research Centre, which found that: "An assumed 20% reduction in the agricultural non-CO_2 greenhouse gas emissions would require [a cumulative] emissions reduction of nearly 425 $MtCO_2eq$ between 2021 and 2030, compared to the reference projection. Such a 20% reduction of non-CO_2 emissions from agriculture was examined in the EcAMPA study, concluding that the impacts on production would be significant and substantial emission leakage could occur". The IA further notes that "in a scenario without explicit subsidization of mitigation technologies, supply reductions of all activities would be significant, ranging from 1.3% (poultry) to 8.9% (beef meat activities). Livestock herds reduce substantially, especially for beef production (16.1%)", and production leakage would occur. However, "in subsidized scenarios, the production impacts are more limited, although at the cost of a large budget". The figures mentioned for the latter scenario are 6.6% for livestock herds and 4.1% for beef supply, at a cost of up to 15.6 billion for the EU budget. But the study mainly looked at the adoption by farmers of a set of twelve "mitigation technologies" such as "anaerobic digestion, nitrification inhibitors, fallowing of histosols, and precision farming". Under another modelling framework (GAINS), in an option with no flexibility, "agriculture non-CO_2 emissions would have to be reduced by 78$MtCO_2eq$ in 2030, assuming a 20% reduction in 2030 compared to 2005." With a "medium flexibility" option, "agricultural non-CO_2 mitigation would still need to deliver emission reductions in the order of magnitude of 25 $MtCO_2eq$. In the GAINS model these can be achieved by mitigation options which, while not free from up-front costs, have no or little net cost, for instance because they are associated with efficiency improvements. One such important mitigation option that would result in such efficiency gains is breeding of cattle focused on health and fertility improvements."

Another model (EUCLIMIT[39]) estimates that "without flexibility, a carbon price of €120/t CO_2eq would be needed to achieve a 20% reduction in emissions in 2030 (or 84 $MtCO_2eq$)."

Under a low flexibility option "access to LULUCF credits is restricted to 35Mt in 2030. Assuming that the full amount of credits would be used, the agriculture non-CO_2 reduction needed would be around 49 $MtCO_2eq$ (84 minus 35 Mt) in 2030 at a marginal cost of €42/tonne. As a result, price increases would be much more limited than without access to LULUCF credits. Consumption reductions would be smaller, production losses would be smaller and (net) trade losses would be smaller."

According to the IA, "under the Medium flexibility option, the pressure to reduce agricultural emissions would be sharply decreased. Given the limited reduction needed by agricultural non-CO_2 emissions (31 $MtCO_2eq$) price increases for agricultural commodities would be much more limited, and consequently production and consumption changes would be very modest and generally below 1% (and as low as 0.1% for dairy products and meat). Net trade effects would be below 1% except for meat (which nevertheless decreases by just 5%, compared to over 25% under the reference)." Finally, "granting high flexibility (i.e. up to 425$MtCO_2$), and using LULUCF credits would offset the entire expected reduction of Agricultural non-CO_2."

Professor Matthews, an expert on the CAP, comments that, "The analytical modelling behind the Commission's impact assessment supports the view that significant agricultural mitigation is costly and that (for a given carbon price) the agricultural mitigation potential is lower than in other sectors. However, it also suggests that there is a relevant potential for abatement in agriculture which could be taken up with a value on carbon similar to that in place in other sectors of the economy."[40] He also notes that "the assumed absence of agricultural mitigation in the Commission's scenarios is a function of the modelling strategy, not because of technical difficulties in reducing agricultural emissions."

6.7 LULUCF FLEXIBILITY

According to the Commission, "to adjust this effort and avoid adverse impacts on the agriculture sector, flexibility from LULUCF could be envisaged from between around half to the full level of this assumed reduction [of 20%] for the period. Flexibility could be determined for each Member State, in accordance with a need justified by its agricultural non-CO_2 sector."

In its proposal, the Commission chose the "Medium flexibility" option, according to which: "Up to two thirds of the assumed emissions reductions could be undertaken in the LULUCF sector, i.e. 280 Mt between 2021-2030".

According to the IA, "while the overall distribution is varied [across Member States], the projections overall show a positive picture for the EU with respect to the strong potential to deliver cost-effective enhanced mitigation in the LULUCF sector, through afforestation and agricultural land management," in the order of -959 Mt/CO_2 for the period 2021-2030 (of which -437 Mt is for agricultural land and -452 for afforested land)."

In absolute terms, under the medium flexibility option, the Member States with the highest credit generation potential from afforestation and agricultural land would be France (58MtCO_2), Spain (29), Ireland (25), Germany (22), and Poland (22).

Member States would generate credits from agricultural land and/or afforestation. Forest management has been excluded from the LULUCF credits which can be used in the ESR, due to the high level of uncertainty affecting accounting of this sector, which follows different rules.

The flexibility allowed for each Member State would vary according to the share of their agricultural non-CO_2 emissions, based on the share of this sector in the ESD between 2008-2012. There are three bands of flexibility: Member States with an ESR share of 25% or higher of agricultural non-CO_2 emissions could get up to 15% of their emissions reduced through LULUCF credits; Member States with a share of agricultural emissions ranging from 14% to 24.9% could get up to 7.5% reduced, and those with less than 14%, 3.75%.

The proposal also allows for flexibility in the ETS. Member States are entitled to use up to 100 MtCO_2 credits in the period 2021-2030 to offset emissions in the ESR sector (agriculture, transport, building, etc.) which is equal to 2% or 4% of their 2005 non-ETS emissions. Member states would need to decide before 2020 if they want to use this flexibility.

The IA also envisages some positive effects of this flexibility mechanism, since action would be incentivised under LULUCF, and Member States would have to ensure that the LULUCF sector remains stable and complies with the no debit rule, while also establishing incentives for additional afforestation and sequestration on agricultural land[41].

According to the Commission, this would have positive environmental impacts since agricultural soils in Europe are losing carbon as a result of the current management practices. By enabling Member States to generate credits on agricultural land, additional actions to protect or improve soil carbon could be expected. These mitigation actions would be favourable for the organic carbon content of soils and potentially for biodiversity.

Table 6: Options examined by the Commission regarding the LULUCF flexibility towards ESR between 2021-2030

	Option 1	Option 2	Option 3	Option 4
Level of flexibility	**No flexibility**	**Low flexibility**	**Medium flexibility**	**High flexibility**
Cumulative contribution from LULUCF in MtCO_2eq. for 2021-2030	None	190 Mt credits	280 Mt credits	425 Mt credits
Agriculture non-CO_2 emissions reduction in 2030 in MtCO_2eq.	84	49	31	13
Percentage of emissions reduction relative to 2030 agriculture emissions	20%	12%	7%	3%
Marginal costs euros/tCO_2eq.	120	42	21	10

Source: Professor Alan Matthews, based on EUCLIMIT modelling

Table 7: Proposed targets and access to new flexibilities in the LULUCF sector

	2030 target compared to 2005	Maximum annual flexibility (as % of 2005 emissions)	
		One-off flexibility from ETS to effort sharing regulation	Flexibility from land use sector to effort sharing regulation*
LU	-40%	4%	0.2%
SE	-40%	2%	1.1%
DK	-39%	2%	4.0%
FI	-39%	2%	1.3%
DE	-38%		0.5%
FR	-37%		1.5%
UK	-37%		0.4%
NL	-36%	2%	1.1%
AT	-36%	2%	0.4%
BE	-35%	2%	0.5%
IT	-33%		0.3%
IE	-30%	4%	5.6%
ES	-26%		1.3%
CY	-24%		1.3%
MT	-19%	2%	0.3%
PT	-17%		1.0%
EL	-16%		1.1%
SI	-15%		1.1%
CZ	-14%		0.4%
EE	-13%		1.7%
SK	-12%		0.5%
LT	-9%		5.0%
PL	-7%		1.2%
HR	-7%		0.5%
HU	-7%		0.5%
LV	-6%		3.8%
RO	-2%		1.7%
BG	0%		1.5%

* These figures are estimates. The limit is expressed in absolute million tonnes over 10 years in the proposal

Source: European Commission 2016f, Impact Assessment

6.8 CONCLUSION ON FLEXIBILITY

In practice this means that, at EU level, the agriculture sector would only have to reduce its emissions by around 6-7% if the full flexibility is used. The flexibility mechanism was designed explicitly by the Commission to avoid any impact on the level of production, especially in the livestock sector, or on prices. Moreover, the EU reference scenario implies that very little mitigation is expected from agriculture in the EU as a whole, beyond what is already expected from existing policies.

It seems that the Commission has underplayed the potential for mitigation in agriculture, and the modelling it uses in its impact assessments emphasises the view that significant agricultural mitigation would be costly. But estimations, in particular costs estimations, are based on modelling studies, which always imply a high level of uncertainty. Different models are based on diverse assumptions, which give a wide range of results and only take into account a limited number of technical options for mitigation.

There are also uncertainties regarding the actual emissions reductions that will be achieved on the ground by Member States with their existing policies. The projections used by the Commission appear relatively optimistic in this respect, in particular as far as the potential to achieve high energy efficiency gains is concerned.

All Member States retain a lot of room for manoeuvre on how to best meet their ESR targets, and in deciding the extent to which the agriculture sector will have to undertake additional mitigation efforts. In any case, it is clear that a small group of Member States will have to reduce their agricultural emissions more significantly.

IFOAM EU believes that all emissions from the agriculture sector should be addressed together (CO_2 and non-CO_2) and therefore welcomes the inclusion in the accounting of carbon sequestration in cropland and grassland. Allowing Member States to generate credits with soil carbon sequestration could drive the necessary actions to improve the status of European soils, which will also deliver positive side-effects for adaptation and productivity.

It would also allow the agriculture sector a certain level of flexibility in relation to the ESR targets for those Member States where a high proportion of their emissions come from agriculture. But the level of flexibility granted by the Commission proposal (280 Mt) is very high and will not sufficiently incentivise mitigation action in the agriculture sector. Moreover, afforestation can have detrimental effects on biodiversity and the environment as it is often performed on agriculture land, as a monoculture of alien species, which creates problems for the local fauna and flora.

The EU's agriculture sector should have a higher level of ambition emissions reduction. This would drive investments and the development of a long-term roadmap for mitigation and adaptation, and affect other environmental impacts of agriculture. A broader set of mitigation options should also be considered, on both the supply side and the demand side. It is important to address agricultural production and food consumption together. With an all-encompassing food systems view it would be possible also to address any carbon leakage related to changing production volumes triggered by some mitigation measures.

The estimates on the potential of a conversion to organic agriculture to reduce emissions presented in section 4 above do not take into account the economic aspects, unlike the different Commission scenarios presented above. However, these estimates show the considerable biophysical mitigation potential of sustainable agricultural practices, as illustrated by organic agriculture, and provide arguments for more ambitious mitigation in agriculture.

6.9 THE ROLE OF THE COMMON AGRICULTURAL POLICY (CAP)

6.9.1 THE COMMON AGRICULTURAL POLICY

The Common Agricultural Policy (CAP), which represents 40% of the EU budget, already provides some tools and funding to help farmers adopt practices that can reduce GHG emissions. However, mainstreaming climate-friendly practices which can also bring benefits for other aspects of the environment calls for a fundamentally new approach to the CAP.

Established in 1962, the CAP is the European policy to provide food security for the European citizens, as well as decent working conditions and standards for the farmers producing within the EU. Since its introduction, the CAP has been through several reforms that have changed the approach taken to achieve those goals (European Commission 2012). The 2000 Reform introduced Pillar 1, which regulates direct payments to farmers and market measures, and Pillar 2, which concentrates on rural development mechanisms. Thus, the CAP is no longer only product-centred, but it now also includes an environmental and rural development agenda (Bailey, Lang et al., 2016). Now, the 2013 Reform is in place, which involves an annual budget of around 59 billion euros, about 40% of the annual EU budget and in all about 30% of this spending is allocated to environmental and climate action.

6.9.2 CLIMATE FRIENDLY INSTRUMENTS AND MEASURES OFFERED UNDER THE CAP

The main mechanism for encouraging the uptake of environmentally and climate-friendly practices has been the financing of agro-environmental measures through EU's rural development programmes (RDP). Currently RDPs represent about 25% of the overall CAP budget available at EU level, with Member States legally bound to use a third of their RDP spending on environmental and climate measures. Under this spending payments are also offered in the majority of Member States for farmers who wish to convert or maintain their land under organic production largely based on a farm system approach.

In addition to these Pillar 2 measures, the 2013 reform the introduced of a new instrument under Pillar 1 known as the greening component. This aims to link the system of farmers' direct payments as income support to the uptake of more environmentally sustainable practices. While the greening component is only in its first phase of implementation, initial experiences in the Member States have shown that, due to questionable exemptions and flexibility, it is often possible to meet the greening requirements without making significant changes to industrial practices in agriculture. In many cases the introduction of the greening component has indeed caused the lowering of ambition for schemes targeted at environmental and climate action under RDPs[42].

For the current CAP, the Commission notes in the LULUCF Impact Assessment that a number of mitigation actions related to agricultural soils and land use management and change can already receive support under the measures available within the CAP, and that "attention could be paid to how Member States choose to implement (or not) these policy tools, and how they design the detailed rules, definitions and support measures. Focus should be made on uptake of measures and targeting areas with greatest mitigation potential."

In theory, greening payments have the potential to deliver climate action, in particular through the maintenance of permanent pastures. But "actual benefits will depend on the choices Member States have made to implement the measures, given the significant flexibilities available, the area that is subject to the greening requirements (once exemption criteria have been taken into account) as well as what changes to farmland management ensues on the ground."[43]

The CAP therefore provides a range of instruments and measures with varying degrees of ambition and impact to support the uptake of climate mitigation actions which are mainly determined at national and/or regional levels. Many are provided in the form of financial support to farmers and land managers for meeting certain conditions, which may or may not entail changes to their current practices – particularly in the case of the greening component. Based on legal requirements, financial compensation and other conditions, the farmer or land manager decides how or whether to apply many of these instruments and measures.

In the case of agro-environmental measures under RDPs, it is up to Member States to largely decide the extent to which such measures will aim to achieve climate objectives. These measures as with other CAP instruments are not dedicated solely to climate goals but often include other objectives such as competitiveness, climate adaptation, enhanced biodiversity, reduced risk of soil erosion, diffuse pollution or flooding etc. Nevertheless, the design and in particular the multi-annual approach of RDPs are seen to be the most cost-effective in most Member States. This is because of its high mitigation potential combined with many other environmental and economic benefits. One of the motivations for such an approach is the possible reluctance of Member States to implement actions that are only designed for climate mitigation. At the same time the evidence base for determining the actual impact of individual measures applied at farm level remains limited. According to a study by RICARDO-AEA (2016), it is a matter of the utmost importance to find a way to use the CAP's Common Monitoring and Evaluation Framework (CMEF) to recognize and report on mitigation effects, even in those CAP measures whose primary goal is not the mitigation of climate change.

6.9.3 MOVING TOWARDS A CAP THAT INCENTIVISES AND REWARDS FARM SYSTEM APPROACHES

Despite 30% of CAP spending being allocated to environmental and climate action, the fact remains that many aspects of the current CAP lack any real ambition to encourage farmers and land managers to change to more climate-friendly practices. However, with the right incentives the CAP has great potential to make European agriculture more climate-friendly as part of a wider sustainability agenda in the agri-food sector. Instead of allocating money primarily for individual actions, payments to farms must be holistic and targeted at those farmers whose approaches inherently promote the environmental and socio-economic sustainability of their own farms, their regions and local citizens. Prioritising public money for farm system approaches would enable farmers to make sound decisions on all aspects of sustainability for their entire farm enterprise, and in collaboration with other farmers, while at the same time meeting societal expectations.

7. CONCLUSIONS AND RECOMMENDATIONS

Adopt a systemic approach to reduce GHG emissions from food production and to transition towards sustainable food systems

A systemic approach is essential to reducing GHG emissions linked to food production and consumption in the EU, to help the agriculture sector adapt to climate change while not endangering food security, and to achieve sustainable development goals, in particular on the restoration of ecosystems services. A silos approach or a sole focus on mitigation risks leading to further industrialisation of European agriculture, loss of farmers' livelihoods and environmental trade-offs.

It is inevitable that agriculture and food production have an impact on the environment. However, organic farming offers a system that can reduce environmental impacts compared to conventional farming. Climate change mitigation is not (and should not be) a primary objective of organic farming, but increased conversion to organic agriculture can contribute to the reduction of GHG emissions, while also bringing important benefits, such as improved system resilience to the effects of climate change, maintaining or improving biodiversity on farmland, conserving soil fertility, reducing eutrophication and water pollution, and improving food security and farmers' sovereignty.

A linear increase of the share of organic farming on EU agriculture land from 6% to 50% from 2016 to 2030 would reduce or compensate cumulative GHG emissions from agriculture from 2016 to 2030 by 7.5-8.5% through increased soil carbon sequestration (-5.5%) and reduced nitrogen fertilizer application rates (between -2 and -3%). It would also lead to a reduction of emissions linked to the production of mineral fertilizers, equivalent to 4-5% of agriculture-related emissions. Furthermore, increased use of European pastures and reduced reliance on imported feed would significantly reduce emissions linked to feed production and associated land use change in the countries where this feed is produced.

However, these benefits might come at the cost of reduced agricultural yields, meaning that more land would be needed to produce the same amount of agricultural goods. Therefore, an increased share of organic farming and grassland-based animal production must go hand-in-hand with changes in food consumption patterns, including a shift towards more plant-protein based diets and a reduction in food wastage. The issue about what is produced to meet human needs, what is produced for intermediate production purposes (e.g. livestock feed) and what is wasted between the field and the kitchen, needs to be part of the discussion.

Support sustainable grazing on well-managed grasslands

When adopting a whole food-systems view, a combination of organic agriculture and grassland-based livestock production with reduced total production volumes fares well along most environmental indicators and leads to lower GHG emissions. This is mainly achieved via the reduction in total emission volumes from reduced animal numbers and reduced nitrogen application rates. Grassland based production with adequate stocking-rates should therefore be supported for ruminants, and concentrate feed imports should be minimized, which would also contribute to the reduction of nitrogen levels.

A number of measures linked to stocking rates could help to orientate livestock production towards sustainable grazing on well-managed grasslands:

- Strengthen legislation on farm animal welfare and its implementation to ensure that livestock is only kept in relation to land capacity and in proportionate numbers

- Mandatory environmental impact assessments if enlargement of livestock herds or stables are planned in areas with already high livestock densities

- Introduction of a compulsory farm gate balance for all farms with livestock above 2 livestock units per hectare (under the Nitrates Directive)

- Support should only go to investments in stables that are suited for high animal welfare conditions comparable to organic standard (and only for land related livestock systems with less than 2 livestock units/hectare)

- Information campaigns for healthy food choices with less but

high quality animal products, preferably from organic farming

A reduction of EU production has to go hand in hand with a reduction in consumption to ensure net positive effects on sustainability and to avoid leakage due to replacing reduced domestic production for domestic consumption by imports.

Reduce emissions from fertilized soils

The second largest part of non-CO_2 emissions comes from nitrous oxide emissions from fertilized soils. Those emissions directly relate to nitrogen inputs. A general reduction in nitrogen inputs would therefore reduce those emissions, but also eutrophication, and would have beneficial effects on biodiversity. The Nitrates Directive has already been quite effective in this direction, but EU climate action should specifically support further action towards the reduction of nitrogen inputs on agricultural land. Organic agriculture is a production system that has a significant potential in this regards, as nitrogen levels per hectare tend to be lower than in non-organic systems.

Nevertheless, specific incentives are needed to achieve ambitious reduction goals for the nitrogen surplus across the EU, with corresponding reductions in GHG emissions. For this, a tax on nitrogen could be established; it would apply if the nitrogen-balance deviates beyond a certain threshold of a balanced nitrogen-balance, e.g. beyond 10% positive deviation from this. The details and level of this tax would need to be carefully designed. Regarding monogastric production, the tax on nitrogen surplus would need to be designed in such a way that it would adequately address nitrogen flows and their disposal from monogastric production units.

Adapt indicators and measures of success

Measuring outputs and impacts of farming through single criteria, as is typically the case – e.g. yields of specific crops, GHG emissions per kilogramme of product – disregard negative externalities and tend to favour "efficiency" approaches, large-scale industrial monocultures and industrial livestock systems, which can achieve high yields through the intensive use of inputs such as manufactured nitrogen fertiliser and concentrate feed. Diversified systems are by definition geared towards producing diverse outputs, whilst delivering a range of environmental and social benefits on and off the farm, with reduced negative externalities and reduced dependency on external inputs (e.g. fossil-fuels).

For an encompassing sustainability assessment of food production systems, it is thus crucial to complement efficiency measures with more systemic aspects that make it possible to address overall production levels (often framed under "sufficiency"), overall environmental impacts, as well as the role certain resources play in a food systems context (often framed under "consistency").

Environmental concerns – such as nitrate losses into groundwater or biodiversity loss through over-fertilization and overgrazing – are the main rationale behind organic agriculture standards on stocking density, limiting livestock to less than two units per hectare in most productive areas. Animal welfare is another reason, because lower stocking densities offer more movement to animals. Therefore, the very purpose of the organic paradigm is producing less livestock while increasing the share of crops for human consumption.

Such is the role of organic livestock production in the discussion of climate change mitigation and we have to emphasize that such assessments are unavoidably more complex than assessing single emission intensities per kilogram of product. For achieving truly sustainable systems, this whole food system perspective including consumption and optimal use of available resources, such as grasslands, has to be adopted, complementing the partial assessments that focus on efficiency via the measurement of GHG emissions per kilogram of product only.

Moreover, for effective reduction of GHG emissions from agriculture production, fluxes occurring outside the agricultural sector need to be taken into account, such as the emissions linked to the production of mineral fertilizers. For livestock production, emissions from land use and land use change linked to concentrate feed production or conversion of forest to pasture or arable crop production should be accounted for and included in life cycle analyses.

Consider a broader set of mitigation measures, also targeting the demand side

Instead of an intensive export-based model, the EU should promote the production of quality meat, keeping in mind that the livestock sector is essential to the nutrient cycle and optimizing the use of grasslands. When addressing mitigation in agriculture, the EU and national governments should also explicitly engage in a discussion on the role of consumption and food waste. Measures should be taken to raise consumer's awareness on the benefits of a sustainable diet, in which the shares of meat, fish, fruits, vegetables, bread, fat, sugar or salt have their fair share at the crossing of common sense and pleasure.

Sustainable diets involve eating less but more sustainably produced animal products. To improve the sustainability of animal production systems, it is necessary to promote adequate stocking rates on farms, to stop monocultures of soya and maize and the use of pesticides associated to them, to apply and verify strict rules for slaughterhouses, and to pay a fair and remunerating price to producers. Such changes in consumption are important to avoid that a switch to organic agriculture and grassland-based animal production with lower production levels leads to increased imports and leakage effects with regard to emissions and land-use change.

Maintain ambition in the Effort Sharing Regulation and LULUCF proposal

The EU agriculture sector should have a higher level of ambition for emissions reductions, which could drive investments and the development of a long-term roadmap to 2050 for mitigation and adaptation, and other environmental impacts of agriculture.

A certain level of flexibility for agriculture may be justified for Member States with a high share of emissions in the agriculture sector, but the high level of flexibility currently granted by the Commission proposal implies that very little mitigation (by the order of 6-7%) is expected from agriculture for the EU as a whole. This level of flexibility was proposed explicitly by the Commission to avoid any impact on the level of production, especially in the livestock sector, and on prices.

Accounting for soil carbon sequestration in cropland and grassland is relevant and coherent with a more systemic approach. Soils are pivotal in regulating emissions and the cycling of CO_2 and other greenhouse gases. Appropriate land use and soil management lead to improved soil quality and fertility, it can help compensate the rise of atmospheric CO_2 and can improve system resilience. Allowing Member States to compensate a certain level of emissions with soil carbon sequestration can drive necessary action to improve the status of European soils, which will also deliver positive side-effects for adaptation and productivity.

Flexibility should therefore be limited to soil carbon sequestration, landscape elements (e.g. hedgerows, single trees) and agroforestry, and exclude pure forestry offset. Afforestation can have detrimental effects to biodiversity and the environment, as it is often performed on agriculture land, as a monoculture of alien species which creates problems to the fauna and flora of the area. Mitigation measures in the LULUCF section should not endanger biodiversity and be consistent with the EU Biodiversity objectives.

The EU LULUCF sink is expected to decrease by 2030 and beyond, due to increased forest harvesting. But carbon sequestration in the land sector has a crucial role to play to meet the long-term objective of the Paris agreement. The EU should therefore set an EU-wide LULUCF emission target, more ambitious than the no debit rule at the national level. It should however be kept in mind that soil carbon sequestration is not permanent, and that the sink capacity can again be lost in case beneficial management practices change to less beneficial ones. Moreover, the saturation dynamics when the soils reach a new equilibrium regarding soil carbon contents mean that additional sequestration then tends towards zero, typically after few decades.

Engage in a food transition towards agroecology

The EU should engage in a food systems transition, equivalent to the energy transition, and move agriculture towards agroecological approaches such as organic farming and agroforestry (Hilbeck et al., 2015). A food transition towards agroecology can go a long way to the EU meeting its commitments to implement the 2030 Agenda for Sustainable Development and the Sustainable Development Goals.

There is an urgent need for a transition from the existing agro-food systems to sustainable agroecological systems. At both national and European levels, there is an absence of broad-based political support, regulatory frameworks and appropriate economic incentives – or they are just in their infancy. Just as the industrial, mechanized systems of monoculture that transformed post-war global agriculture could only be installed with massive public investments and the concerted efforts of all the relevant segments of society, so too will the next transformation of agriculture require a similar concerted effort for its success – an effort that involves science, research and technology combined with adequate policies and economic incentives.

Funds must be provided and opportunities created for scaling up the best agroecological systems and integrating them into a coherent supply and value chain. The EU and national governments should support the development of regional food systems. Training and extension work for agroecological production and fair trade must be integrated into academic and vocational education programmes. Significant investment is now needed to research and develop new economic paradigms that penalize business models contributing to environmental degradation, and reward those that protect and promote biodiversity, and eliminate environmental pollution and other harmful practices. Final product prices must reflect the true costs of production by internalizing all the externalities, such as biodiversity loss, water pollution and GHG emissions. A food transition towards agroecology involves the development of a more coherent, complementary and consistent EU policy framework.

Mainstream environment and climate-friendly farming systems under the CAP

A new CAP, aligned to the UN's 2030 Agenda for Sustainable Development (Falkenberg, 2016) and focusing on incentivising and rewarding the tangible, environmental and societal outputs of farming, would help to keep farmers in business, while providing high-quality food and contributing to the EU's goals for rural viability, climate change and the environment. To this end, successive reforms should move the CAP towards a new model of farm payments based on agroecological outcomes.

Mainstreaming public money for public goods would require policymakers to make fundamental changes to the current CAP by introducing a flagship payment model for stimulating environmental and socio-economic services delivered at the farm level. This flagship payment model would include efforts by farmers to mitigate and adapt to climate change, but also other public good efforts related to biodiversity, soil and water quality, social capital and rural viability.

Addressing climate action via the multi-target approach of agroecological outcomes would be more efficient, as it would optimally capture synergies between the goals.

Establish a research and implementation flagship programme for the transition of Europe's food systems

In order to achieve food and nutrition security and sustainable agriculture, a transition of the EU food system is needed. Many lock-in factors prevent the dominant food system to change. Policies from the local to the global level need to be re-designed and better integrated, new farming systems based on ecological approaches are needed, new supply chains need to be set-up, and innovation systems, including extension and education need to adapt. Given the huge number of actors involved and the many interactions in food systems, such transition cannot be addressed by one single project. IFOAM EU calls for a flagship programme with considerable amount of budget that is able to make significant advances in the transition of Europe's food systems. Such a programme should foster the cross-fertilization between the organic and conventional food and farming sector. The flagship programme should include support actions that translate the outcomes of the funded projects into policy options.

Improve data availability

There is still a lot of uncertainty about the precise mitigation potential of agricultural practices when it comes to specific and detailed numbers. Increased data collection and research are important, but even in this situation of prevailing uncertainty on many aspects, there are some clear and robust results that provide a basis for mitigation in agriculture. Lower animal numbers, lower nitrogen inputs and increased use of organic fertilizers, and optimised crop rotations lead to lower methane emissions from enteric fermentation and manure management, lower nitrous oxide emissions from fertilized soils and higher soil carbon sequestration. These mechanisms should lay the foundation of any strategy for climate change mitigation in agriculture, and they should be supported without needing to wait for further research results. Parts of these mechanisms come with reduced production volumes, and it is thus indispensable to combine them with consumption side measures towards less animal products and less food wastage.

REFERENCES

AGUILERA, E., LASSALETTA, L., GATTINGER, A. & GIMENO, B. S. 2013a. Managing soil carbon for climate change mitigation and adaptation in Mediterranean cropping systems: A meta-analysis. Agriculture, Ecosystems & Environment, 168, 25-36.

AGUILERA, E., LASSALETTA, L., SANZ-COBENA, A., GARNIER, J. & VALLEJO, A. 2013b. The potential of organic fertilizers and water management to reduce N_2O emissions in Mediterranean climate cropping systems. A review. Agriculture, Ecosystems & Environment, 164, 32-52.

AZADI, H., SCHOONBEEK, S., MAHMOUDI, H., DERUDDER, B., DE MAEYER, P. & WITLOX, F. 2011. Organic agriculture and sustainable food production system: Main potentials. Agriculture, Ecosystems & Environment, 144, 92-94.

BADGLEY, C., MOGHTADER, J., QUINTERO, E., ZAKEM, E., CHAPPELL, M. J., AVILES-VAZQUEZ, K., SAMULON, A. & PERFECTO, I. 2007. Organic agriculture and the global food supply. Renewable Agriculture and Food Systems, 22, 86-108.

BAILEY, A., LANG, T. & SCHOEN, V. 2016. Does the CAP still fit? : Food Research Collaboration Policy Brief.

BARAŃSKI, M., ŚREDNICKA-TOBER, D., VOLAKAKIS, N., SEAL, C., SANDERSON, R., STEWART, G. B., BENBROOK, C., BIAVATI, B., MARKELLOU, E., GIOTIS, C., GROMADZKA-OSTROWSKA, J., REMBIAŁKOWSKA, E., SKWARŁO-SOŃTA, K., TAHVONEN, R., JANOVSKÁ, D., NIGGLI, U., NICOT, P. & LEIFERT, C. 2014. Higher antioxidant and lower cadmium concentrations and lower incidence of pesticide residues in organically grown crops: a systematic literature review and meta-analyses. British Journal of Nutrition, 112, 794-811.

BELLARBY, J., FOEREID, B. & HASTINGS, A. 2008. Cool farming: Climate impacts of agriculture and mitigation potential. Greenpeace International, Amsterdam.

BELLARBY, J., TIRADO, R., LEIP, A., WEISS, F., LESSCHEN, J. P. & SMITH, P. 2013. Livestock greenhouse gas emissions and mitigation potential in Europe. Global change biology, 19, 3-18.

BENBROOK, C. M. 2012. Impacts of genetically engineered crops on pesticide use in the U.S. -- the first sixteen years. Environmental Sciences Europe, 24, 24.

BENBROOK, C. M. 2016. Trends in glyphosate herbicide use in the United States and globally. Environmental Sciences Europe, 28, 3.

BILLETER, R., et al., 2008. Indicators for biodiversity in agricultural landscapes: a pan-European study. J. Appl. Ecol. 45, 141–151. doi:10.1111/j.1365-2664.2007.01393.x

BOHAN, D. A., BOFFEY, C. W. H., BROOKS, D. R., CLARK, S. J., DEWAR, A. M., FIRBANK, L. G., HAUGHTON, A. J., HAWES, C., HEARD, M. S., MAY, M. J., OSBORNE, J. L., PERRY, J. N., ROTHERY, P., ROY, D. B., SCOTT, R. J., SQUIRE, G. R., WOIWOD, I. P. & CHAMPION, G. T. 2005. Effects on weed and invertebrate abundance and diversity of herbicide management in genetically modified herbicide-tolerant winter-sown oilseed rape. Proceedings of the Royal Society B: Biological Sciences, 272, 463.

BROOKS, D. R., BOHAN, D. A., CHAMPION, G. T., HAUGHTON, A. J., HAWES, C., HEARD, M. S., CLARK, S. J., DEWAR, A. M., FIRBANK, L. G., PERRY, J. N., ROTHERY, P., SCOTT, R. J., WOIWOD, I. P., BIRCHALL, C., SKELLERN, M. P., WALKER, J. H., BAKER, P., BELL, D., BROWNE, E. L., DEWAR, A. J. G., FAIRFAX, C. M., GARNER, B. H., HAYLOCK, L. A., HORNE, S. L., HULMES, S. E., MASON, N. S., NORTON, L. R., NUTTALL, P., RANDLE, Z., ROSSALL, M. J., SANDS, R. J. N., SINGER, E. J. & WALKER, M. J. 2003. Invertebrate responses to the management of genetically modified herbicide–tolerant and conventional spring crops. I. Soil-surface-active invertebrates. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 358, 1847.

BRYNGELSSON, D., WIRSENIUS, S., HEDENUS, F. & SONESSON, U. 2016. How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. Food Policy, 59, 152-164.

Climate Analytics, 2016. What does the Paris Climate Agreement mean for Finland and the European Union? Technical Report, June 2016. Available: http://climateanalytics.org/files/ca_paris_agreement_finland_eu.pdf

CROWDER, D. W. & REGANOLD, J. P. 2015. Financial competitiveness of organic agriculture on a global scale. Proceedings of the National Academy of Sciences, 112, 7611-7616.

CUYPERS, D., GEERKEN, T., GORISSEN, L., LUST, A., PETERS, G., KARSTENSEN, J., PRIELER, S., FISHER, G., HIZSNYIK, E. & VAN VELTHUIZEN, H. 2013. The impact of EU consumption on deforestation: Comprehensive analysis of the impact of EU consumption on deforestation. Brussels: European Union

(Technical Report–2013–063).

DANILA, A. M., FERNANDEZ, R., NTEMIRI, S., MANDL, N. & RIGLER, E. 2016. Annual European Union greenhouse gas inventory 1990–2014 and inventory report 2016: Submission to the UNFCCC Secretariat. EEA Report No 15/2016. European Commission, DG Climate Action, European Environment Agency, Brussels.

DE PONTI, T., RIJK, B. & VAN ITTERSUM, M. K. 2012. The crop yield gap between organic and conventional agriculture. Agricultural Systems, 108, 1-9.

DEIKE, S., PALLUTT, B. & CHRISTEN, O. 2008. Investigations on the energy efficiency of organic and integrated farming with specific emphasis on pesticide use intensity. European Journal of Agronomy, 28, 461-470.

DURMIC, Z., MOATE, P., ECKARD, R., REVELL, D., WILLIAMS, R., VERCOE, P. 2014, In vitro screening of selected feed additives, plant essential oils and plant extracts for rumen methane mitigation, Journal of the Science of Food and Agriculture 94(6): 1191-1196.

EEA 2016. Annual European Union greenhouse gas inventory 1990–2014 and inventory report 2016. European Environmental Agency EEA.

EUROPEAN COMMISSION. 2016a. The CAP: direct support "greening" [Online]. European Union, Brussels. Available: http://ec.europa.eu/agriculture/direct-support/greening/index_en.htm (Accessed 30/06/2016).

EUROPEAN COMMISSION. 2016b. Climate action: Climate strategies & targets [Online]. Available: http://ec.europa.eu/clima/policies/strategies/index_en.htm (Accessed 30/06/2016).

EUROPEAN COMMISSION. 2016c. Effort Sharing Decision [Online]. European Union, Brussels. Available: http://ec.europa.eu/clima/policies/effort/index_en.htm (Accessed 30/06/2016).

EUROPEAN COMMISSION. 2016d. The EU Emissions Trading System (EU ETS) [Online]. European Union, Brussels. Available: http://ec.europa.eu/clima/policies/ets/index_en.htm (Accessed 30/06/2016).

EUROPEAN COMMISSION 2016e. Impact Assessment accompanying the document on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry into the 2030 climate and energy framework and amending Regulation No 525/2013 of the European Parliament and the Council on a mechanism for monitoring and reporting greenhouse gas emissions and other information relevant to climate change.

EUROPEAN COMMISSION 2016f. Impact Assessment accompanying the Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 for a resilient Energy Union and to meet commitments under the Paris Agreement and amending Regulation No 525/2013 of the European Parliament and the Council on a mechanism for monitoring and reporting greenhouse gas emissions and other information relevant to climate change. Brussels.

EUROPEAN COMMISSION, E. 2012. The Common Agricultural Policy: a story to be continued.

EUROPEAN COMMISSION, E. 2013. Overview of CAP Reform 2014-2020. Agricultural Policy Perspectives Brief N°5* / December 2013.

EUROPEAN COUNCIL 2013. 529/2013/EU of the European Parliament and of the Council of 21 May 2012 on accounting rules on greenhouse gas emissions and removals resulting form activities relating to land use, land-use change and forestry (LULUCF) and on information concerning actions relating to those activities. Official Journal of the European Union, Brussels.

EUROPEAN ECONOMIC COMMUNITIES 1991. Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Communities, 375, 12.

EUROPEAN UNION 2016. Agriculture and LULUCF in the 2030 Framework – Final Report. Prepared by ICF Consultation Limited, Alterra, COWI, Ecological Institute and Umweltbundesamt GmbH, London.

EUROSTAT. 2016a. Agri-environmental indicator - mineral fertiliser consumption [Online]. Available: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_mineral_fertiliser_consumption.

EUROSTAT. 2016b. Agriculture - greenhouse gas emission statistics [Online]. Available: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agriculture_-_greenhouse_gas_emission_statistics (Accessed 5/7/2016).

EUROSTAT. 2016c. Statistics Explained: Organic farming statistics [Online]. Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Organic_farming_statistics#Further_Eurostat_information (Accessed 28/10/2016)

FALKENBERG, K. 2016. Sustainability Now! A European Vision for Sustainability. EPSC Strategic Notes.

FAO 2013a. Food Wastage Footprint - Impacts on Natural Resources. Rome: Food and Agriculture Organization of the United Nations FAO.

FAO 2013b. Food Wastage Footprint - Toolkit. Rome: Food and Agriculture Organization of the United Nations FAO.

FAO 2016. The Agriculture Sectors in the Intended Nationally Determined Contributions: Analysis. Food and Agriculture Organization of the United Nations, Rome.

FAOSTAT. 2016. Food and Agriculture Organization of the United Nations Statistics Division: Official Homepage [Online]. Available: http://faostat3.fao.org/home/E (Accessed 17/08/2016).

FERTILIZERS EUROPE 2013. EU fertilizer market key graphs.

FLIEßBACH, A., OBERHOLZER, H.-R., GUNST, L. & MÄDER, P. 2007. Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. Agriculture, Ecosystems & Environment, 118, 273-284.

FOLEY, J. A., RAMANKUTTY, N., BRAUMAN, K. A., CASSIDY, E. S., GERBER, J. S., JOHNSTON, M., MUELLER, N. D., O'CONNELL, C., RAY, D. K., WEST, P. C., BALZER, C., BENNETT, E. M., CARPENTER, S. R., HILL, J., MONFREDA, C., POLASKY, S., ROCKSTRÖM, J., SHEEHAN, J., SIEBERT, S., TILMAN, D. & ZAKS, D. P. M. 2011. Solutions for a cultivated planet. Nature, 478, 337-342.

FRANK, S., SCHMID, E., HAVLÍK, P., SCHNEIDER, U. A., BÖTTCHER, H., BALKOVIČ, J. & OBERSTEINER, M. 2015. The dynamic soil organic carbon mitigation potential of European cropland. Global Environmental Change, 35, 269-278.

FULLER, R. J., NORTON, L. R., FEBER, R. E., JOHNSON, P. J., CHAMBERLAIN, D. E., JOYS, A. C., MATHEWS, F., STUART, R. C., TOWNSEND, M. C., MANLEY, W. J., WOLFE, M. S., MACDONALD, D. W. & FIRBANK, L. G. 2005. Benefits of organic farming to biodiversity vary among taxa. Biology Letters, 1, 431-434.

GABRIEL, D., CARVER, S. J., DURHAM, H., KUNIN, W. E., PALMER, R. C., SAIT, S. M., STAGL, S. & BENTON, T. G. 2009. The spatial aggregation of organic farming in England and its underlying environmental correlates. Journal of Applied Ecology, 46, 323-333.

GABRIEL, D., SAIT, S. M., HODGSON, J. A., SCHMUTZ, U., KUNIN, W. E. & BENTON, T. G. 2010. Scale matters: the impact of organic farming on biodiversity at different spatial scales. Ecology Letters, 13, 858-869.

GATTINGER, A., MULLER, A., HAENI, M., SKINNER, C., FLIESSBACH, A., BUCHMANN, N., MÄDER, P., STOLZE, M., SMITH, P., SCIALABBA, N. E.-H. & NIGGLI, U. 2012. Enhanced top soil carbon stocks under organic farming. Proceedings of the National Academy of Sciences, 109, 18226-18231.

GAUPP-BERGHAUSEN, M., HOFER, M., REWALD, B. & ZALLER, J. G. 2015. Glyphosate-based herbicides reduce the activity and reproduction of earthworms and lead to increased soil nutrient concentrations. Scientific Reports, 5, 12886.

GERLACH, F., GRIEB, B. & ZERGER, U. 2013. Sustainable biogas production - A handbook for organic farmers. Sustaingas.

GOMIERO, T., PAOLETTI, M. G. & PIMENTEL, D. 2008. Energy and Environmental Issues in Organic and Conventional Agriculture. Critical Reviews in Plant Sciences, 27, 239-254.

GOMIERO, T., PIMENTEL, D. & PAOLETTI, M. G. 2011. Environmental Impact of Different Agricultural Management Practices: Conventional vs. Organic Agriculture. Critical Reviews in Plant Sciences, 30, 95-124.

GRAINGER, C., BEAUCHEMIN, K. a., 2011. Can enteric methane emissions from ruminants be lowered without lowering their production? Anim. Feed Sci. Technol. 166-167, 308–320.

HART, K. 2014. The fate of green direct payments in the CAP reform negotiations: the role of the European Parliament. Institute for European Environmental Policy (IEEP), Brussels.

HART, K., WEINGARTEN, P., POVELLATO, A., PIRZIO-BIROLI, C., BALDOCK, D., OSTENBURG, B., VANNI, F. & BOYES, A. 2011. What tools for the European agricultural policy to encourage the provision of public goods? Report prepared for the European Parliament.

HILBECK, A., OEHEN, B. (eds) 2015. Feeding the People: Agroecology for nourishing the world and transforming the agri-food system. IFOAM EU, Brussels.

HIÇ, C., PRADHAN, P., RYBSKI, D. & KROPP, J. P. 2016. Food Surplus and Its Climate Burdens. Environmental Science & Technology, 50, 4269-4277.

HOLE, D. G., PERKINS, A. J., WILSON, J. D., ALEXANDER, I. H., GRICE, P. V. & EVANS, A. D. 2005. Does organic farming benefit biodiversity? Biological Conservation, 122, 113-130.

HÜLSBERGEN, H.-J. & RAHMANN, G. (eds.) 2015. Klimawirkungen und Nachhaltigkeit ökologischer und konventioneller Betriebssysteme – Untersuchungen in einem Netzwerk von Pilotbetrieben: Forschungsergebnisse 2013-2014, Braunschweig: Johann Heinrich von Thünen-Institut.

IFOAM EU. 2015a. FERN - IFOAM EU PRESS RELEASE: New research shows risk of including land use and forests in EU's emission target [Online]. Available: http://www.ifoam-eu.org/en/news/2015/06/16/fern-ifoam-eu-press-release-new-research-shows-risk-including-land-use-and-forests.

IFOAM EU. 2015b. IFOAM EU at COP21 - Industrial farming leads to soil degradation, not to soil carbon sequestration [Online]. Available: http://www.ifoam-eu.org/en/news/2015/12/02/ifoam-eu-cop21-industrial-farming-leads-soil-degradation-not-soil-carbon.

IPCC 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 4: Agriculture, Forestry and Other Land Use. Intergovernmental Panel on Climate Change (IPCC).

IPES-FOOD 2016. From uniformity to diversity: a paradigm shift from industrial agriculture to diversified agroecological systems. International Panel of Experts on Sustainable Food systems (IPES-Food).

KHAN, S. A., MULVANEY, R. L., ELLSWORTH, T. R. & BOAST, C. W. 2007. The Myth of Nitrogen Fertilization for Soil Carbon Sequestration Journal of Environmental Quality, 36, 1821-1832.

KILCHER, L. 2007. How organic agriculture contributes to sustainable development. Journal of Agricultural Research in the Tropics and Subtropics, Supplement, 89, 31-49.

KLEVENHUSEN, F., KREUZER, M. & SOLIVA, C. R. 2011. Enteric and manure-derived methane and nitrogen emissions as well as metabolic energy losses in cows fed balanced diets based on maize, barley or grass hay. Animal, 5, 450-461.

KNAPP, J. R., LAUR, G. L., VADAS, P. A., WEISS, W. P. & TRICARICO, J. M. 2014. Invited review: Enteric methane in dairy cattle production: Quantifying the opportunities and impact of reducing emissions. Journal of Dairy Science, 97, 3231-3261.

KOLBE, H. Wasserschutz und Ökologischer Landbau. SIGÖL-Fortbildungskurs Ökologischer Landbau 29, Bad Düben, Freistaat Sachsen, 04.03.2004., 2004.

KOLBE, H. 2009. Effects of conventional and organic land use types on water protection criteria in Germany. Saechsisches Landesamt fuer Umwelt, Landwirtschaft und Geologie, D-Dresden, Abteilung Pflanzliche Erzeugung.

LEIFELD, J. 2016. <div xmlns="http://www.w3.org/1999/xhtml">Current approaches neglect possible agricultural cutback under large-scale organic farming. A comment to Ponisio et al.</div>. Proceedings of the Royal Society B: Biological Sciences, 283.

LORENZ, K. & LAL, R. 2016. Chapter Three - Environmental Impact of Organic Agriculture. In: DONALD, L. S. (ed.) Advances in Agronomy. Academic Press.

LUGATO, E., BAMPA, F., PANAGOS, P., MONTANARELLA, L. & JONES, A. 2014. Potential carbon sequestration of European arable soils estimated by modelling a comprehensive set of management practices. Global Change Biology, 20, 3557-3567.

MÄDER, P. & BERNER, A. 2012. Development of reduced tillage systems in organic farming in Europe. Renewable Agriculture and Food Systems, 27, 7-11.

MARTIN, C., MORGAVI, D. P. & DOREAU, M. 2010. Methane mitigation in ruminants: from microbe to the farm scale. animal, 4, 351-365.

MATTHEWS, A. 2012. Environmental public goods in the new cap: impact of greening proposals and possible alternatives. Committee on Agriculture and Rural Development, European Parliament, Brussels.

MEIER, M. S., STOESSEL, F., JUNGBLUTH, N., JURASKE, R., SCHADER, C. & STOLZE, M. 2015. Environmental impacts of organic and conventional agricultural products – Are the differences captured by life cycle assessment? Journal of Environmental Management, 149, 193-208.

MONDELAERS, K., AERTSENS, J. & HUYLENBROECK, G. V. 2009. A meta-analysis of the differences in environmental impacts between organic and conventional farming. British Food Journal, 111, 1098-1119.

MONIER, V., MUDGAL, S., ESCALON, V., O'CONNOR, C., ANDERSON, G., MONTOUX, H., REISINGER, H., DOLLEY, P., OGLIVIE, S. & MORTON, G. 2011. Preparatory study on food waste across EU 27. Technical Report (2010-054). European Commission, Paris.

MULLER, A. 2009. Benefits of organic agriculture as a climate change adaptation and mitigation strategy in developing countries.

MULLER, A. & AUBERT, C. 2014. The Potential of Organic Agriculture to Mitigate the Influence of Agriculture on Global Warming—A Review. In: BELLON, S. & PENVERN, S. (eds.) Organic Farming, Prototype for Sustainable Agricultures: Prototype for Sustainable Agricultures. Dordrecht: Springer Netherlands.

MULLER, A., JAWTUSCH, J., GATTINGER, A., GÖLTHENBOTH, F. & OLESEN, J. 2011. Mitigating Greenhouse Gases in Agriculture -A challenge and opportunity for agricultural policies. Report commissioned by Brot für die Welt "(Germany)„Brot für alle "(Switzerland), Dan-ChurchAid (Denmark) and Church of Sweden, Brot für die Welt, Stuttgart.

MULLER, A., OSMAN-ELASHA, B. & ANDREASEN, L. 2013. The potential of organic agriculture for contributing to climate change adaptation. In: HALBERG, N. & Muller, A. (eds.) Organic Agriculture for Sustainable Livelihoods. Routledge.

MULLER, A., Schader, C., El-Hage Scialabba, N., Hecht, J., Isensee, A., Erb, K.-H., Smith, P., Klocke, K., Leiber, F., Stolze, M. and Niggli, U., 2016, Strategies for feeding the world more sustainably with organic agriculture, submitted and under review in revised form

MULVANEY, R. L., KHAN, S. A. & ELLSWORTH, T. R. 2009. Synthetic Nitrogen Fertilizers Deplete Soil Nitrogen: A Global Dilemma for Sustainable Cereal Production. Journal of Environmental Quality, 38, 2295-2314.

NIGGLI, U., FLIESSBACH, A., HEPPERLY, P. & SCIALABBA, N. 2009. Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems. Rome: Food and Agriculture Organization of the United Nations (FAO).

O'MARA, F. Greenhouse gas production from dairying: Reducing methane production. Advances in dairy technology: proceedings of the Western Canadian Dairy Seminar, 2004. Advances in Dairy Technology, Volume 16, 295-309.

PARDO, G., MORAL, R., AGUILERA, E. & DEL PRADO, A. 2015. Gaseous emissions from management of solid waste: a systematic review. Global Change Biology, 21, 1313-1327.

PÉREZ DOMÍNGUEZ, I., FELLMANN, T., WEISS, F., WITZKE, P., BARREIRO-HURLÉ, J., HIMICS, M., JANSSON, T., SALPUTRA, G. & LEIP, A. 2016. An economic assessment of GHG mitigation policy options for EU agriculture (EcAMPA 2). JRC Science for Policy Report, EUR 27973 EN, 10.2791/843461.

PIMENTEL, D., HEPPERLY, P., HANSON, J., DOUDS, D. & SEIDEL, R. 2005. Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems. BioScience, 55, 573-582.

PONISIO, L. C. & KREMEN, C. 2016. System-level approach needed to evaluate the transition to more sustainable agriculture. Proceedings of the Royal Society B: Biological Sciences, 283.

PONISIO, L. C., M'GONIGLE, L. K., MACE, K. C., PALOMINO, J., DE VALPINE, P. & KREMEN, C. 2015. Diversification practices reduce organic to conventional yield gap. Proceedings of the Royal Society of London B: Biological Sciences, 282, 20141396.

REGANOLD, J. P. & WACHTER, J. M. 2016. Organic agriculture in the twenty-first century. Nature Plants, 2, 1-8.

RICARDO-AEA 2016. Effective performance of tools for climate action policy - meta-review of Common Agricultural Policy (CAP) mainstreaming. Report for the European Commission -

DG Climate Action.

ROCHA, M., SFERRA, F., SCHAEFFER, M., ROMING, N., ANCYGIER, A., PARRA, P., CANTZLER, J., COIMBRA, A. & HARE, B. 2016. What does the Paris Climate Agreement mean for Finland and the European Union? Technical Report, June 2016. Climate Analytics, Berlin.

RUSER, R. & SCHULZ, R. 2015. The effect of nitrification inhibitors on the nitrous oxide (N_2O) release from agricultural soils—a review J. Plant Nutr. Soil Sci. , 1-18.

SCHADER, C., MULLER, A., EL-HAGE SCIALABBA, N., HECHT, J., ISENSEE, A., ERB, K.-H., SMITH, P., MAKKAR, H., KLOCKE, P., LEIBER, F., SCHWEGLER, P., STOLZE, M. & NIGGLI, U. 2015. Impacts of feeding less food-competing feedstuffs to livestock on global food system sustainability. Journal of the Royal Society Interface, 12, 20150891.

SCIALABBA, N. E.-H. & Muller-LINDENLAUF, M. 2010. Organic agriculture and climate change. Renewable Agriculture and Food Systems, 25, 158.

SEJIAN, V., LAKRITZ, J., EZEJI, T. & LAL, R. 2011. Forage and flax seed impact on enteric methane emission in dairy cows. Res J Vet Sci, 4, 1-8.

SEUFERT, V., RAMANKUTTY, N. & FOELY, J. A. 2012. Comparing the yields of organic and conventional agriculture. Nature, doi:10.1038/nature11069.

SHIBATA, M. & TERADA, F. 2010. Factors affecting methane production and mitigation in ruminants. Animal Science Journal, 81, 2-10.

SKINNER, C., GATTINGER, A., MULLER, A., MÄDER, P., FLIEBBACH, A., STOLZE, M., RUSER, R. & NIGGLI, U. 2014. Greenhouse gas fluxes from agricultural soils under organic and non-organic management — A global meta-analysis. Science of The Total Environment, 468–469, 553-563.

SMITH, P. 2014. Do grasslands act as a perpetual sink for carbon? Global Change Biology, 20, 2708-2711.

SMITH, P., BUSTAMANTE, M., AHAMMAD, H., CLARK, H., DONG, H., ELSIDDIG, E. A., HABERL, H., HARPER, R., HOUSE, J. & JAFARI, M. 2014. Agriculture, forestry and other land use (AFOLU). Climate change 2014: mitigation of climate change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

SMITH, P., MARTINO, D., CAI, Z., GWARY, D., JANZEN, H., KUMAR, P., MCCARL, B., OGLE, S., O'MARA, F., RICE, C., SCHOLES, B., SIROTENKO, O., HOWDEN, M., MCALLISTER, T., PAN, G., ROMANENKOV, V., SCHNEIDER, U., TOWPRAYOON, S., WATTENBACH, M. & SMITH, J. 2008. Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society B: Biological Sciences, 363, 789-813.

SMITH, P., MARTINO, D., CAI, Z., GWARY, D., JANZEN, H., KUMAR, P., MCCARL, B., OGLE, S., O'MARA, F. & RICE, C. 2007. Agriculture. In 'Climate change 2007: mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change'. (Eds B Metz, OR Davidson, PR Bosch, R Dave, LA Meyer) pp. 497–540. Cambridge University Press: Cambridge, UK.

ŚREDNICKA-TOBER, D., BARAŃSKI, M., SEAL, C., SANDERSON, R., BENBROOK, C., STEINSHAMN, H., GROMADZKA-OSTROWSKA, J., REMBIAŁKOWSKA, E., SKWARŁO-SOŃTA, K., EYRE, M., COZZI, G., KROGH LARSEN, M., JORDON, T., NIGGLI, U., SAKOWSKI, T., CALDER, P. C., BURDGE, G. C., SOTIRAKI, S., STEFANAKIS, A., YOLCU, H., STERGIADIS, S., CHATZIDIMITRIOU, E., BUTLER, G., STEWART, G. & LEIFERT, C. 2016a. Composition differences between organic and conventional meat: a systematic literature review and meta-analysis. British Journal of Nutrition, 115, 994-1011.

ŚREDNICKA-TOBER, D., BARAŃSKI, M., SEAL, C. J., SANDERSON, R., BENBROOK, C., STEINSHAMN, H., GROMADZKA-OSTROWSKA, J., REMBIAŁKOWSKA, E., SKWARŁO-SOŃTA, K., EYRE, M., COZZI, G., LARSEN, M. K., JORDON, T., NIGGLI, U., SAKOWSKI, T., CALDER, P. C., BURDGE, G. C., SOTIRAKI, S., STEFANAKIS, A., STERGIADIS, S., YOLCU, H., CHATZIDIMITRIOU, E., BUTLER, G., STEWART, G. & LEIFERT, C. 2016b. Higher PUFA and n-3 PUFA, conjugated linoleic acid, α-tocopherol and iron, but lower iodine and selenium concentrations in organic milk: a systematic literature review and meta- and redundancy analyses. British Journal of Nutrition, 115, 1043-1060.

STOLZE, M., ZANOLI, R., MEREDITH, S. 2016. Organic in Europe Expanding Beyond a Niche. In: MEREDITH, S. and WILLER, H., eds. Organic in Europe: Prospects and Developments 2016

TILMAN, D. & CLARK, M. 2014. Global diets link environmental sustainability and human health. Nature, 515, 518-522.

TITTONELL, P. 2014. Food Security and Ecosystem Services in a Changing World: It is time for Agroecology. Agroecology for Food Security and Nutrition. Food and Agriculture Organization of the United Nations (FAO), Rome.

TUCK, S. L., WINQVIST, C., MOTA, F., AHNSTRÖM, J., TURNBULL, L. A. & BENGTSSON, J. 2014. Land-use intensity and the effects of organic farming on biodiversity: a hierarchical meta-analysis. Journal of Applied Ecology, 51, 746-755.

TUOMISTO, H. L., HODGE, I. D., RIORDAN, P. & MACDONALD, D. W. 2012. Does organic farming reduce environmental impacts? – A meta-analysis of European research. Journal of Environmental Management, 112, 309-320.

UN. 2016. The Sustainable Development Goals, United Nations Official Homepage [Online]. Available: https://sustainabledevelopment.un.org/?menu=1300 (Accessed 30/06/2016).

UNFCCC 2015. ADOPTION OF THE PARIS AGREEMENT: Draft decision_/CP.21 at the COP21. United Nations Framework Convention on Climate Change (UNFCCC).

UNFCCC. 2016. Summary of the Paris Agreement. United Nations Framework Convention of Climate Change [Online]. Available: http://bigpicture.unfccc.int/#content-the-paris-agreemen (Accessed 30/06/2016).

VAN DOORN, A., LESSCHEN, J. & KUIKMAN, P. 2012. Next phase of the European Climate Change Programme: Analysis of member states actions to implement the effort sharing decision and options for further community-wide measures-Agriculture sector–Policy case studies report. AEA Technology plc, Didcot.

VDLUFA (2004): Humusbilanzierung. Methode zur Beurteilung und Bemessung der Humusversorgung von Ackerland. Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten. http://www.vdlufa.de/joomla/Dokumente/Standpunkte/08-humusbilanzierung.pdf

WEIDEMA, B. P., BAUER, C., HISCHIER, R., MUTEL, C., NEMECEK, T., REINHARD, J., VADENBO, C. O. & WERNET, G. 2013. The ecoinvent database: Overview and methodology. Data quality guideline for the ecoinvent database version 3. www.ecoinvent.org.

WEISS, F. & LEIP, A. 2012. Greenhouse gas emissions from the EU livestock sector: A life cycle assessment carried out with the CAPRI model. Agriculture, Ecosystems & Environment, 149, 124-134.

WEST, T., POST, W. (2002): Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis.
Soil Science Society of America Journal 66, 1930-1946

WESTHOEK, H., LESSCHEN, J. P., ROOD, T., WAGNER, S., DE MARCO, A., MURPHY-BOKERN, D., LEIP, A., VAN GRINSVEN, H., SUTTON, M. A. & OENEMA, O. 2014. Food choices, health and environment: Effects of cutting Europe's meat and dairy intake. Global Environmental Change, 26, 196-205.

WOLLENBERG, E., RICHARDS, M., SMITH, P., HAVLÍK, P., OBERSTEINER, M., TUBIELLO, F. N., HEROLD, M., GERBER, P., CARTER, S., REISINGER, A., VAN VUUREN, D., DICKIE, A., NEUFELDT, H., SANDER, B. O., WASSMANN, R., SOMMER, R., AMONETTE, J. E., FALCUCCI, A., HERRERO, M., OPIO, C., ROMAN-CUESTA, R., STEHFEST, E., WESTHOEK, H., ORTIZ-MONASTERIO, I., SAPKOTA, T., RUFINO, M. C., THORNTON, P. K., VERCHOT, L., WEST, P. C., SOUSSANA, J. F., BAEDEKER, T., SADLER, M., VERMEULEN, S. & CAMPBELL, B. M. 2016. Reducing emissions from agriculture to meet the 2°C target. Global Change Biology, 1-19.

ZEIGER, M. & FOHRER, N. 2009. Impact of organic farming systems on runoff formation processes—A long-term sequential rainfall experiment. Soil and Tillage Research, 102, 45-54.

APPENDIX

Table 8: Different mitigation measures for the agriculture sector. Based on Muller and Aubert, 2014, Bryngelsson et al., 2016, Smith et al., 2008, Pérez Domínguez et al., 2016, RICARDO-AEA, 2016

Measure	Sub-measure	Potential for organic agriculture (yes/no)	Mitigating Effect
Reduce energy use	Reduced heating in greenhouses	Yes, already done with some organic labels, such as Knospe	Reduces emissions
	Use energy efficient machinery	Yes	Reduces emissions
	Optimise machinery use (Precision Farming Techniques)	Yes	Reduces emissions
	Reduce / stop the use of synthetic agrochemicals	Yes, already part of the organic regulations	Reduces emissions
	Use pest-resistant crop varieties in order to reduce the use of agrochemicals	Yes	Reduces emissions
	Produce / use bioenergy	Yes	Reduces emissions
Reduce GHG emissions in the livestock sector	Use 4-5% lipids as feed additives	Rather not, as feed additives are contested	15-20% methane emission reduction
	Increase the share of concentrate feed instead of roughage	Rather not, against the values of organic agriculture	Reduces methane emissions by 1/3
	Avoid the use of concentrate feed	Yes, as the use of concentrate feed in organic farming is already restricted	Reduces emissions caused by deforestation, land use change and soil carbon losses
	Increase the longevity of dairy cows	Yes	Reduces emissions by 13% if the number of lactations is doubled
	Increase the productivity of milk/meat yields per animal	Yes – to a certain extent (longevity, double use, etc.)	Reduces emissions
	Reduce the number of ruminants kept and switch from ruminants to monogastric animals (e.g. pigs and poultry) kept	Yes	Reduces emissions
	Vaccination against methanogenic bacteria in the rumen	No, against the values of organic agriculture	Reduces emissions
	Breed ruminants for lower methane emissions	Yes	Reduces emissions
Reduce GHG emissions from fertilizer use (organic and inorganic)	Avoid the production and use of synthetic fertilizers and use organic fertilizers (e.g. either by organic farming and / or precision farming practices)	Yes	1-10 kg CO_2 e per kg N and increases soil organic carbon
	Improve the fertilization timing	Yes	Reduces emissions
	Increase the use of legumes on crop rotations	Yes, already practiced often in organic agriculture	Increases soil organic carbon and reduces the needed fertilized input (N-fixing crops)
	Use nitrification inhibitors	Rather not, as such inhibitors are against the values of organic agriculture	Reduces emissions
	Optimise manure management (storage facilities)	Yes	Reduces 1/3 to ¾ of the emissions
	Optimise compost production	Yes	Reduces N_2O emissions
Reduce GHG emissions from soils, LULUC and biomass	Reduce tillage	Yes	Indications that it increases soil organic carbon
	Implement agroforestry and set-aside areas, woody buffer strips, plantation of hedges and permanent grass cover	Yes	Increases soil organic carbon. In agroforestry systems 3–8 t CO_2-eq/ha/y
	Avoid drainage of wetland	Yes	Reduces emissions
	Avoid soil erosion by using cover/catch crops	Yes	Reduces emissions
	Optimise crop rotations	Yes	Increases soil organic carbon by 0.8 t CO_2-eq/ha/yr
	Avoid soil compaction	Yes	Reduces N_2O emissions
	Use biochar	Yes, to a certain extent: in organic agriculture, C in the form of organic fertilizers is preferable to biochar.	Increases soil organic carbon
	Conserve / restore wetland, peatland and prevent deforestation and removal of farmland trees	Yes	Reduces emissions
	Avoid the burning of biomass and crop residues and leave cropresidues on the soil surface	Yes	Reduces emissions
Reduce GHG emissions from food wastage	Improve storage and handling of food products	Yes	Reduces emissions

ENDNOTES

1. UNFCCC 2015. ADOPTION OF THE PARIS AGREEMENT: Draft decision_/CP.21 at the COP21. United Nations Framework Convention on Climate Change (UNFCCC). Available: https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf .

2. Different greenhouse gases contribute differently to global warming. Methane (CH_4) contributes about 30 times as strongly as CO_2, and nitrous oxide about 300 times. This factor is used to establish a common metric for greenhouse gases, by relating them to the amount of CO_2 that would cause the same global warming. This is the CO_2-equivalent (CO_2-eq). Thus, 1 tonne of CH_4 equals about 30 tCO_2-eq. More details in an accessible form can be found in a FCRN blog post by Martin Persson (http://www.fcrn.org.uk/fcrn-blogs/umpersson/livestock%E2%80%99s-carbon-footprint-importance-comparing-greenhouse-gases).

3. EUROPEAN COMMISSION 2016e. Impact Assessment accompanying the document on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry into the 2030 climate and energy framework and amending Regulation No 525/2013 of the European Parliament and the Council on a mechanism for monitoring and reporting greenhouse gas emissions and other information relevant to climate change. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016SC0249.

4. Enteric fermentation only occurs in ruminants, and does not take place in pigs or chickens. Pig and chicken production lead to emissions via manure management, and to indirect emissions from concentrate feed production.

5. These are direct emissions from agriculture in the accounting, but within this, there are direct and indirect N_2O emissions from fertilizer application, the latter being emitted after a range of steps only (volatilisation, etc.), the former being emitted directly from the soils.

6. These categories (soil carbon losses from managed cropland and grassland, land conversion to cropland and grassland) as well as emissions and sinks from existing forests and land converted to forests, from managed organic soils and from land conversion to settlements, comprise the so-called "land use, land use change and forestry" (LULUCF) emissions and sinks.

7. The main source countries for such imports are Argentina, Brazil and Paraguay. In these countries, the emission factor for deforestation is about 400-450 tCO_2-eq/ha (FAOSTAT, http://faostat3.fao.org/download/G2/GF/E); to obtain a first rough estimate, we therefore apply these emission factors to the reported areas of embodied deforestation.

8. Using a gross average of 4.4 tCO_2-eq/tN for urea and 8.8 tCO_2-eq/tN for ammonium nitrate production, and some additional CO_2 emissions from urea application (WEIDEMA, B. P., BAUER, C., HISCHIER, R., MUTEL, C., NEMECEK, T., REINHARD, J., VADENBO, C. O. & WERNET, G. 2013. The ecoinvent database: Overview and methodology. Data quality guideline for the ecoinvent database version 3. www.ecoinvent.org.), we can assume an average of 8 tCO_2-eq/tN from the production of mineral fertilizers (assuming roughly 75% nitrates, 25% urea, FERTILIZERS EUROPE 2013. EU fertilizer market key graphs.), including 0.73 tCO_2-eq/t Urea from urea application, i.e. about 1.3 tCO_2-eq/tN from urea application (IPCC 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories - Volume 4: Agriculture, Forestry and Other Land Use. Intergovernmental Panel on Climate Change (IPCC). chapter 11). Combined with the total of about 10 MtN from mineral fertilizers used in the EU (EUROSTAT. 2016a. Agri-environmental indicator - mineral fertiliser consumption [Online]. Available: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_mineral_fertiliser_consumption.), this results in 80 MtCO_2-eq.

9. Waste food is often dumped in landfills where it decays under anaerobic conditions, emitting considerable amounts of methane, or it is incinerated with additional (fossil) energy input, thus leading to CO_2 emissions.

10. In absolute terms, this is about 1,100-1,200 MtCO_2eq.

11. Numbers are available for 2008 and EU-27 only. In absolute terms, this percentage is about 170 MtCO_2-eq. This includes emissions related to these volumes along the whole value chain including production, not only the end-of-life phase, i.e. dumping.

12. In total, about 500 MtCO_2-eq. The emissions from the production of these quantities are part of agricultural emissions; the additional emissions arising along the value chain are reported under the respective sector emissions (transport, industry, etc.), and end-of-life emissions are accounted for in the wastage sector emissions.

13. We quote the description as provided in this report: "Nitrification inhibitors (NI) are compounds that slow down (inhibit) the conversion (nitrification) of ammonium ions (NH_4+) to NO_3-. Inhibitors could be applied as part of mineral N fertilizer formulations, to manures in storage and when spread on land, be periodically sprayed on grazing land at critical times of enhanced nitrification, or administered to animals in slow release boluses. Nitrification inhibitors may be applied at the same time as fertilizers or manure applications. The rationale for using NIs is that the rate of nitrification is slowed. NO_3- forms at a rate that the crop can use, increasing N efficiency and reducing environmental losses through N_2O emissions and NO_3- leaching."

14. Roughage feeds, such as grass, forage and maize silage, are feeds with a relatively high fibre content and correspondingly lower digestibility compared to feed concentrate, which is based on high protein and calorie-rich grains, grain legumes, soybean meal, etc.

15. www.sustaingas.eu

16. See also the short and easily accessible overview of soil carbon sequestration and its potentials and challenges, by the IFOAM-EU Group: http://www.ifoam-eu.org/en/news/2015/12/02/ifoam-eu-cop21-industrial-farming-leads-soil-degradation-not-soil-carbon

17. http://eur-lex.europa.eu/legal-content/ENTXT/?uri=CELEX:52016PC0479

18. This is in fact also reflected in their figure S1 in the supporting material, where they indicate a potential of 4-6% rather than 1-3%

19. Article 7 of the ESR proposal.

20. This is understandable, as a key difference between organic and conventional systems is usually the nitrogen input level – reducing N inputs in conventional systems to match organic systems reduces conventional yields and therefore the yield gap, while increasing N inputs in organic systems to match conventional levels increases organic yields and again reduces the yield gap.

21. www.sustaingas.eu

22. The carbon stored in soils in the sequestration process stems from organic fertilizers (manure and compost) as well as biomass residues that remain in or are applied to the soils (roots remaining in the soils after harvest and root exudates during the cropping period).

23. Covering all biophysical potential, not only agriculture, the technical potential is estimated to be 750 MtCO_2-eq.

24. We again emphasize that emissions from fertilizer production are not accounted for under agricultural emissions in the GHG inventories. Furthermore, as far as mineral fertilizers are imported to the EU, reductions would not even be accounted for in the EU inventory, as international climate change mitigation policies and agreements generally refer to national system boundaries.

25. This calculation assumes that conversion is implemented on 1/15 of half the available cropland each year from 2016 to 2030, until 50% of all cropland is organic in 2030. The soil carbon sequestration rate starts with its full potential for each newly converted area. Thus the area converted in 2016 has only half the original sequestration rate in 2030, while an area converted in 2023 still has 75% of its sequestration potential in 2030.

26. Assuming a linear increase to 50% organic production by 2030, this change would result in an average reduction of 5%.

27. The linear decline in the sequestration value to half by 2030 results in a cumulative reduction of about 9% if 50% of the land is converted to organic agriculture. Continuing this trend for another 15 years adds another 3% of mitigation. But the overall sequestration rate might drop more slowly, as the 50% conversion is only reached in 2030 and the earlier years would be characterized by lower conversion rates, so the sequestration potential on these areas would remain untapped until they are converted.

28. Other meta-studies on the yield gap are DE PONTI, T., RIJK, B. & VAN ITTERSUM, M. K. 2012. The crop yield gap between organic and conventional agriculture. Agricultural Systems, 108, 1-9, BADGLEY, C., MOGHTADER, J., QUINTERO, E., ZAKEM, E., CHAPPELL, M. J., AVILES-VAZQUEZ, K., SAMULON, A. & PERFECTO, I. 2007. Organic agriculture and the global food supply. Renewable Agriculture and Food Systems, 22, 86-108, PONISIO, L. C., M'GONIGLE, L. K., MACE, K. C., PALOMINO, J., DE VALPINE, P. & KREMEN, C. 2015. Diversification practices reduce organic to conventional yield gap. Proceedings of the Royal Society of London B: Biological Sciences, 282, 20141396.; see also LEIFELD, J. 2016. <div xmlns="http://www.w3.org/1999/xhtml">Current approaches neglect possible agricultural cutback under large-scale organic farming. A comment to Ponisio et al.</div>. Proceedings of the Royal Society B: Biological Sciences, 283. and PONISIO, L. C. & KREMEN, C. Ibid. System-level approach needed to evaluate the transition to more sustainable agriculture. DE PONTI, T., RIJK, B. & VAN ITTERSUM, M. K. 2012. The crop yield gap between organic and conventional agriculture. Agricultural Systems, 108, 1-9. find a similar yield gap of about 20%; BADGLEY, C., MOGHTADER, J., QUINTERO, E., ZAKEM, E., CHAPPELL, M. J., AVILES-VAZQUEZ, K., SAMULON, A. & PERFECTO, I. 2007. Organic agriculture and the global food supply. Renewable Agriculture and Food Systems, 22, 86-108. find an overall lower yield gap for developed countries of about 10%, but their data-base is lower in quality regarding comparability of the systems compared. PONISIO, L. C., M'GONIGLE, L. K., MACE, K. C., PALOMINO, J., DE VALPINE, P. & KREMEN, C. 2015. Diversification practices reduce organic to conventional yield gap. Proceedings of the Royal Society of London B: Biological Sciences, 282, 20141396., finally, again find a similar yield gap of 20%, but emphasize that this yield gap is lower at 10% when comparing similar N input levels only. This is understandable, as one key difference between organic and conventional systems usually is the nitrogen input level – reducing N inputs in conventional

systems to match organic systems thus reduces conventional yields and the yield gap, while increasing N inputs in organic systems to match conventional levels thus increases organic yields and again reduces the yield gap.

29. COM (2015) 337 - Proposal amending Directive 2003/87/EC to enhance cost-effective emission reductions and low carbon investments

30. COM/2016/482 - Proposal for a Regulation on binding annual greenhouse gas emission reductions by Member States from 2021 to 2030 for a resilient Energy Union and to meet commitments under the Paris Agreement and amending Regulation No 525/2013 of the European Parliament and the Council on a mechanism for monitoring and reporting greenhouse gas emissions and other information relevant to climate change

31. COM/2016/479 - Proposal on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry into the 2030 climate and energy framework and amending Regulation No 525/2013 of the European Parliament and the Council on a mechanism for monitoring and reporting greenhouse gas emissions and other information relevant to climate change.

32. Norway and Iceland are also interested in participating in this effort, and their involvement will be decided in accompanying legislation. Norway has stated its interest in being fully involved in the ESR.

33. IFOAM EU. 2015a. FERN - IFOAM EU PRESS RELEASE: New research shows risk of including land use and forests in EU's emission target [Online]. Available: http://www.ifoam-eu.org/en/news/2015/06/16/fern-ifoam-eu-press-release-new-research-shows-risk-including-land-use-and-forests.

34. SWD/2016/0249 final - 2016/0230 (COD) - COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT Accompanying the document Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry into the 2030 climate and energy framework and amending Regulation No 525/2013 of the European Parliament and the Council on a mechanism for monitoring and reporting greenhouse gas emissions and other information relevant to climate change – http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016SC0249

35. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014SC0015&from=EN; Table 40 page 138

36. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0247&from=EN; page 137

37. http://capreform.eu/is-agriculture-off-the-hook-in-the-eus-2030-climate-policy/

38. PÉREZ DOMÍNGUEZ, I., FELLMANN, T., WEISS, F., WITZKE, P., BARREIRO-HURLÉ, J., HIMICS, M., JANSSON, T., SALPUTRA, G. & LEIP, A. 2016. An economic assessment of GHG mitigation policy options for EU agriculture (EcAMPA 2). JRC Science for Policy Report, EUR 27973 EN, 10.2791/843461. https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/economic-assessment-ghg-mitigation-policy-options-eu-agriculture-ecampa-2

39. This modelling is based on the 2016 Reference projection, and uses the CAPRI model for agricultural non-CO_2 emissions, applying AR4 global warming potentials and the GLOBIUM model for the LULUCF part

40 . Alan Matthews, Professor Emeritus of European Agricultural Policy in the Department of Economics at Trinity College, Dublin, Ireland, writes a blog on the CAP reform: http://capreform.eu/mitigation-potential-in-eu-agriculture/

41. Impact assessment COM/2016/479 - Proposal on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry into the 2030 climate and energy framework and amending Regulation No 525/2013 of the European Parliament and the Council on a mechanism for monitoring and reporting greenhouse gas emissions and other information relevant to climate change

42. Hart, K., Weingarten, P., Povellato, A., Pirzio-Biroli, C., Baldock, D., Ostenburg, B., Vanni, F., Boyes, A., (2011): What tools for the European agricultural policy to encourage the provision of public goods? Report prepared for the European Parliament; Matthews, A., (2012): Environmental public goods in the new cap: impact of greening proposals and possible alternatives. Committee on Agriculture and Rural Development, European Parliament, Brussels. Available at: www.europarl.europa.eu/RegData/etudes/note/join/2012/474534/IPOL-AGRI_NT(2012)474534_EN.pdf; Hart, K., (2015a): The Fate of Green Direct Payments in the CAP Reform Negotiations. In: Swinnen, J.F.M. (ed.) The Political Economy of the 2014-2020 Common Agricultural Policy. Centre for European Policy Studies (CEPS), Brussels/Rowman and Littlefield International, London p. 245-276. Available at: www.ceps.eu/system/files/Political%20Economy%20of%20the%20CAP_Final_small.pdf.

43. Ricardo study: Report for European Commission - DG Climate Action (Effective performance of tools for climate action policy - meta-review of Common Agricultural Policy (CAP) mainstreaming)

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