Growing organic – a multifunctional component of English land use policy

Contents

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Summary

Overview

In this paper OF&G explores how land use in England would change if we were to see an increase in organic farming, estimating the benefits we might expect to realise if 10% or 25% of agricultural land in England were organically managed – a three- or eight-fold increase from the 3.5% of the agricultural land area at present.

Organic farming balances food, nature, and climate priorities through delivery of a sustainable farming system combining modern science and technology with traditional farming practices to maintain the long-term fertility of the soil and use less of the Earth's finite resources whilst producing high quality, nutritious food. It is underwritten by legally binding, compulsory standards giving certainty around claims and benefits of the approach.

Organic techniques have been developed from an understanding of and research into soil science, crop breeding, animal husbandry and ecology. The maintenance of soil fertility relies principally on the use of legumes, crop rotations, the application of composted animal manures and ground rock minerals. Pests, diseases and weeds are normally controlled by choice of appropriate species and varieties, appropriate rotations, mechanical cultivation, protection of natural pest enemies, physical barriers and thermal processes.

Synthetic fertilisers, pesticides, growth regulators and a number of livestock feed additives are prohibited although some specified materials can be used in severely restricted circumstances.

The outcome is an organic farming system that is substantially different from non-organic farming, one which is within

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planetary boundaries and that enhances biodiversity, reduces climate change impact whilst ensuring better animal welfare.

A government land use strategy is expected, and it is to be hoped that this will balance the land use needs for rural and urban land. There is no single 'right' way to produce food – and the answer will lie in dovetailing different approaches that reflect the topographical, climate and management experience of farmers across the UK. It is important however to realise the significant contribution Organic Farming can deliver in achieving the wider climate and biodiversity restoration goals, within this wider framework.

This paper reflects the widely acknowledged potential for organic farming to reliably deliver a resilient food production system alongside much reduced, multi-faceted environmental impacts. Organic farming delivers both wide and deep gains across both the food system and wider environment.

The organically managed crop area and livestock production and the environmental impact (increased biodiversity, reduced fertiliser and pesticide use, reduced greenhouse gas emissions) have been estimated assuming either 10% or 25% of England's agriculture is converted to organic farming, compared to the 3.5% at present.

Two scenarios were developed, firstly the Equal Shares (ES), where the area of each organic crop is in the same proportion as each crop in current non-organic farming. Secondly the Ideal Organic (IO), where the proportion of each crop (cereal, legumes, grass-clover pasture etc.) is designed to balance fertility building as well as exploitative cropping. The total area of organically managed land would be 855,132 Ha (at 10%) or 2,137,832 Ha (at 25%).

Organic crop area in England

In the IO scenario, based on a land use that provides a balance between organic fertility building and exploitative cropping:

- There would be 165,177 Ha of organic cereals (at 10%) or 412,649 Ha (at 25%), representing 19.3% of the total organic area, up from 14.2% at present.
- The area of organic horticulture would be 38,114 Ha (at 10%) or 95,285 Ha (at 25%). This would be equivalent to 4.5% of the total organic area.
- Temporary grassland and fodder crops would occupy 159,432 Ha (at 10%) and 398,531 Ha (at 25%), equivalent to 18.6% of the total organic area. This is a reduction from 28.2% of organic area taken up by temporary grass and fodder crops at present.
- Other arable crops (peas, beans and other legumes) would occupy 128,131 Ha (at 10%) and 320,622 (at 25%), 15.0% of the total area of organic area, up significantly from the 2.2% at present.
- The area of permanent grassland would be 321,259 Ha (at 10%) and 803,148 Ha (at 25%). This would represent 37.6% of the total organic land area, a reduction from the 47.6% (143,485 Ha) at present. Rough grazing would comprise 43,039 Ha (at 10%) and 107,596 (at 25%), or 5% of the total organic land area, up from 12,041 (4%) at present.

Compared with the IO scenario, the ES scenario would have:

- A higher proportion of cereals – 31.0% compared to 19.3% in the IO scenario, and a lower proportion of horticultural crops (2.5%), reflecting the high levels of cereal production and the low proportion of horticultural crops in the current conventional land use allocation.
- There would be a lower proportion of temporary grass and fodder crops (9.3%) and a similar proportion of other arable crops (14.6%).
- The proportion of permanent grassland and rough grazing would remain the same.

Organic crop output

- Organic crop output would be reduced by approximately 5% of conventional output under the 10% IO or ES scenarios, and would be reduced by approximately 13% under the 25% IO or ES scenarios.
- Output of cereals would increase less in the IO scenario than the ES scenario, reflecting the lower area of organic arable crops in the IO scenario.
- The IO scenario assumes that area of horticultural crops would increase substantially to replace imports by home production.

Organic livestock production

- In 2022 241,000 LU were kept on organic farms, 2.9% of the total in England.
- In the IO scenario this would increase to 557,000 LU (6.8% of the total in England) in the 10% IO scenario and to 1.39 million LU (17.0%) in the 25% IO scenario.
- In the ES scenario the increase would be to 486,000 LU in the 10% ES scenario (5.95% of the total in England) and to 1.2 million LU (14.9%) in the 25% ES scenario.
- The reduction in total livestock numbers resulting from 25% organic farmland is highly relevant for reducing greenhouse gas emissions and balance the projected reduction in crop output.
- Based on organic production in 2022, ruminant numbers are reduced by 2.7% and non-ruminants by 1.5% compared with the situation that might exist if all land were stocked at the current rate on non-organic land.
- In the 10% IO scenario ruminant livestock would reduce by 5.8% (14.4% in the 25% IO scenario).
- In the 10% ES scenario ruminant livestock would reduce by 4.8% (12.05% in the 25% ES scenario)
- In the 10% IO scenario non-ruminant livestock would reduce by 5.0% (12.5% in the 25% IO scenario).
- In the 10% ES scenario non-ruminant livestock would reduce by 5.0% (12.52% in the 25% ES scenario)

Biodiversity

- Biodiversity benefits of organic farming are the combined results of changes in land use with longer and more diverse crop rotations, non-use of herbicides and substantially reduced use of other pesticides, non-use of synthetic fertiliser and lower livestock stocking rates and greater use of pasture-based production.
- Number of arable plant species 95% higher on organic farms, and the number of field margin plant species 21% higher.

- Number of farmland bird species 35% greater on organic farms.
- Number of pollinator species 23% higher on organic farms and abundance 26% higher.
- Abundance of earthworm species 78% greater and biomass almost double on organic farms.

Synthetic fertiliser use

- The area of organic farming in England in 2022 reduced synthetic nitrogen fertiliser compared to the use of nitrogen fertiliser if there were no organic farming by 21,500 Tonnes (3.29% of total fertiliser use).
- A 10% uptake of organic farming in England in the IO scenario could be expected to reduce total nitrogen fertiliser use by 61,000 T, or 9.4% of total N consumption with no organic farming. A 25% uptake of organic farming in England in the IO scenario would be expected to reduce total nitrogen fertiliser use by 152,000 (23.4% of total nitrogen fertiliser consumption with no organic farming.
- A 10% uptake of organic farming in England in the ES scenario could be expected to reduce total nitrogen fertiliser use by 65,000 T, or 10% of total N consumption with no organic farming. A 25% uptake of organic farming in England in the ES scenario could be expected to reduce total nitrogen fertiliser use by 163,000 T, or 25% of total N consumption with no organic farming.

Synthetic pesticide use

- The area of organic farming in England in 2022 reduced pesticide use by 198,279 kg a.i. equivalent to 1.65% of total pesticide use in non-organic farming.
- In the 10% IO scenario the reduction in pesticide use would be 617,065 kg a.i., or 8.45% of total pesticide use. In the 25% IO scenario, the reduction would be 2,542,401 kg a.i., or 21.12% of total pesticide use.
- In the 10% ES scenario reduction in pesticide use would be 1,541,563 kg a.i. or 12.8% of total pesticide use. In the 25% ES scenario, the reduction would be 2,823,500 kg a.i. or 23.45% of total pesticide use.

Greenhouse gas emissions

- In 2022, organic farming delivered an estimated reduction of 523 kT CO_2e, or 1.67 % of total adjusted GHG emissions from agriculture and crop/grass LULUCF in 2019.
- The IO scenario is estimated to deliver, at 25%, a reduction of 2,656 kT CO_2e per year, 9.11% of English agriculture-related emissions, and at 10%, 1,142 kT CO_2e per year, 3.64% of English agriculture-related emissions.
- The ES scenario is estimated to deliver, at 25%, a reduction of 1,839 kT CO_2e per year, 5.87% of English agriculture-related emissions, and at 10%, 736 kT CO_2e per year, 2.35% of English agriculture-related emissions.
- The reduction in emissions per Ha from the area of organic land in 2022 was 1,735 kg CO_2e per Ha, or 47.3% of non-organic emissions – 968 kg CO_2e per Ha less from livestock, 192 kg CO_2e per Ha less from cropped land and 574 kg CO_2e per Ha less from temporary grassland.
- In the IO scenario, the reduction in emissions is reduced to 1,335 kg CO_2e per Ha (36.4% of non-organic emissions per Ha). In the ES scenario it is 860 kg CO_2e per Ha (23.46% of non-organic emissions per Ha).

Conclusions

- The clear definition of organic farming practices, included in legally regulated standards, allows for the consequence of the implementation of organic farming on the area of organic crops, the numbers of livestock and the environmental impact of increased uptake of organic farming in England.
- As a consequence, the environmental impact of conversion to organic farming (to 10% or 25% of England's farmland) can be estimated.
- The potential impact of organic farming is significant – even at the currently low level of uptake (3.5%), with a higher proportion it would make a valuable contribution to the achievement of the Government's environmental targets.
- Organic farming enhances biodiversity, reduces the use of synthetic fertilisers and pesticides, and reduces the emission of greenhouse gases.
- Support for the uptake of organic farming through Defra's Environmental Land Management Sustainable Farming Incentive and through the Countryside Stewardship can go some way to enable the increased uptake of organic production in England.
- New policies are required to provide the necessary advice to farmers wishing to convert to organic methods, improve the flow of knowledge and information and to invest in research and development to further improve the performance of organic farming.

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1. A land use policy for England including organic farming

In the Government Food Strategy[1], Defra promised a land use framework in 2023, to ensure that net zero and biodiversity targets are met, whilst also supporting a healthier diet of affordable produce. Evidence based and value for money interventions will be developed to enable more sustainable diets supported by government resources channelled towards long-term policies that help meet objectives included in the Environment Improvement Plan and the Environment Act.

Ahead of the publication of the Government's land use framework, this paper estimates the impact of an increase in the area of organically managed land in England from the current 3.5% to 10% and 25%.

A framework for land use must encompass all land uses – rural, urban, developed and undeveloped. Agricultural use for food and fibre production, non-agricultural uses including forestry and water catchments, as well as town and country planning and infrastructure. A national agricultural land use strategy must sit well alongside developing local land use strategies. To achieve success, both top-down and bottom-up approaches are required[2].

Including organic land management in the land use framework is one way to support sustainable production on farms. Organic production achieves positive environmental outcomes due to the crop and livestock husbandry practices deployed on organic farms. We believe that it is an intervention that offers value for money.

Meeting the climate change and biodiversity commitments depends on how farming uses the land and the diet that we eat. A sustainable diet is defined by what and how much is produced in England and imported from elsewhere, whether unprocessed or processed, how much of different foods are consumed and how much is wasted throughout the supply chain from farm to final consumer. Changes in food consumption patterns are acknowledged by many to be essential – indeed the way we consume now is a recognised part of the problem. Sustainable dietary solutions include consuming less but better meat, more fruit and vegetables, more pulses and whole grains – all recognised as being central to sustainable and healthy diets[3]. Policies can be more or less dirigiste or laissez faire, they are politically determined, and they are subject to commercial interests. At present, our food system is failing to meet sustainability goals.

Finch et al[4] compared nine future UK land use 'exploratory scenarios'. Two organic scenarios were included (organic on-farm measures and a nature-based solution (NBS) with organic farming). The annual greenhouse gas (GHG) emissions, breeding bird habitat index, and food production were evaluated in all scenarios. The organic on-farm measures scenario reduced total GHG emissions from agriculture to a lesser extent than the GHG reduction achieved by the nature-based with organic farming scenario. The increase in breeding bird habitat index was greater for the NBS with organic farming than for the organic farm measures scenario, whilst food production was reduced to a smaller extent in the organic on-farm measures scenario than the NBS with organic farming

A report from Green Alliance – *Shaping UK land use: priorities for food, nature and climate*[5] proposed five alternative land use scenarios. The first scenario (recommended by Green Alliance) foresees 60% of farmland managed agroecologically by 2050, as the primary way to balance food, nature, and climate priorities. Organic systems are recognised by Green Alliance as an agroecological way of farming. This paper considers the consequence of an increase in the area of organically and agroecologically managed land in England.

At present organic farmland accounts for just 3.5% of England/UK agricultural area[6]. The more organic farmland, the greater the positive impact on our environment. Our analysis enumerates the environmental outcomes that might be expected from an increase of organic farming to 10% or 25% of agricultural land in England. The EU's Farm to Fork Strategy[7] has proposed that 25% of Europe's farmland should be managed organically.

The Farm to Fork strategy has had widespread support including from the European Parliament, citizen groups, consumer organisations as well as farmer and environmental groups. Recently this positive outlook has been reversed with proposals for a sustainable Food Law dropped by the European Commission and the Farm to Fork Strategy scaled back[8,9]. The Farm to Fork Strategy has been criticised by Wageningen Economic Research[10] in a study funded by the pesticide lobby group Crop Life Europe. It has also been the subject of criticism from the Economic Research Service of the USDA[11] However both critiques miss the point that the Farm to Fork strategy has a holistic vision for transformation of our food system – both production and consumption[12]. This 360^{0} vision is essential if we are to meet the challenges head on.

All EU member states have committed to funding organic conversion and maintenance support for 10% of the utilisable agriculture area (UAA) as organic by 2027 in their national CAP Strategic Plans. They have also set organic land area targets for 2027 and 2030 that could result in almost 20% of EU UAA organically managed by 2030. To help deliver this, all but two member states have put in place national organic action plans for the short to medium term, these go further than the commitments made in their CAP Strategic Plans[13].

We have modelled the consequence of a 10% and 25% uptake of organic farming in England. We present the outcome in terms of organic land area devoted to different organic crop types and livestock, the organic crop and livestock, and estimate the impact on key environmental criteria (biodiversity, synthetic fertiliser and pesticide use, greenhouse gas emissions). Any change on this scale must consider the impact on food security, human diets and also factor in the high levels of wasted food from our current food and farming systems. Such a transformation will also require suitable policies to support the farmers' conversion to an organic system.

Modelling a 100% conversion to organic has revealed that enough food would be produced, provided there is a change in consumption patterns and a reduction in the current levels of food wastage[14]. A study that modelled the greenhouse gas

(GHG) impacts of converting all farming to organic in England and Wales assumed that current consumption levels of livestock products and levels of food waste would remain the same, and consequently concluded that GHG impact would increase, in part due to the requirement for more imported organic food and feed to meet current consumption patterns, the authors concluded that this would impose an impact elsewhere[15]. In the unlikely event of a wholesale conversion to organic in the UK would inevitably mean that lower livestock numbers, reduced concentrate feeding, lower consumer demand for meat and milk and reduced food waste would be coupled with a reduced requirement for imported food. This was successfully achieved during the second world war; however, no one so far has suggested that we should be put on a war footing.

An assessment of the environmental impact arising from organic farming on 25% of Europe's land[16] has revealed:

- Synthetic nitrogen fertiliser use would be reduced by 26%, equivalent to 2.7 million tonnes less synthetic nitrogen fertiliser,
- Pesticide use would be reduced on organic land by 90-95%,
- Biodiversity would increase by 30% on organically managed land,
- Reduced greenhouse gas emissions,
- Water and air quality would be improved,
- Pollution would reduce,
- Antimicrobial and anthelmintic use would reduce on organic farms.

Based on this European assessment, organic management on a proportion of land in England as part of a coordinated land use policy would deliver environmental gains in line with Government's policy objectives outlined in Defra's delivery plan for the environment and so contribute to a greener countryside as envisaged in the Environment Improvement Plan[17].

Organic farming is a legally recognised and defined agroecological and regenerative approach to farming. Defined in organic standards that make clear the husbandry requirements and the prohibited practices, organic farms are annually inspected, verified and certified by organic Control Bodies[18].

The peer reviewed scientific evidence for the positive environmental outcome of organic farming is clear. The land use strategy proposed provides a verified approach to contribute to the delivery our shared environmental ambitions.

This report outlines the impact of more organic farming in England compared with our current level of 3.5% (300,000 ha), one-third of the EU average. We are lagging behind our neighbours and thus not getting the environmental benefit that could be achieved.

The area of organic land in England in 2030 is estimated based on the Business As Usual linear trend from the current 3.5%. Two growth scenarios are presented. Both would result in a substantial increase in organic land area by 2030: a three-fold increase to 10% (855,000 hectares), approximately the average proportion of organic land in EU member states at present, an eight-fold increase to 25% (2.1 million hectares), the target for organically managed land in the European Farm to Fork Strategy.

2. Organic farming for Food Production, Nature and Climate

Organic farming is a land sharing approach to food production and nature, enhancing the environment, protecting against climate change, and improving animal welfare. It is midway on a continuum between re-wilding and intensification. A 'three-compartment model' is advocated by conservation organisations and in the National Food Strategy[19]. The three compartments include:

- Wild and semi-natural land use,
- Organic and agroecologically manged land for environment and food,
- Intensive production.

The House of Lords land use inquiry[20] concluded that "… *a multifunctional approach lends itself most clearly to a principle of land sharing, delivering multiple benefits simultaneously in the same location. We recognise that different locations are suited for different benefits and any decisions must be driven by local circumstances and priorities. A 'three compartment' model should only be considered if it is understood as a continuum of land use rather than a specification with rigid boundaries. … … The concepts of integration and multifunctionality are key to any successful land use framework. At present, land use policy is often delivered in a siloed manner with conflicts and trade-offs not adequately explored or resolved.*" A blended approach has been recently recommended as appropriate to maximise the benefit to biodiversity in the UK[21] with a mix of land sparing for re-wilding, land sharing with food production and environmental outcomes and intensive high yield agricultural land use.

Land sharing usually involves a mixed farming system – balancing crop and livestock production with environmental outcomes. Organic farming is multifunctional and is well suited to mixed farming, it is therefore, in principle, an example of a widely favoured land sharing approach. There is synergy between fertility building legume pasture and nitrogen fixing crops where the nutrients accumulated by the fertility building phases of the rotation are exploited by the following nutrient demanding crops in the rotation.

An organic rotation with 25-50% fertility building crops works well on organic farms. It reduces greenhouse gas emissions and brings real benefits to above and below-ground biodiversity – birds, mammals, plants, insects, invertebrates, and microbial life in the soil. It also helps to control weeds, pests, and diseases. Organic management can also be appropriate for wild and semi-natural areas.

Organic land use in England in 2022 is shown in Table 1, the total organic area amounted to 3.5% of the Utilisable Agricultural Area (UAA). Half of the organically managed land was permanent pasture (including rough grazing), 24.8% was in temporary pasture, 16.5% in arable crops and 2.7% was in vegetable crops (including potatoes).

Table 1: Fully organic and in-conversion land use in England – 2022

Source: Defra organic statistics

Organic Land Use	'000 Ha	% of total
Cereals	42.7	13.7
Other arable crops	8.6	2.8
Fruit & nuts	2.2	0.7
Vegetables (inc. potatoes)	8.4	2.7
Herbaceous & ornamentals	0.6	0.2
Temporary pasture	77.4	24.8
Permanent pasture	155.5	49.8
Woodland	11.5	3.7
Unutilised land	1.4	0.4
Unknown	4.1	1.2
TOTAL	**312.4**	**100.0**

3. Crop area, output and environmental impact of organic land management in England

3.1 Methodology and scenarios

The estimates of the area of organically managed land, crop production and livestock numbers arising from an increased uptake of organic farming in England are based on agricultural statistics data for all agriculture[22] , and specifically for organic agriculture[23] in England. This data has been used to calculate the share of either 10% or 25% organic agricultural land use and the associated livestock numbers compared with non-organic land, in 2030.

A 5-year baseline (2018-2022) was used for projecting future organic land use and for most variables. Where comparisons are made, for example with non-organic land use, synthetic nitrogen fertiliser or pesticide use, data from either 2022 or 2021 were used.

Values for non-organic production were based on the difference between total and organic values. This is necessary to get a representation of the non-organic sector, as the organic sector can no longer be considered a negligible component of the total values in many cases. In some cases (e.g. reductions in crop and livestock output, nitrogen use and greenhouse gas and ammonia emissions), an adjusted 2022 value was calculated based on zero organic farming, so that actual 2022 organic farming impacts could be estimated and presented on a similar basis to the 2030 projections.

The results presented in this report are summarised from detailed modelling carried out by the Organic Policy, Business and Research Consultancy[24]. The categorisation of crops and land uses varies slightly between the different sources. Some adjustments have been made to account for this, but inconsistencies remain[25].

The impact of either a 10% or 25% uptake of organic on the area of organically managed land in different crops, on synthetic nitrogen fertiliser and pesticide use, on GHG emissions and on biodiversity have been estimated based on the area of land under organic management and the numbers of organically managed livestock associated with this land use.

To assess potential organic land area in England in 2030, and so the consequent environmental impact, we analysed the data on the basis of three scenarios:

1. **Business As Usual (BAU):** Linear trend projections to 2030 based on the five-year time-series data for 2018-2022.
2. **Equal Shares (ES):** Based on an increase of organic land area in England with land use in line with the current conventional land area allocation.
3. **Ideal Organic (IO):** Based on expert judgement of organic land use allocation and livestock numbers, considering the need for: a balance between 'fertility building' and 'exploitative' cropping to achieve a nutrient balance, a significant reduction in consumption of non-ruminant livestock products, and an increase in vegetable and fruit production.

In the IO scenario it is assumed that:

- Cereals would increase as for the linear trend based on 2018-2022.
- Grain legumes would be 50% greater than in the ES.
- Oilseeds would be 10% less than ES.
- Potatoes would be 75% more than ES.
- Vegetables would be 75% more than ES.
- Temporary grass and fodder crops would be 100% more than ES.
- Fruit and nuts would be 75% more than ES
- Permanent grass and rough grazing would be the same as ES.

It should be noted that the estimates arising from these scenarios represent 'what if?' calculations, not forecasts of the likelihood of particular outcomes and are based on the available data for organic production, with conservative assumptions. As better data becomes available the estimates can be revised.

The likelihood of a scenario depends on the objectives and implementation of farming, land use and associated policy and the funding that is made available. The likelihood will also depend on other external market factors, as well as the chosen diet of organic food consumers (whether private individuals or in catering). These factors are further considered in Section 5.

The Business As Usual (BAU) scenario (based on linear projections from the trend over the past five years) is not further discussed. The following sections show the outcome of the Ideal Organic (IO) and the Equal Shares (ES) scenarios. The ES scenario (based on organic crops in the same proportion as for non-organic) does not provide a nutrient balance through the organic rotation. The IO scenario is based on organic land use that will achieve a nutrient balance.

3.2 Impact of organic land management on crop area in England

The impact of Ideal Organic (IO) and Equal Shares (ES) scenarios at 10% or 25% on organic crop area are shown in Table 2, compared to the actual situation in 2022. Key facts:

- The area of permanent grassland would remain unchanged under organic management – cultivation of permanent grassland is not permitted, neither to temporary leys nor to arable cropping, in organic standards.
- The ES scenario, where the area of crops on organically managed land would be in the same proportions as on non-organic, shows that cereals would make up 31.0%, horticulture would be 2.5%, temporary grass and fodder crops would be 9.3%, other arable crops (including peas, beans and other legumes) would be 14.6%, and permanent grassland would be 5%. This balance of cropping and grass would not achieve a nutrient balance.
- The IO scenario is based on land use that provides a balance between fertility building phases (legume leys, grain legume arable crops) and exploitative phases (cereals and vegetables). Thus there is a lower proportion of cereals (19.3%) in IO than in the ES scenario (31%), with other arable crops (including peas and beans) comprising 15.0% in both IO and ES.
- The proportion of fertility building crops would amount to just over one-third of all organic land in the IO scenario, and the area of organic cereals would be equivalent to the area of temporary grass and fodder crops. We believe that this would achieve a nutrient balance, essential in the organic system that is not reliant on external sources of nitrogen from synthetic fertilisers.
- The IO scenario assumes an increase the area of organic horticultural crops compared to the current area (4.5% compared to 3.7%) this is a greater proportion of horticultural crops than is the case under ES (2.5%). With the relatively high proportion of horticultural crops imported to England, an increase of the horticulture area is in line with reducing our reliance on imported vegetables.

3.3 Impact on organic crop output

- The impact of Ideal Organic (IO) and Equal Shares (ES) scenarios at 10% or 25% on organic crop output are shown Table 3 (overleaf), compared to the organic crop output in 2022. Key facts:
- Estimating organic crop yields involves assumptions and the approach taken is outlined in Appendix A1.
- Overall, organic crop output would be reduced by approximately 5% of conventional output, whether under the 10% IO or ES scenarios, and would be reduced by approximately 13% under the 25% IO or ES scenarios.
- Output of cereals would increase less in the IO scenario, compared to the ES scenario, reflecting the lower area of organic arable crops in the IO scenario, designed to contribute to a nutrient balance.
- The ES scenario reveals the extent of non-organic cereal production in England compared to other cropping. This would not be achievable in an organic system, where a nutrient balance without the use of synthetic nitrogen fertilisers is the aim.
- Output of other arable crops (including peas and beans) would increase substantially in the IO scenario, reflecting the need to grow grain legumes as a component for livestock feed, as well as for human consumption.

Table 2: England organic crop area projections to 2030 for different land uses/crops (hectares) under current, 10% and 25% scenarios. England total UAA: 8,551,325 hectares.

	Current: 2022		Ideal Organic: 2030 – IO			Equal Shares: 2030 – ES		
	Ha	% of O	10% Ha	25% Ha	% of O	10% Ha	25% Ha	% of O
Cereals	42,700	14.2	165,177	412,649	19.3	254,854	662,135	31.0
Horticulture[1]	11,145	3.7	38,114	95,285	4.5	21,779	54,449	2.5
Temp. grass & fodder	84,828	28.2	159,412	398,531	18.6	79,706	199,266	9.3
Other arable[2]	6,674	2.2	128,131	320,622	15.0	124,495	311,238	14.6
Permanent grassland	143,485	47.7	321,259	803,148	37.6	321,259	803,148	37.6
Rough grazing	12,041	4.0	43,039	107,596	5.0	43,039	107,596	5.0
TOTAL	300,873	100.0	855,132	2,137,831	100.0	855,132	2,137,832	100.0

Notes:
[1] – Horticulture includes: vegetables, potatoes, salads, fruit and nuts [2] – Other arable includes: peas, beans, other legumes

- Horticultural crops would increase substantially in the IO scenario compared to the ES scenario. IO assumes that organic vegetables imports would be replaced (as far as is possible) by home production and that the demand for organic vegetables would increase.
- The lower output of horticultural crops in the ES scenario reflects the fact that a relatively low proportion of agricultural land is devoted to these crops.
- The lower yield of organic crops will result in a reduction in crop output compared to the output from non-organic farming. The extent of the reduction in both IO and ES will depend on the percentage uptake (10% or 25%) and will vary with the crop type. In the case of the IO 10% scenario, approximately 3% less cereals would be produced (8% in the 25% IO) compared to the total production of non-organic crops; 5% less other arable crops (12% in the 25% IO); and a 9% reduction in the case of horticultural crops (22% in the 25% IO). In the case of the ES scenario, the reduction in crop yield would be 5% cereals in the 10% ES (13% in the 25% ES); 4% drop in production of other arable crops in the 10% ES (11% in the 25% ES); and a 5% reduction in horticulture crop production (13% in the 25% ES).

3.4 Impact on Livestock Numbers

The impact of Ideal Organic (IO) and Equal Shares (ES) scenarios at 10% or 25% on livestock production is shown in Table 4, compared to the actual situation in 2022. Estimating organic livestock involves assumptions and the approach taken is outlined in the Appendix A2.

Key facts:

Impact of organic farming on livestock numbers

- In 2022 241,000 LU were kept on organic farms, 2.9% of the total in England.
- In the IO scenario this would increase to 557,000 LU (6.8% of the total in England) in the 10% IO scenario and to 1.39 million LU (17.0%) in the 25% IO scenario.
- In the ES scenario the increase would be to 486,000 LU in the 10% ES scenario (5.95% of the total in England) and to 1.2 million LU (14.9%) in the 25% ES scenario.
- The lower numbers of livestock units in the ES scenarios compared with the IO scenarios are the result of the lower proportion of temporary grassland in the ES scenario.

Table 3: England organic crop output ('000 tonnes) projections to 2030 for different crops under current, 10% and 25% scenarios.

England total crop output 28,896,648 Tonnes.

	Current: 2022	Ideal Organic: 2030 – IO		Equal Shares: 2030 – ES	
	T	10% T	25% T	10% T	25% T
Cereals	164,278	635,481	1,587,568	1,018,963	2,547,408
Other arable[1]	1,980	140,559	351,397	118,107	295,268
Horticulture[2]	146,271	666,316	1,665,790	380,752	951,880
TOTAL	312,529	1,442,356	3,604,755	1,517,822	3,794,556

Notes:

[1] – Other arable includes: peas, beans, other legumes [2] – Horticulture includes: vegetables, potatoes, salads, fruit and nuts

Table 4: England under organic management, total livestock (Livestock Unit - LU), under current, 10% and 25% scenarios

Livestock type	Current	Ideal Organic: 2030 – IO		Equal Shares: 2030 – ES	
		10%	25%	10%	25%
	Livestock Units (LU)				
Dairy	45,000	95,000	238,000	80,000	199,000
Other cattle	129,000	275,000	687,000	230,000	575,000
Sheep	31,000	66,000	166,000	55,000	139,000
Goats	0	0	1,000	0	0
Pigs	9,000	29,000	72,000	29,000	72,000
Poultry[1]	27,000	91,000	228,000	92,000	230,000
TOTAL	**241,000**	**557,000**	**1,391,000**	**486,000**	**1,216,000**
% of non-organic	**2.94**	**6.80**	**17.01**	**5.95**	**14.86**

Notes: [1] – Poultry – eggs and meat

Reduction in livestock numbers in England

- Table 5 show the projected reductions for ruminants (cattle, sheep and goats) and for non-ruminants (pigs and poultry) under different scenarios.
- The reduction in total livestock numbers resulting from 25% organic farmland is highly relevant for reducing greenhouse gas (section 3.8) and ammonia emissions, as well as balancing the projected reduction in crop output (section 3.2).
- Based on organic production in 2022, ruminant numbers are reduced by 2.7% and non-ruminants by 1.5% compared with the situation that might exist if all land were stocked at the current rate on non-organic land.
- In the 10% IO scenario ruminant livestock would reduce by 5.8% (14.4% in the 25% IO scenario).
- In the 10% ES scenario ruminant livestock would reduce by 4.8% (12.1% in the 25% ES scenario)
- In the 10% IO scenario non-ruminant livestock would reduce by 5.0% (12.5% in the 25% IO scenario).
- In the 10% ES scenario non-ruminant livestock would reduce by 5.0% (12.5% in the 25% ES scenario)
- The projected reductions in livestock numbers are compatible with the continuing decline in consumer demand for livestock products. Large cohort studies in France[26] and earlier studies in Germany have demonstrated that organic consumers typically consume even less meat and dairy products and more plant-derived products, potentially even reducing the total land area needed to feed the population despite yield reductions19. Recent trends towards veganism and vegetarianism are likely to enhance this.
- Total UK livestock numbers declined in the 2018-2022 period, by 4% on average and by 8-10% for pigs and poultry. Further future declines in livestock numbers could be absorbed through the growth of organic land area, leaving non-organic production less affected.

3.5 Biodiversity impact of organic farming

- Given the diversity of farm types and the wide range of habitats and organisms impacted, it was not possible to conduct a similar quantitative analysis to the other environmental impacts assessed in this report. But it is not unreasonable to expect that a 10 or 25% share of organic farming in UK or England agriculture could increase farmland biodiversity by 3-8% in total. This could be further enhanced if the integration of natural habitats and landscape elements could be increased as part of nature restoration on farmland.
- Impacts on biodiversity are an important aspect of an increased share of organic farming, affecting a wide range of species from soil micro-organisms and earthworms to plants, insects, birds, wild mammals and

Figure 1: Number of studies that show organic farming having a positive (green bar), negative (red bar) or no effect (number in white circle) on biodiversity of various animal and plant groups in comparison to non-organic farm management. Summary of 95 scientific studies.
Source: Pfiffner L. and Balmer O. FiBL 2011)[52]

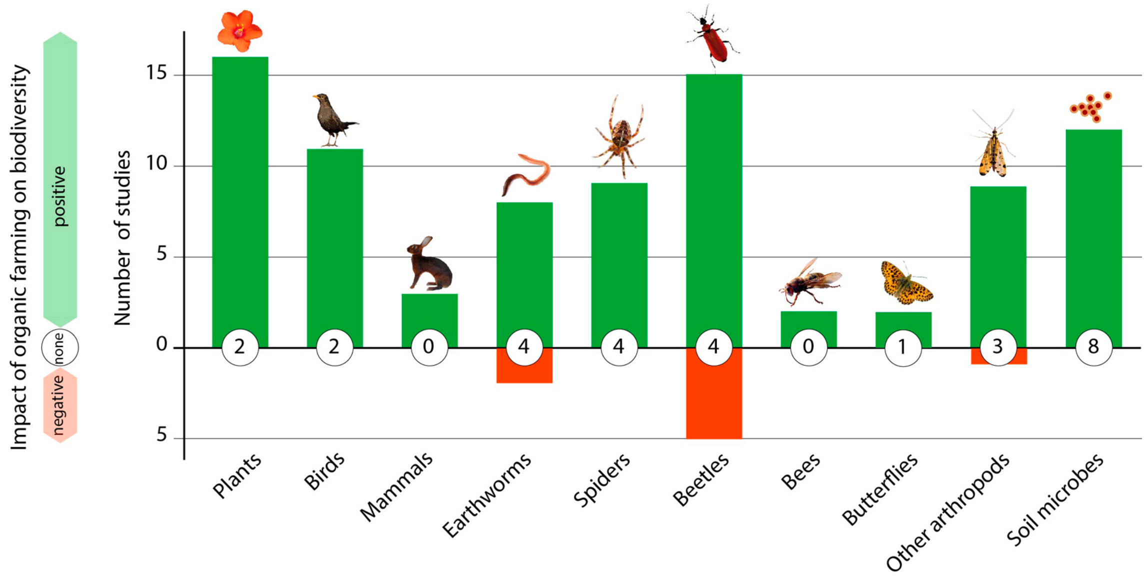

Table 5: Percentage reduction in total England livestock numbers by livestock category on organic land under different scenarios

Livestock type	Current	Ideal Organic: 2030 – IO1		Equal Shares: 2030 – ES2	
		10%	25%	10%	25%
Cattle, sheep & goats	2.7	5.8	14.4	4.8	12.1
Pigs & poultry	1.5	5.0	12.5	5.0	12.5

aquatic life. The impacts have been reviewed in some detail in Sanders and Hess (2019)[27] and Lampkin and Pearce (2021)[28] . They are illustrated, for example, in Figure 1[29] , with some reviews concluding that biodiversity may be increased overall by 30% on organic cropland.

Across the 75 studies reviewed, Sanders and Hess (2019) found that:

- the number of arable plant species was 95% higher,
- the number of field margin plant species was 21% higher,
- the number of farmland bird species was 35% higher, and their abundance 24% higher,
- the number of insect pollinator species was 23% higher, and their abundance 26% higher,
- the abundance of earthworm species was 78% higher, and their biomass 94% higher,
- overall, for flora 86% and for fauna 49% of the comparisons showed clear advantages from organic management,
- only 2 of 75 studies reviewed showed negative effects in 12 out of 312 comparisons.

The biodiversity benefits result from a combination of factors, including:

- Changes in land use associated with extended and diversified crop rotations, including more spring crops impacting on farmland bird populations,
- Non-use of herbicides and substantially reduced use of other pesticides,
- Reduced livestock stocking rates and emphasis on free-range and pasture-based production,
- Reduced nitrogen and phosphate fertiliser use and ammonia depositions protecting nutrient-sensitive species and reducing eutrophication of surface waters,
- Integration of natural habitats and landscape elements, including flower and grass strips and agroforestry, to support beneficial insects, pollinators and other features that also benefit the production system.

3.6 Impact of organic land management on synthetic fertiliser use

The impact of Ideal Organic (IO) and Equal Shares (ES) scenarios at 10% or 25% on synthetic fertiliser use is shown in Table 6, compared to the actual situation in 2022. Estimating the reduction in synthetic fertiliser use as a result of organic conversion involves assumptions and the approach taken is outlined in the Appendix A3. Key facts:

Reduction in nitrogen fertiliser use in England through organic farming

- The area of organic farming in England in 2022 reduces synthetic nitrogen fertiliser consumption by 21,500 Tonnes (3.29% of total fertiliser use).
- A 10% uptake of organic farming in England in the IO scenario could be expected to reduce total nitrogen fertiliser use by 61,000 T, or 9.4% of total N consumption with no organic farming. A 25% uptake of organic farming in England in the IO scenario would be expected to reduce total nitrogen fertiliser use by 152,000 (23.4% of total nitrogen fertiliser consumption with no organic farming.
- A 10% uptake of organic farming in England in the ES scenario could be expected to reduce total nitrogen fertiliser use by 65,000 T, or 10% of total N consumption with no organic farming. A 25% uptake of organic farming in England in the ES scenario could be expected to reduce total nitrogen fertiliser use by 163,000 T, or 25% of total N consumption with no organic farming.

Impact of reduction in fertiliser use through organic farming in England (and UK)

- The reduction in nitrogen fertiliser use through organic farming is important in and of itself. Menegat et al. (2022)[30] estimate EU28 nitrogen fertiliser use to contribute a total of 102.4 Mt CO_2e annually to greenhouse gas emissions, or 9.2 kg CO_2e/kg N used. ammonia emissions
- As significant as the impact on CO_2e emissions is the combined impact on water quality and biodiversity.

Table 6: England under organic management, synthetic fertiliser use reduction (T nitrogen) for different crops, under current, 10% and 25% scenarios.

England total synthetic fertiliser use 2022 (assuming no organic): 650,400 T nitrogen

	Current 2022	Ideal Organic: 2030 – IO T N fertiliser reduction		Equal Shares: 2030 – ES T N fertiliser reduction	
	3.5%	10%	25%	10%	25%
Cereals	6,000	21,000	54,000	34,000	86,000
Horticulture[1]	1,000	4,000	10,000	2,000	6,000
Temp grass & fodder	8,000	16,000	39,000	8,000	20,000
Other arable[2]	0	6,000	16,000	7,000	17,000
Permanent grassland	6,000	13,000	34,000	13,000	34,000
TOTAL	**21,000**	**61,000**	**152,000**	**65,000**	**163,000**
% reduction N fert	**3.29**	**9.38**	**23.44**	**10.00**	**25.00**

Notes:
1 - Horticulture includes: vegetables, potatoes, salads, fruit and nuts
2 - Other arable includes: peas, beans, other legumes

- The modelling completed has not included an estimate of the potential reduction in nitrate leaching, but this could be substantial as organic farming is known to reduce nitrogen balances and consequentially nitrate leaching[31] .
- The 152,000 T, or 163,000 T reduction in N fertiliser use in England that could result from 25% of land area managed organically (IO and ES respectively) could generate a total reduction in emissions of CO_2e emissions of nearly 1.5 million T annually.
- At the level of the UK, where total agricultural GHG emissions amount to 44.8MT CO_2e[32] (there are no England specific data on total emissions), 25% organic land would generate a reduction of 2.2 Mt CO_2e, or 5% of current UK agricultural GHG emissions. This is equivalent to almost 700 kg CO_2e for each ha of organic land.
- About 38% of this reduction is relates to manufacturing and distribution (mainly energy use), with the balance due to reduced nitrous oxide emissions from soils. Impact of GHG reductions arising from organic are further discussed in Section 3.8.

Table 7: England under organic management, pesticide reduction (kg active ingredient a.i.) for different crops under current, 10% and 25% scenarios.

England total pesticide use 2021: 12,041,184 kg a.i.

	Current 2022	Ideal Organic: 2030 – IO Kg a.i. reduction			Equal Shares: 2030 – ES Kg a.i. reduction		
		10%	25%	% of total	10%	25%	% of total
Cereals	111,403	430,942	1,076,587	42%	690,996	1,727,489	61%
Horticulture[1]	64,961	295,061	737,653	29%	168,606	421,516	15%
Temp grass & fodder	5,892	11,073	27,682	1%	5,536	13,841	<1%
Other arable[2]	10,508	267,663	669,707	26%	251,831	629,576	22%
Permanent grassland	5,542	12,208	30,519	1%	12,208	30,519	1%
Rough grazing	63	224	559	<1%	224	559	<1%
TOTAL	**198,279**	**1,017,171**	**2,542,707**		**1,129,401**	**2,823,500**	
% reduction pesticide	**1.65**	**8.45**	**21.12**		**9.38**	**23.45**	

Notes:
1 - Horticulture includes: vegetables, potatoes, salads, fruit and nuts
2 - Other arable includes: peas, beans, other legumes

Table 8: Potential reduction in pesticide active substance use due to organic management for different crop and pesticide categories. Note: actual pesticide active substance use data is not available for organic farming in the UK and most other countries. 100% values are consistent with organic regulations or normal practice. Other values are working minimum assumptions, actual values could be lower.

	Fungicides incl copper	Sulphur	Herbicides	Insecticides	Seed Treatments	Molluscicides	Growth regulators	Other incl physical
Cereals	100%	50%	100%	90%	100%	100%	100%	100%
Grain legumes	90%	50%	100%	90%	100%	100%	100%	100%
Oilseeds	90%	50%	100%	90%	100%	100%	100%	100%
Potatoes	70%	50%	100%	90%	100%	90%	100%	100%
Vegetables	70%	50%	100%	70%	100%	70%	100%	80%
Temp grass	100%	100%	100%	100%	100%	100%	100%	100%
Fallow	100%	100%	100%	100%	100%	100%	100%	100%
Other arable	90%	50%	100%	90%	100%	100%	100%	100%
Fruits, nuts	50%	25%	100%	70%	100%	100%	100%	80%
Perm grass	100%	100%	100%	100%	100%	100%	100%	100%
Rough grazing	100%	100%	100%	100%	100%	100%	100%	100%

Source: Lampkin & Padel (2023) estimates

3.7 Impact of organic land management on synthetic pesticide use

The impact of Ideal Organic (IO) and Equal Shares (ES) scenarios at 10% or 25% on synthetic pesticide use is shown in Table 7, compared to the actual situation in 2022. Estimating the reduction in synthetic pesticide use as a result of organic conversion involves assumptions outlined in the Appendix A4. Key facts:

Reduction in pesticide use through organic farming

- The area of organic farming in England in 2022 reduced pesticide use by 198,279 kg a.i. equivalent to 1.65% of total pesticide use.
- In the 10% IO scenario the reduction in pesticide use would be 1,017,171 kg a.i., or 8.45% of total pesticide use. In the 25% IO scenario, the reduction would be 2,542,401 kg a.i., or 21.12% of total pesticide use.
- In the 10% ES scenario reduction in pesticide use would be 1,541,563 kg a.i. or 12.8% of total pesticide use. In the 25% ES scenario, the reduction would be 2,823,500 kg a.i. or 23.45% of total pesticide use.
- The larger impact of the ES scenario on pesticide use compared to the IO scenario is because there is a greater proportion of arable cropping in the ES scenario.
- The overall impact on pesticide use in specific crop and pesticide categories have been estimated to assess the overall impact on pesticide use of more widespread adoption of organic farming (Table 8).
- On the basis of our assumptions, organic farming is likely to reduce pesticide use by 100% on grassland, by 98% on arable land and by 95% overall. The main exceptions to these high reductions are horticulture, with potatoes estimated to deliver at least 80% reduction, other vegetables 85%, and fruit 50%. Major component of horticultural use include copper fungicides, sulphur and permitted insecticides.

3.8 Impact on greenhouse gas emissions

The impact of Ideal Organic (IO) and Equal Shares (ES) scenarios at 10% or 25% on reduction of greenhouse gas emissions (kT CO_2e and kg CO_2e per Ha) has been estimated for England. Estimating the reduction in greenhouse gas emissions as a result of organic conversion involves assumptions and the approach taken is outlined in the Appendix A5. Key facts:

Impact of organic farming on greenhouse gas emissions in England (kT CO_2e)

- The potential for reduced UK greenhouse gas (GHG) emissions from 10% and 25% organic land, compared to emission reduction in 2022 are presented in Table 9. Total emission savings have been calculated based on the UK reduction in the emissions in kg/Ha CO_2e in Table 9.
- In 2022, organic farming delivered an estimated reduction of 523 kT CO_2e, or 1.67 % of total adjusted[33] GHG emissions from agriculture and crop/grass LULUCF in 2019.
- The IO scenario is estimated to deliver, at 25%, a reduction of 2,656 kT CO_2e per year, 9.11% of English agriculture-

Table 9: England under organic management, total kTCO_2e reduction (calculated according to the reduction in kgCO_2e / ha estimates in Table 14), under current, 10% and 25% scenarios.

England total agricultural and LULUCF emissions 31,344 kg CO_2e assuming no organic farming.
Source: Lampkin and Padel (2023) estimates

Source of emissions	Current	Ideal Organic: 2030 – IO		Equal Shares: 2030 – ES	
		10%	25%	10%	25%
	kT CO_2e reduction				
Livestock	292	699	1,748	586	1,464
Agricultural soils	58	158	395	150	375
Temporary grass	173	285	713	0	0
TOTAL	**523**	**1,142**	**2,856**	**736**	**1,839**
% of non-organic	**1.67**	**3.64**	**9.11**	**2.35**	**5.87**

Table 10: England under organic management, reduction in CO_2e emissions, kg / Ha, under current, 10% & 25% scenarios.

England agricultural and LULUCF emissions 3,695 CO_2e kg per Ha assuming no organic farming.
Note: Temporary grassland mainly CO_2 sequestration, Agricultural soils mainly N_2O, Livestock mainly CH_4. % values are share of total adjusted 2019 GHG emissions (agriculture and crop/grass LULUCF, full column represents total GHG reductions, kgCO_2e per Ha, on all organic land). **Source: Lampkin and Padel (2023) estimates**

Source of emissions	Current	Ideal Organic: 2030 – IO	Equal Shares: 2030 – ES
	Kg CO_2e / ha reduction		
Livestock	969	817	685
Agricultural soils	192	185	175
Temporary grass	574	333	0
TOTAL	**1735**	**1335**	**860**
% of non-organic	**47.33**	**36.42**	**23.46**

related emissions, and at 10%, 1,142 kT CO_2e per year, 3.64% of English agriculture-related emissions.

- The ES scenario is estimated to deliver, at 25%, a reduction of 1,839 kT CO_2e per year, 5.87% of English agriculture-related emissions, and at 10%, 736 kT CO_2e per year, 2.35% of English agriculture-related emissions.
- The difference in the reduction of emissions in the IO and the ES scenarios is the result of the difference in the crop areas estimated (see Table 2).
- The emission reduction is greater in the IO compared to the ES scenario due to the higher proportion of grass and clover fertility building crops in IO (18.6%) compared to the ES (9.3%) scenario and a greater proportion of cereals and other arable crops in the ES (40.3%) compared to the IO (34.3%).
- This emphasises the outcome of the carbon sequestration potential grass and legume fertility building phase characteristic of organic rotations.
- The estimated emissions reduction in the IO and ES scenarios exclude the emissions arising from the reduced use of manufactured synthetic nitrogen fertilisers (Table 7). The reduction amounts to 61 kT nitrogen fertiliser (10% IO), 152kT (25% IO) and 65kT (10% ES), 163 kT (25% ES). This non-use of nitrogen fertiliser equates to an additional saving of 2.13 kT CO_2e (IO 10%), 5.31 kT CO_2e (25% IO) and 2.27 kT CO_2e (ES 10%), 5.69 kT CO_2e (ES 25%).

Impact of organic farming on per Ha greenhouse gas emissions in UK (kg CO2e per Ha)

- The kg CO_2e per Ha emissions for livestock, cropped land and temporary grass land in the IO and ES scenarios compared to the actual emissions in 2022 are presented in Table 10.
- The total emissions from UK agriculture were 3,665 kg CO_2e per Ha, assuming that there was no organic farming.
- The reduction in emissions per Ha from the area of organic land in 2022 was 1,735 kg CO_2e per Ha, or 47.3% of non-organic emissions – 968 kg CO_2e per Ha less from livestock, 192 kg CO_2e per Ha less from cropped land and 574 kg CO_2e per Ha less from temporary grassland.
- In the IO scenario, the reduction in emissions is reduced to 1,335 kg CO_2e per Ha (36.4% of non-organic emissions per Ha). In the ES scenario it is 860 kg CO_2e per Ha (23.46% of non-organic emissions per Ha).
- Emissions associated with the manufacturing of the fertiliser would add a further 300 kg CO_2e per Ha in the IO scenario, or 888 kg CO_2e per Ha in the ES scenario

4. Conclusion

This assessment of an organic land use policy presents the impact of a 10% (three-fold increase) or 25% (eight-fold increase) conversion of England's land to organic management. It shows that there are considerable benefits to be gained.

A clear land use policy that incorporates an organic option would help to ensure that the benefits already being delivered by existing organic farmers are secured whilst also encouraging more organic land management and thus further enhancing the environmental benefit.

The organic approach delivers on multiple objectives and provides multiple benefits. Organic has a proven track record with scientifically demonstrated outcomes, as revealed by the modelling in this organic land use policy paper. Organic farming can be an option for system change. Organic production is an exemplar of agroecological and regenerative principles.

The clear definition of organic farming practices, included in legally regulated standards, allows for the consequence of the implementation of organic farming on the area of organic crops, the numbers of livestock and the environmental impact of increased uptake of organic farming in England. As a consequence, the environmental impact of conversion to organic farming (to 10% or 25% of England's farmland) can be estimated.

The potential impact of organic farming is significant – even at the currently low level of uptake (3.5%), with a higher proportion it would make a valuable contribution to the achievement of the Government's environmental targets. Organic farming enhances biodiversity, reduces the use of synthetic fertilisers and pesticides, and reduces the emission of greenhouse gases.

Support for the uptake of organic farming through Defra's Environmental Land Management Sustainable Farming Incentive and through the Countryside Stewardship can go some way to enable the increased uptake of organic production in England.

New policies are required to provide the necessary advice to farmers wishing to convert to organic methods, improve the flow of knowledge and information and to invest in research and development to further improve the performance of organic farming.

Further work is required to estimate the costs and the value of the benefits arising from conversion to organic. It is clear that the benefits do not necessarily have a financial value, however, this does not mean that they are worthless, merely that they can't be easily valued.

Appendices

A1 Estimating Organic Crop Yields:

- Estimating the expected yield of crops under organic management has been based on an analysis of available data. Meta-analyses of organic yield data[34] have concluded that globally, on average, organic yields are 20% lower than non-organic. However, this hides a high degree of variation between crops and between countries. Crops which in a particular region are produced conventionally with high nitrogen inputs, for example wheat in northern Europe, tend to show much larger yield differences than crops produced with less, and the same crop grown in different parts of the world at different intensities may show very little difference.
- Analysis of Eurostat data of selected conventional agricultural products and of similar organic products produced in each EU country and the UK confirm the difference between crops like wheat with high nitrogen use conventionally and therefore higher yield gaps, and crops like oats, rye, durum wheat and grain legumes, where less nitrogen is used, and the yield gap is correspondingly lower. For horticulture, other factors may be involved, which are not possible to assess on the basis of the data sets available. For vegetables, grading standards including unit size may be relevant factors affecting yield assessments, and horticultural systems are notoriously diverse in terms of scale and cropping activities.
- UK organic yields as a proportion of non-organic[35] estimated using the approach outlined above were somewhat higher than the EU averages calculated from Eurostat data, and were therefore assumed to be:

  - Cereals 50%

  - Potatoes 60%

  - Vegetables 50%

  - Other arable 65%

  - Fruit 60
- Productivity of organic systems will be increased by a combination of better quality land converting, better training and advice on system optimisation, and further research to improve organic systems. A 20% improvement in yield per hectare seems to be reasonable.
- It is necessary to be very cautious about the quality of organic yield data available, and the extent to which it reflects the productive potential of organic systems. There are also further issues to be considered when looking at relative yield data, especially from agricultural survey data such as the Farm Business Survey. Conservative output estimates have been made, based on the fact that:

  - Farms may be mixed organic and conventional, or in-conversion, with no clear identification of individual product status in the survey returns.

  - The organic farms may be present based on a sampling frame for all of agriculture rather than ensuring a representative sample of organic farms, with group averages not providing a like for like comparison and more complex analytical approaches needed to ensure comparability.

  - Organic farms that converted earlier may also be predominantly drawn from more extensive holdings, in which case productivity differences are determined more by location than by management.

  - Research evidence shows that yields tend to increase on organic farms during and after conversion, due to a combination of developing skills and experience as well as the system benefits, for example from rotations becoming better established.
- The question of the physical productivity of organic farms is much debated, in part due to concerns that environmental benefits achieved on a per hectare basis may not be realised on a per tonne of product basis, leading to the exporting or leakage of environmental problems to land elsewhere, often in other countries.
- There is also a tendency to focus on individual crop yields, rather than on total system yield and its relationship to demand or human needs. Most cereals produced in the EU,

Table A1: Organic share of total UK and England crops and livestock, 2022

Crop/Livestock Category	Organic share of UK total (%)	Organic share of England total (%)
Agricultural land	3.13	3.52
Permanent grassland	4.07	4.47
Arable land	2.91	2.93
Cattle	3.1	4.25
Sheep	2.22	2.09
Goats	1.08	1.25
Poultry	1.95	1.63
Pigs	.67	0.64

for example, are used to feed to livestock, while ruminant livestock at least could be more reliant on grassland rather than cereals in their diets, and potentially more animals can be sustained per hectare of grassland than per hectare of cereals. Thus it might be expected that a reduction in cereal output under organic management would be balanced by a reduction in livestock production with more reliance on pasture to feed ruminant livestock, reduced consumer demand for non-ruminant products and ruminant meat and dairy products, and reduced food waste. Together these would mean that whole system output would be sufficient. These are complex questions to answer, but it is necessary to do so to get the full picture.

A2 Livestock in Organic Farming

- Table 1 shows the total organic share in UK and England of crops and livestock in 2022.
- Although organic farming is often associated with the keeping of livestock and the use of livestock manures, this does not mean that livestock numbers will increase overall as a result of converting more land to organic. More typically, livestock numbers are reduced compared with non-organic production due to a combination of:

  - the prevalence of extensive grassland in many regions,

  - the non-use of nitrogen fertiliser on grassland,

  - the reduced use of cereals as feed for ruminants, and

  - free-range production of non-ruminants.
- This can be seen from the lower shares of organic in total livestock numbers compared with organic land shares in 2022 (Table A1):
- To estimate 2030 organic livestock numbers, we have assumed that numbers will increase in proportion to the area of temporary and permanent grassland for ruminants, and arable land including temporary grassland for non-ruminants. Average stocking rates were calculated on this basis, using the livestock unit (LU) conversion factors defined by Eurostat[36] . As our dataset was limited to consistent values for dairy cattle and other bovine animals only, we used a compromise value of 0.75 LU/head for other bovines. The average stocking rates in the UK and England in 2022 were calculated as summarised in Table A2.
- The higher relative stocking rates per ha total agricultural area result from inclusion of temporary grass in both forage and agricultural area, and from the full rough grazing area being included in total agricultural land.
- These stocking rates were used to estimate the increase in total livestock units for ruminants and non-ruminants under different scenarios, and proportional increases were applied to the individual livestock category numbers.

A3 Nitrogen supply in organic and non-organic farming systems.

- Organic farming does not use synthetic nitrogen fertiliser, which has significant positive environmental impacts, including:

  - reduced climate-relevant nitrous oxide and ammonia emissions,

  - reduced nitrate leaching affecting water quality, and

  - positive biodiversity impacts through the reduction of eutrophication in surface waters and the protection of N-sensitive species.
- Nitrogen fertiliser production is also an energy intensive process, accounting for 50% of energy use in European agriculture[37] as well as GHG emissions of about 3.5t CO_2e/t N[38] . This is normally attributed to manufacturing rather than agriculture in GHG inventories. This clearly results in an underestimate of the agriculture related GHG emissions, since the GHG emissions arising from the manufacture of fertiliser is an essential component of the ultimate agricultural use and consequent emissions.
- The primary source of nitrogen in organic farming is biological fixation through legumes, in particular clover/grass or lucerne/grass mixtures which according to the IPCC[39] have negligible direct nitrous oxide and ammonia emissions.
- This approach to nitrogen supply also results in significantly reduced nitrate leaching risks (except at the point of ploughing-in the grass-clover pasture, which only happens on approximately half – or less – of the total organically farmed area).
- This approach to nitrogen supply also contributes to other

Table A2: Organic stocking rates for ruminants and non-ruminants compared with non-organic, UK and England, 2022

	UK		England	
	Organic stocking (LU/ha)	% of non-organic	Organic stocking (LU/ha)	% of non-organic
Grazing livestock units per adjusted forage hectare *	0.85	62	0.94	67
Non-ruminant livestock units per arable hectare	0.30	57	0.25	50
Total livestock units per hectare agricultural land	0.74	82	0.80	85

* Rough grazing converted 4:1

benefits including increased soil carbon, soil biodiversity and pollinators.

- The utilisation of the fertility building forage crops including legumes by livestock and the recycling of the nutrients through livestock manures and slurries or biogas digestate can however lead to nitrous oxide and ammonia emissions as well as losses to water courses, but these losses are reduced at least in proportion to the reductions in livestock numbers on organic farms (see Section 4.7).

Synthetic fertiliser use on non-organic crops

- Data on nitrogen fertiliser use for most individual crops and grassland can be found in the annual British Survey of fertiliser practice[40] . For the purposes of this modelling exercise, it was necessary to combine values for different crops, which we did using a simple averaging approach generating values ranging from 0kgN/ha on grain legumes, uncropped areas and rough grazing, to 130kgN/ha on cereals. On this basis, 650,400 Tonnes synthetic nitrogen fertiliser N were applied in England, on average 57 kg/ha, on non-organic land in 2022.

A4. Use of pesticides in organic and non-organic farming

- The use of pesticides in agriculture and concerns about their potential impacts on the environment and human health have been a major influence on the development of organic farming and the demand for organic food over more than seventy years. During this time many synthetic conventionally used active ingredients have been prohibited, reflecting these environmental concerns. When in the EU the UK implemented the Sustainable Use of Pesticides Directive[41] and the National Action Plan[42] to deliver a reduction in pesticide use.
- UK pesticide use data is available from the FERA pesticide surveys for different crop groups conducted every few years[43] . These provide detailed information on the quantity of active substances used for different crop and pesticide categories. Much more detailed data is also available on individual products, but these have not been used in this assessment since the vast majority are not permitted for use in organic farming.
- According to the 2020 and 2021 Fera survey reports, a total of 14.5 million kg of active substances (AS) were applied to UK farmland annually (Table A3). The average data shown are for all land in these categories, although actual use values would be higher as not all the land was treated.
- While the use of active substances as an indicator of pesticide use is more precise than total product quantities, which may include water for dilution or other non-active substances, it has little relevance in terms of potential toxicity or environmental impact. The development of the Harmonised Risk Indicator20 at EU level is an attempt to address this, by grouping active substances in generic hazard categories. This is, however, not adequate[44] to assess many of the products used in organic farming, such as sulphur and vegetable oils, where the whole product counts as an active ingredient and are used in larger quantities but with minimal environmental impact.
- This undermines the potential contribution of organic farming to pesticide reduction targets. There are more sophisticated approaches available, such as the Pesticide Load Index[45] (PLI) developed in Denmark, implemented in a number of countries, and supported by University of Hertfordshire databases[46] on active substances. However, the application of the PLI approach requires information on individual active substances not currently available in the UK, nor through Eurostat.

Use of pesticides in organic farming

- As far as organic farming is concerned, not all pesticides are prohibited, but the vast majority are, and for some categories such as herbicides, no products are permitted.

Table A3: Annual pesticide active substance use in UK agriculture, 2020/21 Source: FERA Pesticide Use Surveys

Adjusted agricultural area (excl common rough grazing)	Total pesticide AS use (kg)	Average pesticide AS use (kg/ha)
Arable land	14,492,687	0.9
- Cereals for grain	13,745,906	2.3
- Grain legumes	8410025	2.6
- Oilseeds	649917	2.6
- Potatoes	1123393	3.2
- Vegetables, herbs, other hort	1925983	14.1
- Temp grass, incl land for pigs	671558	5.3
- Other arable crops (fodder, sugar beet, maize)	85321	0.1
Fruits, berries and nuts	879709	1.9
Permanent grassland	495855	14.8
Rough grazing	230691	0.0

- Many of the permitted products[47] (Table A4) are either natural, food-based, or microbes such as Bacillus thuringiensis.
- In general terms, chemically synthesised pesticides are prohibited, with a few exceptions such as ferric phosphate as a molluscicide, copper compounds used as fungicides, and products like deltamethrin permitted only for use as an insecticide in pheromone traps.
- There is however a big difference between products being permitted for use in organic farming and their actual use in practice, which may be restricted to a small number of specialist crops. There is currently no dataset available indicating how much pesticide is actually used in organic farming, on what crops and on what proportion of land area.
- While organic regulations specify that records on the use of pesticides need to be kept by farmers, and these are checked by the authorised control bodies, the data are not normally collected or collated for analysis of actual usage at a sector level.

Use of copper-based fungicides in organic farming

- Of the permitted products in organic farming, copper compounds have attracted the most critical attention, due to the potential environmental impact of copper accumulation in soils. This problem is well-recognised within the sector, with several research projects and regulatory adjustments leading to significant reductions in copper use over time[48]. Historically (from 1992), 40 kg Cu/ha over five years were permitted in organic farming, reduced to 30 kg in 5 years in 2008. The current EU organic and pesticide regulations permit a maximum of 28 kg Cu/ha over a seven-year period, or 4 kg/ha per year on average, and copper is identified as a candidate for substitution.
- In a study[49] of the use of copper-based fungicides in 12 European countries (BE, BG, DE, DK, EE, ES, FR, HU, IT, NO, CH and UK), Tamm et al. (2022) estimated that 3,258 t copper metal per year is used by organic farming, equivalent to 52% of the permitted annual dosage according to the EU organic regulations. This amount is split between olives (1,263 t/year), grapes (990 t/year), and almonds (317 t/year), followed by other crops, including potatoes, with much smaller annual uses (80 t/year). In 56% of the allowed copper use cases (countries × crops), farmers use less than half of the permitted amount of copper, and in 27%, they use less than a quarter.
- As statistics specifically for copper compounds are not readily available, we have attempted to analyse the potential scale of organic copper use relative to total copper use at the European level (Table A5). We have done this on the basis of the Tamm et al. study with respect to average copper use on different organic crops (potatoes 2.0, vegetables 0.4, fruit and nuts 1.6, grapes 2.8, citrus 2.4, olives 2.0, other permanent crops 1.2 kg/ha) multiplied by the total area of those crops. Less than 4 t Cu were estimated to used on organic farms in the EU in 2020, representing 30% of total EU27 sales, and 50% of the permitted usage levels in organic farming.
- 70% of copper use in EU agriculture is attributable to conventional farms, which is consistent with the findings of a recent French study[50]. However, average use per ha is higher on organic land than on non-organic, as non-organic farmers make use of alternative products.

A5. Greenhouse gas emissions from agriculture

- Four main sources of greenhouse gas emissions from agriculture:
  - Breakdown of soil organic matter and crop residues releasing mainly carbon dioxide (CO_2), potentially reversible if cultivated land is restored to grassland or forestry
  - Enteric fermentation in the digestive system of ruminant livestock, and livestock manures generally, releasing mainly methane (CH_4)

Table A4: Main active substances used in organic farming by pesticide category

Category	Usage in organic farming
Herbicides	None
Fungicides & bactericides	Copper, Sulphur
Insecticides & nematicides	Pyrethrum, biologicals
Seed dressings	None
Molluscicides	Ferric phosphate
Growth promoters	Negligible (citrus oils for storage)
Other	Mineral & vegetable oils

Table A5: Estimated copper fungicide (Cu) use on organic farms in EU27 Member States, CH, NO and UK

Country	Total sales 2020 (t)	Estimated organic use (t)	Organic as % of total	Organic max at 4kg/ha limit	Organic as % of total
EU27	12,312	3,762	30.6%	6,797	55.2%
UK	50	12	23.2%	26	51.3%

- Mineralisation of nitrogen from fertilisers and atmospheric deposition in soils releasing mainly nitrous oxide (N_2O)

- Energy use in the manufacturing of inputs like fertilisers and for mechanical operations on farmland, releasing mainly CO_2

- Ammonia (NH_3) emissions from livestock and fertiliser use are also relevant as an indirect source of nitrogen leading to N_2O emissions.
- The IPCC methodologies and national inventories for greenhouse gas emission reporting are notoriously complex. We have not attempted to calculate a complete carbon budget for organic farming due to data limitations. Instead, we have focused on some areas where clear potential for reduction exists. These three areas are:

- Reduced livestock numbers (Section 3.4) and pro rata impacts on methane emissions,

- Reduced N-fertiliser use (Section 3.6) and pro rata impacts on N_2O emissions, and

- Increased proportion of temporary grassland in arable rotations (but not in equal share scenarios), with potential for carbon sequestration (reconversion to permanent grassland could be more effective, but assumed not to be significant land use change in this context)

- This analysis bridges the Agricultural and LULUCF cropland and grassland categories in the IPCC national inventories but does not include energy use in manufacturing or on farms. In particular the energy use for nitrogen fertiliser production is significant, accounting for 50% of energy use in agriculture.
- For practical reasons, we have used the UK data for 2019 published by Eurostat as the basis for total GHG emissions. The Eurostat data covers a limited number of key parameters listed in Table A6, which lists the assumptions made to estimate potential greenhouse gas emission reductions. The assumptions link to sections of this report, including crop areas, livestock numbers, nitrogen fertiliser use and ammonia emissions.
- We are conscious that there are many other ways in which organic management might reduce greenhouse gas emissions or increase carbon sequestration, for example:

  - Improved manure management and application systems
  - Reduced tillage
  - Changes in livestock diets
  - Changes in rooting depth of crops due to reduced surplus application of fertilisers, leading to more carbon stored lower in soil profile
  - Inclusion of plantain in diverse forage mixtures reducing N_2O emissions[51]
- Due to the lack of appropriate data on the uptake of these practices on organic farms, we have not included any estimates of their impacts in this analysis.

Table A6: Assumptions used to estimate organic reductions for Eurostat published emissions parameters

GHG Emissions parameter	Assumption used
- Livestock	Sum of enteric and manure management reductions
- - Enteric fermentation	Sum of component reductions
- - - Enteric fermentation of cattle	Reduced pro rata to reduction in number of cattle
- - - Enteric fermentation of sheep	Reduced pro rata to reduction in number of sheep
- - - Enteric fermentation of swine	Reduced pro rata to reduction in number of pigs
- - - Enteric fermentation of other livestock	Reduced pro rata to reduction in number of livestock
- - Manure management	Sum of component reductions
- - - Cattle manure management	Reduced pro rata to reduction in number of cattle
- - - Sheep manure management	Reduced pro rata to reduction in number of sheep
- - - Swine manure management	Reduced pro rata to reduction in number of pigs
- - - Other livestock manure management	Reduced pro rata to reduction in number of livestock
- - - Manure management - indirect N2O emissions	Reduced pro rata to reduction in number of livestock
- Rice cultivation	No change
- Managed agricultural soils	Combination of N-fertiliser and ammonia reductions
- - Managed agricultural soils - direct N2O emissions	Reduced pro rata to reduction in total N-fertiliser use
- - Managed agricultural soils - indirect N2O emissions	Reduced pro rata to reduction in ammonia emissions excluding manure management (see above)
- Prescribed burning of savannas	Not applicable
- Field burning of agricultural residues	Total of cereals, other agricultural residues reductions
- - Field burning of cereals residues	Reduced by % of cereals land organic as not permitted
- - Field burning of pulses residues	No change
- - Field burning of tubers and roots residues	No change
- - Field burning of sugar cane residues	No change
- - Field burning of other agricultural residues	Reduced by % of arable land organic as not permitted
- Liming	No change
- Urea application	Reduced pro rata to reduction in total N-fertiliser use
- Other carbon-containing fertilisers	Reduced pro rata to reduction in number of livestock
- Other agriculture	No change
Land use, land use change, and forestry (LULUCF)	No change in unspecified categories, only cropland
- Cropland	Only unconverted grassland
- - Drainage, rewetting, other management of organic and mineral cropland soils - emissions and removals	No change
- - Unconverted cropland	50% increase in temporary grassland @ 5t CO2e/ha
- - Land converted to cropland	No change, assumed permanent grassland maintained
- Grassland	No change
- - Drainage, rewetting, other management of organic and mineral grassland soils - emissions and removals	No change
- - Unconverted grassland	No change
- - Land converted to grassland	No change

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