Farm sector modelling under the Ten Years for Agroecology project

Final Report

Soil Association

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Executive summary

This report summarises agroecology modelling by eftec and Strutt & Parker for the Soil Association. It builds on work by IDDRI on the effects of a transition to agroecology at the European and UK levels. The objective of the project is to provide insight into the changes that a shift to agroecological farming and diets would involve at the England farm level. It does not consider the desirability of such a change or tell farmers what they must do, but rather it explores whether it is feasible and provides the basis for a discussion about its implications.

The Modelling Process

The work has built an initial model, mainly using Farm Business Survey data, of the current agricultural system in England, and of the potential 2018 Organic and 2050 Agroecological scenarios. 2018 Organic models a scenario where all existing conventional farms in England in 2018 are operating as broadly similar farm types but as organic farms, based on currently available data. This farm level model of outputs is then compared to the higher level agroecological model for 2050 developed by IDDRI.

Using FBS data, the baseline model covers nine dominant current farm types in England and summarises their average agricultural outputs and economic performance (with and without subsidy) – both at the farm level and grossed up to country level.

The model then analyses what would happen to output and performance if all these farms migrated to agroecological practices, as characterised by seven typical current English organic farm types. These '2018 Organic scenario' practices are represented using assumptions on yields and stocking rates based on data on organic systems that are available for England; these yields are generally lower than the yields used in the IDDRI modelling of future agroecological systems (2050 Agroecological scenario), which is referred to as 'Ten Years for Agroecology ' or TYFA, and which additionally assumes some increase in yields due to research and improvements in farm systems.

The work has identified and applied methods to use the model outputs to calculate changes in the monetary value of key benefits from the natural environment, under the 2050 scenario. The model has been discussed and reviewed with the Soil Association, IDDRI and other expert advisors, which has helped to refine assumptions.

Farming Results – "going organic"

Current conventional farming in England does not meet current food demand for almost all products and as expected, the percentage of current domestic demand that is met, which is called 'domestic coverage', falls further for all food products in the model if all farms in England became organic.

However, the transition to agroecology in the IDDRI TYFA model also envisages a significant shift towards healthier and more sustainable diets (the 'TYFA diet'), so a further stage of our modelling looks at domestic coverage assuming a shift to this 'TYFA diet'. This moves closer to the net import-export balance found in the IDDRI model.

The modelling of economic impacts of a transition of this nature is highly dependent on a number of assumptions and is thus illustrative and not predictive. However, a number of very generalised observations can be made. Under the scenario in which current conventional farm types convert to organic farm types based on current typologies, overall farm income increases. This is dependent on a number of factors and varies according to farm type. The key factors are maintenance of current farmgate prices, the high degree of diversification income reflected in current organic farm businesses, and continued payments for the environmental public benefits of organic farming. Therefore, the Farm Business Income figure for 2018 Organic needs to treated with care and as an illustration only. It could however be considered as a guide for government of the role for continued significant investment for the enhanced public good benefits of organic and agroecological farming.

The further transition to the agroecological scenario

Under the IDDRI agroecological scenario for 2050, domestic demand for most farm products is lower, due to the change to a more sustainable 'TYFA diet', apart from for fruit (called permanent crops /orchards in the tables) and vegetables. This is despite factoring in the increase in population in England by 2050 and is partly due to a switch away from farm production to feed livestock toward crops that feed people; and greater use of pasture instead of grain and soya to feed livestock.

So despite the lower yields for many commodities compared to conventional ones ~~depicted~~ in the agroecological scenario, domestic coverage of most farm products increases, with small falls in coverage for oilseeds, milk and sheep meat. Production will be greater than domestic demand for some farm products (including cereals, oilseeds, sugar beet and pig meat), so some produce could be exported.

If the higher yields assumed in the IDDRI modelling are achieved through R&D-driven improvements, this is positive in terms of the ability of England to grow more of the food it will need, and the impacts on natural capital. That scenario requires a significant change in the balance of crops grown (e.g., less cereals, more pulses and legumes, more fruit and vegetables). This would not be realised through the straightforward organic conversion scenario in the 2018 Organic model, and would likely require significant changes on a large number of farms. There would probably be fewer changes on farms that continue to grow field-scale crops, significant changes on farms that start to produce fruit and vegetables and a shift towards integrated cropping and livestock operations.

The level of production under the IDDRI agroecological scenario assumes projected 2050 crop and livestock yields based on a meta-analysis by Ponisio et al that are generally higher than current organic yields in England. The projected yields for most crops are higher than typical current organic yields, so there is a need to critically review potential yields of all organic crops, which will identify crops which need R&D effort to increase yields (where this is possible). The yields for most livestock used by IDDRI and current organic yields are similar, but there is a large difference in the yield for poultry meat, which should be investigated further[1].

Other changes identified that inform the potential transition to future organic and agroecological approaches include:

- The total area of vegetables, including potatoes and carrots, increases significantly under the 2050 Agroecological scenario, raising significant issues of transition and investment costs.
- The overall area classified as arable crops increases under the 2018 Organic scenario, but this is due to a large increase in fertility-building red clover (which is included in this heading as an integral part of the rotation of arable systems). Under the 2050 Agroecological scenario, cereal output drops, whilst that of grass/forage decreases as do overall livestock numbers, reflecting the diet changes described in the "TYFA diet".
- Due to minimal oilseed production on current organic farms and restricted data on UK organic yields, oilseed production does not feature in the 2018 Organic scenario, but it needs to be reinstated in the 2050 model to ensure compatibility with the TYFA diet whilst avoiding imports.
- The proportion of farms that have significant livestock enterprises increase in the 2018 Organic scenario, from around 60% of farms to 69%, although overall livestock numbers fall slightly.
- Employment in farming appears to decrease slightly under the 2018 Organic scenario, but this may be an artefact due to using labour input coefficients from the Farm Business Survey; this should be investigated further as it could be expected that labour units per unit of output increase (as well as costs per unit of output).
- There is a significant increase in woodland area as part of 10% green infrastructure on farms in the 2018 Organic scenario including agroforestry and small woodland expansion, increasing woodland cover in line with the Climate Change Committee target of 19%.

Natural Capital Results

The analysis of natural capital values quantifies impacts on air quality (and human health), emissions and sequestration of green house gases, and water quality of the shift seen in the 2018 Organic scenario[2]. The total present value of these natural capital benefits over the next 60 years is estimated at £74bn. This figure is significant in the context of the current environmental impacts and income from farming, and therefore future policy support.

In the short term, carbon emissions reductions due to ending artificial fertiliser use and

[1] *The improvements in domestic coverage in the 2050 TYFA scenario also reflect a shift to more mixed farming systems and more diverse food production better suited to agroecological farming, in conjunction with diet shift. Overall organic yield gaps are greatest for cereals and reduce with less reliance on cereal crops for animal feedstock.*

[2] *Analysis was applied to the 2018 Organic scenario only. This is because the factors that drive the natural capital impacts quantified (e.g. tree cover, livestock units, fuel and fertiliser use), and therefore the results, are similar between the 2018 Organic and 2050 agroecological scenarios. However, it should be noted that there are material agricultural differences between the two scenarios in terms of agricultural activity (e.g. vegetable production).*

sequestration in trees, and reductions in air quality, have the largest monetary value. Over time, carbon benefits increase in relative value as new tree cover matures and the £ value per tC02e emissions increases, so carbon reduction benefits dominate the present values (PV, calculated over 60 years).

The natural capital benefits calculated are almost certainly an under-estimate. In particular due to methodological issues it has not been possible to include soil carbon sequestration in the calculation and this is likely to be significant.

Conclusion

Overall the results of this work suggest that:

- An agroecological transition in England is a realistic prospect, and is worthy of further investigation as a means of achieving environmental, climate, economic and social targets for the sector and wider society.
- The natural capital benefits of a transition (through the reduction in negative impacts from agriculture) are material in relation to the scale of economic activity in the sector and to the case for government spending and policy to support such a transition.

Contents

1.Introduction

The aim of this project is to provide insight into the changes that a wholesale shift to agroecology would involve for the UK, at both a farm and macro-economic level.

To do so, a model of English agriculture is developed, allowing a comparison of the current (baseline) production with an agroecological production model (based on current organic metrics) and then a further comparison with the outcomes of the IDDRI[3] agroecological model. This is then linked to natural capital evidence to assess some potential wider values to society from resulting changes in public goods. The analysis does not consider the desirability of such a change or provide advice on how farmers could make such a transition, but it does assess some of the benefits that might accrue, and identify some of the policy challenges that will arise in such a transition.

To achieve the project aims, the objectives of the modelling are to:

- Better understand the changes that a shift to agroecology would involve, in order to encourage and engage those involved in food production and the food chain more widely in shaping that change.
- Illustrate some of the farm level and macro level challenges of going down this route and help inspire a policy debate on the issues.
- Work jointly to scope, refine, undertake, and present this work in a way that will have maximum credibility and impact with policy makers and thought leaders in the farming sector.
- Produce a product that illustrates the changes a shift to agroecology would involve and provide a platform for further work stages.

Agroecological approaches are not always precisely defined, but involve minimising the use of external synthetic inputs (i.e. chemical fertilisers and pesticides), restoring soils and enhancing the biodiversity of farmland. It is often associated with changes in the social dimension of farming. The work has involved research into previously untested areas of analysis. It is therefore exploratory, and while it aims to enhance the evidence base available to inform agricultural policies and strategy, it can also provide learning through challenge and discussion. The need to think through changes to agricultural systems is urgent in the face of multiple challenges, including achieving net zero carbon emissions across the UK, reversing widespread biodiversity loss, and reducing water pollution from agriculture.

To respond to these challenges, small marginal changes to farming systems will not be sufficient. It requires fundamental changes, and therefore modelling of the transition of agriculture to a more sustainable system is needed. This transition has already been analysed in detail for mainland Europe[4], and translated into an initial analysis of what TYFA looks like at the UK level, working alongside the Food, Farming and Countryside Commission (FFCC[5]).

IDDRI's work is complemented by the modelling in this report, which provides granularity and an initial analysis of some economic and farm level impacts. There remains a need for more detailed micro and

[3] IDDRI: www.iddri.org/en. References to its modelling work are below.
[4] Poux, X., Aubert, P.-M. (2018). An agroecological Europe in 2050: multifunctional agriculture for healthy eating. Findings from the Ten Years For Agroecology (TYFA) modelling exercise, Iddri-AScA, Study N°09/18, Paris, France.
[5] Food, Farming and Countryside Commission (ffcc.co.uk)

macro analysis of the transition to agroecological farming, expanding on both our modelling and IDDRI's work. This project is a small step in developing that thinking for the UK, starting with England.

This project has taken two contrasting approaches to illustrate some of the issues that will need to be addressed:

1. The first is to model the conversion of existing conventional farming in England to organic farming based on existing farming patterns and organic production levels. This hypothetical exercise was chosen to illustrate a baseline case of what a wholesale conversion to agroecological farming might look like. A 'bottom up' approach was used, which aggregates the outputs from different farm types, to illustrate how much agricultural production and domestic coverage of England's food demand / needs would change from the current situation.

2. This is then contrasted with the IDDRI European modelling results scaled to an England level. The original IDDRI work illustrated how a broadly self-sufficient Europe could be sustained through agroecological farming, albeit with modified diets. This is a more 'top down' approach, in which it is more difficult to see the effects at the farm level. Comparing the two scenarios enables us to identify some of the issues that will need to be addressed.

2. Model Approach

This section describes the modelling and analysis used for the agricultural model and natural capital benefit calculations.

2.1 Structure of the agricultural model

The project has developed a Microsoft Excel™-based spreadsheet model comparing the current structure of farming in England (the 'conventional' baseline) to two scenarios:

1. An 'all organic' scenario, in which conventional farming in England is converted to organic farming based on existing organic farming patterns and production levels (hereon referred to as the '2018 Organic' scenario).
2. The IDDRI agroecological European modelling results scaled to an England level (hereon referred to as the '2050 Agroecological' scenario.

The baseline of the current situation in England is based on conventional farming systems that reflects the type and number of different farms across the country. To simplify building the model, a single baseline year was chosen - 2018/19 - which was the latest year for which comprehensive data was available. This scenario is referred to as 'Conventional' or the 2018 baseline in the model. Being based on recent Government survey data, it is regarded as a robust baseline.

The model can be amended to perform sensitivity analyses and respond to changes in policies. The model provides data for the English agricultural system, for broad farm types (e.g. lowland grazing livestock), and average farm- type level data for areas, outputs, costs and other variables. Therefore, the model can produce reports at farm level that are linked to the assumptions made at the national level. The variables and assumptions in the model can be altered to explore alternative scenarios (within the limitations of the data and Excel layout), so it can be tailored to individual circumstances to some extent.

Although all UK farming policy is of interest for this analysis, the modelling approach was restricted to England. This was done to reduce the complexity of the modelling process, enabling use of a practical group of farm types in the analysis, which in turn allowed a model to be generated that allows comparison between the baseline and a transition scenario[6]. However, it raised challenges in downscaling some data from UK to England level.

The initial model results are illustrative and will benefit from further testing. The model tried to reproduce and develop IDDRI's modelling of Europe and the UK; while a lot of the underlying assumptions and data was available for those models, not all of it was and some of the differences in results between the England model and IDDRI's could be due to differences in assumptions used. Also, the model differs from the IDDRI UK scenario because it was derived from scaling up existing organic farm type data without changing the structure and number of farm types, while IDDRI's model was based on sets of assumptions for land use

[6] *One of the main benefits of restricting the model to England only is that it allowed data to be used without any manipulation or combining from the Farm Business Survey. It would have been a much more complicated task to try to combine data from England, Scotland, Wales and Northern Ireland. It is possible to extend the modelling to the whole of the UK now that the structure of the model has been designed and we would recommend building the data up to UK level country-by-country.*

for three agrarian regions[7].

This initial stage of work provides a platform for further phases, which may involve bringing together different disciplines and specialisms. The outputs from this stage in the project are intended to form the basis for further research projects. Further work could include more detailed analysis of the natural capital and economic impacts at both farm and aggregate level, further development of the macro-level economic impacts, and topics such as the policy issues to be addressed in the transition, infrastructure requirements, employment patterns etc.

To support the modelling of these scenarios robust data that includes land use, livestock numbers, yields, costs and financial returns from the different farm types was sourced. In addition the data, ideally, must be updated regularly to enable the model to be kept up-to-date. A number of datasets were considered, such as the Nix Farm Management Pocketbook and other costing books. Data from the Farm Business Survey (FBS) was selected for the scenarios (Conventional and 2018 Organic) as it is: considered to be the most comprehensive; paid for and used by the government (so results may be more widely accepted by government departments); independently collected and verified by agricultural universities; available at England level; and updated annually.

The FBS data is based on nine 'robust' farm types that account for almost all farms in England[8]. These were used to represent the typical farm for each farm type and the data used in the model is the average figure for each farm type, including yields[9]. The data was sourced from the FBS website, FBS reports and Defra publications. The sources used are referred to in the model.

For the 2018 Organic scenario, data is from the FBS's Organic Farming in England 2018/19 report, the 2017 Organic Farm Management Handbook, which is the latest available, and some data from personal communications with the Soil Association's team. To use this data, the modelling defines a set of organic farm types that are based on the organic farm types used by the FBS. It was assumed that conventional farms would convert to their closest organic equivalent (see **Table 2.1**). This is not, of course, a "real world" assumption since normally organic conversion implies a significant enterprise change, but for the purposes of modelling this assumption is needed.

The same farm data (in **Table 2.1**) is also used for the modelling of the 2050 agroecology scenario. The key differences in the 2050 scenario being to use: (i) IDDRI's agroecological yields, where known; and (ii) IDDRI's increased areas of fruit and vegetable production.

Using this modelling structure, further scenarios could be investigated to inform thinking on agricultural policy. Other scenarios could include a business as usual scenario for 2050 that factored in the influence of expected climate change, and a net-zero transition scenario, to inform the UK Climate Change Committee's

[7] *One of the effects of the modelling approach used for England is that all (or at least most) of the organic farms will achieve a nutrient balance individually. In IDDRI's approach this balance may not happen at the farm level. IDDRI has described this by stating, 'The mixed nature of farming systems does not need to be reached at the farm level, and some field crop systems or, alternatively, livestock systems can reach a certain level of specialisation, provided that the complementarity between the cropping systems and the livestock systems can be organised at a territorial level'.*

[8] *There is a tenth robust farm type which is called 'Non classifiable' but no / little data is published for it.*

[9] *It may be possible to extend the model so that it takes into account the different levels of economic performance of the different farm types, such as a low performance band of the bottom 25% of economic performers, a medium performance band of the middle 50% of performers and a high performance band of the top 25% of performers. This would make the model considerably more complex and may only be possible for the conventional baseline and not the 2018 Organic scenario due to FBS sample sizes affecting data availability and reliability.*

analysis by using the Committee's assumptions on changes to farming systems. Both of these scenarios may help illustrate opportunities for easier to implement changes and also potential challenges or friction points. The model can also be reduced to work at a regional level by changing the number of farms of each type to match current numbers in each region.

Table 2.1: Number of farms by farm type under two scenarios

Conventional (or 2020 baseline)	Number of farms assumed		2018 Organic	Number of farms assumed
Cereals	13,989	→	Stockless arable	13,989
General cropping	5,911	→	Mainly arable	5,911
Horticulture	2,752	→	Horticulture	2,752
Dairy	5,839	→	Specialist dairy	2,920
		"	Mainly dairy	2,920
Grazing livestock (LFA)	6,928	→	Upland (LFA-DA) livestock	6,928
Grazing livestock (lowland)	12,791	→	Lowland livestock	12,791
Mixed	6,003	→	Mainly arable	6,003
Pigs	1,338	→	Pigs	1,338
Poultry	1,573	→	Poultry	1,573
Total	**57,124**		**Total**	**57,124**

Table 2.2: Comparison of yields used in the modelling

t/ha	Baseline / conventional	2018 Organic model yields	2050 IDDRI agroecology yields[10]
Winter wheat	8.4[11]	3.7[12]	5.7
Spring wheat	5.5	4.0	5.7
Winter oats	5.0	4.4	4.3
Spring barley	5.4	3.0	4.7
Spring beans	2.4	1.5	2.3
Potatoes, maincrop	37.1	23.0	29.0
Carrots	Not shown in FBS data	25.0	25.0
Winter triticale	Not shown in FBS data	3.0	5.7
Oilseeds	3.4	n/a[13]	
Sugar beet	68.0	n/a[14]	
Vegetables	21.1	15.8	17.3
Orchards	21.5	16.2	10.2

2.1.1 The spreadsheet and model

The model was built in a Microsoft Excel™ spreadsheet and a description of how it is structured and functions is in a separate user manual.

[10] IDDRI's yields assume some increase in yields due to research and improvements in farm systems.
[11] The average yield in the FBS for both winter and spring wheats is a blend of first and second wheat yields.
[12] The average of the top third of organic wheat yields was 4.4 t/ha.
[13] Not included in the 2018 Organic model as little organic crop is grown in England and no data is available in FBS.
[14] Not included in the 2018 Organic model as little organic crop is grown in England and no data is available in FBS.

2.2 Analysis of natural capital benefits

Building on the agricultural modelling, an assessment of the expected environmental benefits from the transition to the 2018 Organic and 2050 Agroecology scenarios has been made. The scope of the analysis is the impacts from changes within farming systems from livestock, machinery and vegetation in the farmland area. Other impacts in the agricultural value chain (e.g., manufacture of chemicals, transportation of farm produce) are outside scope.

This analysis has adopted a natural capital approach, and as with the agricultural activity model, it builds on assumptions and parameters used for the 2018 Organic scenario. It is a linked but separate modelling step, using data from the farming models, but without feedback into the farming model. The key data that drive analysis of natural capital impact (e.g. livestock numbers, tree cover, fuel use) are very similar between the 2018 Organic and 2050 Agroecology scenarios (although they vary in other ways). Therefore, only calculations for the 2018 Organic scenario are used to illustrate the potential environmental impacts of organic conversion and agroecological transition.

The model considers how the changes to natural capital (e.g., woodland area, livestock) will result in changes to flows of public goods to wider society. The benefits considered were selected for analysis on the basis of being known to be significant within the UK (e.g., based on values from ONS' UK Natural Capital Accounts) and readily availability of data to calculate monetary values of impacts within the project timescale. This means that some material impacts (e.g., changes to biodiversity) are not adequately captured. The approach for each benefit is described below.

The value of these public goods has been estimated based on established models used by ONS/Central government, as captured in Defra's ENCA guidance[15]. It aims to identify the order of magnitude of different impacts, to understand their relative significance and to scope how more detailed and/or spatially explicit analysis would help refine them. The main analysis is of the overall welfare value to society (of public goods), but consideration is also made of potential revenues from environmental markets (e.g., from carbon credits).

The reductions in livestock impacts on air quality and greenhouse gas emissions are based on existing emissions per livestock unit (LU) in each of the main livestock categories (Cattle, Sheep, Pigs, Poultry) in England. These emissions are reduced in line with the estimated percentage reductions in the numbers livestock units, in each livestock category, for the 2018 Organic scenario, compared to the conventional baseline.

The carbon sequestration in woodlands and increased air pollutant removal by woodlands are both based on an assumed change in woodland area. The area of woodland cover in the 2018 Organic scenario has been estimated as part of the agricultural modelling. This increase in woodland (and tree cover) is part of the 'agroecological infrastructure' in IDDRI's model, and is assumed to be integrated into the farmed landscape in ways that are not detrimental to production (e.g. on marginal land, through shelter belts, and in agro-forestry)[16]. For a more accurate analysis, much more detailed modelling, including spatially explicit

[15] *Enabling a Natural Capital Approach (ENCA): Guidance - GOV.UK (www.gov.uk)*
[16] *NB The area of arable and forage crops is just over 200,000 hectares lower in the 2018 Organic scenario and some of this land could also be used for woodlands and the 'agroecological infrastructure'.*

assumptions of change, would be needed.

The calculation of natural capital values sums the annual changes in environmental impacts over 60 years. In the 2018 Organic scenario, unless otherwise stated, environmental changes are assumed to be instantaneous and have an average start of 2020. Under this scenario, it is assumed that environmental impacts related to new areas of woodland (carbon sequestration and air pollutant removal benefits) do not take effect until 2030. This reflects the lag in benefits due to the time it takes trees to grow sufficiently to provide these benefits to a significant level.

2.2.1 Greenhouse gases

The change in greenhouse gas (GHG) emissions between the conventional baseline and 2018 Organic scenario is estimated based on carbon sequestration in trees, emissions associated with livestock, fertiliser and fuel. Soil carbon changes are not included in the analysis:

1. Carbon sequestration in trees

The proportion of woodland cover in the conventional baseline is scenario is 3.9%. For the 2018 Organic and 2050 Agroecological scenarios, this is expected to increase to 9.4% - an increase of coverage of approximately 506,000 hectares. This new woodland would provide carbon sequestration benefits.

An average per hectare rate of carbon sequestration for England was estimated by dividing the total tonnes of CO2e sequestered by woodland in England in 2017 (Woodland natural capital account, 2020)[17] by the area of woodland in England (Provisional woodland statistics, 2020)[18] published by ONS and Forest Research, respectively. These calculations include an assumption, described above, that the benefits of increasing tree cover begin in 2030. No further lag to allow additional woodland growth has been made.

2. Reduced GHG emissions from reduction in livestock numbers.

Under the conventional baseline, livestock produce 8.94 million tCO2e of emissions each year. Under the 2018 Organic scenario, a decrease in livestock emissions of 10.2% is estimated: corresponding to a decrease in emissions of 0.91 million tCO2e/yr.

3. Reduced emissions of GHG from ending the use of inorganic fertiliser (a source of $N0_2$, a significant GHG).

It is assumed that there is a 100% reduction in the use of inorganic fertilisers in the 2018 Organic scenario. The ending of inorganic fertiliser use would save the 2.14 million tCO_2e/yr which they generate (National Atmospheric Emissions Inventory (2020)[19]). Note that GHG impacts from agrochemical manufacture and use are outside the scope of the analysis, as are other supply chain impacts such as feed and nutrient transport.

4. Reduced GHG emissions from reduced fuel use in operations, based on a reduction in fuel agricultural costs under each scenario.

Under the 2018 Organic scenario the purchase of fuel for agricultural operations falls by 20.5%, due to

[17] *ONS (2020) Woodland natural capital accounts, UK: 2020*
[18] *Forest Research (2020) Provisional Woodland Statistics: 2020 Edition. [online]. Available at: https://www.gov.uk/government/statistics/provisional-woodland-statistics-2020-edition*
[19] *National Atmospheric Emissions Inventory (2020). Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990 – 2018. [online]. Available at: https://naei.beis.gov.uk/reports/reports?report_id=1000*

factors such as lower applications of synthetic chemicals and better soil management. Currently UK agricultural fuel use is 1.41 million tonnes of oil equivalent[20]. England accounts for 74% of the gross output from UK agriculture[21], so is assumed to generate 74% of emissions from fuel. Therefore, the reduction in agricultural fuel use is estimated to save 488,000 tCO_2e/yr in the 2018 Organic scenario.

Changes to GHG emissions are valued based on Government guidance on the non-traded cost of carbon[22]. Based on BEIS guidance for valuing greenhouse gas emissions, this gives annual savings of £1.9 billion in 2030 under the 2018 Organic scenario. Values are reported in 2020 prices. The value of these savings rises to approximately £2.59 billion in 2050 (2020 prices), due to the escalating valuation of the damage from carbon emissions.

The total net reductions in GHG emissions from agriculture are shown in **Table 2.3**. Net reductions in GHG emissions are estimated at 6.84 million tCO_2e/yr in the 2018 Organic scenario.

Table 2.3: Summary of GHG Impacts of 2018 Organic Scenario

Carbon summary		Million tCO_2e/yr (2030)	2030 value (£m, 2020 prices)	£m PV60 (2020-2080)
New woodland - sequestration		3.3	927	21,916
Reduced emissions	Livestock	0.91	255	8,050
	Fertiliser	2.14	599	18,875
	Machinery	0.48	137	4,314
Total		**6.84**	**1,918**	**53,156**

2.2.2 Air pollution

Changes in air pollution impacts were considered in relation to two processes:

1. Changes in tree cover:

- Trees are assumed to be distributed evenly across England. The value of additional pollutant removal, in terms of protecting public health, is estimated using the Defra Survey of Agriculture data and the CEH-eftec tool[23].
- The physical flow (kg per ha) and monetary flow (£ reduced health costs) are calculated as an average of the value of benefits of new woodland[24].
- The air quality improvement due to an increase in tree cover under the 2018 Organic scenario saves 3.3 million kg/year of air pollutants. This corresponds to a reduced health cost worth £664m/ yr.

[20] *ONS (2020) Energy use by industry group, source and fuel, 1990 to 2018. [online] Available at: https://www.gov.uk/government/statistics/agriculture-in-the-united-kingdom-2019https://www.ons.gov.uk/economy/environmentalaccounts/datasets/ukenvironmentalaccountsenergyusebyindustrysourceandfuel*
[21] *Defra (2020) Agriculture in the United Kingdom 2019. [online].*
[22] *BEIS. (2021). Valuation of energy use and greenhouse gas. Supplementary guidance to the HM Treasury Green Book on Appraisal and Evaluation in Central Government. Data tables 1 to 19: supporting the toolkit and the guidance. Available at: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal#history*
[23] *Pollution Removal by Vegetation (ceh.ac.uk)*
[24] *This assumes that the new farm woodland has the same spatial distribution as new woodland that would be created to bring all local authorities in England up to <10% tree cover. These average values are then applied to the 500,000 ha of new woodland generated across England. This average figure can be applied to different areas of new woodland creation estimated through any future changes to the agroecological model.*

2. Reductions in emissions from livestock

- Under the conventional baseline, livestock produce a variety of air pollutants in the UK, including 178,000 tonnes of ammonia[25] per year, which is damaging to human health.
- Simplistically estimated in proportion to livestock numbers, approx. 25% of these emissions originate in England[26] - 46,000 tonnes of ammonia.
- A 20.4% decrease in livestock emissions under the 2018 Organic scenario avoids 9,419 additional tonnes of ammonia being produced annually.
- Based on UK average damage costs of ammonia of £7,923 per tonne (UK government, 2021[27]), this gives a benefit from reduced air pollution of £75 million per year under the 2018 Organic scenario.

Note that there is uncertainty about how changes in the level of emissions translates into lower impacts: emissions sources are distributed differently across the landscape. The amount of damage per tonne of emission is contingent upon the emission source's distance from populated areas.

2.2.3 Water quality

The 2018 Organic scenario assumes ending the use of chemical inputs in agriculture. Synthetic fertilisers in agriculture are estimated to account for approx. 90% of fertiliser used in England, the remaining 10% is derived from livestock systems (Defra, 2021[28]). This would lead to a significant reduction (but not eradication) of the surplus of nutrients from farm systems. Use of pesticides would also end.

The reduction in fertiliser associated with ending use of inorganic fertiliser might almost completely remove the surplus of nutrients in farming systems that results in water pollution. However, lags in soil nutrient build up/cycling, climatic variables and other factors means this is uncertain. Furthermore, uses of organic fertiliser in place of inorganic fertiliser could potentially cause local nutrient surpluses. Therefore, based on expert judgement, it is (conservatively) assumed that there is a 75% reduction in the impact of diffuse agricultural sources on the quality of rivers in both scenarios. There is potential for further analysis of additional benefits to water quality in lakes and coastal waters.

This impact is valued based on the number of rivers with Water Framework Directive status below good due to agricultural nutrients. A 75% reduction in these nutrient impacts results in 10,400 km of rivers improving their WFD status. The values used are derived from the NWEBS data[29], widely used by the Environment Agency. These give a total value of £279 million per year for river water quality improvements in the 2018 Organic scenario. Unlike the other benefits included in these accounts, which are not expected to produce benefits until 2030, water quality benefits are expected to occur immediately from 2020 onwards, and the present value presented has been calculated on this basis.

Reduction in agricultural diffuse pollution will also result in reduced water treatment costs for the water

[25] *Defra (2021a) Inventory of Ammonia Emissions from UK Agriculture 2019. [online]. Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat07/2103191000_UK_Agriculture_Ammonia_Emission_Report_1990-2019.pd f*
[26] *Defra (2021) Inventory of Ammonia Emissions from UK Agriculture. [online]. Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat07/2103191000_UK_Agriculture_Ammonia_Emission_Report_1990-2019.pdf*
[27] *Gov.uk (2021). Air quality appraisal: damage cost guidance. [online] Available at: https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance*
[28] *Defra (2021) Fertiliser usage on farms: Results from the Farm Business Survey, England 2019/20.*
[29] *Metcalfe, P. (2012). Update of CRP WFD Benefit Value - Economic Component, report for the Environment Agency.*

sector, and therefore likely lower household water bills. Analysis of this benefit is not possible without further assumptions to link ending use of agrochemicals to reduced nutrient concentrations in water abstracted for treatment by water companies. The savings depend on other sources of nutrient pollution in water, and the capital and operating costs of water treatment processes where savings would arise.

2.2.4 Key unquantified benefits

While the services reported within these accounts are substantial, there are likely several other ecosystem services that would be impacted under both scenarios which have not been covered in these assessments. All the individual benefits in Defra's ENCA guidance (2020) were considered for inclusion in the account. Notable omissions include flood risk regulation, landscape values, food production, and soil quality. These services were excluded due to the nature of the model used for the 2018 Organic scenario (e.g. they are not spatially explicit), as well as the limited wider economic evidence currently available for evaluating some ecosystem services. Additionally, ENCA's 'bundled' ecosystem services were excluded to avoid double-counting with the individual benefits already captured. A qualitative assessment has been prepared for unquantified services which are believed to be impacted substantially in both scenarios.

In addition to these ecosystem service benefits, there could also be substantial human health benefits under the 2018 Organic scenario as a result of healthier diets. These impacts have not been modelled.

Recreation

It is expected that recreational value of farmland increases under the 2018 Organic scenario. This is due to diversification of farming types in local areas and a reduction in chemical inputs, both of which support an increased biological and landscape diversity.

Analysis of this value has been undertaken for the two agriculturally least diverse regions of England (North West and Eastern). In each of these regions, the total value of outdoor recreation is estimated at around £1 billion, with approx. £300 million of that derived from recreational uses of agricultural areas. Unfortunately, uncertainty over the local baseline state of the agricultural environment used for recreational activity means that the change in landscapes used for recreation, and therefore the change in value, cannot be accurately modelled. This analysis may be more feasible if a regionally disaggregated agroecological model within England is developed.

Recreational benefits from use of the natural environment in England are estimated at around £8.2 billion, with approx. £2.4 billion of this value derived from recreational uses of agricultural areas. This analysis relates primarily to local recreation and does not take account of tourism spending associated with visits to the natural environment. It also does not allow for any changes to access to farmland. Under the an organic/agroecological scenario, the more diverse landscape, with 10% green infrastructure, would facilitate provision of a denser network of footpaths (e.g., alongside more hedgerows) with lower opportunity cost to farming. These factors would be expected to increase recreational values significantly.

Biodiversity

Biodiversity can be described as "*the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this* *includes diversity within species, between species and of ecosystems*"[30]. As an essential component of ecosystem cohesion, high levels of biodiversity of both flora and fauna improve the provision of several other ecosystem services. Though essential in ecosystems, the monetary valuation of biodiversity is developing, complex, and, in many contexts, contentious. There are qualitative indicators, such as the presence of Sites of Special Scientific Interest (SSSIs) or Special Protection Areas (SPAs) which can be used as proxies for the abundance of biodiversity in an area. Predicting where such sites may occur into the future under the 2018 Organic scenario would be incredibly complicated and has not been performed. Under this scenario, however, the reduced levels of fertiliser and machinery fuel use or conducive to lower pressure on natural assets and can help to facilitate an increase in biodiversity.

[30] CBD (2006) https://www.cbd.int/convention/articles/?a=cbd-02

3. Results and Conclusions

The key outcome of this project to develop the agricultural model is that overall, the model works; it connects significant amounts of data and produces results that are coherent and stimulate further discussion.

3.1 Agricultural modelling results

3.1.1 Comparison of the conventional baseline with the 2018 Organic scenario

This section outlines what the changes in land use, production and its value and domestic coverage of demand for different agricultural products would be if all conventional farms converted to organic production (see Table 2.6).

Land use

Arable crops

The overall area of land used for arable crops would increase by 13%, almost entirely due to large increases in spring beans (widely used in organic as dual fertility-building and cropping, and to replace soya for feed) (409% of current area) and fertility-building red clover (826,000ha). The areas of all other crops would fall. See Table 2.6.

Forage crops

The area of forage crops would decrease to 85% of its current area; however, the greater area of red clover grown in mixed systems, which is accounted for under arable crops, would mean the overall area available to feed livestock would increase slightly.

Production in tonnes

Arable crops

Despite the increase in arable area, the total tonnage of all arable crops would more than half in the 2018 Organic scenario, due to a combination of smaller areas of crops grown (apart from spring beans and potatoes) and lower yields. Cereals production would be 49% of current levels. Due to low areas currently in organic production, resulting in limitations to FBS data, the model shows no oilseed rape or sugar beet being grown, and low levels of vegetable and fruit production.

Livestock

There is a similar picture for livestock production, with production of all types of livestock falling. Beef production would remain similar (95% of current production) and sheep production drop to 83% of current production. Milk production would fall (to 62% of current production) but the largest reductions would occur for pigs and poultry meat (to 15% and 27% of current production respectively), due to much lower stocking rates in organic systems.

Value of production

The value of the arable crops and livestock produced has also been modelled based on the current prices paid to producers; in practice due to the large changes in production in tonnes, the prices of crops and livestock are likely to change significantly, but this has not been modelled in this analysis which rests on current conventional and organic farm gate prices.

Arable crops

The value of the arable crops produced falls (to 90% of current value), with lower total value for all crops apart from spring beans, potatoes and winter oats.

Livestock

The value of the livestock produced increases (to 103% of current value). The value of beef, poultry and eggs produced increases, mainly due to the higher price currently paid to producers for organic products. The value of milk produced would fall (to 76% of current value) as the reduction in the number of cows and lower yields is not fully offset by the higher organic milk price. The value of pig meat production would fall significantly (to 26% of current value), due to the large reduction in tonnes produced.

Domestic coverage of England demand

Current demand for the main food products (including for livestock feed) produced on UK farms was modelled by IDDRI[31] based on the current diet of the current UK population; this has been scaled down to England level and compared with what the 2018 Organic scenario could produce (see **Table 3.1**).

As expected, the percentage of current domestic demand that is met, which is called 'domestic coverage', falls for all food products. Therefore, as expected, the 2018 Organic scenario based on current organic systems shows a decline in current coverage levels[32].

Table 3.1: Domestic food demand, output and coverage – conventional baseline compared with 2018 Organic scenario

	Physical domestic demand / needs	Physical domestic output	Domestic coverage (%)	Physical domestic output	Domestic coverage (%)
mt unless otherwise stated	CONV 2018	CONV 2018	CONV 2018	ORGANIC 2018	ORGANIC 2018
	84%				
Cereals	21.3	19.2	90%	9.2	43%
Oilseed	2.0	2.9	146%	1.0	49%
Pulses legumes	Inc in oilseed	Inc in oilseed	Inc in oilseed	Inc in oilseed	Inc in oilseed
Permanent crops / orchards	3.9	0.7	18%	0.5	13%
Vegetables	4.0	2.2	55%	1.0	25%
Sugarbeet	11.8	9.3	78%	0.0	0%
Potatoes	5.6	4.2	76%	3.9	70%
Milk	11.9	8.9	74%	5.5	46%
Beef (tec)	0.9	0.5	51%	0.5	48%
Sheep (tec)	0.3	0.1	56%	0.1	44%
Pig (tec)	1.2	0.7	58%	0.1	9%
Poutry (tec)	1.7	1.4	79%	0.4	22%
Eggs (m doz)	0.7	0.5	65%	0.4	53%
Population (m)	55.4				

[31] Poux, X and Schiavo, M. Modelling an agroecological UK in 2050 – findings from TYFA REGIO. IDDRI. Draft Study – N°01/2021
[32] NB Current conventional baseline production does not meet current domestic demand for most products either. See **Table 3.1**.

Livestock distribution and numbers

As shown in Table 2.6, the proportion of farms that have significant livestock enterprises would increase in the 2018 Organic scenario, from around 60% of farms to 69%, as most of the organic farms use mixed cropping and stocked farm systems; the only farms without livestock would be the stockless arable farms and horticultural units (assuming they remain as a 'stand alone' farm type, which they might not) (see **Table 2.1**):

- On general cropping farms there would be significantly more livestock and slightly more on mixed farms.
- On dairy farms the number of dairy cows would reduce (by approx. 100 cows per farm).
- On both upland and lowland livestock farms, the number of sheep may increase, possibly as a result of more land being used to grow feed for the livestock.
- It is not possible to model how the distribution of pigs and poultry will change from the current conventional scenario to the 2018 Organic scenario as they do not appear in the general Farm Business Survey data. Therefore they have only been modelled at England level and not at farm level.

Farm Business Income

The effect on farm profits across England was also modelled, based on current yields, prices and variable and fixed costs. It produced estimates of Farm Business Income, which is the measure of overall farm profitability favoured by Defra, for the individual farm types, which were aggregated to produce England level estimates.

Table 3.2: Farm profits and Farm Business Income – conventional baseline compared with 2018 Organic scenario (£bn/yr)

	Conventional 2018	Organic 2018
Income from agriculture	0.3	1.0
Income from agri-environment work	0.2	0.7
Income from Basic Payment scheme	1.6	1.1
Income from diversified activities	0.7	2.3
Total Farm business income (main farm income measure)	**2.8**	**5.1**

For England, Farm Business Income almost doubles under the 2018 Organic scenario to £5.1bn, compared with £2.8bn for the baseline, due to changes in profits from the four 'profit centres' of farm businesses:

1. Profits from agriculture quadruple under the 2018 Organic scenario to approx. £1bn pa, mainly due to higher profitability of organic livestock production.
2. Income from agri-environment work triple to approx. £0.7bn pa, as the income from agri-environment schemes is much higher on organic farms than on conventional ones; this is possibly as more land receives agri-environment payments on the organic farms compared with schemes for conventional farms.
3. The Basic Payment Scheme (BPS) is treated the same in both scenarios, except that the increase in agri-environment income (see 2) is assumed to be justified by the public benefits supported (see Section 3.2), and financed by a reduction in Basic Payments. It should be noted that BPS is being phased out over the agricultural transition period of 2021 to 2027 in

England, so this 'profit centre' disappears by 2028. These assumptions mean that public payments do not affect comparison of the two scenarios.

4. Profits from diversified activities triple to approx. £2.3bn pa, as organic farms appear to generate more income from diversification than conventional ones.

As a result of changes under 2 and 3 above, the total amount of government support under the 2018 Organic scenario through farm payments would be unchanged (at £1.8bn pa). In practice, how much overall government support there will be is uncertain, due to the phase-out of the Basic Payment scheme, and the introduction of ELMS.

However, more support could be needed for diversified activities, and prices and other determinants of income could fluctuate. Therefore, the Farm Business Income figures for 2018 Organic need to be treated with care and as an illustration only. It could however be considered as a guide for government of how much farm spending would need to switch to organic transition and environmental support under the ELMS, in order to deliver the enhanced public good benefits that organic farming provides.

The variation in farm incomes across farm types as a result of transition towards an agroecological system are explored, using similar assumptions, in a farm level study *The economics of a Transition to Agroecological Farm Businesses* (Cumulus Consultants, 2022, report to the Soil Association).

Table 3.3: **Land use and agricultural impacts summary - conventional baseline compared with 2018 Organic scenario**

	Conventional			Organic			Conventional		Organic			
	ha / no	Production t	Output £	ha / no	Production t	Output £	Yield t/ha	£/t or head	Yield t/ha	£/t or head	ORG as % of CONV (ha)	ORG as % of CONV (t)
Arable crops												
Winter wheat	1,610,497	13,528,178	2,232,149,450	828,105	3,063,989	928,296,673	8.4	165	3.7	303	92%	49%
Spring wheat	0	0	0	484,005	1,936,021	423,988,581	5.5	164	4.0	219		
Winter oats	170,893	854,465	140,986,795	770,787	3,391,462	1,068,310,554	5.0	165	4.4	315	Included in cereals above	
Spring barley	798,880	4,313,951	720,429,896	232,806	698,418	201,842,765	5.4	167	3.0	289		
Spring beans	159,342	382,421	80,308,497	651,756	977,633	294,267,666	2.4	210	1.5	301	409%	42%
Potatoes, maincrop	59,084	2,192,022	449,364,533	169,142	3,890,274	1,167,082,264	37.1	205	23.0	300	286%	177%
Carrots	0	0	0	40,482	1,012,054	394,700,892			25.0	390		
Winter triticale	0	0	0	47,185	141,556	31,142,306			3.0	220		
Oilseeds	565,178	1,921,606	641,816,386	0	0	0	3.4	334				
Sugar beet	152,977	10,402,454	280,866,253	0	0	0	68.0	27				0%
Vegetables	106,953	2,256,072	1,303,549,061	64,537	1,019,685	736,462,352	21.1	578	15.8	722	60%	90%
Orchards	31,562	678,574	740,769,318	31,027	502,641	685,888,928	21.5	1,092	16.2	1,365	98%	74%
Red clover GM	0	0	0	826,102	0	0						
Total arable crops	**3,655,367**	**36,529,745**	**6,590,240,188**	**4,145,935**	**16,633,734**	**5,931,982,980**					**113%**	**46%**
Forage crops												
Short term leys	0			809,842								
Medium / long term leys	0			1,929,871								
Kale / forage rye	0			25,737								
Forage swedes	0			16,993								
Forage rape	0			16,993								
Forage maize	0			47,185								
Permanent grassland	0			1,146,534								
Total forage crops	**4,693,892**			**3,993,156**							**85%**	

	Conventional			Organic			Conventional		Organic			
	ha / no	**Production t**	**Output £**	**no**	**Production t**	**Output £**	**Yield t/ha**	**£/t or head**	**Yield t/ha**	**£/kg output**	**ORG as % of CONV (ha)**	**ORG as % of CONV (t)**
Livestock												
Beef finishing, 18 m		473,137	1,709,918,808	964,220	450,853	1,871,038,961				4.15	95%	95%
Beef finishing, 24 m				224,311	Included in beef above							
Single suckler cows				1,246,582	Included in beef above							
Dairy cows (F/H)				894,805	Included in beef above							
Dairy milk (li)		8,804,511,678	2,641,353,503	Included in dairy cows above	5,452,942,209	2,006,682,733			6,094	0.368		62%
Dairy replacements				176,301								
Tack sheep				471,853							82%	
Upland sheep				3,398,654								
Lowland sheep		135,866	603,246,510	8,920,343	112,549.1	499,718,154				4.44		83%
Pigs		714,087	1,049,707,878	232,382	106,232	270,890,784				2.55		15%
Poultry		1,437,349	1,843,364,409	54,633,712	382,436	3,288,949,478				8.60		27%
Poultry (eggs only; not birds; production in dozen eggs)		608,290,581	406,946,399	16,683,476	388,724,992	544,214,988				1.40		64%
Total livestock			**8,254,537,506**	**87,846,640**		**8,481,495,099**						
Per forage ha												
Farm summary												
Arable crops	44%			51%								
Forage / livestock	56%			49%								
Whole farm	8,349,259			8,139,091								
Number of farms	57,124			54,213								
Area of woodlands and other land	340,498			846,644								
Labour input (full-time equivalents or AWU)	137,737			125,425								

3.1.2 Feeding_England with a 'sustainable diet'

The previous section established that, assuming current organic yields, domestic supply coverage based on current diets would decrease, due to lower yields (see Table 2.2 for yields and Table 3.1 for the change in domestic supply coverage).

This section develops the analysis by looking at the agroecological transition developed by IDDRI. It looks to a further hypothetical 2050 scenario and is based on significant changes happening by 2050, which are: (i) that there is a transition to a 'sustainable diet', which is significantly different to the current UK diet, and (ii) an assumption that the UK will eliminate imported animal feed, which allows the UK to stop imported deforestation.

IDDRI's analysis was carried out for the UK so has been scaled down to England level and compared with the baseline conventional and the 2018 Organic scenarios (see **Table 3.3**).

Domestic demand and coverage

Under the IDDRI agroecological scenario, domestic demand for all farm products is lower (apart from fruit-called permanent crops /orchards in the tables- and vegetables), despite the increase in population in England, due to the change to a 'sustainable' diet.

Because of the higher yields assumed in this scenario, domestic coverage of most farm products increases compared with the current conventional situation, with small falls in coverage for oilseeds, milk and sheep meat. Production will be greater than domestic demand for some farm products (including cereals, oilseeds, sugar beet and pig meat), so some produce could be exported.

The assumption that organic yields could increase with R&D investment suggest that England could grow more of the food it will need to satisfy the "sustainable diet", and there would also be positive impacts on natural capital. The agroecological scenario requires a significant change in the balance of crops grown (e.g., less cereals, more pulses and legumes, more fruit and vegetables). This is likely to require significant changes on a large number of farms – probably fewer changes on farms that continue to grow field-scale crops, and definitely more changes on farms that start to produce fruit and vegetables.

The most significant changes that a switch to a 'sustainable diet' and all farms using an agroecological approach are likely to have are shown in **Table 3.4**, and listed below. The yield gaps between current and needed production are very significant for some crops and they should be explored with crop scientists to assess the feasibility of reducing them. Information should be gathered from farms that have converted to organic systems to identify the main challenges that they faced, where additional skills and training were needed and to record the effects on yields, farm production and profits, so that they can be used as examples for other farmers. Such a significant change to a farming system as converting to an organic or agroecological system will only be made by a large proportion of farmers if they are absolutely sure that the benefits are real.

Table 3.4: Domestic food demand, output and coverage – conventional baseline compared with IDDRI's 2050 agroecological scenario

	Physical domestic demand / needs	Physical domestic output	Domestic coverage (%)	Physical domestic demand/needs	Physical domestic output	Domestic coverage (%)
mt unless otherwise stated	CONV 2018	CONV 2018	CONV 2018	IDDRI ENG 2050	IDDRI ENG 2050	IDDRI ENG 2050
	84%					
Cereals	21.3	19.2	90%	11.8	13.1	112%
Oilseed	2.0	2.9	146%	1.9	3.8	144%
Pulses legumes	Inc in oilseed	Inc in oilseed	Inc in oilseed	0.7	Inc in oilseed	Inc in oilseed
Permanent crops / orchards	3.9	0.7	18%	5.6	3.9	69%
Vegetables	4.0	2.2	55%	7.0	4.3	61%
Sugarbeet	11.8	9.3	78%	0.5	0.9	156%
Potatoes	5.6	4.2	76%	1.9	1.7	88%
Milk	11.9	8.9	74%	7.2	5.0	70%
Beef (tec)	0.9	0.5	51%	0.6	0.5	78%
Sheep (tec)	0.3	0.1	56%	0.2	0.1	44%
Pig (tec)	1.2	0.7	58%	0.4	0.4	109%
Poutry (tec)	1.7	1.4	79%	0.8	0.7	87%
Eggs (m doz)	0.7	0.5	65%	0.3	0.3	80%
Waste coefficient						
Population (m)	55.4			65.3		

Crops

- Much less cereals and oilseeds produced (and current organic yields would need to increase).
- More legumes and pulses produced (and current organic yields would need to increase).
- Much more vegetables and fruit produced (as an increase of 8 – 11 fold and 3 – 7 fold are needed respectively from current production levels or 2018 Organic England levels. Current organic yields are adequate / broadly similar to those used by IDDRI).
- Much less sugar beet grown.

Livestock – largely based on current organic yields which appear adequate

- Less milk produced.
- About the same amount of beef produced.
- More sheep meat produced.
- Much less pig meat produced.
- Many fewer eggs produced.

Yields

The level of production under the IDDRI agroecological scenario assumes projected 2050 crop and livestock yields based on a meta-analysis by Ponisio et al[33], which are generally higher than current organic yields in England:

- The projected yields for most crops are higher than typical current organic yields, in some cases by over 50%, so there is a need to critically review potential yields of all organic crops, which will identify crops which need R&D effort to increase yields (where this is possible)[34].
- The yields for most livestock used by IDDRI and current organic yields are similar, but there is a large difference in the yield for poultry meat, which should be investigated further.

Table 3.5: Domestic food demand, output, coverage and yields –compared with IDDRI's 2050 agroecological scenario compared with the 2018 Organic scenario

	Physical domestic demand / needs	Physical domestic demand/ needs	Physical domestic output	Domestic coverage (%)	Physical domestic output	Domestic coverage (%)	Yields		
mt unless otherwise stated	CONV 2018	IDDRI ENG 2050	IDDRI ENG 2050	IDDRI ENG 2050	ORGANIC 2018	ORGANIC 2018	IDDRI UK 2050	ORGANIC 2018	% difference
	84%								
Cereals	21.3	11.8	13.1	112%	9.2	79%	5.7	3.7	54%
Oilseed	2.0	1.9	3.8	144%	1.0	51%	2.7	-	-
Pulses legumes	Inc in oilseed	0.7	Inc in oilseed	Inc in oilseed	Inc in oilseed	Inc in oilseed	2.3	1.5	53%
Permanent crops / orchards	3.9	5.6	3.9	69%	0.5	9%	10.2	16.2	-37%
Vegetables	4.0	7.0	4.3	61%	1.0	15%	17.3	15.8	9%
Sugarbeet	11.8	0.5	0.9	156%	0.0	0%	44.5	-	-
Potatoes	5.6	1.9	1.7	88%	3.9	204%	29	23	26%
Milk	11.9	7.2	5.0	70%	5.5	76%	5,200	6,094	-15%
Beef (tec)	0.9	0.6	0.5	78%	0.5	76%	126	142	-11%
Sheep (tec)	0.3	0.2	0.1	44%	0.1	52%	56	56	-1%
Pig (tec)	1.2	0.4	0.4	109%	0.1	30%	1,018	579	76%
Poutry (tec)	1.7	0.8	0.7	87%	0.4	46%	2,132	1,000	113%
Eggs (m doz)	0.7	0.3	0.3	80%	0.4	124%	1,719	1,664	3%
Waste coefficient									
Population (m)	55.4	65.3							

[33] *Ponisio LC, M'Gonigle LK Mace KC, Palomino J, de Valpine P, Kremen C. 2015 Diversification practices reduce organic to conventional yield gap. Proc. R. Soc. B 282: 20141396. http://dx.doi.org/10.1098/rspb.2014.1396*

[34] *All of the modelling carried out for this project, and IDDRI's modelling too, is based on 'average' yields. There may be significant variation in yields, above and below the averages, between top and bottom performing organic farmers, which is the case for conventional farmers. This needs to be investigated as, if it is the case, then effort should be invested in increasing the yields on the bottom performing organic farms. Doing this will require better data on organic yields and on the physical and financial performance of organic farms. The data that is currently available is not adequate for this and it is recommended that a much larger sample of organic farms is surveyed as part of the Farm Business Survey (FBS) to help address this data gap.*

3.2 Natural Capital Results

The analysis of natural capital values quantified impacts on air quality (and human health), emissions and sequestration of greenhouse gases, and water quality.

The results, summarised in **Table 3.6**, suggest that reduction in Greenhouse Gas Emissions are the large source of benefit, but improvements in air quality due to air pollutant removal by new woodland and decrease in nutrient pollution pressure on waterbodies are also significant (calculated over 60 years).

Table 3.6: Natural Capital Impacts under the 2018 Organic scenario

Impact	Indicator of change	Physical Measure		Monetary Values		
		2030 Value	Unit	2030 Value (£m, 2020 prices)	PV60 (£m)	PV60 (%) of total value
Air Quality	Change in ammonia emissions	9,419	tonnes	75	1,957	2.6%
	Change in PM2.5 removal by woodland	3,331	tonnes	664	11,701	15.8%
Carbon Reduction	Change in emissions from livestock	911,111	tCO2e	255	8,050	10.9%
	Change in emissions from inorganic fertiliser use	2,136,277	tCO2e	599	18,875	25.5%
	Change in emissions from agricultural machinery use	488,305	tCO2e	137	4,314	5.8%
	Change in sequestration by woodland	3,309,173	tCO2e	927	21,916	29.6%
Water Quality	Decrease in nutrient pressure from agriculture	10,424	km	279	7,325	9.6%
Total				**2,936**	**74,139**	

The equivalent 2030 annual impacts are approximately 11% of the £26.7. billion of gross output, 31% of the £9.4 billion of GVA and 72% of the £4.1 billion of farm income in the UK[35] in 2020. It is approximately the same scale as the subsidies paid to the sector in the UK in 2020[36]. The present values are calculated over a 60 year period, but assume that benefits start in 2020. Further assumptions on the speed of transition to the organic scenario could be used to refine these calculations.

To further put the natural capital impacts in context:

- They would give a reduction of approximately 15% of current GHG emissions from agriculture in the UK.
- Air pollutant removal by new woodland of £664m/yr is a significant proportion of the current value of this benefit in the UK – it is valued at £1,006m/yr in 2015 and £508m/yr in 2030. The relevant data are not broken down to England level, but England does have the majority of impacts, due to having a large majority of the population that are exposed to air pollutants.
- Water quality: the current value of impacts on the ecological status of rivers due to agricultural

[35] *Base data from: Agriculture in the UK 2020 (publishing.service.gov.uk)*
[36] *Brexit next steps: Farm funding in 2020 (parliament.uk)*

pollutants is £362m/yr. Due to the improved condition of water bodies in the Organic scenario, the value of this impact is reduced by £279m/yr, 75% of total current value.

Selected UK ecosystem service values from ONS (2019) are shown in Tables 3.7 and 3.8. These values represent the whole of the UK and are not disaggregated by devolved administration. While the figures in Table 3.6 represent the change that the 2018 Organic scenario is expected to yield, Tables 3.7 and 3.8 shows the annual stocks of each service at a given time (2019). Therefore, caution should be exercised before directly comparing the figures in these Tables.

Table 3.7: ONS ecosystem service stocks and values, 2019

Impacts	Physical Flows		Monetary Flows	
	2019 Value	Unit	Annual value (£m)	Asset value (£m)
Air Quality	1,311,000	tonnes	1,382	45,899
Carbon Reduction	8,888,000	tCO2e	2,110	105,997
Water Abstraction	6,550,000,000	m^3	4,057	109,868

Table notes:

- The 'Air Quality' figures capture the removal of *all* air pollutant types by vegetation in terms of avoided healthcare costs associated with exposure to pollutants (i.e., not exclusive to woodland nor PM2.5).
- The figures shown for carbon reduction are show the 'gross' sequestration of carbon across all habitat types. The values reported do not give consideration to carbon flux. Currently, it is estimated that the UK emits more greenhouse gases than it removes from land use, land use change, and forestry.
- UK natural capital accounts currently do not reflect benefits derived from water quality. The volume and value of water abstracted are presented here to show that while water quality has not been valued, this benefit is likely substantial for England as several billion cubic metres of water are abstracted annually.

Table 3.8: ONS Woodland Accounts ecosystem service stocks and values, 2017

Impact	Physical Flows		Monetary Value (£m 2017)
	2017 Value	Unit	
Air Quality	268,700	tonnes	938
Carbon Reduction	8,350,000	tCO2e	1200

Table note: This table demonstrates the value of select services included in the UK woodland account.

3.3 Conclusions

Having started from a blank canvas (or spreadsheet) this project has established a statistical model to illustrate a shift from, current agricultural patterns to an all organic scenario (2018 Organic) based on current organic farming data. It has then compared these scenarios with the results from IDDRI's work on an agroecological transition, which includes a change to a more sustainable diet.

This is a useful exercise to help illuminate the potential transition of agriculture in England to a more sustainable future model, and provides a basis to build on with more detailed work. The agroecological model output has been linked to three significant improvements in natural capital values, for green house gas emissions, and water and air pollution impacts, all of which would improve (i.e. reduce current negative impacts) significantly.

This project informs the potential pathway of a transition. For example, it highlights a significant deficit in future vegetable production in England which is already a significant net importer of vegetables, but investment would be needed to increase production capacity, and address supply chain barriers. Other scenarios could be modelled in the same way, including a business as usual scenario for 2050 that factors in the influence of expected climate change (by amending yields and gross margins/ cost assumptions), and a net-zero transition scenario, to inform the UK Climate Change Committee's analysis by using the Committee's assumptions on changes to farming systems by amending livestock numbers and woodland (and energy crop) areas.

The results suggest that:

- An agroecological transition in England is not a realistic prospect and is worthy of further investigation as a means of achieving environmental, climate, economic and social targets for the sector and wider society.
- The natural capital benefits of a transition (through the reduction in negative impacts from agriculture) are material in relation to the scale of economic activity in the sector and to the case for government spending and policy to support such a transition.

The modelling itself is relatively simple in structure, but complex to construct and check due to the large volume of data used across the breakdowns of typical farm types used. The completed model allows the Soil Association to help inform a debate about an agroecological transition for England, using for example:

- Data on the likely financial and natural capital values of the 2018 Organic scenario.
- Information on the implications of the transition to advocate for policy and payments and / or training for specific farm types (e.g., fruit production or organic farming) or land uses (e.g., woodland management) and/or increased R&D into organic production.
- The importance of the transition to advocate for more research and better data, for example by including a larger sample of organic farms in the FBS.
- The model to consider other policy implications, such as the case for a fertiliser tax or agri-environment payment levels based on the potential benefits of the transition.

Compared to the model that we built for this project for England, IDDRI's model is overall more sophisticated, but the model reported here has some additional features (including building from farm level and including farm profits), which are important for policy design.

As expected, this initial modelling step relies on significant assumptions and raises many questions, so overall has a medium level of uncertainty. Significant sources of uncertainty relate to:

- Future changes, including in the 'business as usual' baseline, in particular due to climate change and technological change in conventional systems.
- Future conventional and organic farm gate prices.
- Future technological changes that could enable the agroecological transition, including improvements in yields from production systems.
- The need to further validate assumptions on land uses and livestock yields.
- The static nature of the model in terms of some feedbacks (e.g., changes to farm areas when some crop types increase, or changes to prices for specific produce). There is potential for significant further work to develop the model.

- The need to increase vegetable and fruit production.

3.3.1 Further work

In the short term, there is need for further review of the model with IDDRI, in particular in relation to the livestock unit, livestock yield and assumptions about sufficiency of animal feed, and if possible with Farm Business Survey staff. Following that, checks could be made on the dietary implications of the modelled farm outputs.

Other areas where more detail or technical modelling steps could be added include:

- Quantifying how a more diverse farmed landscape with less intensive production and lower agro-chemical inputs would be better for biodiversity. However, the spatial distribution and species groups that would benefit are uncertain, and require further analysis.
- Identifying whether, in the working model, simplifications can be made, such as removing unneeded elements and making elements more dynamic (e.g., gross margin / ha changes if yields change) and having a simpler presentation of results.
- Scenario testing and sensitivity analysis, such as using the UK Climate Change Committee's assumptions on changes to farming systems, to increase understanding of the model and to check feedbacks that will help interpret the implications of the agroecological scenario. In particular, further examination of the nitrogen balance across farm types is needed.
- While there are connections between calculations of yields, crops, and livestock units in the model, making the use of land assets more dynamic to reflect feedbacks.
- Quantifying currently unquantified natural capital impacts that could be valued with more research, including in relation to biodiversity and recreational/tourism value from the agricultural landscape. However, some of the relevant values may require a more spatially explicit modelling, which would require significant additional analysis.
- Extending the model to other UK countries, but this would require using different farm types and would require detailed knowledge of the most relevant data for these. However, the structure of the model for England would provide a useful basis for such work.

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