Exploring the effects on UK food security and land use of four scenarios describing socio-economic responses to COVID-19

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and

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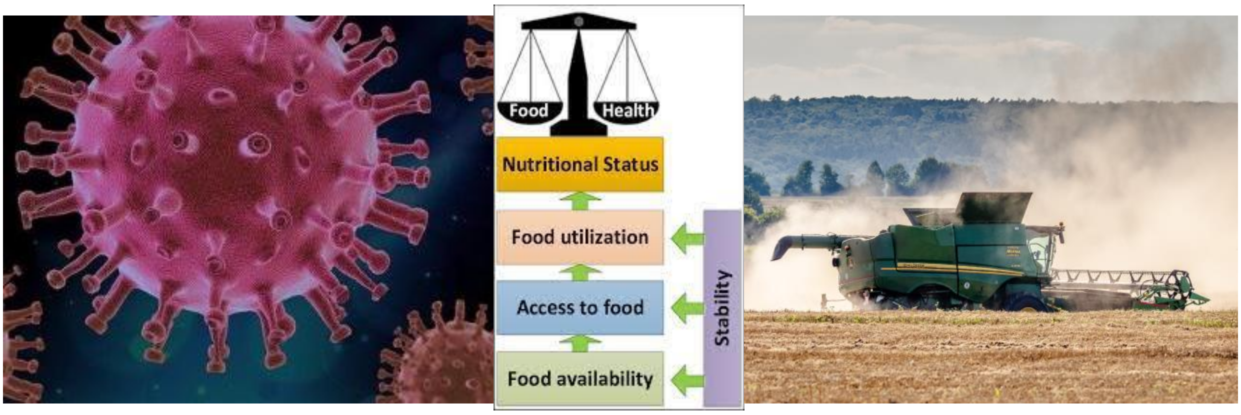

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Executive Summary

The way that the UK Government and others respond to the challenges of COVID-19 recovery and Brexit will have major effects on the UK food system and land use. We examined the effect of four contrasting plausible scenarios, determined by experts, on UK land use and food security, using the IAP2 European-scale land allocation model. The scenarios were assumed to apply to both the UK and the rest of Europe.

Assumptions regarding the level of food imports and the increase in agricultural yields have a major effect on land use in the UK. A trade liberalisation scenario, called Back to Basics and assuming a 10% increase in net imports and increased agricultural yields (+10% from 2020 to 2030), enabled the supply of agricultural and forestry products to match demand, and provided opportunity for greater afforestation in the UK (+5.5%). However increased negative environment effects are anticipated from increased food and timber production outside Europe and associated logistics costs such as transportation, storage, and refrigeration. A UK Recovery First scenario, assuming no change in net imports but similar increased yields also enabled afforestation albeit at a lower level (+2.3%).

Scenarios involving a reduction in net imports reduced the availability of agricultural land for other purposes. Using the IAP2 model, the Best of British scenario, which assumed a 10% reduction in net imports and an allocation of 10% of the arable area to bioenergy, was predicted to result in a small decline in woodland area (-0.4%). A Green UK First scenario added additional constraints of no increase in agricultural yields, a requirement for 5% of arable land to be used for conservation, and reduced fertiliser use (-26%). Whilst this scenario was able to match the supply of crop and milk products to demand, there was a shortfall in meat (-25%) and timber supply (-54%), and the drive to maximise food production (in the absence of other constraints) was predicted to result in the conversion of woodland (-12.5%) to grassland (+12.2%). Matching supply to the demand for meat and 81% of the demand for timber was possible by reducing the demand for meat by 30%, the area of bioenergy crops and conservation area on arable land to zero and maintaining current fertilizer application rates. The results highlight the real trade-offs between a lack of yield increases, increasing use of agricultural land for bioenergy, reduced imports, reduced fertilizer use, current meat consumption levels, increases in tree cover, and food and timber security.

Using soil function indicators, we also highlight how land use changes that may occur under the four scenarios, either positively or negatively impact key environmental benefits supported by soil (carbon storage, primary productivity, water supply, nutrient availability and pollination). Each scenario produces a range of spatially explicit impacts on these soil functions across the UK, with none being 'all positive' or 'all negative'. The Back to Basics and UK Recovery First scenarios are overall more positive in their predicted impacts than the Best of Britain and Green UK First scenarios. Each region sees a variation in land use change impacts across the scenarios, with most regions having some 'mostly positive' and some 'mostly negative' consequences.

In the context of post-pandemic recovery to maintain the UK's food and nutrition security, these results highlight the complexity of balancing objectives from multiple pressures including trade negotiations (affecting imports and exports), improving diet, climate change mitigation (reducing fertiliser use, producing bioenergy, woodland creation) and maintaining healthy soils and ecosystems.

Key points

- A spatial land use model responsive to socio-economic and technological drivers was used to explore trade-offs between UK agricultural yield improvement, food and timber security, bioenergy, net import levels, and targeted increases in tree cover.
- Increasing net food imports create beneficial environmental effects in the UK, but negative offshore effects.
- Top-down targets for high levels of bioenergy production on agricultural land and reduced fertilizer use reduced the release of land for afforestation.
- Methods to reduce UK meat consumption increases alternative options for land use.
- On the basis of the opportunity costs of land, increases in tree cover are easiest to achieve in Wales, Northern England, and southern Scotland.
- Soil function indicator modelling indicated that some scenarios of future land use in the UK have markedly more positive impacts on soil functionality than others. These impacts appear strongly linked to increasing or decreasing net food imports.

Acknowledgements

The UK food and nutrition security during and after the COVID-19 pandemic (C-19 FNS) project is funded by the Economic and Social Research Council (ES/V004433/1) under the UK Research and Innovation Open Call on COVID-19. The Integrated Assessment Platform (IAP2) is publicly available at the following website: http://impressions@project.eu/show/IAP2_14855

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1 Introduction

In 2021, the United Kingdom left the European Union and thereby the Common Agricultural Policy which provided the framework within which British land managers have taken land use decisions since 1972. Moreover, the COVID-19 pandemic has caused major disruption within sections of the food supply chain, particularly in the hospitality sector, and many households have faced increased financial constraints undermining their food and nutrition security.

The National Food Strategy, commissioned by the UK government, produced an initial report in July 2020, and a final report in July 2021 (National Food Strategy 2020, 2021). The report highlighted the need to implement measures to ensure the nourishment of the most disadvantaged children in the UK, and the importance of the UK in ensuring high environmental and animal welfare standards for food imports. The National Food Strategy (2021, page 12) concludes that is "not possible to build a sustainable, healthy and fair food system by doing business as usual".

In response to the COVID-19 crisis, James Hutton, Chatham House and Cranfield University developed plausible scenarios to examine the evolution of the food system in the UK. Through a series of workshops, experts in the food system developed four scenarios describing how UK demographics, economy, public health, institutions and governance, technological advances in UK food and agriculture, and approaches to ecology and climate could develop during the period 2020 to 2030. These scenarios are described by Duckett et al. (2021). The aim of this paper is to examine, using a land-allocation model, how those scenarios could affect land use in the United Kingdom, the balance between demand and supply for crop and livestock products and timber, and the use of fertilizer and levels of nitrogen leaching. Although there are a range of caveats in using such models and scenarios, they can also provide insights into some of the major trade-offs.

1.1 Background to this report

This report is part of a series focussed on the UK's food and nutrition security. The overall project context is to assess the pandemic impact on food and nutrition security, assess options for alternative approaches to food production in the UK, and subsequently explore what lessons can be learned in respect of addressing other risks, particularly climate change, biodiversity loss, and ecosystem degradation.

Further details of the project is available here: COVID-19 Food and nutrition security | The James Hutton Institute. Other associated reports are:
UK food and nutrition security in a global COVID-19 context: an early stock take (Chatham House)
UK food and nutrition security in a global COVID-19 context: an update (Chatham House)
An overview assessment of the COVID-19 pandemic on the UK food and nutrition security (James Hutton Institute).

2 Methodology

2.1 Modelling land use and management

The potential effects of different socio-economic scenarios on land use in the UK were examined using a land use allocation model. The selected model was initially developed for Europe as part of an EU project called CLIMSAVE, and a subsequent version, called IAP2, was developed in an EU project called IMPRESSIONS (Impacts and Risks from High-end Scenarios: Strategies for Innovative Solutions) (Holman et al. 2015; Harrison et al., 2019). The Integrated Assessment Platform (IAP2) model comprises a spatial database that assumes that Europe is divided into 24,128 land grid cells of approximately 16 km x 16 km (Table 1).

Table 1. Some of the key characteristics of the Integrated Assessment Platform 2 (IAP2) model (Holman et al. 2015)

Criterion	Description
Resolution	24,128 10' x 10' land grid cells (approximately 16 km x 16 km) (There are 1315 land grid cells for the UK)
Time period	2011-2020; 2021-2030 etc
Baseline	Socio-economic data used 2010 as the baseline year

The overall objective in developing the IAP2 model was to predict agricultural land use under different climate, socio- and techno-economic scenarios (Audsley et al., 2015). The IAP2 framework includes a rural land allocation model called SFARMOD, which assumes that urban areas, areas of flooding, and protected areas cannot decrease in size, but that changes in agricultural and forest areas are possible (Figure 1).

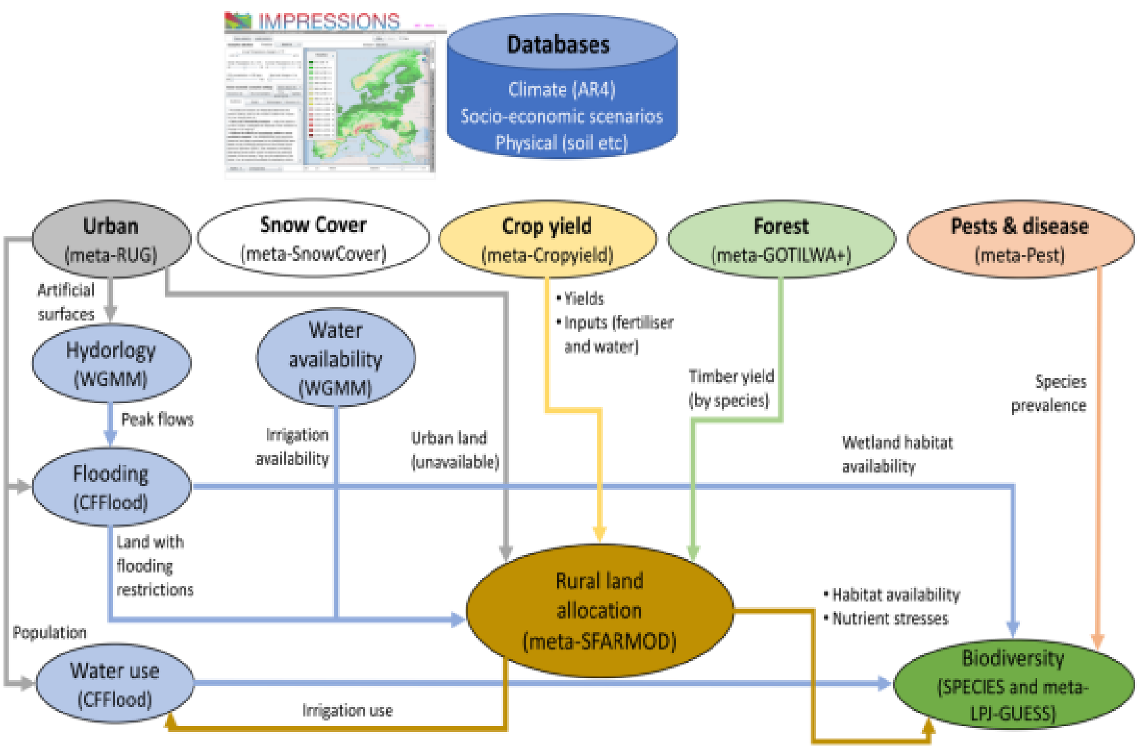


Figure 1. Schematic figure showing the data transfers between the models within the IMPRESSIONS Integrated Assessment Platform, as described in the supplementary material of Lee et al. (2019)

The SFARMOD model uses linear programming to optimise land use (Audsley et al. 2015) based on the results of a metamodel based on ROIMPEL that determines the crop yields for each 10' x 10' grid and soil type combination (Audsley et al. 2006). Using those outputs, SFARMOD calculates the most profitable cropping system that is possible assuming predetermined labour and machinery constraints, restrictions on crop rotation, and the number of days that machinery can be used on the land. The SFARMOD tool also uses forest yield data from a metamodel based on GOTILWA+ (Keenan et al. 2011) and assumes constraints of water availability using a water sector model (Wimmer et al. 2014) (Figure 2).

Within IAP2, a SFARMOD meta-model determines and applies profitability thresholds for arable, intensive grassland, extensive grassland, and forestry systems (Holman et al. 2017). In the original IAP1 model, if the profit was above a pre-designated threshold (for example €350 ha^{-1} for intensive grassland), then that soil type in that grid square would be fully allocated to that land use type (e.g. Cell 1 in Figure 2). If the profitability was below the threshold, the land use would be allocated to extensive grassland or forestry (e.g. in cell 2, the profitability of arable or intensive grassland is below €350 ha^{-1}, so the land is allocated to extensive grassland). If the gross margin is below the threshold for extensive grassland or forestry, then the land is assumed to be unmanaged forest or unmanaged land (e.g. in cell 4 in Figure 2). In the original IAP2 model, the change between land use was assumed to be absolute, but the IAP2 model uses an incremental proportional approach so that a profitability of €351 ha^{-1} for intensive grassland could, for example, result in 51% of the area being intensive and 49% being extensive respectively (Holman et al. 2015)

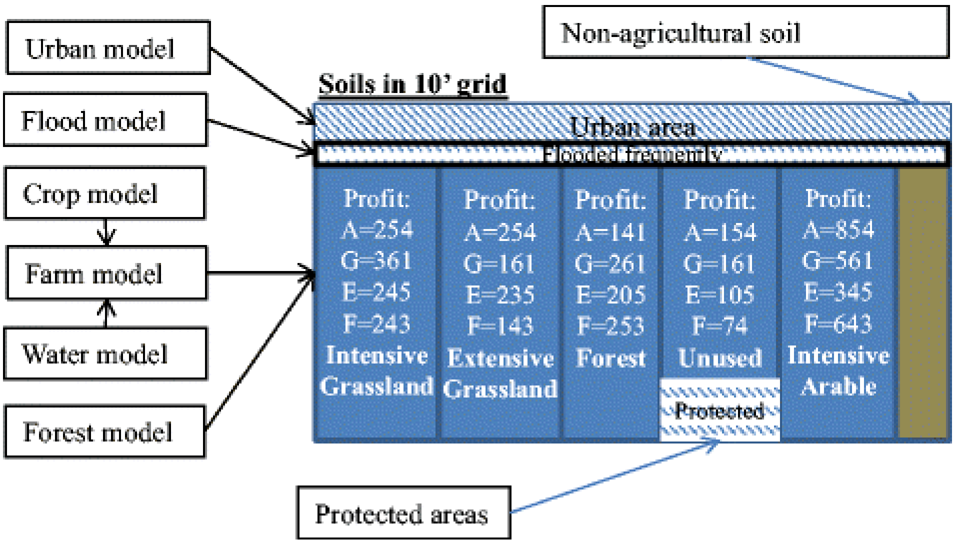


Figure 2. The SFARMOD model calculates the profitability of arable land (A), intensive grassland (G), extensive grassland €, and forest (F) for each soil type in each 10' x 10' grid. The model also designates the urban area, areas of frequent flooding, and limited protected areas. In this schematic example, there are five agricultural soils and an area where there is insufficient soil for agriculture of forestry (Audsley et al. 2015)

2.2 Quantifying the effect of the scenarios on land use drivers

The IAP2 model includes a wide range of inputs which can be adjusted to reflect different climate, socio- and techno-economic scenarios. Meetings were held during May and June 2021 between staff from Cranfield University and the James Hutton Institute to translate the qualitative description of four contrasting socio-economic scenarios (Table 2) into quantified inputs within the IAP2 model (Table 3). Six of the drivers were held constant in each scenario, but there were nine drivers that were altered (Table 3).

Baseline setting: The Food and Nutrition Security and COVID-19 project was designed to determine the effect of different scenarios over a time period of no more than a decade, from a starting point of 2020. Hence the assumed baseline was the default IMPRESSIONS IAP2 default model inputs for 2020. This included a default setting for the population (population change = 0%), and a high oil price (Table 2, Table 3). It was assumed that 3% of the arable area would be used for conservation.

The first scenario, called **"Back to Basics"** assumes increased trade liberalisation and because of the relatively high costs of food production in the UK (and in Europe), it was assumed that this would result in increased imports (+10%). It was also assumed that trade liberalisation would encourage an increase in agricultural productivity of 10% over the 10 years. Although there has been minimal increase in crop yields per hectare in recent years, the production of livestock outputs per animal (for example in the dairy sector) continues to increase (Burgess and Morris 2009). It was also assumed that there was no requirement for 3% of the arable area to be used for conservation and that the general economy showed a high level of growth (+20%).

Table 2. Assumed technical, socio-economic and environmental drivers for the baseline and four scenarios through to 2030

Name of scenario	Key features
Baseline2020	The baseline was based on the IMPRESSIONS estimate of the situation in 2020, which assumed no net change in European population and a high oil price. It was assumed that 3% of the arable area was set aside for conservation activities.
Back to Basics	The scenario assumes a laissez faire trade policy with growing imports (+10%). It is assumed that open trade supports innovation in the food system (10% increase in agricultural yields by 2030 compared to 2010). This was also the most optimistic scenario in terms of GDP growth (20% higher in 2030 than 2010).
UK Recovery First	No strong green recovery; greater tariffs and quotas on imported food. It is assumed that there is no change in the levels of imports and that agricultural yields (and irrigation efficiency) in 2030 have increased by 10% relative to the baseline.
Best of British	A focus on UK food products (and equivalent national schemes across Europe) result in 10% decline in imports. Agricultural yield increases of 10% in 2030 relative to the baseline are also assumed. In addition 10% of the agricultural area is allocated to bioenergy.
Green UK First	This is a green-focus scenario where a reduction in pesticide and fertilizer use prevent an increase in agricultural productivity per hectare. It is assumed that imports are reduced by 10%, that 10% of the area is allocated to bioenergy, and 5% of the arable area is placed in conservation.

The second scenario called "**UK Recovery First"** assumed that the UK Government implemented a recovery strategy that focused on technology, but not specifically green issues. It was assumed that agricultural yields would increase (+10%), and that no arable land was set aside for conservation. In contrast to the Back to Basics scenario, a focus on tariffs was assumed to result in no net change in the level of imports and poor economic performance meant that the level of GDP in 2030 was the same as in 2010.

The third scenario called **"Best of British"** assumed that UK Government support for buying British food resulted in a reduction in the level of imports by 10%. For the exercise, it was assumed that other countries in Europe would follow similar national programmes. In this scenario we also assumed that the UK Government would support a bioenergy programme (10% of the arable area).

Table 3. Assumed changes in technical, socio-economic and environmental drivers for the Baseline and the four scenarios. The changes in net food imports, and the increase in agricultural yield, the arable land used for energy, and the proportion of arable land used for conservation are indicated in bold

Scenario	2020 Base-line	Back to Basics	UK Recov. First	Best Of British	Green UK First				
					V1	V2	V3	V4	V5
Drivers held constant									
Population change (%)	0	0	0	0	0	0	0	0	0
Household preference	3	3	3	3	3	3	3	3	3
Change in oil price (%)	100	100	100	100	100	100	100	100	100
Irrigation cost	1	1	1	1	1	1	1	1	1
Change in white meat preference (%)	0	0	0	0	0	0	0	0	0
GDP change (% from 2010)	0	20	0	0	0	0	0	0	0
Drivers that were varied									
Change in net food imports (%)	0	**10**	**0**	**-10**	**-10**	**-10**	**-10**	**-10**	**-10**
Change in agricultural yields	0	**10**	10	**10**	0	0	0	0	0
Change in beef/lamb preference (%)	0	0	**-5**	**-5**	**-5**	**-30**	**-30**	**-30**	**-30**
Arable land used for bioenergy (%)	0	0	0	**10**	**10**	**10**	0	0	0
Conservation (% of arable land)	3	3	**0**	**0**	**5**	**5**	**5**	**0**	**0**
Reducing diffuse pollution	1	1	**0.9**	1	**1.5**	**1.5**	**1.5**	**1.5**	1
Change in ag. mechanisation	0	0	**20**	0	0	0	0	0	0
Water savings from behaviour (%)	0	0	0	0	**10**	**10**	**10**	**10**	**10**
Water savings due to technology	0	0	0	0	**10**	**10**	**10**	**10**	**10**

The fourth scenario called "**Green UK First**" assumed a negative economic outlook combined with a focus on "green" issues and a 10% reduction in imports starting (Version 1) with the assumption of 10% of the arable area used for bioenergy, 5% of the arable area used for conservation, and a reduction in fertilizer use. A focus of organic agriculture was predicted to result in no increase in agricultural productivity (expressed in terms of yields per hectare) between 2010 and 2030. Version 2 includes the provision for a decline in beef and lamb consumption by 30% by 2030, as recently proposed in the National Food Strategy (Natural Food Strategy 2021). Version 3 and Version 4 assumed no arable land used for bioenergy and conservation respectively, and version 5 removed the constraint of reduced fertilizer use.

The IAP2 model includes a range of drivers. A full set of drivers in provided in Appendix A. The most important drivers, and the assumed values for a baseline condition in 2020, and the four scenarios for 2030 are shown in Table 3.

2.3 Modelling the effects of the scenarios on land use

The effect of the predicted changes in land use, as described the IAP2 model, were used to predict the changes in six main land use categories: urban, arable, intensive grassland, extensive grassland, forest (managed and unmanaged) and "other". In addition, we recorded the effect of the four scenarios on total food and feed production, timber production, the mean fertilizer application rate, and the predicted rate of nitrate leaching. The IAP2 model provides an output for each 16 km x 16 km square. However to present the results, the outputs were averaged or summed for the 12 NUTS2 regions within the United Kingdom (Figure 3)

Figure 3. The 12 NUTS2 areas in the UK

3 Results - land use

3.1 Baseline assumptions

Running the IAP2 land use allocation model for the baseline situation resulted in a modelled urban area for the United Kingdom of 7.1%, an arable area of 15.0%, a grassland area of 42.5%, a forest area of 15.6%, with unmanaged and other areas comprising 19.8% (Table 4).

Table 4. Baseline: modelled proportional areas of different land uses in 12 regions using the IAP2 model

Region or nation	Proportional land use (%)					
	Urban	Arable	Intensive grassland	Extensive grassland	Forest	Other
C: North-East	9.3	15.8	7.4	35.7	19.6	12.2
D: North-West	13.3	4.3	38.6	8.4	24.7	10.7
E: Yorkshire	10.0	32.3	25.6	6.6	14.9	10.8
F: East Midlands	9.4	28.0	51.6	1.2	6.6	3.1
G: West Midlands	12.5	15.7	57.9	1.3	11.8	0.8
H: Eastern England	8.6	48.4	29.8	1.2	7.4	4.6
I: London	75.4	3.2	14.6	0.3	6.5	0.1
J: South East	14.6	10.7	57.6	6.0	7.6	3.5
K: South West	6.8	2.2	59.1	14.9	12.8	4.2
L: Wales	5.3	0.7	43.0	10.2	31.9	9.0
M: Scotland	2.3	13.4	16.7	6.6	17.8	43.2
N: N. Ireland	3.7	8.6	48.0	20.1	6.3	13.2
United Kingdom	7.1	15.0	34.0	8.5	15.6	19.8

The proportion of urban land in the UK in IAP2 (7.1%) is similar to that reported by Eurostat (2021) (6.5%) (Table 5). The proportion of modelled intensive grassland (34.0%) is also similar to grassland area (36%) reported by Eurostat, and the modelled area of extensive grassland and "other" (29%) is broadly similar to proportion reported by Eurostat for shrubland, bare land, wetland and water (26%).

Table 5. Measured land cover in the UK in 2015 (Eurostat 2021)

Region or nation	Area (km^2)	Proportional cover (%)							
		Artificial land	Crop land	Wood-land	Shrub-land	Grass-land	Bare-land	Wet-land	Water
North East	8607	7.1	20.4	9.5	21.2	39.2	1.1	0.4	1.0
North West	14183	11.4	9.2	7.4	19.5	48.6	0.8	1.7	1.4
Yorkshire	15429	9.4	37.5	7.3	12.3	31.5	0.8	0.4	0.8
East Midlands	15643	8.9	46.4	7.1	1.6	33.2	1.5	0.4	0.9
West Midlands	13014	10.3	28.6	10.8	0.7	46.5	1.7	0.2	1.4
East of England	19160	8.5	49.3	10.6	1.2	22.8	6.3	0.8	0.6
London	1576	59.5	3.6	11.4	2.9	22.5	0.0	0.0	0.2
South East	19109	10.2	28.1	18.8	2.5	37.9	0.9	0.5	1.2
South West	23907	5.9	24.3	14.0	2.7	49.7	1.7	0.9	0.7
England	130628	9.4	31.0	11.2	6.3	38.4	2.0	0.7	0.9
Wales	20820	5.4	5.6	15.6	15.2	53.3	1.8	1.9	1.1
Scotland	78971	2.2	7.8	12.4	44.0	22.6	1.2	7.5	2.4
N. Ireland	14155	5.9	3.5	8.6	5.2	66.5	0.7	4.9	4.7
UK	244574	6.5	19.7	11.8	19.1	36.2	1.6	3.2	1.6

There is some discrepancy in that the modelled proportion of cropland (15.0%) is less than the Eurostat value (19.6%), and conversely the modelled area of forest (15.6%) is higher than the Eurostat value of 11.8%. Using the IAP2 model, the highest proportions of cropland are observed in the East, such as in Eastern England (Table 4; Figure 4). The highest levels of intensive grazing occur in the South-West and the Midlands and Northern Ireland. The highest proportion of forest was predicted in Wales, and the highest proportion of unmanaged and other areas was found in Scotland (Figure 5).

a) Urban areas b) Cropland

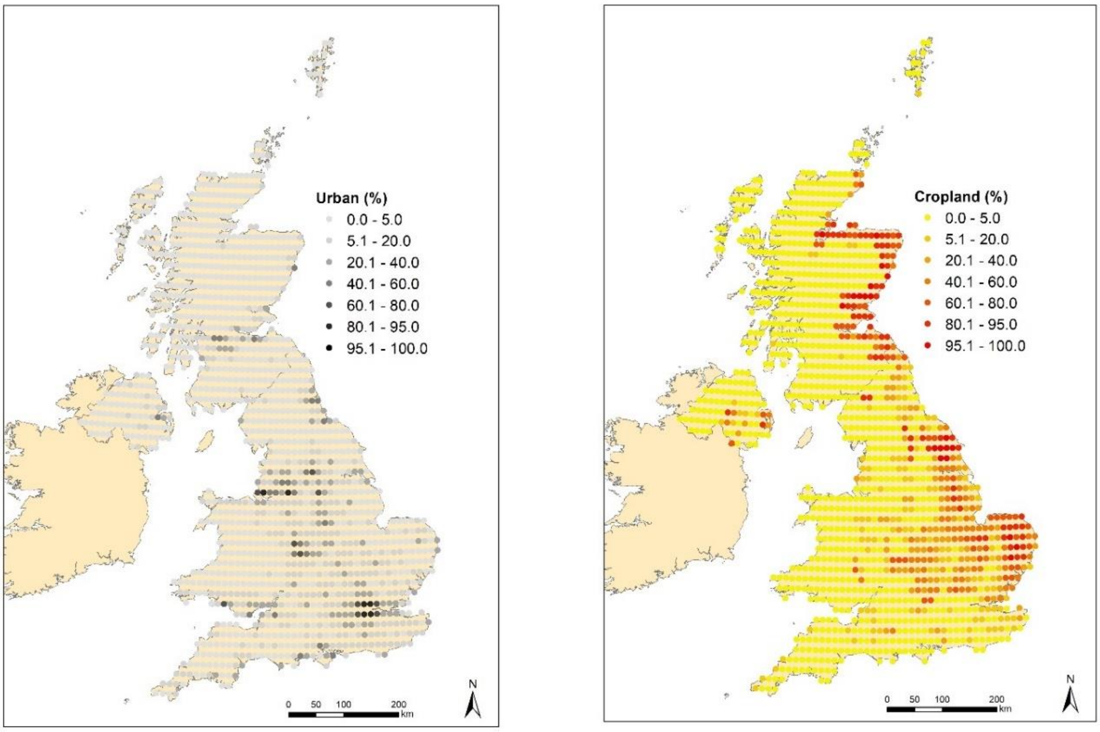
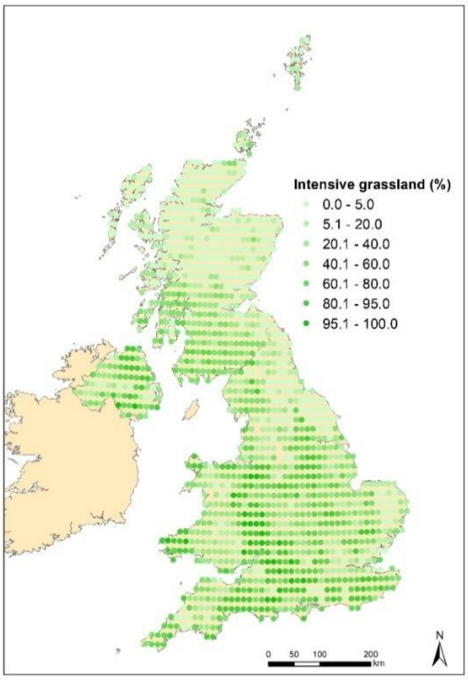
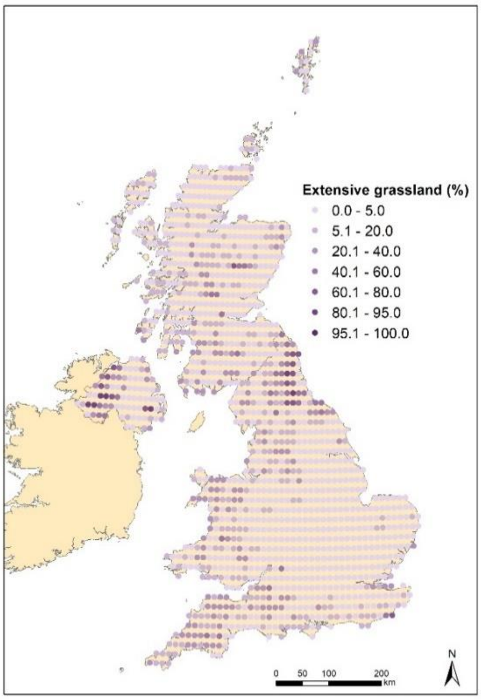


Figure 4. The proportion of a) urban and b) cropland areas according to the Baseline 2020 values

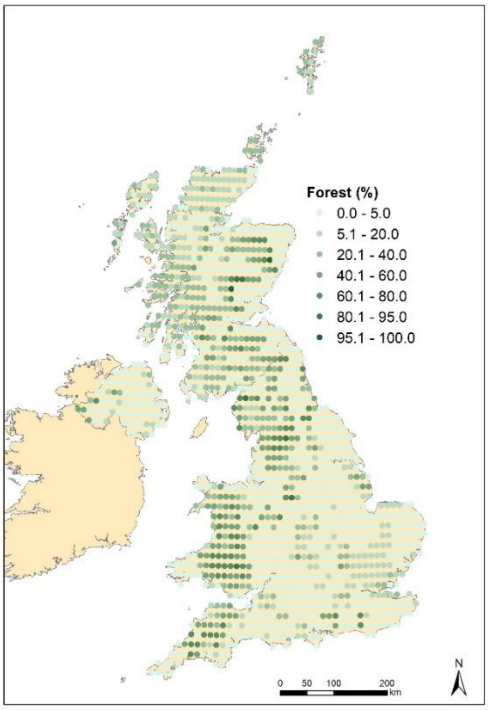
a) Intensive grazing



b) Extensive grazing



c) Forest land



d) Other

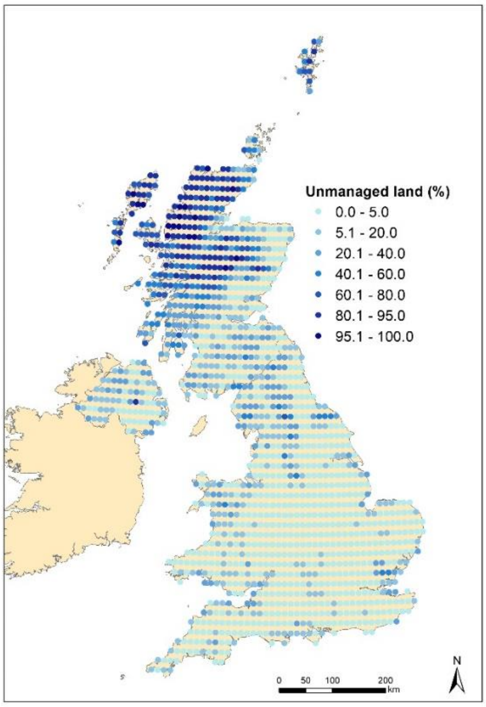


Figure 5. The proportion of a) intensive grassland, b) extensive grassland, c) forest, and d) other land according to the Baseline 2020 values

In addition to modelling the distribution of land use, the IAP2 model was also used to simulate the amount of food and feed production, timber production, fertilizer and pesticide use, and predicted mean rates of nitrate leaching (Table 6).

Table 6. 2020 Baseline: predict level of food and timber production, mean rate of fertilizer application and nitrate loss and pesticide use according to the IAP2 model

Region or nation	Food and feed production (TJ)	Timber production (kt)	Mean fertiliser use (kg N ha^{-1})	Mean nitrate loss (kg N ha^{-1})	Mean pesticide use (dose ha^{-1})
C: North-East	15066	745	78	9	0.9
D: North-West	21743	1510	98	18	0.4
E: Yorkshire	70548	946	142	14	2.7
F: East Midlands	70657	374	162	9	2.3
G: West Midlands	43418	627	142	10	1.6
H: Eastern England	108311	440	144	8	3.7
I: London	1172	40	30	1	0.3
J: South East	55764	516	140	10	1.4
K: South West	47502	1481	132	14	0.6
L: Wales	26521	3302	96	16	0.2
M: Scotland	131538	4066	68	12	0.8
N: N. Ireland	31373	265	128	21	0.7
United Kingdom	623614	14311	106	12	1.2

The modelled level of UK food and feed production is about 624,000 TJ, which assuming a UK population of 66.7 million is equivalent to 25600 kJ per person per day, or about 7 kWh per person per day. This is of the same magnitude as the value of 7.6 kWh per person per day reported by Burgess et al. (2012) as the typical energy content of directly consumed food and the energy of animal feed (crop- and grass-based) needed to produce the animal products consumed by an average person in the UK.

The level of timber production of 14.3 Mt is of a similar magnitude to the national reported production of 11.1 Mt of greenwood delivered in 2019 (Forest Research 2021). The mean fertilizer rate is dependent upon the level of arable and intensive grassland values, and the mean value of 106 kg N ha^{-1} is of the same magnitude of the mean value for manufactured N fertilizer for agricultural land (excluding rough grazing) of 109 kg N per hectare (Defra 2021). The simulated nitrate losses are related to the level of nitrogen application. The simulated loss of 12 kg N ha^{-1} is similar to a calculated rate of 10 kg N ha^{-1} for an application of 240 kg N ha^{-1} as reported for an arable rotation in Cambridgeshire by Onieva Gomez (2011).

Hence although there are some inconsistencies in the detail of the baseline scenario (such a higher than actual area of woodland), in broad terms the IAP2 model still provides a useful baseline to examine the effect of different land use scenarios through to 2030.

3.2 Back to Basics scenario

The first scenario was the most economically positive with a simulated increase in GDP of 20% in 2030, relative to 2010. The Back to Basics scenario assumed a high level of trade liberalisation, an increase in agricultural yields of 10%, and a 10% increase in imports. An effect of the increase in GDP was a small increase in the urban area (+0.3%). The combination of an increase in agricultural yields and imports was to reduce the requirements for land in intensive grassland (-4.6%) and arable crop production (-0.4%) (Table 7).

Table 7. Back to Basics scenario: +10% imports. Proportional areas predicted using IMPRESSIONS model and comparison (in italics) with the Baseline 2020 baseline. The area of "Other" land remained the same as the baseline.

Region or nation	Proportional land use (%)										
	Urban		Arable		Intensive grassland		Extensive grassland		Forest		Other
North-East	9.6	*0.3*	14.0	*-1.8*	2.9	*-4.5*	6.2	*-29.5*	55.2	*35.6*	12.2
North-West	13.4	*0.1*	2.8	*-1.5*	30.7	*-7.8*	13.1	*4.6*	29.2	*4.5*	10.7
Yorkshire	10.1	*0.2*	31.7	*-0.5*	21.7	*-3.8*	6.6	*0.0*	18.5	*3.7*	10.8
East Midlands	10.1	*0.7*	27.7	*-0.3*	50.4	*-1.2*	1.6	*0.3*	7.1	*0.5*	3.1
West Midlands	13.0	*0.5*	16.5	*0.9*	49.5	*-8.4*	7.9	*6.7*	12.2	*0.4*	0.8
Eastern England	9.1	*0.5*	47.6	*-0.8*	30.1	*0.4*	1.2	*0.0*	7.4	*0.0*	4.6
London	75.6	*0.2*	3.2	*0.0*	14.5	*-0.1*	0.3	*0.0*	6.4	*-0.1*	0.1
South East	15.3	*0.7*	9.4	*-1.3*	52.3	*-5.3*	5.4	*-0.6*	14.1	*6.5*	3.5
South West	7.5	*0.7*	1.5	*-0.8*	55.1	*-4.0*	10.0	*-4.9*	21.8	*9.0*	4.2
Wales	5.7	*0.4*	0.7	*0.0*	28.9	*-14.1*	15.0	*4.8*	40.8	*8.9*	8.9
Scotland	2.4	*0.1*	13.2	*-0.1*	12.8	*-3.9*	5.4	*-1.1*	21.2	*3.3*	43.2
N. Ireland	3.9	*0.2*	8.6	*0.0*	47.0	*-1.0*	11.4	*-8.7*	15.5	*9.2*	13.2
United Kingdom	7.4	*0.3*	14.6	*-0.4*	29.4	*-4.6*	7.1	*-1.4*	21.1	*5.5*	19.8

The greatest reductions in intensive grassland were predicted in Wales (-14.1%), the North-West (-7.8%), and the West Midlands (-8.4%) (Table 7). The predicted increase in the forested area was particularly pronounced in the North-East where the area of extensive grass was predicted to decline by 30%, and the area of forest was modelled to increase by 36%. Maps of the changes at a 16 km x 16 km grid level are shown in Appendix C.

The effect of the Back to Basics scenario on food production is shown in Table 18 in Appendix D. Increasing imports by 10% was predicted to reduce UK food and feed production by 6%, with the greatest proportional reductions again occurring in Wales, the North-East and the North-West (Table 18). In turn this enabled an increase in woodland cover, with the greatest absolute increase in timber production modelled to occur in Scotland (+666 kt). On a proportional basis, the IAP2 model predicted that the greatest increase in timber production would occur in the South-East, presumably as unmanaged woodland is brought back into production (+43%). The decline in arable production led to a 9% decline in nitrogen application with the greatest absolute reductions occurring in the North-East England (-34 kg N ha^{-1}) and Wales (-22 kg N ha^{-1}). There was predicted 13% mean reduction in nitrogen leaching, again with the greatest decreases in North-East England and Wales.

3.3 UK Recovery First scenario

The UK Recovery First scenario assumed that there was no change in imports, but there was a 10% increase in yields by 2030, relative to 2020 (Table 8). The IAP2 model predicted that this scenario, applied across Europe, would result in an excess in meat production over demand indicating opportunities for increased exports. The increase in agricultural yields resulted in a decline in the area of both arable (-1.3%) and intensive grassland (-3.6%), and an increase in the area of extensive grassland (2.6%) and forest (2.3%). Maps of the regional distribution of the changes at a 16 km x 16 km grid level are shown in Appendix C.

Table 8. UK Recovery First scenario: no change in imports. Proportional areas predicted using IMPRESSIONS model and comparison (in italics) with the Baseline 2020 baseline. The area of urban and other land was the same as Baseline 2020.

Region	Proportional land use (%)									
	Urban	Arable		Intensive grassland		Extensive grassland		Forest		Other
North-East	9.3	14.2	*-1.6*	3.8	*-3.6*	37.9	*2.2*	22.7	*3.1*	12.2
North-West	13.3	2.6	*-1.7*	30.3	*-8.2*	15.3	*6.9*	27.8	*3.0*	10.7
Yorkshire	10.0	26.7	*-5.5*	27.0	*1.5*	7.9	*1.3*	17.6	*2.8*	10.8
East Midlands	9.4	27.0	*-1.0*	51.6	*-0.1*	1.6	*0.4*	7.4	*0.7*	3.1
West Midlands	12.5	10.6	*-5.0*	55.8	*-2.1*	7.9	*6.7*	12.3	*0.5*	0.8
Eastern England	8.6	46.4	*-2.0*	31.8	*2.0*	1.2	*0.0*	7.4	*0.0*	4.6
London	75.4	3.2	*0.0*	14.6	*0.0*	0.3	*0.0*	6.5	*0.0*	0.1
South East	14.6	7.8	*-2.9*	54.9	*-2.7*	8.6	*2.6*	10.6	*3.1*	3.5
South West	6.8	3.0	*0.8*	53.9	*-5.2*	19.2	*4.3*	12.9	*0.1*	4.2
Wales	5.3	0.7	*0.0*	29.3	*-13.7*	19.4	*9.2*	36.4	*4.5*	9.0
Scotland	2.3	12.8	*-0.6*	13.0	*-3.7*	7.4	*0.9*	21.3	*3.4*	43.2
N. Ireland	3.7	8.6	*0.0*	47.6	*-0.5*	20.4	*0.3*	6.4	*0.2*	13.2
United Kingdom	7.1	13.7	*-1.3*	30.4	*-3.6*	11.1	*2.6*	17.9	*2.3*	19.8

Supply constraint: meat: 234%, timber: 100%

Relative to the baseline, the UK Recovery First scenario was predicted to result in a 4% increase in UK food and feed production (Table 19). However, the increase was uneven with the greatest absolute increase in food and feed production predicted to occur in Eastern England (+11445 TJ) and the East Midlands (+7920 TJ). By contrast proportional declines in food and feed production were predicted for North-West England (-12%) and Wales (-17%). Timber production was predicted to increase in each region, with the greatest absolute increase in Scotland and the greatest relative increase in the South-East. The UK Recovery First scenario was predicted to result in higher nitrogen application rates (+16%) and leaching rates (+18%) than the baseline (Table 19).

3.4 Best of British scenario

The Best of British scenario assumed a similar 10% increase in yield as the UK Recovery First, but the focus included a stronger national agenda as the level of net imports was reduced by 10%, and a green agenda in that 10% of the agricultural land was allocated to bioenergy. The level of crop inputs was assumed to be similar to the baseline.

The IAP2 land use allocation model indicated that the scenario could meet the demand for food, feed, and timber. The combination of the bioenergy crops and reduced level of imports was predicted to lead to a 0.6% increase in the area of cropland, including a 3.8% net change from intensive grassland to arable in Northern Ireland (Table 9). The national area of intensive grassland remained constant, although there were regional changes. The need to increase the arable area was associated with a small decline in the area of extensive grassland (-0.1%) and woodland (-0.4%).

Table 9. "Best of British" (-10% imports; 10% bioenergy; 0% set-aside): proportional areas predicted using IMPRESSIONS model and comparison (in italics) with the Baseline 2020 baseline

Region	Proportional land use (%)									
	Urban	Arable		Intensive grassland		Extensive grassland		Forest		Other
North-East	9.3	15.8	*0.0*	8.1	*0.7*	36.4	*0.7*	18.2	*-1.4*	12.2
North-West	13.3	5.4	*1.1*	38.9	*0.3*	8.0	*-0.5*	23.8	*-0.9*	10.7
Yorkshire	10.0	32.9	*0.7*	25.6	*0.1*	7.1	*0.5*	13.6	*-1.2*	10.8
East Midlands	9.4	28.0	*0.0*	51.7	*0.0*	1.2	*0.0*	6.6	*0.0*	3.1
West Midlands	12.5	14.5	*-1.2*	59.3	*1.5*	1.0	*-0.3*	11.8	*0.0*	0.8
Eastern England	8.6	49.3	*0.8*	31.0	*1.2*	1.2	*0.0*	5.3	*-2.1*	4.6
London	75.4	3.2	*0.0*	14.6	*0.0*	0.3	*0.0*	6.5	*0.0*	0.1
South East	14.6	11.6	*0.9*	56.9	*-0.7*	6.7	*0.7*	6.7	*-0.9*	3.5
South West	6.8	4.0	*1.8*	58.3	*-0.8*	13.9	*-1.0*	12.8	*0.0*	4.2
Wales	5.3	0.7	*0.0*	43.0	*0.0*	10.1	*0.0*	32.0	*0.1*	9.0
Scotland	2.3	13.4	*0.1*	17.0	*0.3*	6.4	*-0.2*	17.7	*-0.2*	43.2
N. Ireland	3.7	12.5	*3.8*	44.3	*-3.8*	20.1	*0.0*	6.3	*0.0*	13.2
United Kingdom	7.1	15.6	*0.6*	34.0	*0.0*	8.4	*-0.1*	15.2	*-0.4*	19.8

The IAP2 model predicted that the Best of British scenario would increase UK food and feed production by 7% to address the 10% reduction in imports (Table 20). The greatest proportional increases occurred in the Northern Ireland and the South-West as intensive grassland was brought into arable production. There was also increase in food production in Eastern England, associated with a decline in the forested area (Table 20). The increase in food production was associated with an increase in nitrogen application (+11%) and nitrate leaching rates (+11%).

3.5 Green UK First scenario

The Green UK First scenario has similarities to the UK Recovery First scenario, assuming a 10% reduction in imports, but it has an even greater emphasis on green issues. In version 1 of this scenario, we assumed that there was no change in agricultural yields from 2010, that 10% and 5% of the arable land would be used for bio-energy and conservation respectively, and there was a reduction in fertilizer use. The IAP2 modelling suggests that this scenario would result in the supply of meat being only 74% of the demand, and the supply of timber being only 46% of the demand (Table 10). The model predicted an increase in the arable area (+4.3%) and intensive grassland (+12.3%), which was offset set by a decline in extensive grassland (-4.0%) and forestry (-12.5%) (Table 10).

Table 10. Green UK First scenario version 1 assuming -10% imports, 10% bioenergy; 5% arable area used for conservation, and reduction in fertilizer use. Proportional areas predicted using IMPRESSIONS model and comparison (in italics) with the Baseline 2020 baseline.

Region	Proportional land use (%)									
	Urban	Arable		Intensive grassland		Extensive grassland		Forest		Other
North-East	9.3	47.1	*31.3*	18.1	*10.7*	7.0	*-28.7*	6.3	*-13.3*	12.2
North-West	13.3	4.7	*0.4*	64.0	*25.5*	6.2	*-2.2*	1.0	*-23.7*	10.7
Yorkshire	10.0	40.5	*8.2*	30.7	*5.1*	7.2	*0.6*	0.9	*-13.9*	10.8
East Midlands	9.4	34.3	*6.3*	50.9	*-0.7*	1.7	*0.5*	0.6	*-6.0*	3.1
West Midlands	12.5	27.3	*11.6*	52.9	*-5.0*	0.8	*-0.5*	5.7	*-6.1*	0.8
Eastern England	8.6	56.0	*7.5*	28.6	*-1.2*	1.2	*0.0*	1.0	*-6.4*	4.6
London	75.4	3.4	*0.3*	20.0	*5.4*	0.3	*0.0*	0.7	*-5.7*	0.1
South East	14.6	20.7	*10.0*	51.0	*-6.6*	5.4	*-0.6*	4.7	*-2.8*	3.5
South West	6.8	7.5	*5.3*	72.7	*13.6*	3.6	*-11.3*	5.3	*-7.5*	4.2
Wales	5.3	0.8	*0.1*	78.2	*35.2*	6.0	*-4.2*	0.7	*-31.2*	9.0
Scotland	2.3	13.4	*0.0*	32.2	*15.6*	5.0	*-1.5*	3.8	*-14.0*	43.2
N. Ireland	3.7	8.8	*0.1*	69.1	*21.1*	3.6	*-16.5*	1.6	*-4.7*	13.2
United Kingdom	7.1	19.3	*4.3*	46.3	*12.3*	4.5	*-4.0*	3.1	*-12.5*	19.8

Supply constraint: meat: 74%, timber: 46%

Like the Best of British scenario, the UK Green First assumes an increase in food and feed production to offset the 10% decline in imports. Because we assumed no yield increase and a reduction in fertiliser use, the level of food and feed production declined in Eastern England (-9%), East Midlands (-8%), and Yorkshire (-4%), in areas where the proportion of cropland is already high (Table 21) and the increase in crop area was unable to offset a decline in yields per hectare. The model assumed that the only way to secure the highest possible level of food and feed security was to convert almost all of the forest area (-12.5%) to intensive grassland (+12.3%).

Version 2 of the UK Green First scenario was run assuming the same inputs as version 1, but with a 30% reduction in beef and lamb consumption. The effect of reducing beef and lamb consumption was relatively small in terms of land use change, but the level of meat sufficiency increased from 74% to 96%, and that for timber increased from 46% to 51% (Table 23).

Version 3 took the next step of reducing the area of arable land used for bioenergy from 10% to 0%. The change reduced the decline in forest cover from 12.1% to 6.4%, but the restriction on imports still led to timber supply only being 64% of the demand (Table 24).

In the fourth version of the Green UK First scenario we also assumed that none of the arable land was set-aside for conservation. The effect of this was relatively small, but it still reduced the predicted increase in the area of arable land from 4.0 to 2.3%, the decline in forest cover was reduced from 6.4% to 6.1% and the supply of timber increased from 64% to 68% of the demand (Table 25).

The last version of the Green UK First scenario combined all of the above changes with the assumption of returning the level of fertilizer application to the baseline situation. The change reduced the predicted increase in the area of arable land from 2.3 to 0.1%, the decline in forest cover was reduced from 6.1% to 2.0% and the supply of timber increased from 68% to 81% of the demand (Table 11).

Table 11. Green UK First scenario version 5 assuming -10% imports, 0% bioenergy, 0% of arable area used for conservation, 30% reduction in red meat consumption, and no reduction in fertilizer use. Proportional areas predicted using IMPRESSIONS model and comparison (in italics) with the Baseline 2020 baseline.

Region	Proportional land use (%)									
	Urban	Arable		Intensive grassland		Extensive grassland		Forest		Other
North-East	9.3	15.8	*0.0*	8.8	*1.4*	36.1	*0.4*	17.8	*-1.8*	12.2
North-West	13.3	4.3	*0.0*	52.8	*14.3*	7.7	*-0.7*	11.2	*-13.6*	10.7
Yorkshire	10.0	32.3	*0.1*	30.6	*5.1*	7.3	*0.7*	9.1	*-5.8*	10.8
East Midlands	9.4	28.0	*0.0*	51.7	*0.1*	1.5	*0.3*	6.2	*-0.4*	3.1
West Midlands	12.5	16.3	*0.6*	58.4	*0.5*	0.7	*-0.6*	11.2	*-0.6*	0.8
Eastern England	8.6	48.7	*0.3*	32.6	*2.9*	1.2	*0.0*	4.3	*-3.1*	4.6
London	75.4	3.2	*0.0*	18.6	*4.0*	0.3	*0.0*	2.5	*-4.0*	0.1
South East	14.6	11.7	*1.0*	57.0	*-0.6*	6.6	*0.6*	6.6	*-1.0*	3.5
South West	6.8	2.2	*0.0*	62.0	*2.9*	11.9	*-3.0*	12.9	*0.0*	4.2
Wales	5.3	0.7	*0.0*	43.4	*0.4*	9.8	*-0.4*	31.9	*0.0*	9.0
Scotland	2.3	13.4	*0.0*	18.7	*2.0*	5.8	*-0.8*	16.6	*-1.2*	43.2
N. Ireland	3.7	8.8	*0.1*	49.2	*1.2*	19.2	*-1.0*	5.9	*-0.3*	13.2
United Kingdom	7.1	15.1	*0.1*	36.5	*2.4*	7.9	*-0.6*	13.6	*-2.0*	19.8

Supply constraint: meat: 96%, timber: 81%

The effect of version 5 of the UK Green First scenario on food and timber production is shown in Table 22. To account for the 10% reduction in imports, relative to the Baseline national food production was increased by 5%, and the level of fertilizer increased by 4%. Even so the prioritisation of food production above timber production meant that predicted timber reduction was reduced by 15% relative to the baseline.

4 Results – land use change and soil functions

The types and scales of potential land use change modelled in Section 3 under the selected scenarios will have impacts on a range of key environmental and socio-economic considerations, including impacts on ecosystem services. Here we investigate the potential consequences on several key indicators: soil functionality (carbon storage, nutrient availability, water supply); pollination and primary productivity using spatial datasets applied to a simplified model (Aitkenhead and Coull 2019) assessing impacts on soil properties, processes and functions. These are assessed under a range of potential land use changes that may occur resulting from the wider consequences of the plausible scenarios. This approach was adopted to reflect soil functions as determinants of the feasibility and desirability of the land use change to maintain ecosystem services, reduce greenhouse gas emissions, and maintain rural business viability.

The purpose here is to explore the scope for land use change considering the biophysical constraints of land capability for agriculture (using Agricultural Land Classification for England and Wales and Land Capability for Scotland) and soil type. It also considered implausible conversions (i.e. from urban to agricultural land) and identified spatially where land use change is possible and evaluated the consequences for key soil properties. We then used this estimated potential change in soil properties to predict impacts on soil function. It is important to note that this approach explored where potential change is *possible*, not where it *will* happen.

4.1 Linking soil functionality and land use change narratives

Land use impacts on soil function were generated by investigating possible management changes on different combinations of soil types, land capability (Scotland and England & Wales) and land cover. The known impacts of possible management changes on soil properties were used to derive impacts on soil functionality through a model (Aitkenhead & Coull, 2019) linking properties, processes and functions. Five examples of soil functionality were considered: carbon storage, primary productivity, water supply, nutrient availability, and support for pollination.

Data for land cover, land capability, soils were used to identify 1511 different combinations of land use, land cover, land capability and soil classes. For each combination , we explored the major potential land use transition .

The land use changes identified were from the existing land use to:

- Arable and Horticulture
- Heath and Wetland Grazing
- Improved Grassland
- Semi-natural Grassland

Existing land use was identified from the CEH Land Cover Map (LCM2015) dataset and recategorized into the above four types. Land uses/covers lying outside these broad classes were not covered in this evaluation.

Maps of impact of each land use change on each soil function were generated and linked to the four plausible scenarios detailed above (Duckett et al. 2021). These were explored in terms of the changes within each of the 12 NUTS regions in the UK and presented in Tables 12-15.

How to read the maps: Each map shows a different soil function and land use transition.

- A negative (-) value indicates the land use transition is possible and has a negative impact on the soil function.

- A value of 0 (blue) indicates three possibilities:
    1. The location is already that type of land use, hence no land use change occurs.
    2. The land use change is not possible due to the biophysical constraints of land capability or soil type.
    3. There is no impact on the soil function.
- A positive (+) value indicates the land use transition is possible and has a positive impact on the soil function.

In the following example for carbon storage impacts from conversion to arable or horticulture (Figure 6), there is only a negative impact.

a) b)

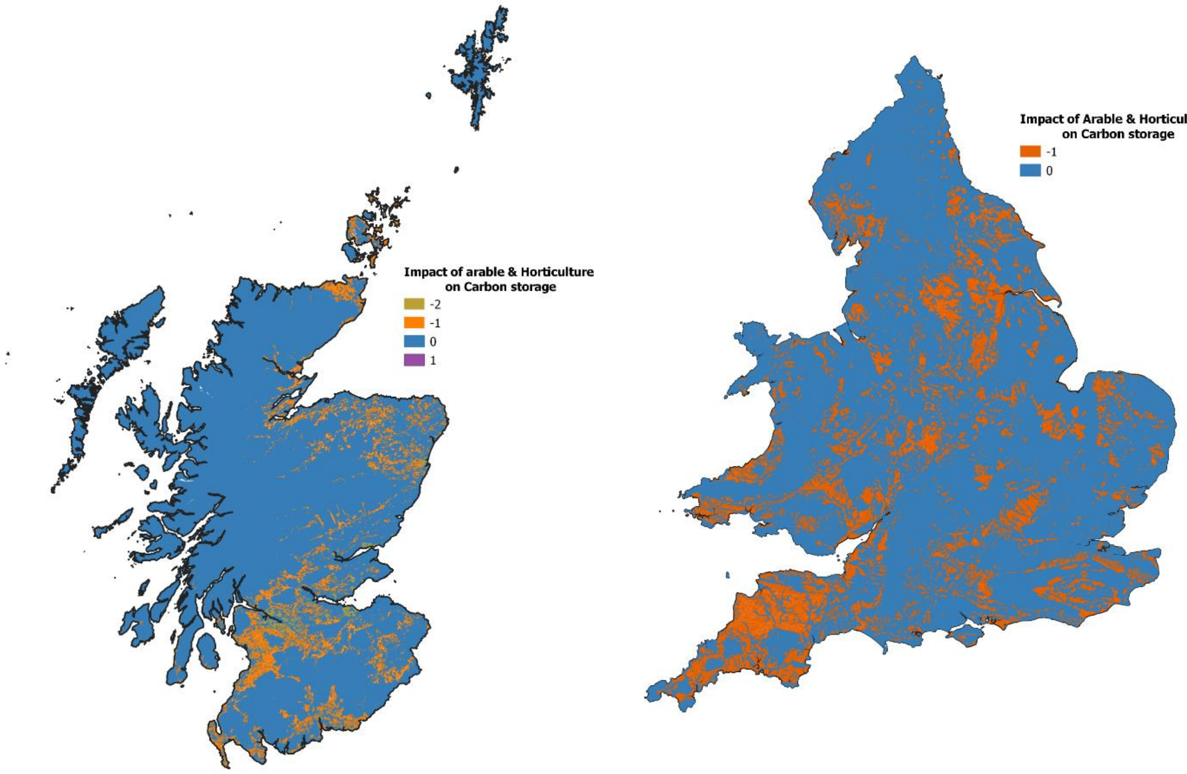


Figure 6. Impact of land use change from current land use to arable and horticulture on soil carbon storage in a) Scotland and b) England and Wales

For each of the scenarios, a table was produced to summarise impacts of changes to soil functionality within each of the NUTS areas (Tables 12-15). In many cases, the changes identified reflected multiple impacts on soil functionality from different processes. Also, the spatial heterogeneity of NUTS areas in terms of soil type and land capability, meant that in many cases, positive and negative impacts were predicted within each NUTS area. The tables below show '**+**' symbols where a positive impact was predicted and '-' symbols where a negative impact was predicted, sometimes together for the same function in the same region. Where no impacts were predicted (either because the rate of change of land use was less than 1% for land use classes that would have caused an impact, or the change given would have had no impact on that function), the cell is empty.

The Back to Basics scenario, which was predicted to enable an increase in forest cover and reduced levels of intensive grassland, generally resulted in positive effects on soil functions related to primary productivity, carbon storage, water supply, nutrient availability, and pollination (Table 18). The effects tended to be the least positive where the reduction in arable production was minimal e.g. the West Midlands and Wales.

Table 12. Back to Basics scenario: indications of land cover change on the soil functions of carbon storage, primary productivity, water supply, nutrient availability and pollination

Region	Carbon storage	Primary productivity	Water supply	Nutrient availability	Pollination
North-East	+	+	+	+	+
North-West	+-	++	++	++	++
Yorkshire	+	+	+	+	+
East Midlands					
West Midlands	-	-+	-	-+	-
Eastern England					
London					
South-East	-				
South-West	+	+	+	+	+
Wales	+-	+-	+-	+-	+-
Scotland	+	+	+	+	+
N. Ireland	+	+	+	+	+

++: very positive effect; +: positive effect; +-: positive and negative effect; -: negative effect; blank entry means minimal effect

The predicted effects of the UK Recovery First scenario had generally positive effects on soil functions, but compared to the Back to Basics scenario, there were also greater negative effects, for example in Eastern England and the South West, where there was no increase in forest cover (Table 19).

Table 13. UK Recovery First scenario: indications of land cover change on the soil functions of carbon storage, primary productivity, water supply, nutrient availability and pollination

Region	Carbon storage	Water supply	Nutrient availability	Pollination	Primary productivity
North-East	++	+	++	++	++
North-West	++-	++-	++-	++-	++-
Yorkshire	+-	+-	++	++-	+++-
East Midlands					
West Midlands	+-	+-	+	+-	+-
Eastern England	-	-		-	-
London					
South-East	+-	-+-	+-	+-	++-
South-West	-	+-	+-	+-	+-
Wales	++-	++-	++-	++-	++-
Scotland	+	+	+	+	+
N. Ireland	+	+	+	+	+

++: very positive effect; +: positive effect; +-: positive and negative effect; -: negative effect; blank entry means minimal effect

The Best of British and the Green UK First scenarios tended to have increasingly negative effects on the predicted levels of soil functions, as the area of forest cover declined and the arable areas increased.

Table 14. Best of British scenario: indications of land cover change on the soil functions of carbon storage, primary productivity, water supply, nutrient availability and pollination

Region	Carbon storage	Primary productivity	Water supply	Nutrient availability	Pollination
North-East	-+	-+	-	-+	-+
North-West	-+-	-+-	-+-	-+-	-+-
Yorkshire	-+-	-+-	--	-+	-+-
East Midlands	-	-	-	-	-
West Midlands	-	-	-	-	-
Eastern England	+-	+-	-	+-	+-
London	+	+	+	+	+
South-East	-	-	-	-	-
South-West	--	--	--	--	--
Wales	-	+-	+-	+-	+-
Scotland	+-	+-	-	+-	+-
N. Ireland	-+-	-+-	-+-	-+-	-+-

++: very positive effect; +: positive effect; +-: positive and negative effect; -: negative effect; blank entry means minimal effect

Table 15. Green UK First scenario: indications of land cover change on the soil functions of carbon storage, primary productivity, water supply, nutrient availability and pollination

Region	Carbon storage	Primary productivity	Water supply	Nutrient availability	Pollination
North-East	-+	-+	-	-+	-+
North-West	+-	+-	+-	+-	+-
Yorkshire	-+-	-+-	--	-+	-+
East Midlands	-	-	-	-	-
West Midlands	-	-	-	-	-
Eastern England	-	-	-	-	-
London	+	+	+	+	+
South-East	-	-	-	-	-
South-West	--	--	--	--	--
Wales	-+	+-	+-	+-	+-
Scotland	+-	+-	+-	+-	+-
N. Ireland	+-	+-	+-	+-	+-

Note: The same predictions were made for both versions of this scenario.
++: very positive effect; +: positive effect; +-: positive and negative effect; -: negative effect; blank entry means minimal effect

Table 20 provides a brief qualitative assessment of the impacts of each scenario on the various NUTS regions. For all the main agricultural areas, a move from the Back to Basics to the UK Recovery First, and onto the Best of British and Green UK First scenarios resulted in a negative effect on soil functions. The opposite effect for London is a result of a possibly erroneous assumption that a proportion of the change to improved grazing is from land that is currently arable.

Table 16. Summary of qualitative assessment of the impact of the four scenarios on soil functions by NUTS2 region

Region	Back to Basics	UK Recovery First	Best of British	Green UK First v1
North-East	Consistently positive	Consistently positive	Mixed, no consensus	Mixed, mostly negative
North-West	Consistently positive	Mixed, mostly positive	Mixed, mostly negative	Mixed, no consensus
Yorkshire	Consistently positive	Mixed, mostly positive	Mixed, mostly negative	Mixed, mostly negative
East Midlands	No impact	No impact	Consistently negative	Consistently negative
West Midlands	Mixed, mostly negative	Mixed, no consensus	Consistently negative	Consistently negative
Eastern England	No impact	Consistently negative	Mixed, no consensus	Consistently negative
London	No impact	No impact	Consistently positive	Consistently positive
South-East	Slight negative	Mixed, no consensus	Consistently negative	Consistently negative
South-West	Consistently positive	Mixed, mostly negative	Consistently negative	Consistently negative
Wales	Mixed, no consensus	Mixed, mostly positive	Mixed, no consensus	Mixed, no consensus
Scotland	Consistently positive	Consistently positive	Mixed, no consensus	Mixed, no consensus
N. Ireland	Consistently positive	Consistently positive	Mixed, mostly negative	Mixed, no consensus

The overall effect of each scenario was relatively consistent on the five selected soil functions showing this analysis did not result in divergent effects for different soil functions (Table 17).

Table 17. Summary of qualitative assessment of four scenarios on five soil functions

	Back to Basics	UK Recovery First	Best of British	Green UK First v1
Carbon storage	Mixed, mostly positive	Mixed, mostly positive	Mixed, mostly negative	Mixed, mostly negative
Primary productivity	Mixed, mostly positive	Mixed, mostly positive	Mixed, mostly negative	Mixed, mostly negative
Water supply	Mixed, mostly positive	Mixed, mostly positive	Mixed, mostly negative	Mixed, mostly negative
Nutrient availability	Mixed, mostly positive	Mixed, mostly positive	Mixed, mostly negative	Mixed, mostly negative
Pollination	Mixed, mostly positive	Mixed, mostly positive	Mixed, mostly negative	Mixed, mostly negative

In conclusion, every scenario produces a range of impacts across the UK, with no scenario being ‘all positive’ or ‘all negative’ for a specific soil function. However, the ‘Back to Basics’ and ‘UK Recovery First’ scenarios are overall more positive in their predicted impacts than the ‘Best of Britain’ and ‘Green UK first’ scenarios. Each region sees a variation in impacts across the scenarios, with most regions have some ‘mostly positive’ and some ‘mostly negative’ scenarios. The exception is West Midlands, for which there are no ‘mostly positive’ scenarios in this study.

5 Discussion

The use of a spatially explicit land use model alongside quantification of predicted effects of four scenarios on selected drivers of land use change highlights the major effect of the scenarios on both the predicted level of food and timber production relative to demand and land use change in the United Kingdom.

There are a number of assumptions made in the analyses. The original IAP2 model was designed to describe changes in European land use, rather than the land use within a specific country such as the United Kingdom. In this report, we have assumed that if the scenario is applied to the UK, it is also applied to the rest of Europe. Hence if the assumption was that imports to the UK decreased by 10%, then the assumption is that the same change would also occur across Europe, i.e. there was toric symmetry. In practice, particularly following Brexit, the drivers determining land use change and the food system in the UK could diverge from those in the member states of the European Union. To account for such effects would require substantial alterations to the IAP2 model.

The results highlight that enabling increases in agricultural yields and maintaining current levels of food, feed and timber imports to the UK creates opportunities to release land for tree planting without undermining food security (Figure 7). In 2019, the UK imported the equivalent of 45% of its food (based on farm-gate prices of unprocessed food) (UK Government 2020). In view of the target to achieve net zero greenhouse gas emissions by 2050, the UK Government is planning a net increase in tree cover in excess of 30,000 ha per year by 2025 (UK Government 2021). If this target is achieved over 10 years, the area of 300,000 ha represents a net land use change of 1.2%. Such increases in tree cover are predicted as possible under the Back to Basics and the UK Recovery First scenarios (Figure 7).

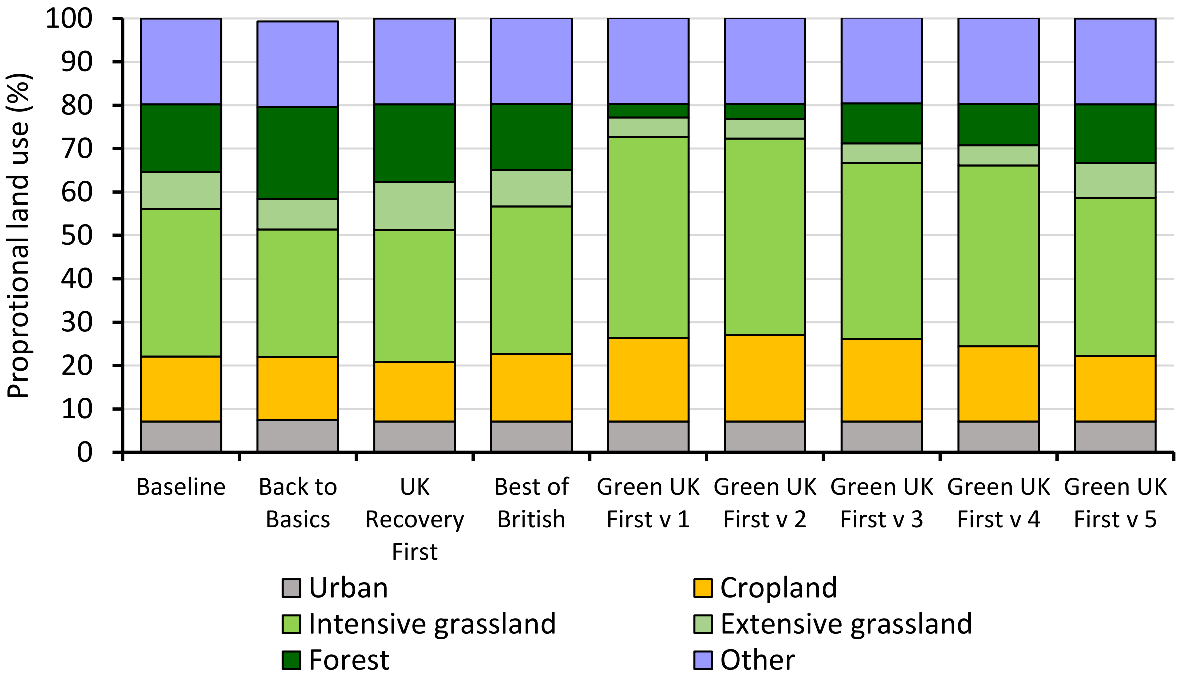


Figure 7. Predicted proportional land use in the UK for the 2020 Baseline scenario; the Back to Basics, UK Recover First, and Best of British scenarios, and five versions of the Green UK First scenario

The results from the UK Recovery First scenario (Table 8) demonstrate that if the location of tree planting is based on the opportunity costs of alternative land uses, the opportunity to increase tree cover in Scotland, Wales, and North-West and North-East England (3.0-4.5%) are greater than those in Eastern England, West Midlands, East Midlands, and Northern Ireland (0-0.7%), where agricultural land use is more profitable. This highlights the potential difficulties if national targets of a 1.2% increase are equally applied across the UK and specifically England.

The Best of British scenario (which assumed a steady increase in agricultural productivity and the capacity to maintain current fertilizer application rates), a drive to reduce imports by 10% and increase bioenergy production resulted in land use trade-offs. In this modelling exercise, the IAP2 model was set-up to ensure firstly that the demand for crops is met, then livestock products, and lastly timber. Hence in order to meet the demand for food, the Best of British scenario predicted a 0.4% decrease in woodland cover (Table 9). In practice this would cause an environmental outcry, as the UK public places a high value on the cultural value of woodland including its use for recreation (Agbenyega et al. 2009). At present the IAP2 model does not have an easy mechanism for “protecting” existing areas of woodland from land use change.

Version 1 of the Green UK First scenario combined five practices that increased the pressure on land use: a 10% reduction in imports, no increase in agricultural yields, allocating 10% of the agricultural area to bioenergy and 5% of the arable area for conservation, and a 26% reduction in nitrogen application rates. The IAP2 model predicted that such a scenario would result in the supply of meat and timber only being 74% and 46% of the demand respectively.

One way to converge the demand and supply of meat is to reduce the demand for meat. The analysis of version 2 indicated that reducing the demand for beef and lamb by 30% could almost bring the supply and demand of meat broadly into balance ($\pm$4%). Numerous studies have highlighted the health and environmental benefits of reduced per capita meat consumption (Vita et al. 2019). OECD (2021) report that whilst UK consumption of beef between 1990 and 2019 was similar, UK consumption of lamb declined from 6.3 kg per capita in 1990 to 3.9 kg per capita in 2019. OECD-FAO (2020) predict that consumption of beef in the United Kingdom will decline by 0.37% per year between 2020 and 2029. The results presented here, as also indicated by Lee et al. (2019) suggest that a reduction in meat consumption can ease food security concerns if the focus is on greener production methods.

As examined in Version 3 of the Green UK First scenario, land use tension is also reduced if bioenergy crops are not grown on arable land. The use of agricultural areas to produce bioenergy is a contentious issue. The original arguments in favour of bioenergy crops included that they were renewable and that they resulted in lower greenhouse gas emissions than the use of fossil fuels such as oil (Ricketts et al. 2008). However, as renewable electricity decreases in price, the prospect of a lack of oil becomes less likely and as the source of electricity production moves from fossil fuels to renewable forms, the capacity of bioenergy crops to reduce greenhouse gas emissions decreases. Moreover, Searchinger et al. (2019) reports that wood used in a power plant typically emits 50% and 200% more CO_2 per kWh than coal and natural gas, respectively. The knock-on effects of increased bioenergy on increased water use and land use are also increasingly recognised (Birdsey et al. 2018; Vita et al. 2019). In fact Vita et al. (2019) highlights bioenergy is likely to back-fire as an environmental intervention. Hence, the European Union (2015), for example, has placed a limit that no more than 7% of transport fuel should be met from selected bioenergy crops grown on arable land by 2020. The modelled change between the Green UK First scenario version 2, which assumed 10% bioenergy (Table 23), and version 3 which assumed 0% bioenergy from agricultural land (Table 24) meant that the decline in forest area was reduced from 12.1% to 6.4%. Within the IAP2 model, bioenergy production is assumed to be produced on previous arable land, and hence growing more bioenergy crops creates a demand for increased food production from other areas (Lee et al. 2019).

Version 5 of the Green UK First highlights the sensitivity of the UK land use predictions (using the IAP2 model) to fertiliser application rates. Enabling fertilizer application rates to be maintained at levels similar to the baseline allowed the supply of meat to match demand ($\pm$4%), and the supply of timber to meet 81% of demand. Hence current levels of food security (although not timber security) could be achieved if imports could be reduced by 10% and no new constraints were placed on fertilizer use. Although top-down constraints on fertilizer use can be problematic; farm-scale approaches such as increased use of fertilizer management software, currently used on 27% of farm in the UK (Defra, 2021), can help to optimise the economic and environmental outcomes of fertiliser use.

The impacts of modelled scenarios on soil function (covering a range of provisioning, regulating and supporting ecosystem functions) varied across scenarios, as well as varying spatially within each scenario. Back to Basics had generally positive impacts across all soil functions, while UK Recovery First had strong positive and negative impacts. Best of British and Green UK First both had largely negative impacts across all soil functions. No scenario was ‘all positive’ or ‘all negative’ in terms of impacts on soil function.

6 Conclusions

The use of a spatially-explicit integrated land use model, that is able to respond to a range of socio-economic drivers, provides a useful way to sense-check four scenarios developed as part of a food and nutritional security study. It also provides opportunity for expert judgement to inform model inputs. The analysis indicated that increasing the level of food imports can reduce the pressures on land use in the importing country, but it is anticipated that negative environmental effects will occur elsewhere. These have not been quantified in this study, and if a country is to pursue the objective of increasing food imports, then it would be responsible to undertake a global life cycle assessment of the probable effects. Methods of increasing agricultural productivity per unit area without increasing negative environmental effects are particularly attractive and should be a focus for research and extension. The study highlights that a drive for greater food sufficiency in the UK is likely to lead to major economic and environmental trade-offs either in terms of food security or the availability of land for expanding tree cover. The study also shows that the use of agricultural land for bioenergy production could cause perverse outcomes such as increased pressure to convert wooded land to farmland. As reported elsewhere, if a UK food policy uses greener methods where yield increases over currently conventional practices are not expected, then reduced meat consumption per capita can be useful in matching food demand and supply. Scenarios that reduced food production in the UK in favour of imports were modelled to have the strongest positive impacts on UK soil function.

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Appendix A. Example drivers selected within the IAP model

Time slice:	2020s
Emission Combo Box Scottish IAP2:	0 (RCP4.5)
Model Combo Box Scottish IAP2:	2 (IPSL-CM5A-MR_WRF)
Emission Combo Box:	0 (RCP2.6)
Model Combo Box:	0 (EC-EARTH_RCA4)
Sensitivity Combo Box:	1 (Middle)
Combo Box SES:	4 (Baseline)
Combo Box SES dummy:	0 (USER DEFINED)
Combo Box SES sc:	0 (SSP1/Mactopia)
Combo Box SES sc Dummy:	0 (USER DEFINED)
Slr Eu Slider:	0.14749
Pop change Slider:	0
Green_red Slider:	0
Ruminant Livestk Products Demand Slider:	-10
NonRuminant Livestck Products Demand Slider:	20
Struct Change Slider:	0
Tech fac Slider:	0
Tech Change Slider:	0
Yield fac Slider:	10
Irrigation Efficiency Factor Slider:	10
GDP_change Slider:	0
Costs fac Slider:	100
Import fac Slider:	029
Bio Energy Crop Demand Slider:	10
Irrigation Cost Slider:	1
Arable Conservation Land Scalar Slider:	5
Crop Inputs Factor Slider:	1.5

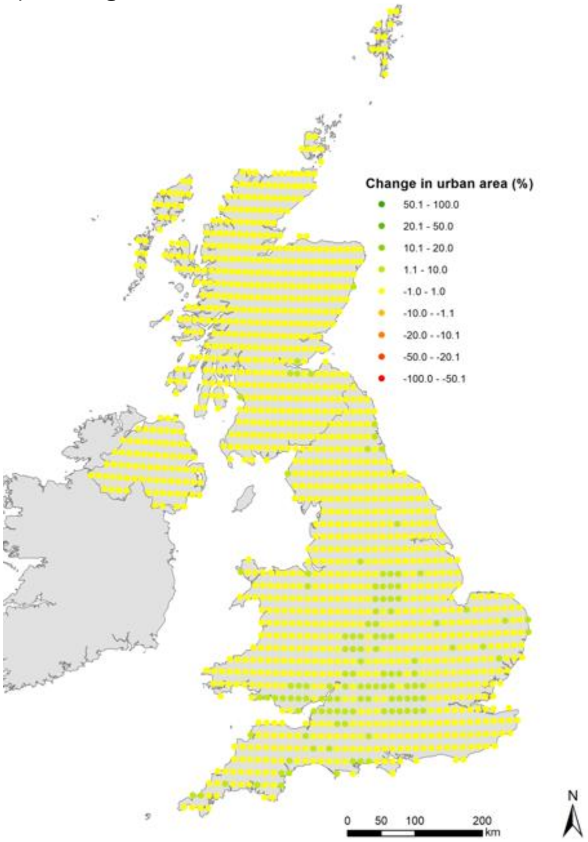
Appendix B. Land cover in the UK in 2015 (Eurostat 2021)

Region or Nation	Area (km²)								
	Total	Artificial land	Crop land	Wood-land	Shrub-land	Grass-land	Bare-land	Wet-land	Water
North East	8607	614	1760	821	1825	3374	91	37	83
North West	14183	1615	1308	1052	2759	6895	107	242	204
Yorkshire	15429	1449	5780	1130	1897	4863	131	63	116
East Midlands	15643	1400	7258	1111	253	5186	237	59	140
West Midlands	13014	1335	3719	1407	85	6050	218	21	179
East of England	19160	1622	9442	2033	224	4361	1209	151	118
London	1576	937	57	179	46	354			3
South East	19109	1941	5369	3584	471	7246	178	90	230
South West	23907	1420	5812	3346	642	11892	410	220	164
England	130628	12333	40505	14663	8202	50221	2581	883	1237
Wales	20820	1126	1159	3256	3157	11106	376	405	236
Scotland	78971	1714	6149	9791	34711	17809	937	5960	1899
N. Ireland	14155	830	489	1220	736	9419	105	696	660
UK	244574	16003	48301	28930	46807	88556	4000	7942	4033

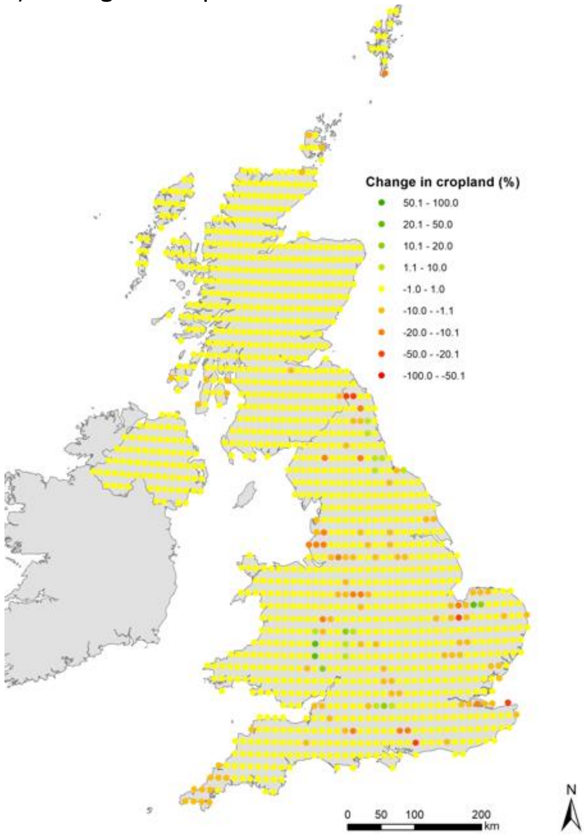
Appendix C. Modelled effects of scenarios on UK land use change

Back to Basics scenario

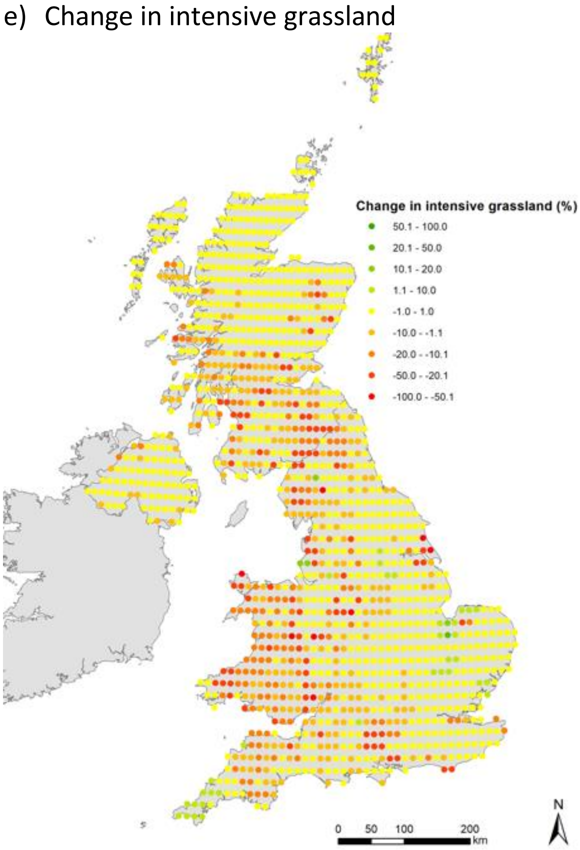
a) Change in urban area



b) Change in cropland



e) Change in intensive grassland



f) Change in extensive grassland

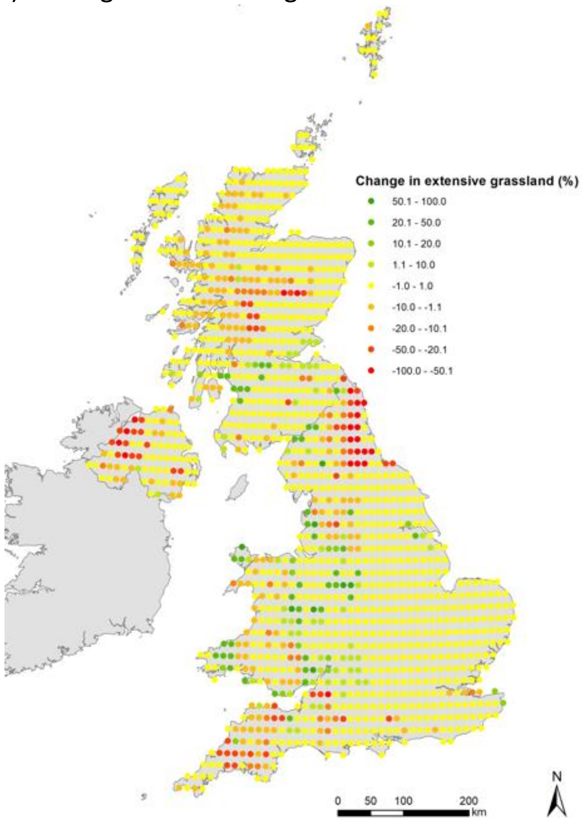


Figure 8 Predicted effect of the "Back to Basics" scenario on land use change relative to the Baseline 2020 prediction in terms of a) urban, b) cropland, c) intensive grassland, and d) extensive grassland

Back to Basics scenario

a) Change in forest

b) Change in unmanaged and other

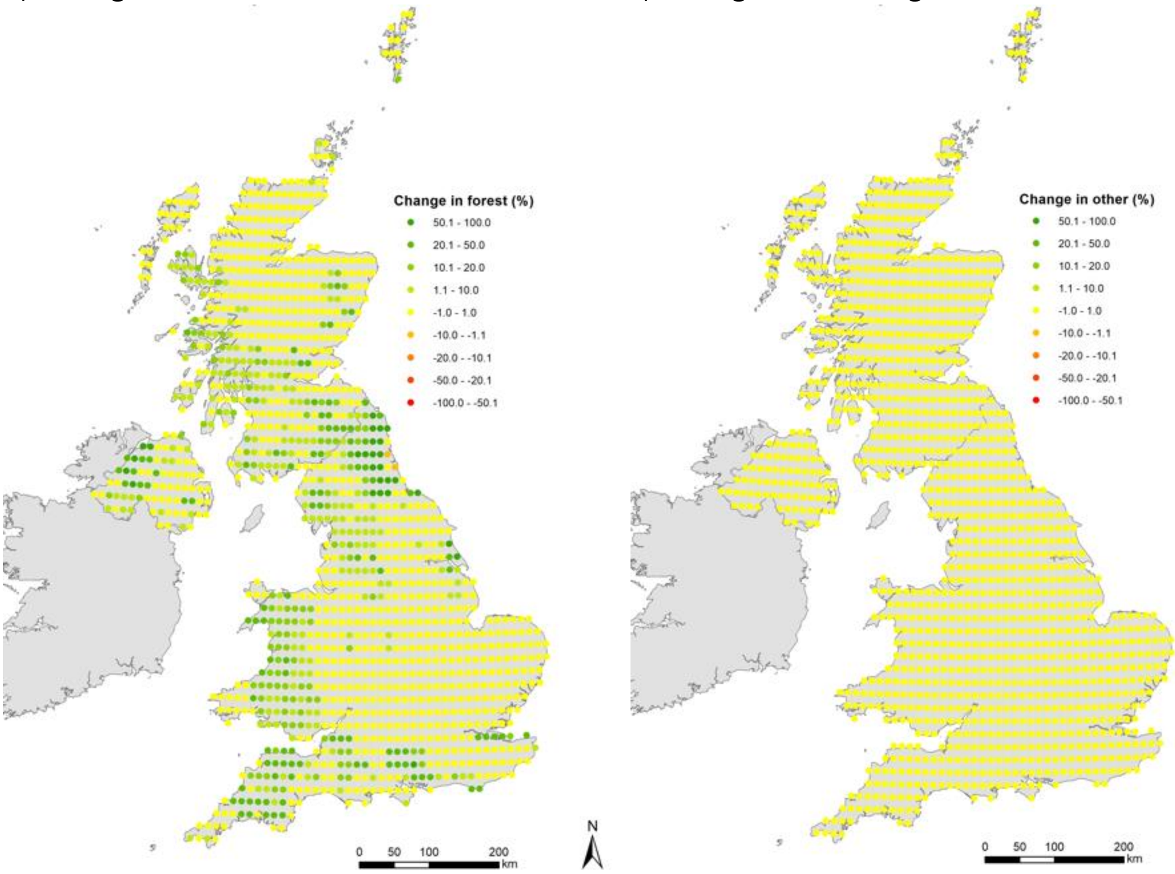
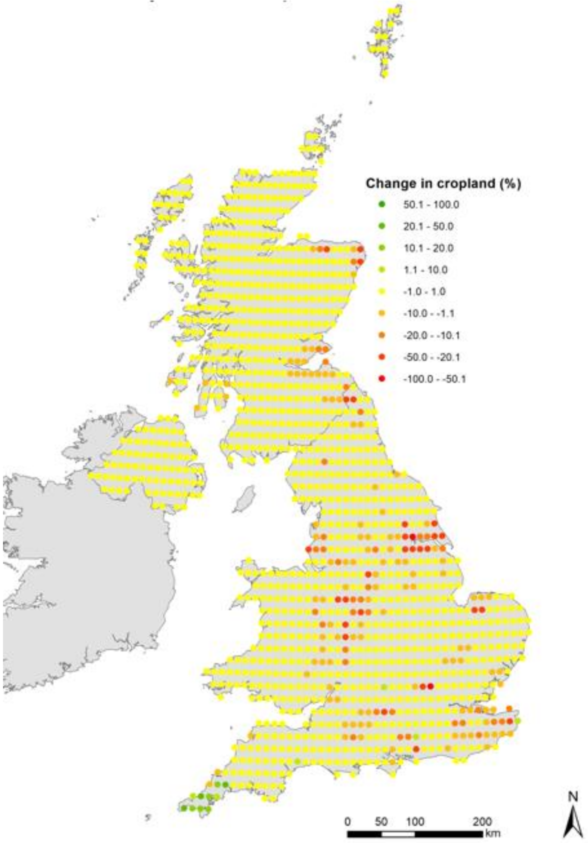


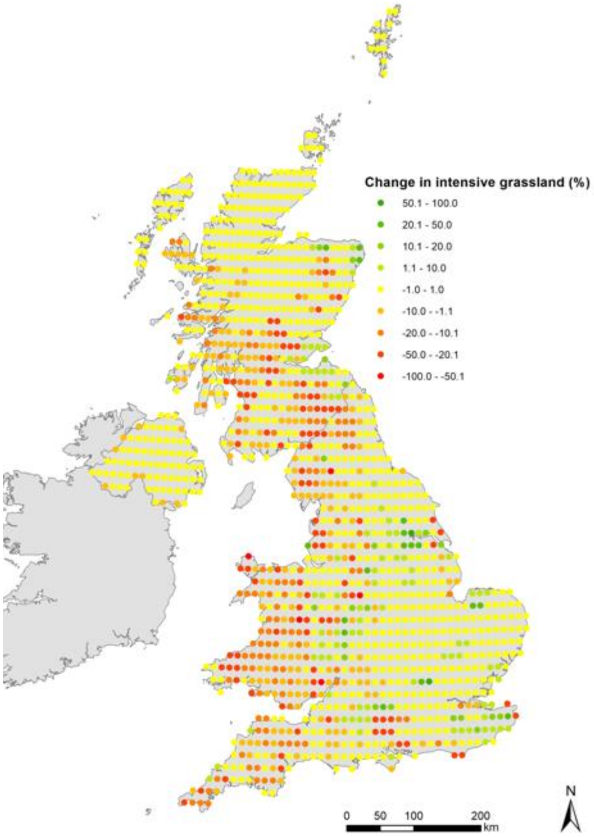
Figure 9 Predicted effect of the Back to Basics scenario on land use change relative to the Baseline 2020 prediction in terms of a) forest, and b) unmanaged and other areas

UK Recovery First scenario

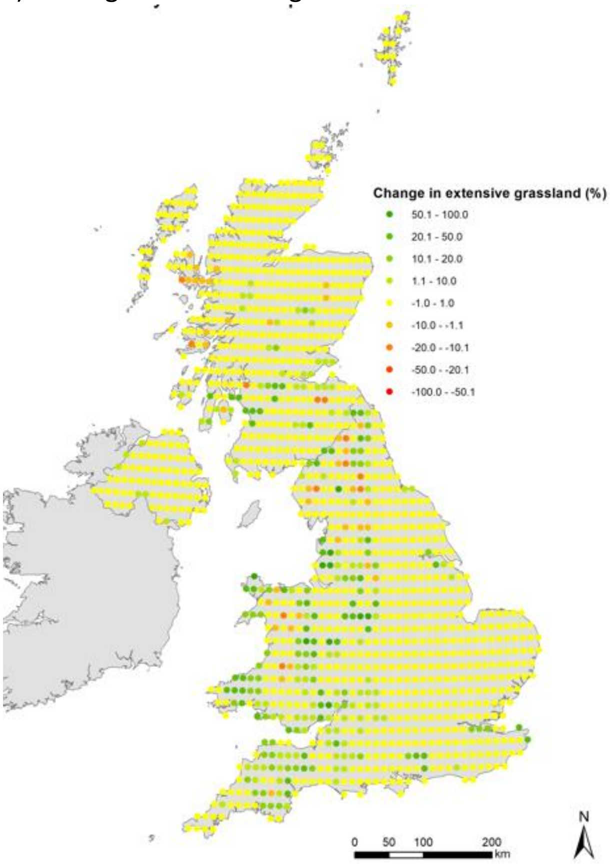
a) Change in cropland



b) Change in intensive grassland



c) Change in extensive grassland



d) Change in forest

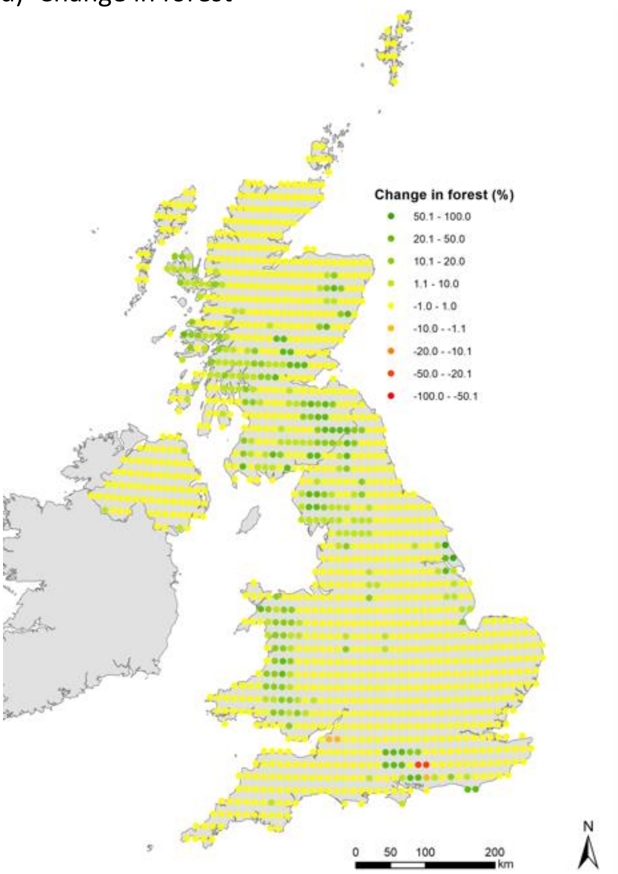
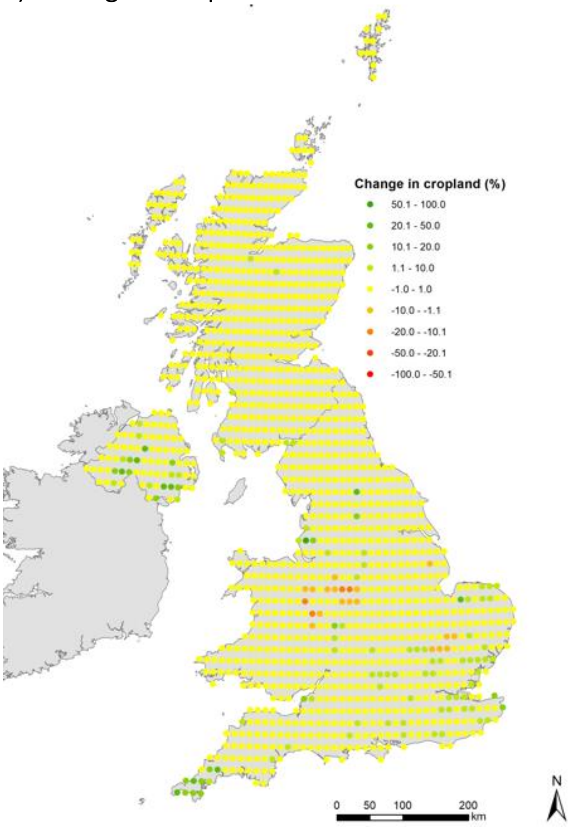


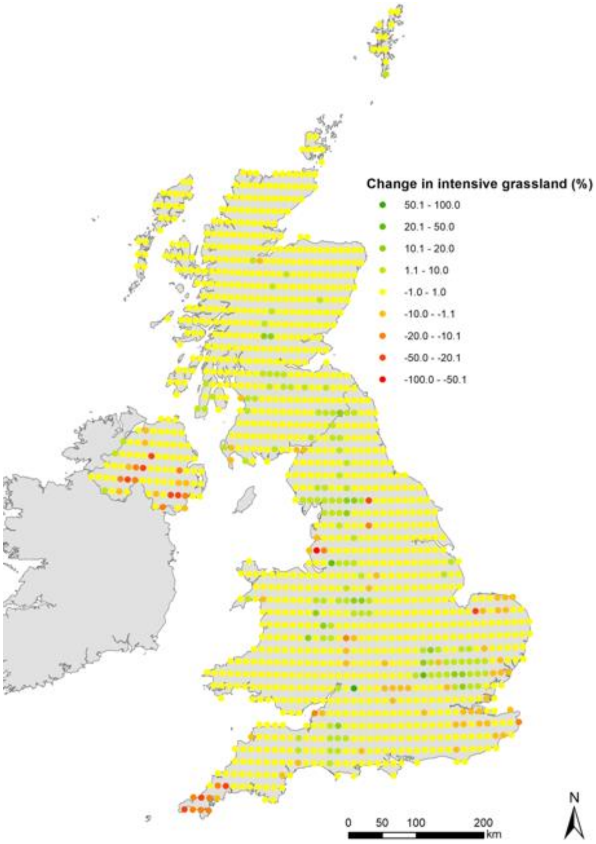
Figure 10 Predicted effect of the UK Recovery First scenario on land use change relative to the Baseline 2020 prediction in terms of a) cropland, b) intensive and c) extensive grassland, and d) forest

Best of British scenario

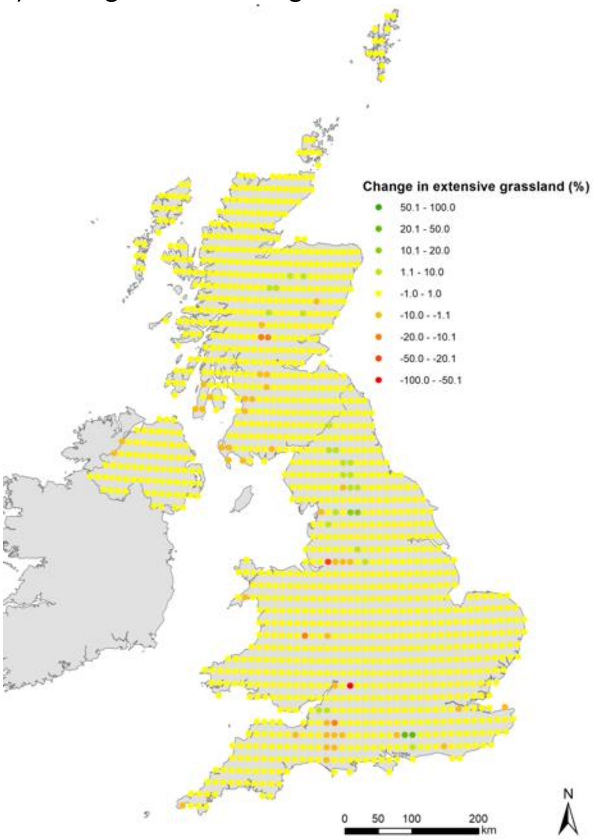
a) Change in cropland



b) Change in intensive grassland



c) Change in extensive grassland



d) Change in forest

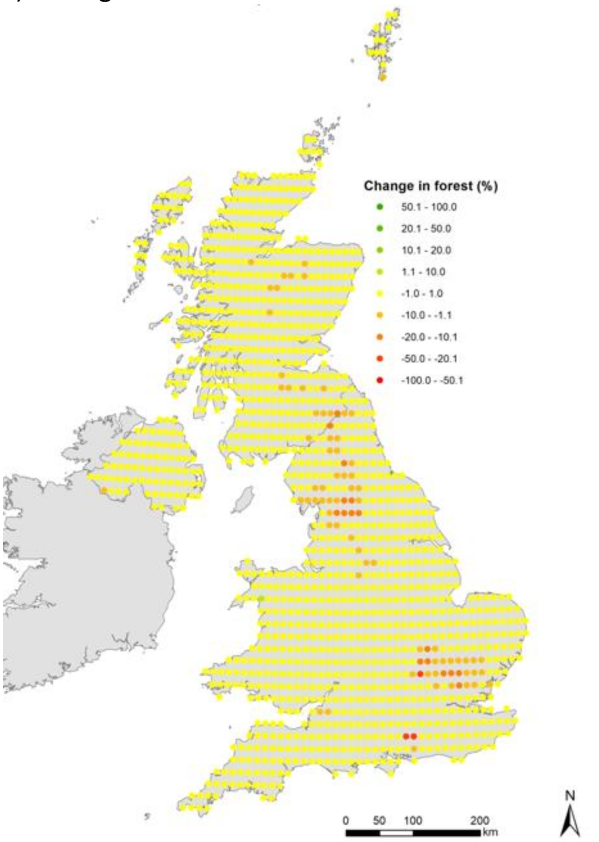
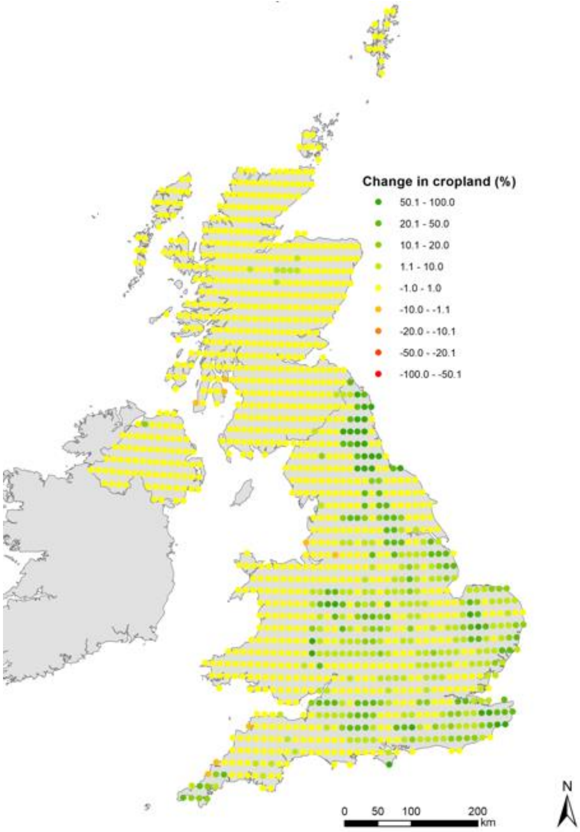


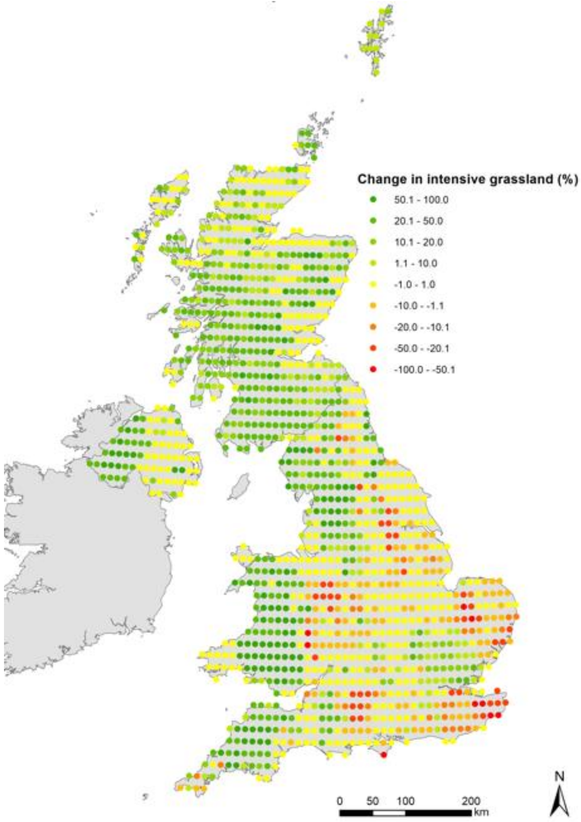
Figure 11 Predicted effect of the Best of British scenario on land use change relative to the Baseline 2020 prediction in terms of a) cropland, b) intensive and c) extensive grassland, and d) forest

Green UK First scenario version 1

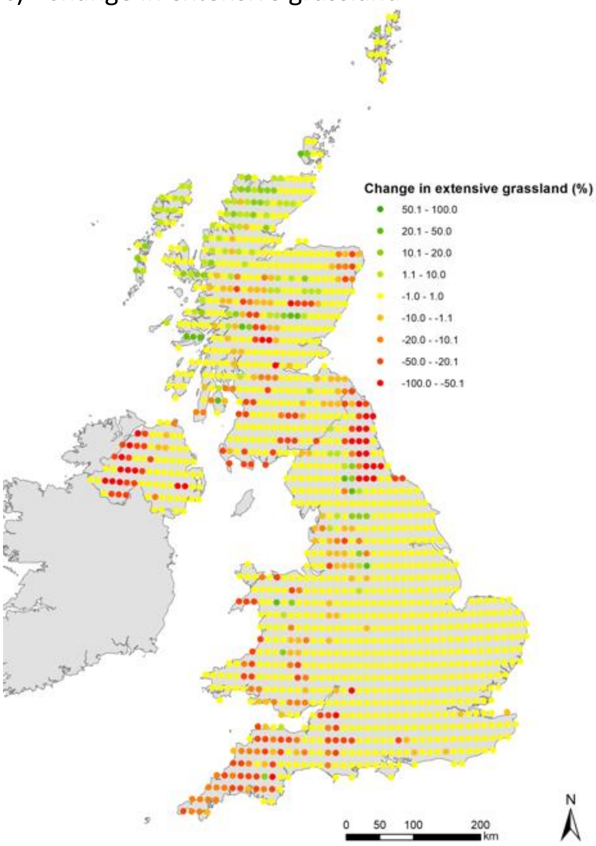
a) Change in cropland



b) Change in intensive grassland



c) Change in extensive grassland



d) Change in forest

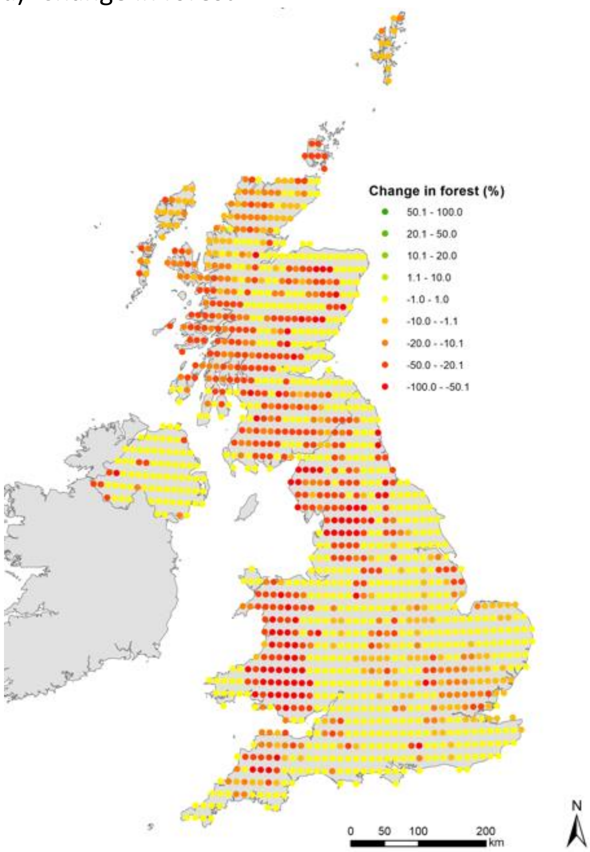
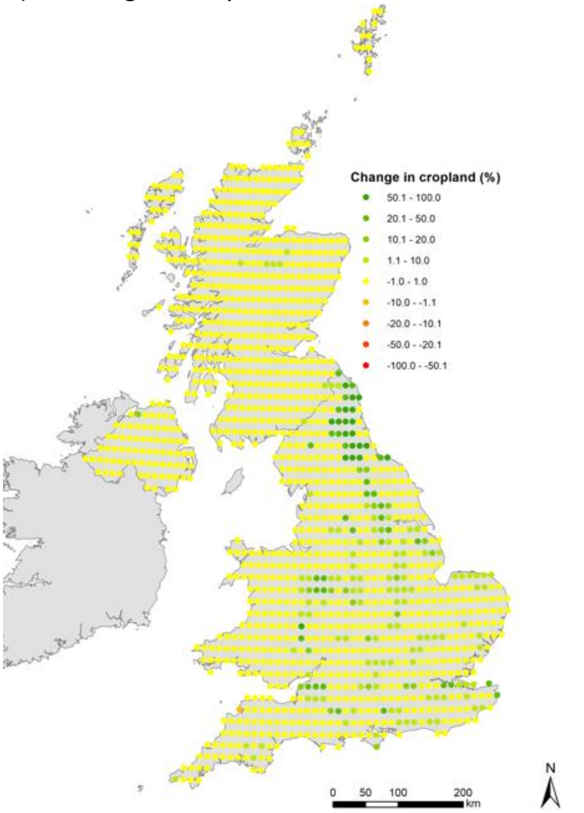


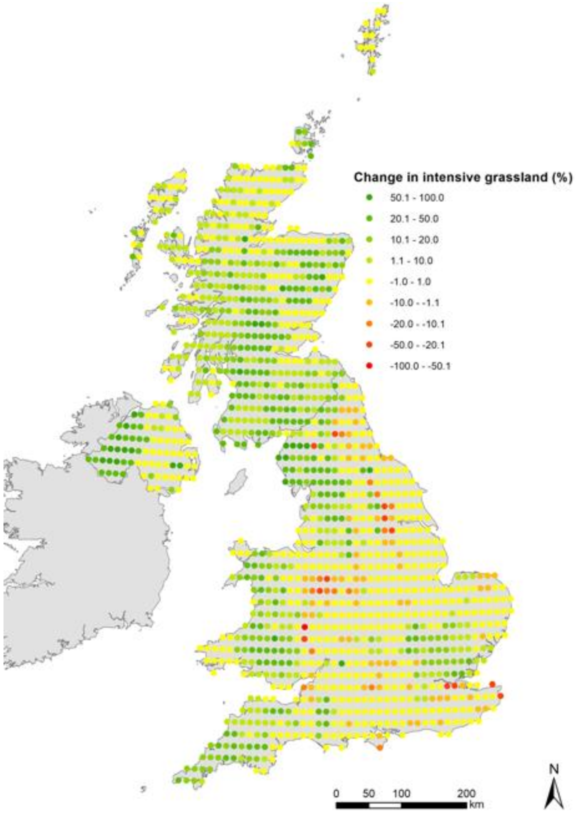
Figure 12 Predicted effect of the UK Green First scenario version 1 on land use change relative to the Baseline 2020 prediction in terms of a) cropland, b) intensive and c) extensive grassland, and d) forest

Green UK First scenario version 4

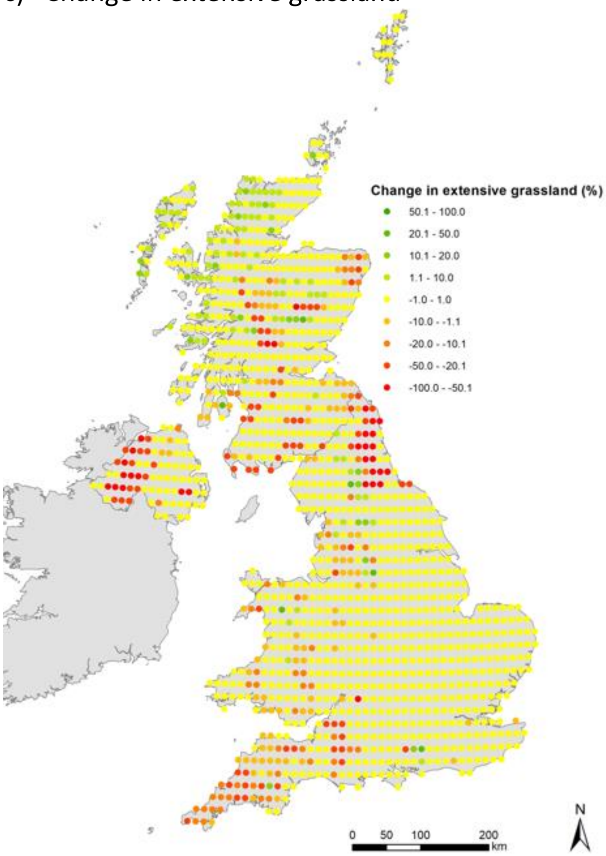
a) Change in cropland



b) Change in intensive grassland



c) Change in extensive grassland



d) Change in forest

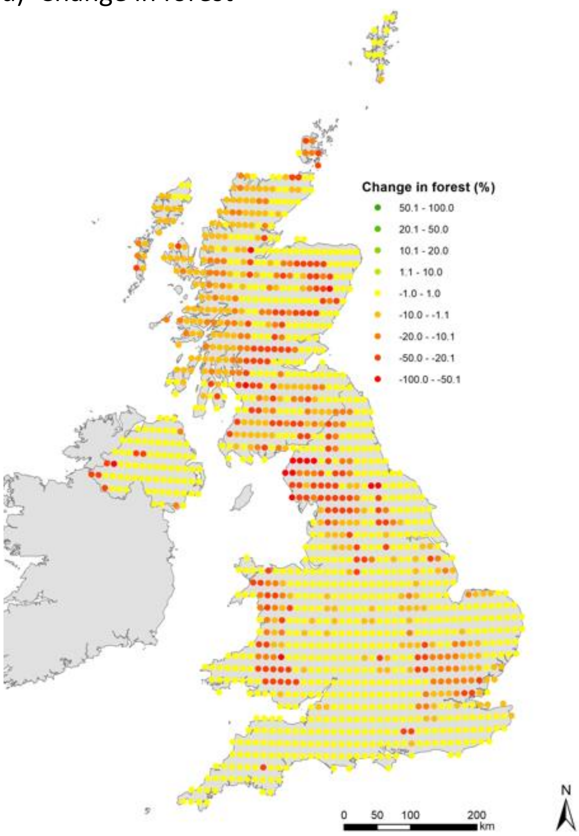
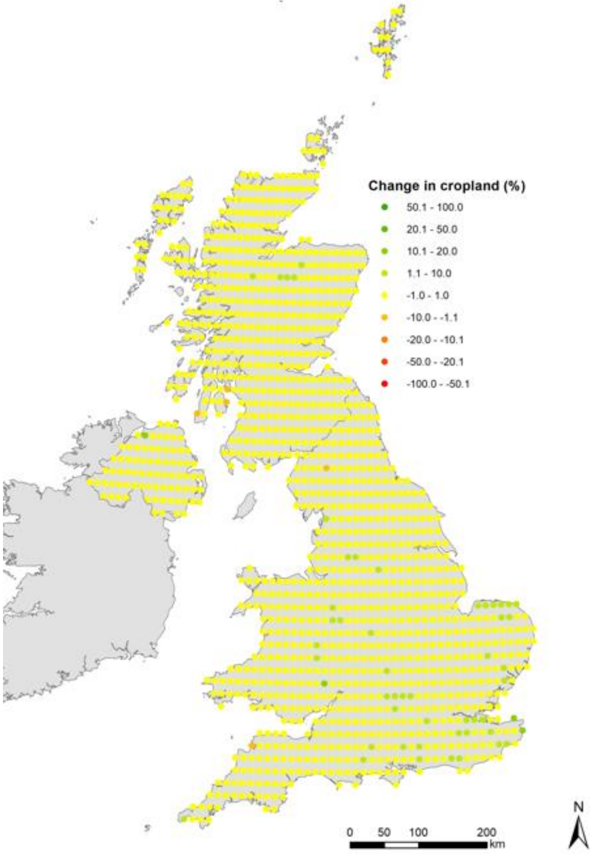


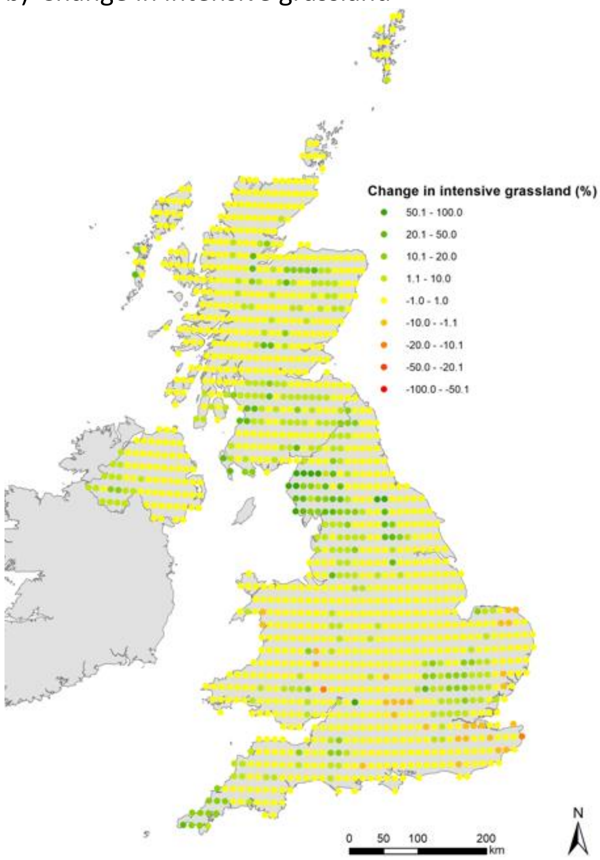
Figure 13 Predicted effect of the UK Green First scenario version 4 on land use change relative to the Baseline 2020 prediction in terms of a) cropland, b) intensive and c) extensive grassland, and d) forest

Green UK First scenario version 5

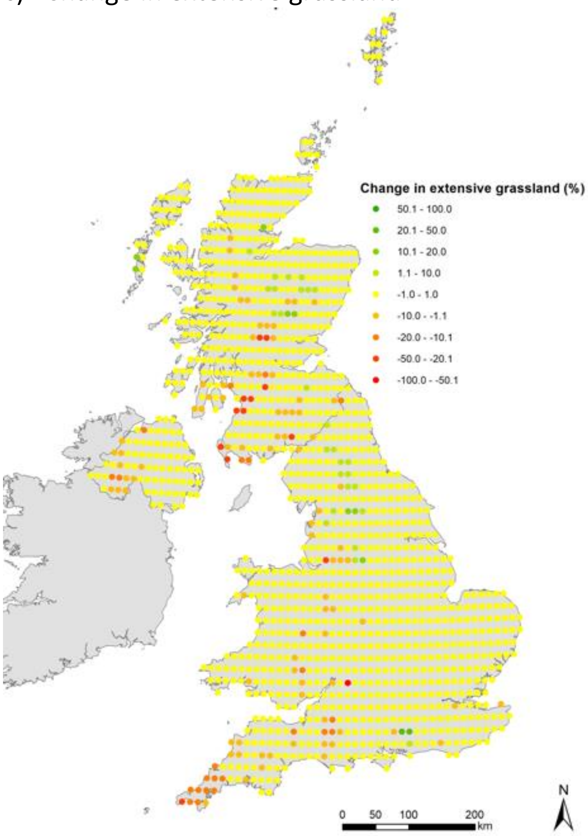
a) Change in cropland



b) Change in intensive grassland



c) Change in extensive grassland



d) Change in forest

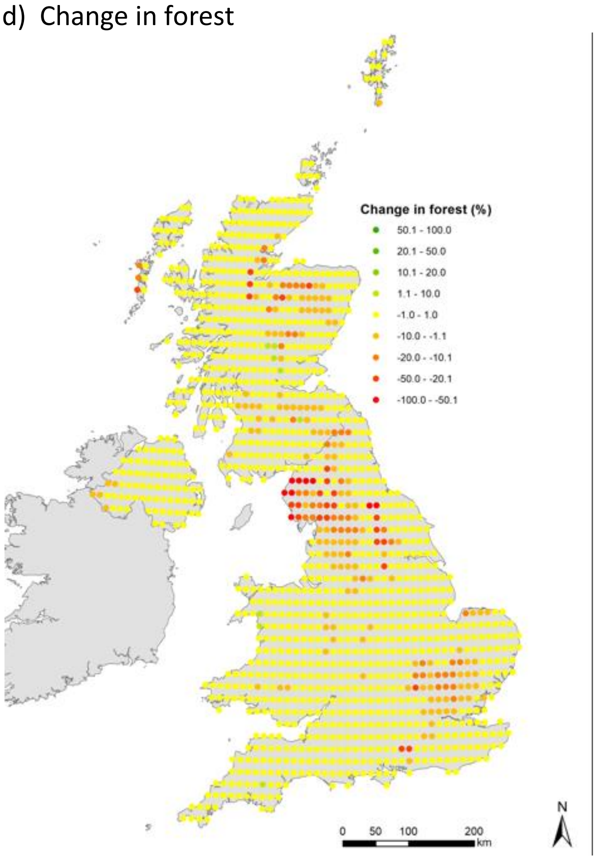


Figure 14 Predicted effect of the "UK Green First version 5" scenario on land use change relative to the Baseline 2020 prediction in terms of a) cropland, b) intensive and c) extensive grassland, and d) forest

Appendix D. Modelled effects of scenarios on changes in food, feed and timber production and nitrogen (N) application and leaching

Back to Basics scenario

Table 18. Predicted effect of the Back to Basics scenario relative to the Baseline on the predicted change in food and feed production, timber production, N application, and N leaching rates

	Change in food and feed prod.		Change in timber production		Change in N application		Change in N leaching	
	(TJ)	(%)	(kt)	(%)	(kg N ha^{-1})	(%)	(kg N ha^{-1})	(%)
North-East	-2764	*-18*	156	*21*	-34	*-44*	*-4.1*	*-45*
North-West	-4431	*-20*	177	*12*	-14	*-14*	*-2.7*	*-15*
Yorkshire	-1795	*-3*	147	*16*	-6	*-4*	*-0.7*	*-5*
East Midlands	-1088	*-2*	27	*7*	-3	*-2*	*-0.3*	*-3*
West Midlands	-884	*-2*	20	*3*	-7	*-5*	*-0.5*	*-5*
Eastern England	-1441	*-1*	-1	*0*	-1	*-1*	*0*	*0*
London	-6	*-1*	0	*0*	0	*0*	*0*	*0*
South East	-4382	*-8*	221	*43*	-11	*-8*	*-0.9*	*-9*
South West	-4082	*-9*	34	*2*	-11	*-8*	*-1.8*	*-13*
Wales	-7223	*-27*	364	*11*	-22	*-23*	*-4.3*	*-28*
Scotland	-8715	*-7*	666	*16*	-8	*-12*	*-1.5*	*-13*
N. Ireland	-653	*-2*	11	*4*	-8	*-6*	*-1.9*	*-9*
United Kingdom	-37465	*-6*	1821	*13*	-10	*-9*	*-1.6*	*-13*

UK Recover First scenario

Table 19. Predicted effect of the UK Recovery First scenario relative to the Baseline on the predicted change in food and feed production, timber production, N application, and N leaching rates

	Change in food and feed prod.		Change in timber production		Change in N application		Change in N leaching	
	(TJ)	(%)	(kt)	(%)	(kg N ha^{-1})	(%)	(kg N ha^{-1})	(%)
North-East	44	*0*	158	*21*	6	*8*	1.6	*17*
North-West	-2650	*-12*	178	*12*	7	*7*	2.0	*11*
Yorkshire	881	*1*	148	*16*	26	*18*	3.5	*25*
East Midlands	7920	*11*	43	*12*	38	*24*	2.4	*27*
West Midlands	-2005	*-5*	23	*4*	29	*20*	2.9	*28*
Eastern England	11445	*11*	0	*0*	37	*26*	2.5	*31*
London	154	*13*	0	*0*	8	*25*	0.4	*31*
South-East	-535	*-1*	212	*41*	24	*17*	2.1	*22*
South-West	3452	*7*	5	*0*	27	*20*	3.7	*27*
Wales	-4557	*-17*	372	*11*	1	*1*	0.3	*2*
Scotland	5131	*4*	744	*18*	7	*10*	1.3	*11*
N. Ireland	3826	*12*	11	*4*	30	*23*	6.4	*30*
United Kingdom	23107	*4*	1895	*13*	17	*16*	2.2	*18*

Best of British scenario

Table 20. Predicted effect of the Best of British scenario relative to the Baseline on the predicted change in food and feed production, timber production, N application, and N leaching rates

	Change in food and feed prod.		Change in timber production		Change in N application		Change in N leaching	
	(TJ)	(%)	(kt)	(%)	(kg N ha^{-1})	(%)	(kg N ha^{-1})	(%)
North-East	576	*4*	-33	*-4*	11	*14*	1.5	*16*
North-West	2987	*14*	-56	*-4*	13	*13*	2.4	*13*
Yorkshire	3246	*5*	-74	*-8*	18	*12*	2.1	*15*
East Midlands	3308	*5*	-16	*-4*	17	*10*	0.9	*10*
West Midlands	2030	*5*	-23	*-4*	16	*11*	1.1	*11*
Eastern England	5609	*5*	-162	*-37*	19	*13*	0.8	*10*
London	77	*7*	0	*0*	3	*11*	0.1	*10*
South East	4916	*9*	-56	*-11*	16	*11*	1.1	*11*
South West	6883	*14*	-62	*-4*	15	*11*	1.5	*11*
Wales	2459	*9*	-1	*0*	10	*10*	1.5	*10*
Scotland	5938	*5*	-27	*-1*	8	*11*	1.3	*11*
N. Ireland	5119	*16*	0	*0*	12	*10*	2.3	*11*
United Kingdom	43148	*7*	-510	*-4*	12	*11*	1.4	*11*

UK Green First scenario (Version 1)

Table 21. Predicted effect of the UK Green First scenario (Version 1) relative to the Baseline on the predicted change in food and feed production, timber production, N application, and N leaching rates

	Change in food and feed prod.		Change in timber production		Change in N application		Change in N leaching	
	(TJ)	(%)	(kt)	(%)	(kg N ha^{-1})	(%)	(kg N ha^{-1})	(%)
North-East	14757	*98*	-738	*-99*	1	*1*	-2.7	*-29*
North-West	5708	*26*	-1509	*-100*	-11	*-11*	-3.5	*-20*
Yorkshire	-2673	*-4*	-945	*-100*	-42	*-30*	-5.4	*-38*
East Midlands	-5777	*-8*	-373	*-100*	-60	*-37*	-4.4	*-48*
West Midlands	2900	*7*	-623	*-99*	-52	*-37*	-5.5	*-52*
Eastern England	-9962	*-9*	-440	*-100*	-51	*-35*	-4.3	*-54*
London	56	*5*	-40	*-100*	-7	*-23*	-0.6	*-43*
South East	2485	*4*	-513	*-99*	-53	*-38*	-5.0	*-52*
South West	10102	*21*	-1476	*-100*	-38	*-29*	-6.0	*-44*
Wales	14092	*53*	-3301	*-100*	-2	*-2*	-1.0	*-6*
Scotland	6683	*5*	-4064	*-100*	-9	*-14*	-2.5	*-21*
N. Ireland	2088	*7*	-265	*-100*	-36	*-28*	-9.3	*-45*
United Kingdom	40458	*6*	-14310	*-100*	-26	*-24*	-3.9	*-31*

Table 22. Predicted effect of the UK Green First scenario (Version 5) relative to the Baseline on the predicted change in food and feed production, timber production, N application, and N leaching rates

	Change in food and feed prod.		Change in timber production		Change in N application		Change in N leaching	
	(TJ)	(%)	(kt)	(%)	(kg N ha^{-1})	(%)	(kg N ha^{-1})	(%)
North-East	767	5	-91	-12	4	5	0.6	7
North-West	4907	23	-768	-51	25	26	6.6	37
Yorkshire	3935	6	-326	-34	9	7	1.1	8
East Midlands	1569	2	-94	-25	1	0	0.2	2
West Midlands	1614	4	-119	-19	1	1	0.1	1
Eastern England	4780	4	-238	-54	5	3	0.2	2
London	179	15	-28	-70	6	20	0.4	27
South East	2007	4	-126	-24	1	1	0.1	1
South West	1651	3	-70	-5	3	2	0.3	2
Wales	241	1	-5	0	1	1	0.1	0
Scotland	7257	6	-285	-7	3	5	0.6	5
N. Ireland	1004	3	-11	-4	2	1	0.3	1
United Kingdom	29912	5	-2162	-15	4	4	0.7	6

Appendix E. Intermediate versions of the Green UK First scenario

Table 23. Green UK First scenario version 2 (-10% imports, 10% bioenergy, 5% of arable area used for conservation, and 30% reduction in beef and lamb consumption): proportional areas predicted using IMPRESSIONS model and comparison (in italics) with the Baseline 2020 baseline

Region	Proportional land use (%)									
	Urban	Arable		Intensive grassland		Extensive grassland		Forest		Other
North-East	9.3	47.4	*31.6*	16.4	*9.0*	6.9	*-28.8*	7.7	*-11.9*	12.2
North-West	13.3	5.0	*0.8*	63.7	*25.1*	6.2	*-2.2*	1.0	*-23.7*	10.7
Yorkshire	10.0	42.2	*9.9*	29.0	*3.5*	7.2	*0.6*	0.9	*-13.9*	10.8
East Midlands	9.4	36.2	*8.2*	49.0	*-2.7*	1.7	*0.5*	0.6	*-6.0*	3.1
West Midlands	12.5	28.1	*12.5*	49.4	*-8.4*	0.8	*-0.5*	8.3	*-3.5*	0.8
Eastern England	8.6	56.0	*7.6*	28.5	*-1.2*	1.2	*0.0*	1.0	*-6.4*	4.6
London	75.4	3.4	*0.3*	20.0	*5.4*	0.3	*0.0*	0.7	*-5.7*	0.1
South East	14.6	21.1	*10.4*	50.6	*-7.0*	5.4	*-0.6*	4.7	*-2.8*	3.5
South West	6.8	8.2	*6.0*	71.5	*12.4*	3.6	*-11.3*	5.8	*-7.0*	4.2
Wales	5.3	0.8	*0.1*	77.8	*34.7*	6.0	*-4.2*	1.2	*-30.7*	9.0
Scotland	2.3	13.5	*0.1*	31.7	*15.0*	5.0	*-1.6*	4.3	*-13.5*	43.2
N. Ireland	3.7	12.6	*4.0*	65.1	*17.1*	3.6	*-16.5*	1.8	*-4.5*	13.2
United Kingdom	7.1	20.0	*5.0*	45.2	*11.2*	4.5	*-4.1*	3.5	*-12.1*	19.8

Supply constraint: milk: 97%, meat: 96%, timber: 51%

Table 24. Green UK First" scenario version 3 (-10% imports, 0% bioenergy, 5% of arable area used for conservation, and 30% reduction in beef and lamb consumption): proportional areas predicted using IMPRESSIONS model and comparison (in italics) with the Baseline 2020 baseline

Region	Proportional land use (%)									
	Urban	Arable		Intensive grassland		Extensive grassland		Forest		Other
North-East	9.3	47.4	*31.6*	8.9	*1.4*	6.9	*-28.8*	15.3	*-4.3*	12.2
North-West	13.3	6.2	*2.0*	54.7	*16.1*	6.3	*-2.2*	8.8	*-15.9*	10.7
Yorkshire	10.0	40.9	*8.6*	26.5	*0.9*	7.0	*0.3*	5.0	*-9.9*	10.8
East Midlands	9.4	32.6	*4.6*	51.5	-0.1	1.6	*0.4*	1.7	*-4.9*	3.1
West Midlands	12.5	23.3	*7.7*	51.7	-6.2	0.7	*-0.6*	10.9	*-0.9*	0.8
Eastern England	8.6	50.1	*1.6*	34.4	*4.6*	1.2	*0.0*	1.1	*-6.3*	4.6
London	75.4	3.2	*0.0*	20.3	*5.7*	0.3	*0.0*	0.7	*-5.7*	0.1
South East	14.6	20.3	*9.6*	50.4	*-7.2*	5.4	*-0.6*	5.7	*-1.9*	3.5
South West	6.8	7.6	*5.4*	63.1	*4.1*	5.8	*-9.1*	12.5	*-0.3*	4.2
Wales	5.3	0.7	*0.1*	54.2	*11.2*	6.5	*-3.7*	24.3	*-7.5*	9.0
Scotland	2.3	13.5	*0.1*	26.9	*10.2*	4.6	*-2.0*	9.5	*-8.4*	43.2
N. Ireland	3.7	12.6	*4.0*	64.4	*16.3*	3.7	*-16.5*	2.4	*-3.8*	13.2
United Kingdom	7.1	19.0	*4.0*	40.5	*6.5*	4.6	*-4.0*	9.2	*-6.4*	19.8

Supply constraint: milk: 95%, meat: 93%, timber: 64%

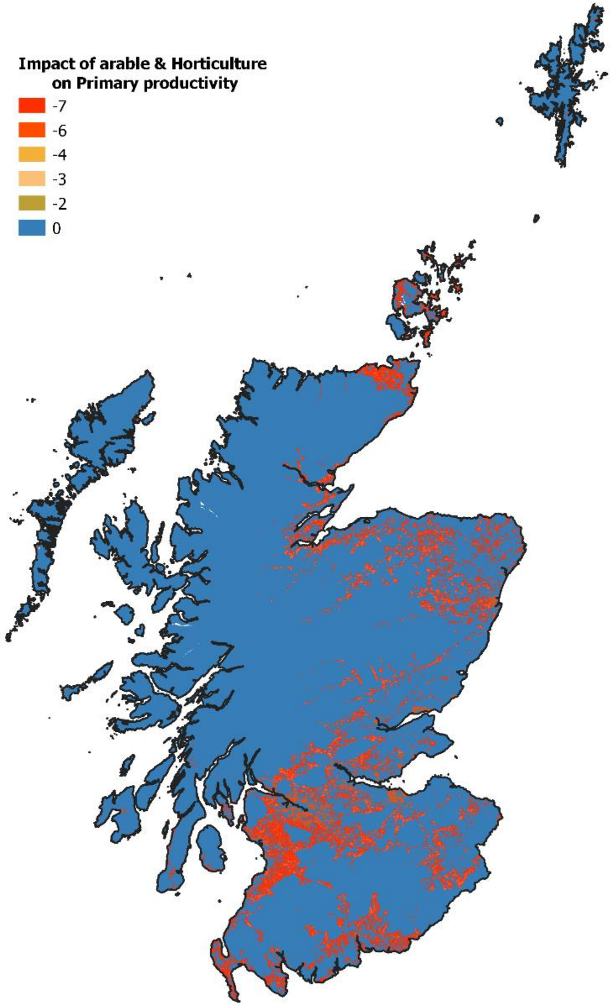
Table 25. "Green UK First" scenario version 4 (-10% imports, 0% bioenergy, 0% of arable area used for conservation, and 30% reduction in beef and lamb consumption): proportional areas predicted using IMPRESSIONS model and comparison (in italics) with the Baseline 2020 baseline

Region	Proportional land use (%)								
	Urban	Arable		Intensive grassland		Extensive grassland		Forest		Other
North-East	9.3	47.4	*31.6*	8.9	*1.4*	6.9	*-28.8*	15.3	*-4.3*	12.2
North-West	13.3	4.6	*0.4*	56.1	*17.5*	6.3	*-2.2*	9.0	*-15.7*	10.7
Yorkshire	10.0	37.2	*4.9*	28.6	*3.0*	6.9	*0.3*	6.6	*-8.3*	10.8
East Midlands	9.4	30.4	*2.3*	51.9	*0.3*	1.6	*0.4*	3.6	*-3.0*	3.1
West Midlands	12.5	21.5	*5.9*	53.4	*-4.4*	0.7	*-0.6*	11.0	*-0.8*	0.8
Eastern England	8.6	49.1	*0.7*	35.1	*5.3*	1.2	*0.0*	1.4	*-6.0*	4.6
London	75.4	3.2	*0.0*	20.3	*5.7*	0.3	*0.0*	0.7	*-5.7*	0.1
South East	14.6	13.9	*3.2*	56.1	*-1.5*	6.2	*0.2*	5.7	*-1.9*	3.5
South West	6.8	3.7	*1.5*	66.8	*7.8*	6.0	*-8.9*	12.5	*-0.3*	4.2
Wales	5.3	0.7	*0.1*	52.7	*9.7*	8.0	*-2.2*	24.3	*-7.5*	9.0
Scotland	2.3	13.4	*0.0*	26.8	*10.1*	4.6	*-2.0*	9.7	*-8.1*	43.2
N. Ireland	3.7	8.8	*0.1*	68.0	*20.0*	3.9	*-16.3*	2.4	*-3.8*	13.2
United Kingdom	7.1	17.3	*2.3*	41.7	*7.6*	4.7	*-3.8*	9.5	*-6.1*	19.8

Supply constraint: milk: 100%, meat: 98%, timber: 68%

Appendix F: Soil function indicators

a)



b)

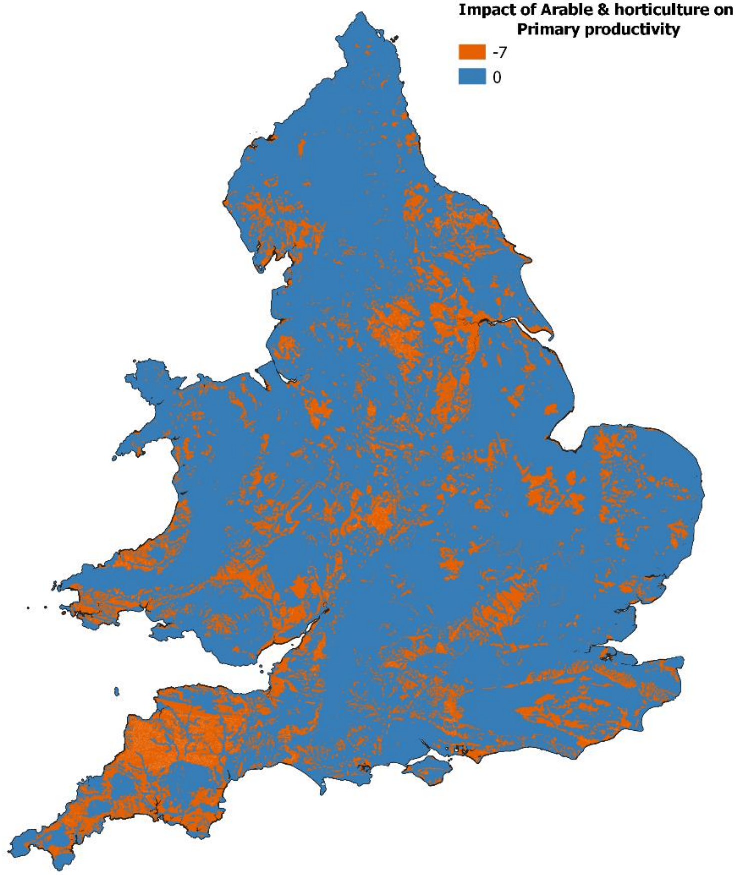
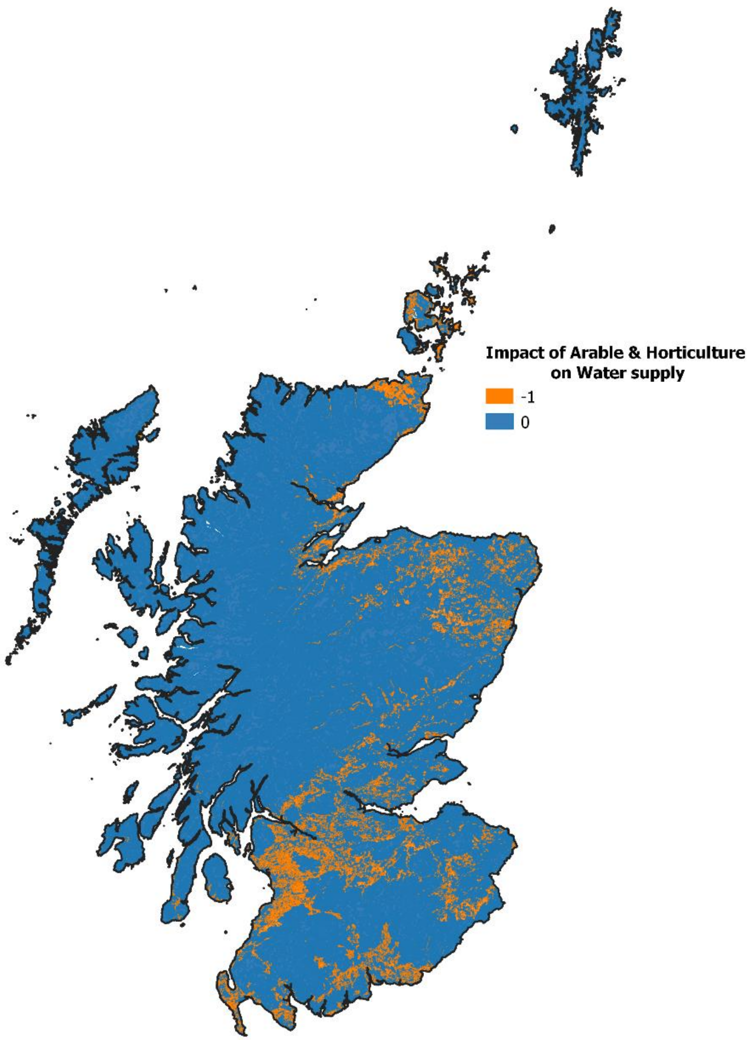


Figure 15. Predicted impact of arable and horticulture on primary productivity in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible. As Arable and Horticulture can only replace other land uses on land with good land capability, these maps show where less intensive management would be replaced on relatively good land.

a)



b)

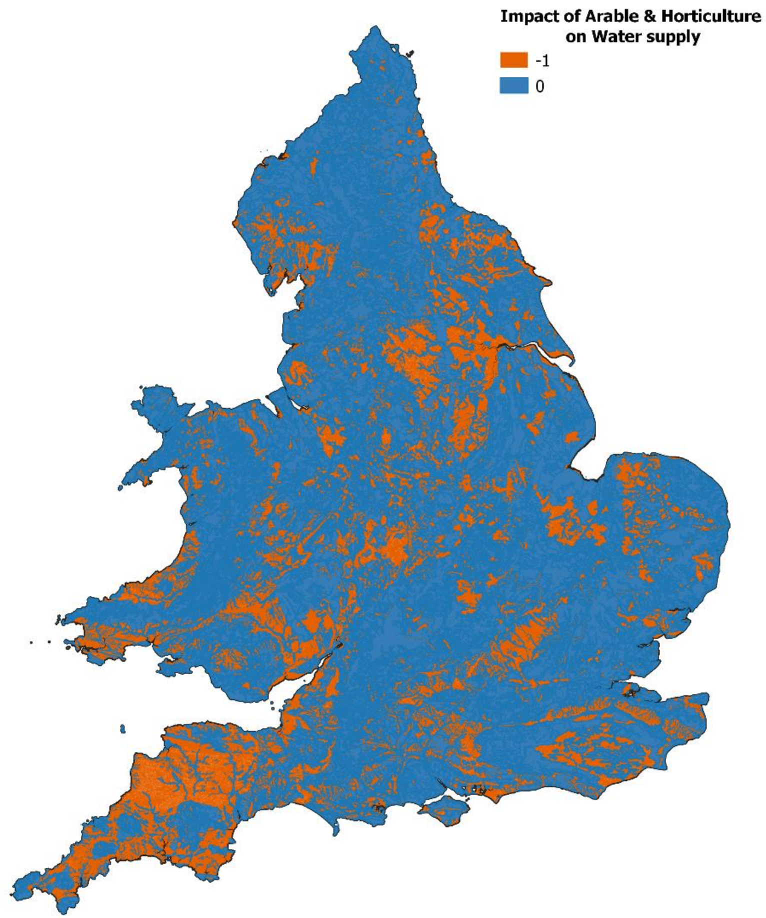


Figure 16. Predicted impact of a change to arable and horticulture on water supply in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

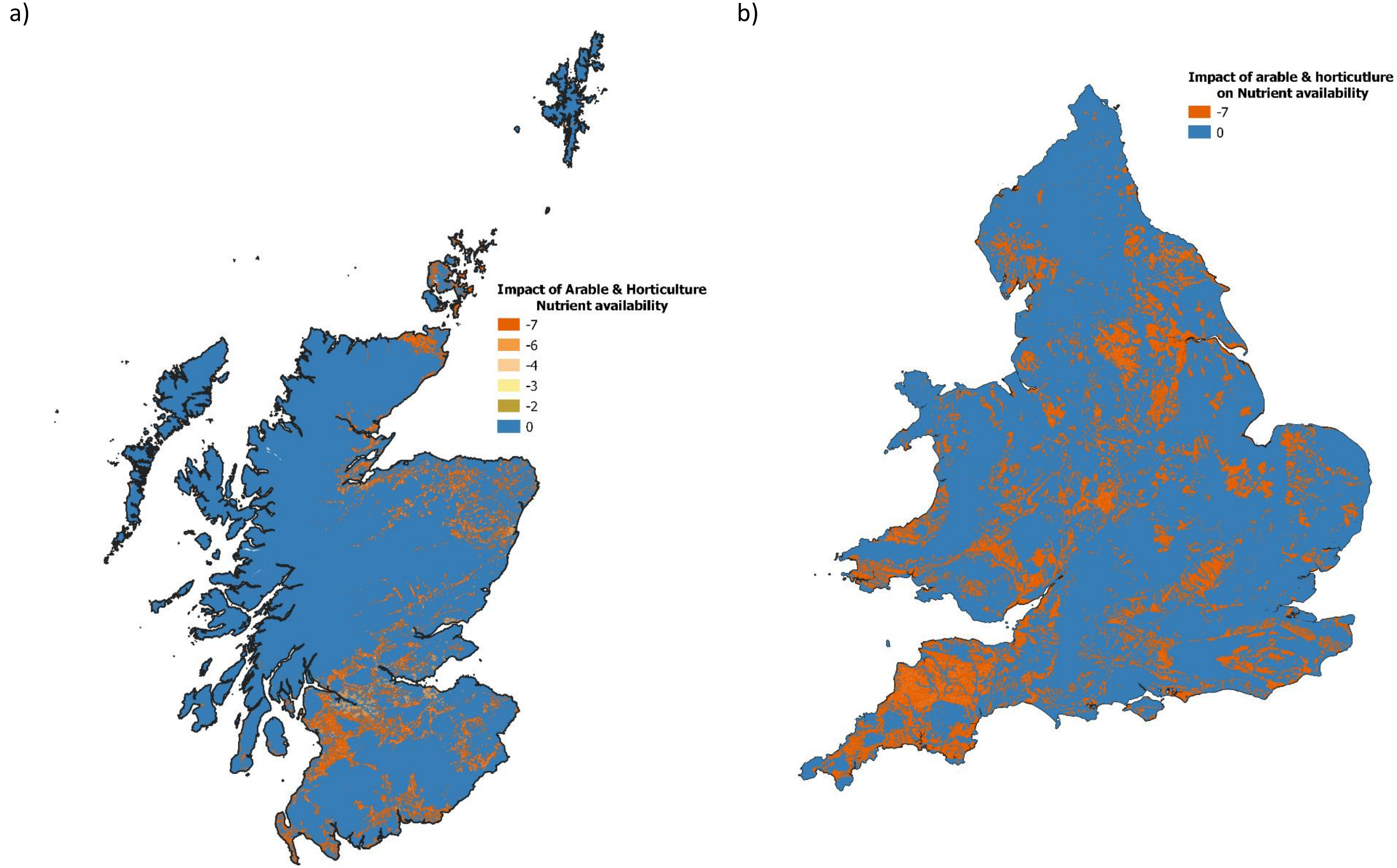


Figure 17. Predicted impact of a change to arable and horticulture on nutrient availability in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

a) b)

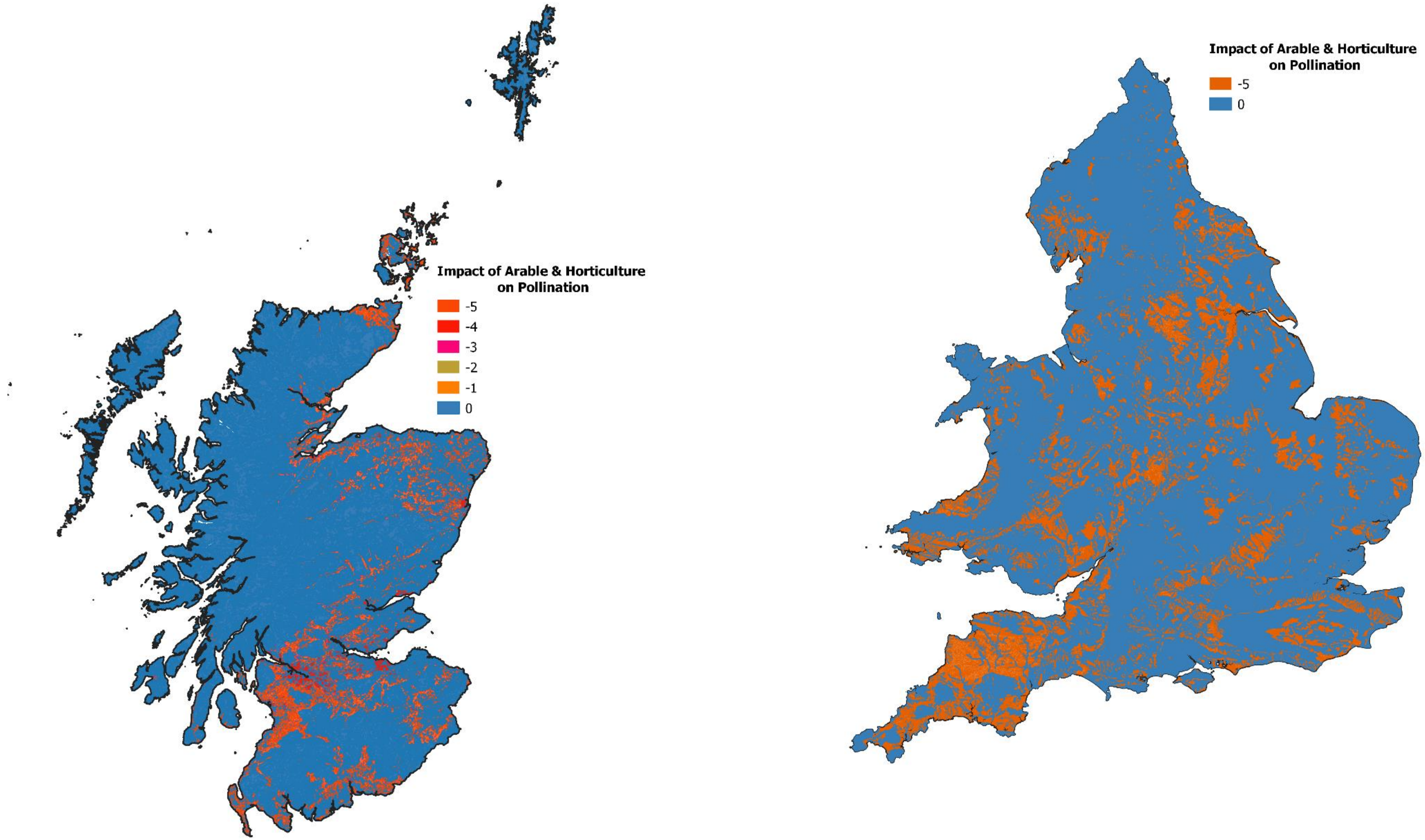
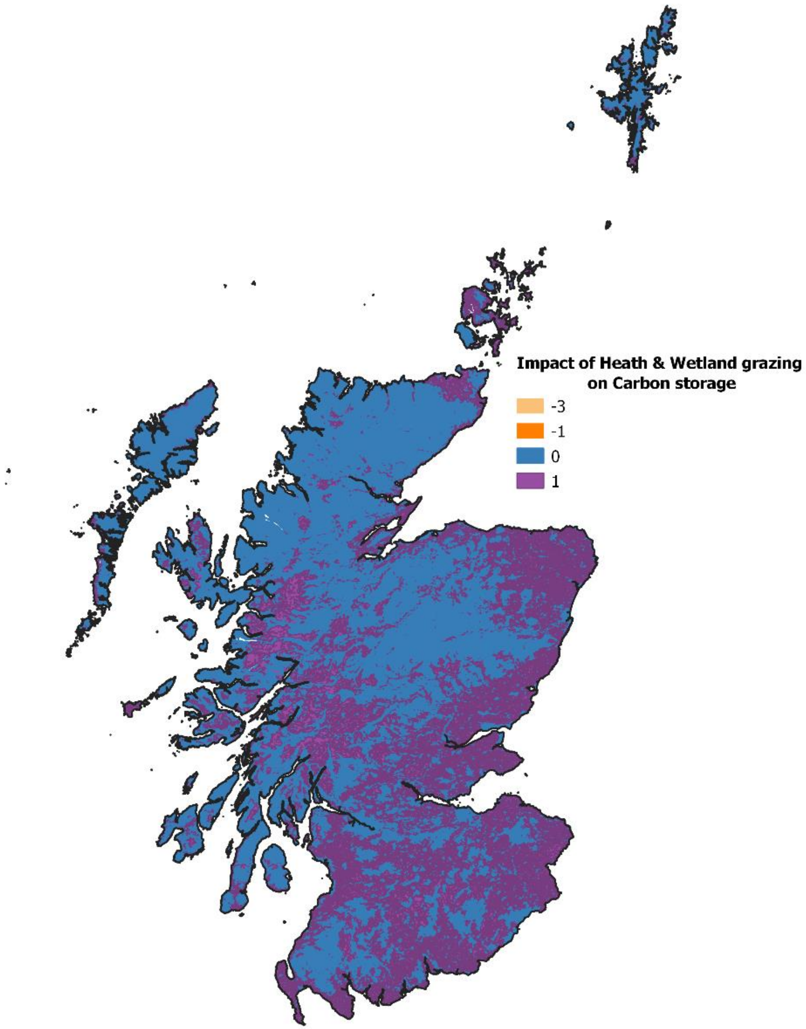


Figure 18. Predicted impact of a change to arable and horticulture on pollination in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

a)



b)

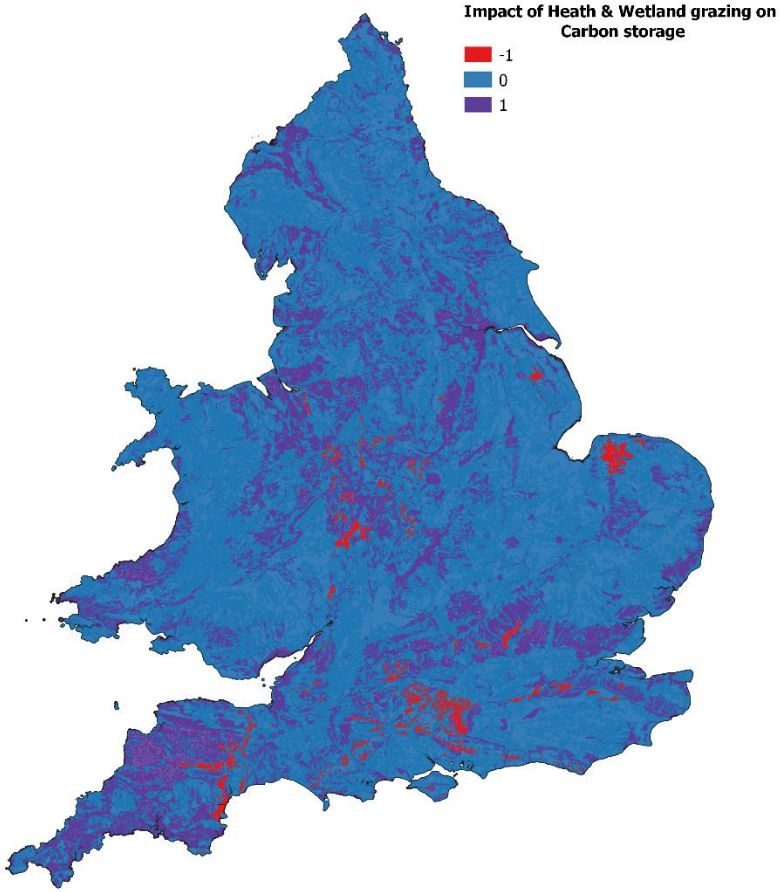


Figure 19. Predicted impact of a change to heath and wetland grazing on carbon storage in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

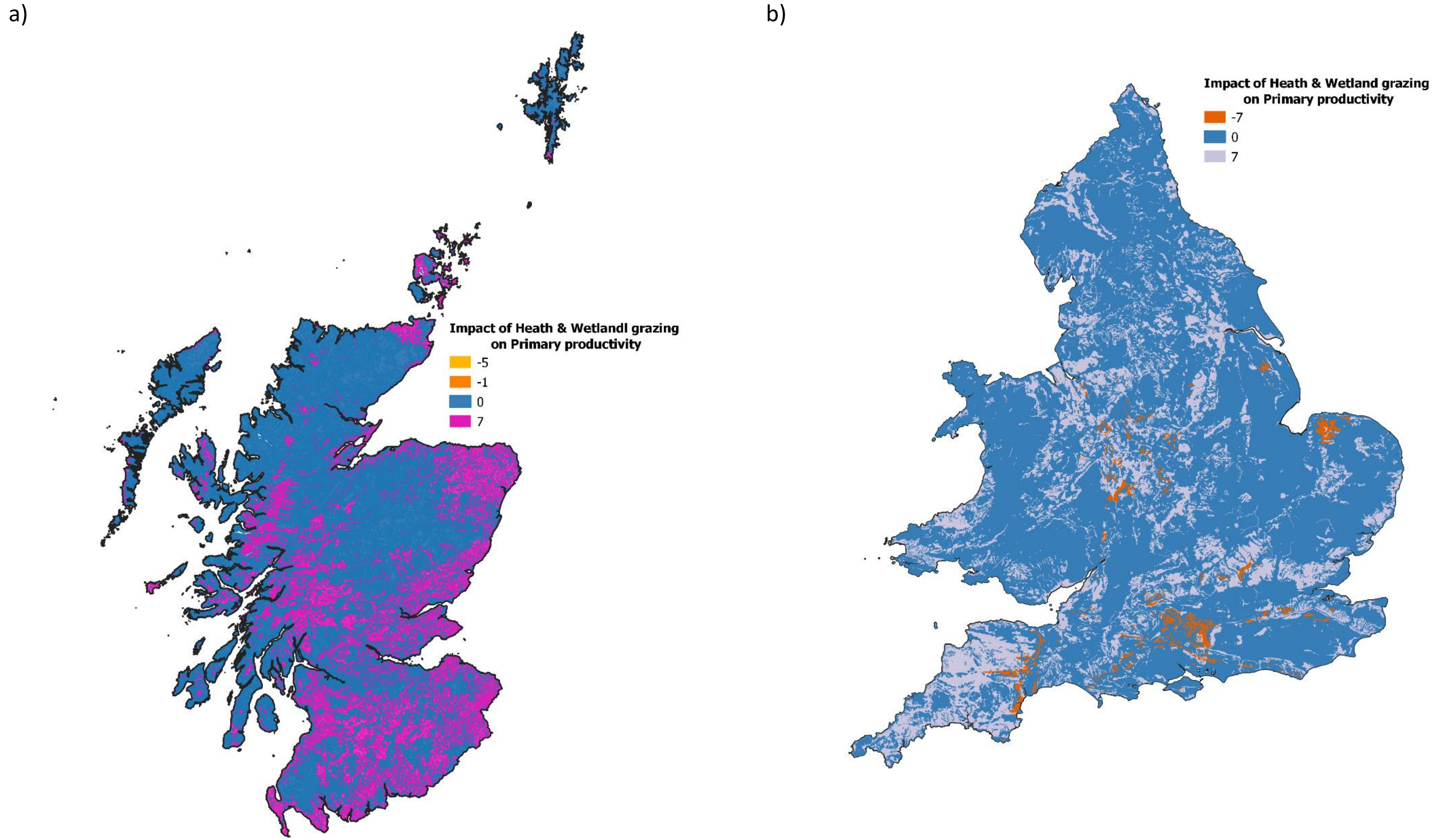


Figure 20. Predicted impact of a change to heath and wetland grazing on primary productivity in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible. These maps show broadly that a reduction in agricultural intensity leads to an improvement in soil function.

a) b)

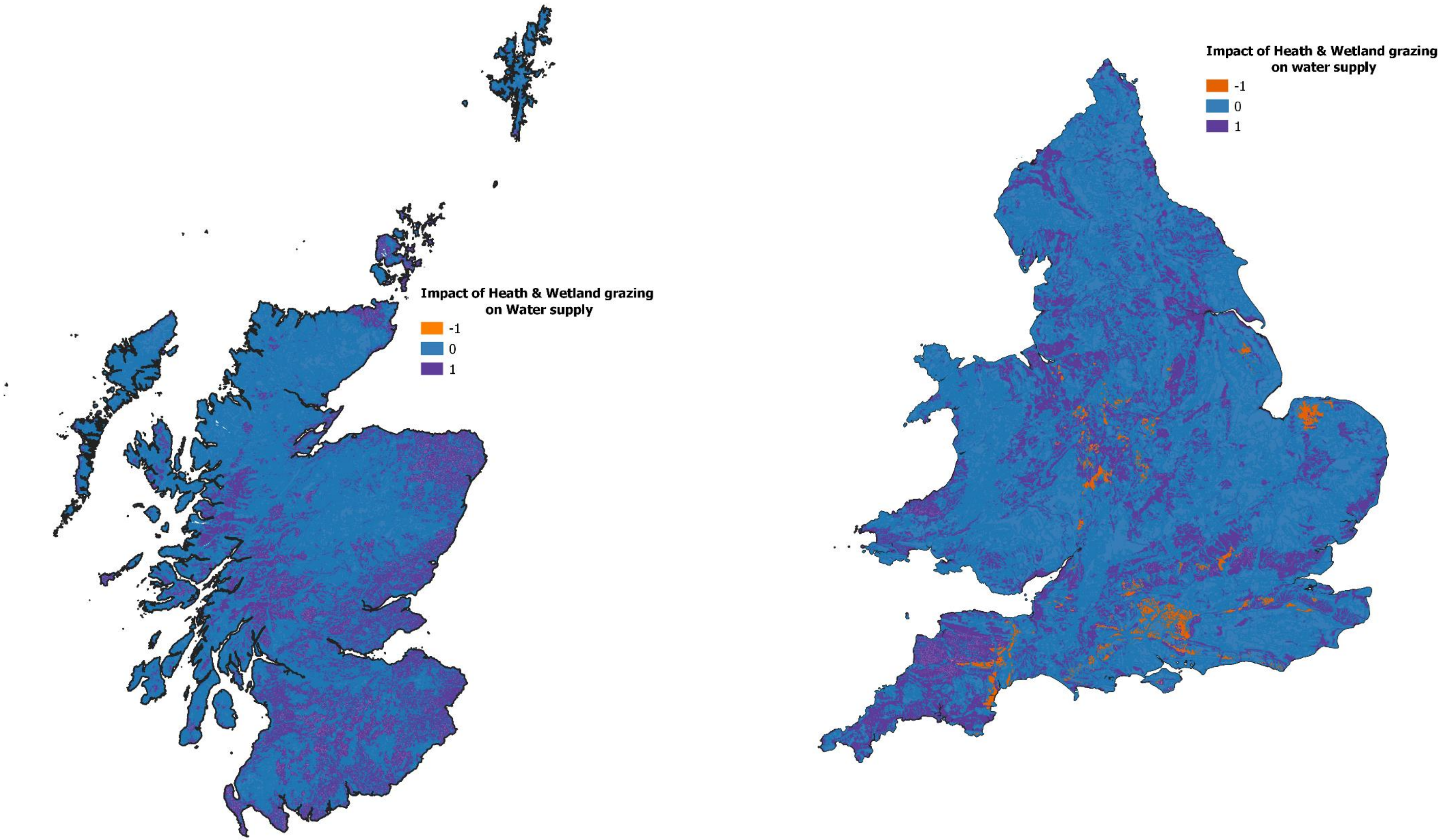


Figure 21. Predicted impact of a change to heath and wetland grazing on water supply in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

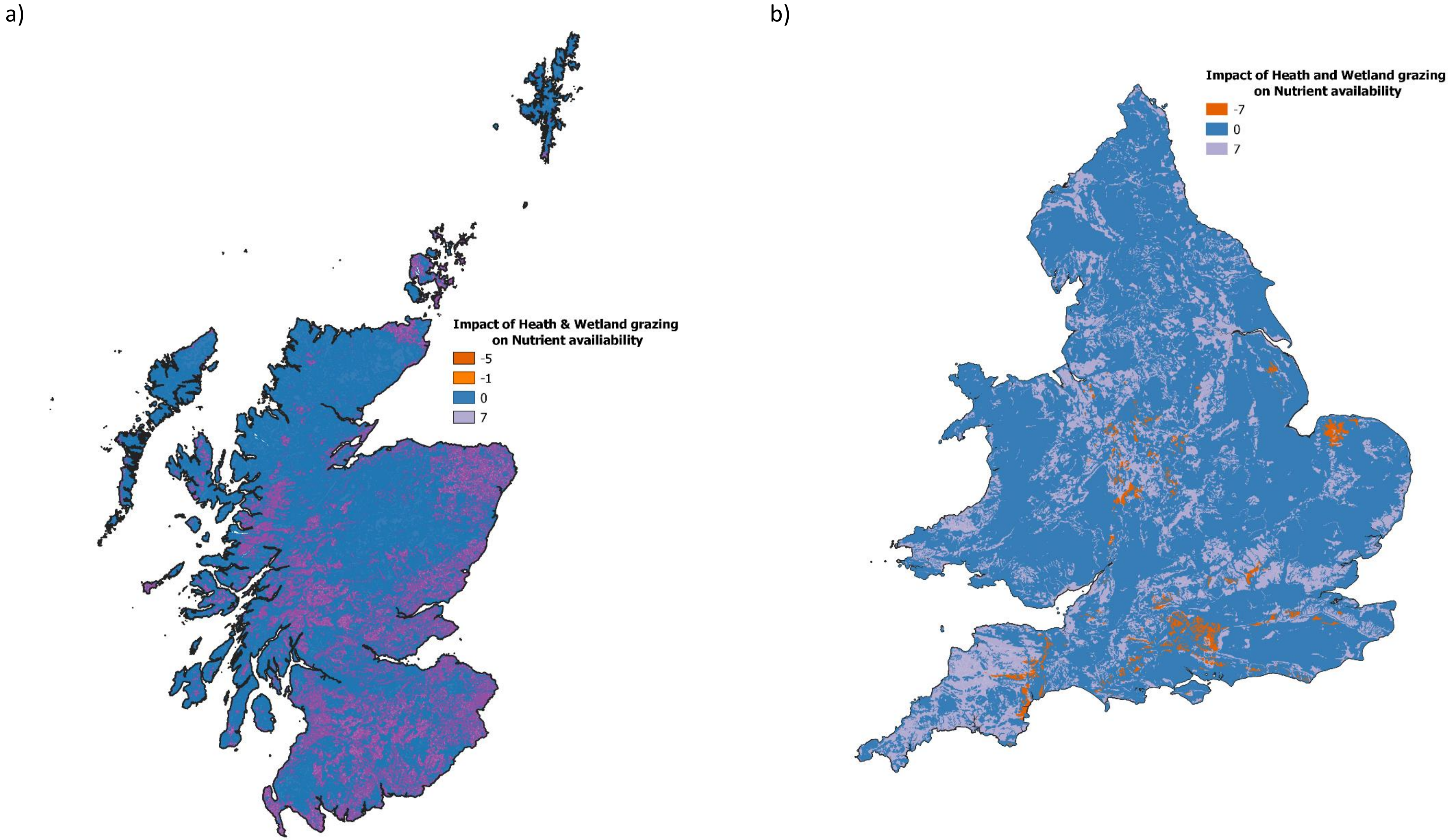
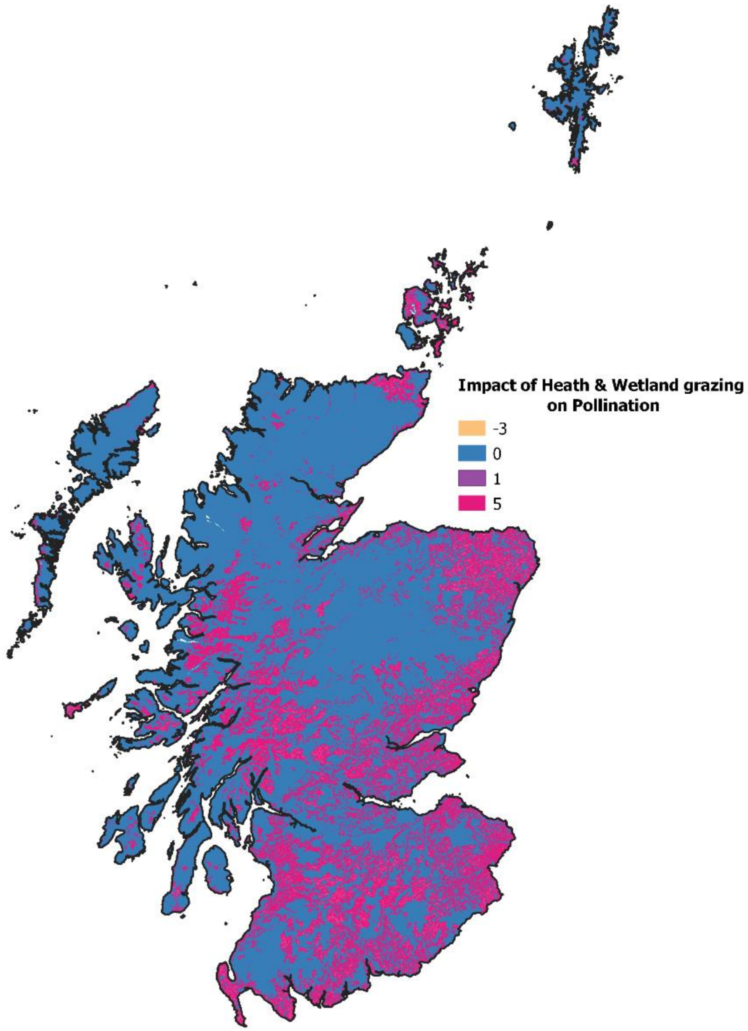


Figure 22. Predicted impact of a change to heath and wetland grazing on nutrient availability in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

a)



b)

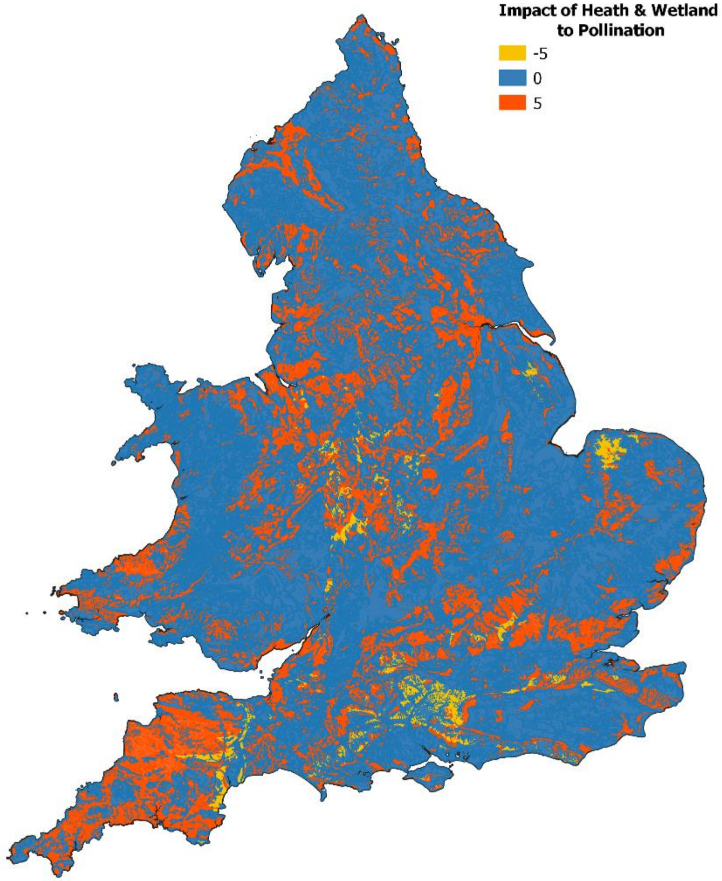
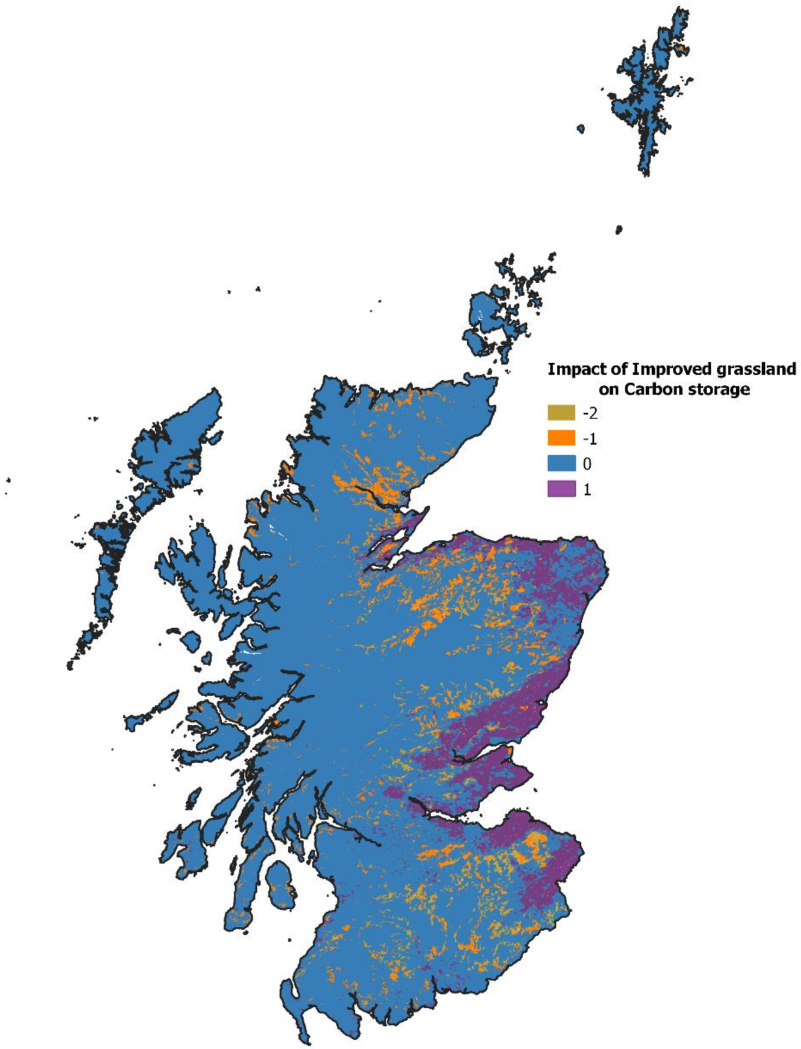


Figure 23. Predicted impact of a change to heath and wetland grazing on pollination in a) Scotland. There was no England and Wales equivalent. Blue areas indicate areas where change is not possible.

a)



b)

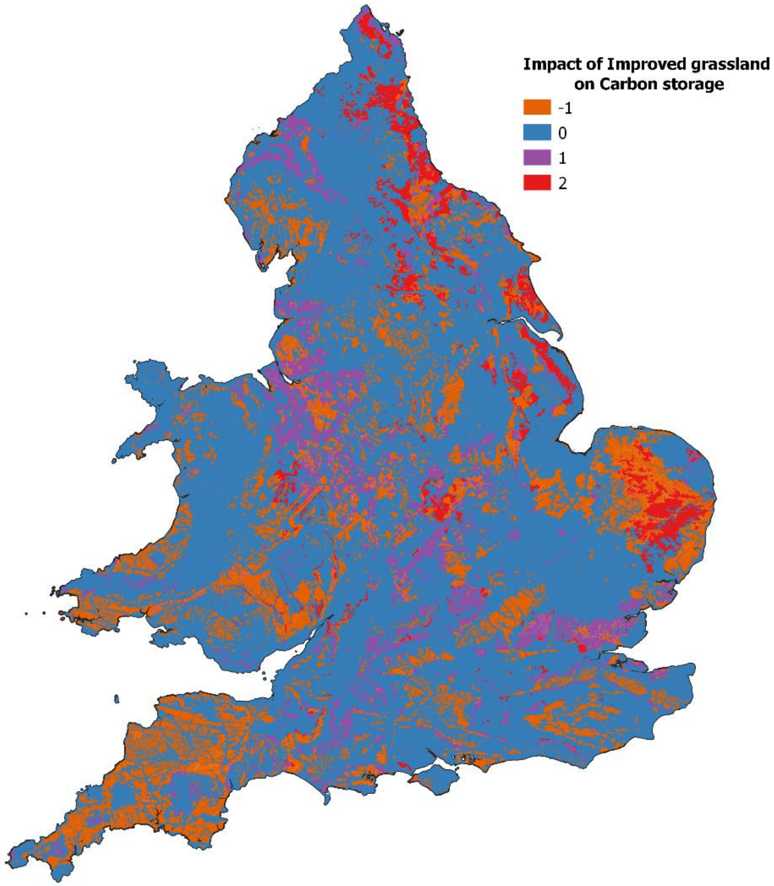


Figure 24. Predicted impact of a change to improved grassland on carbon storage in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible. Positive impacts are shown where there is a transition from arable and horticulture, and negative impacts are generally seen in transition from extensive grassland.

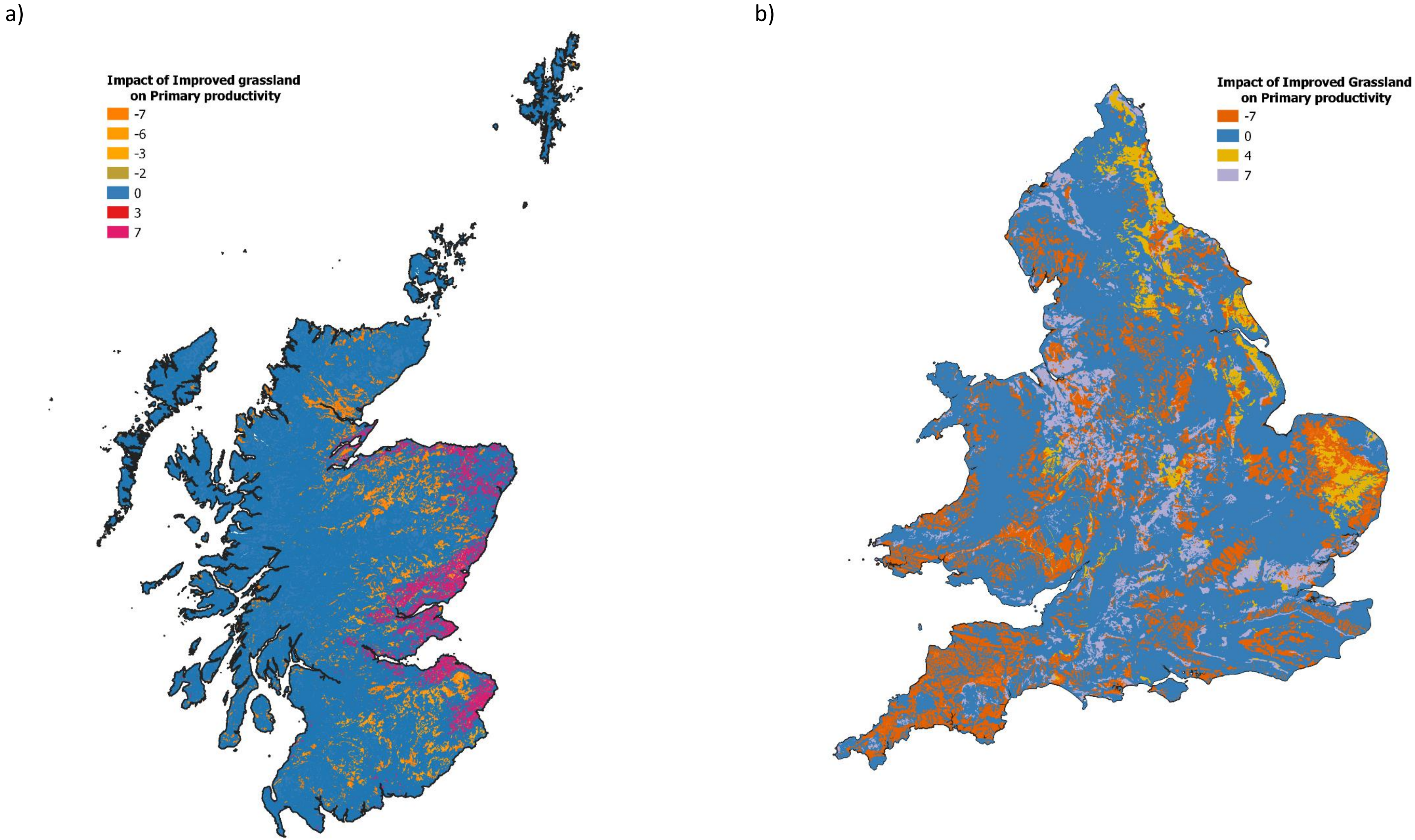
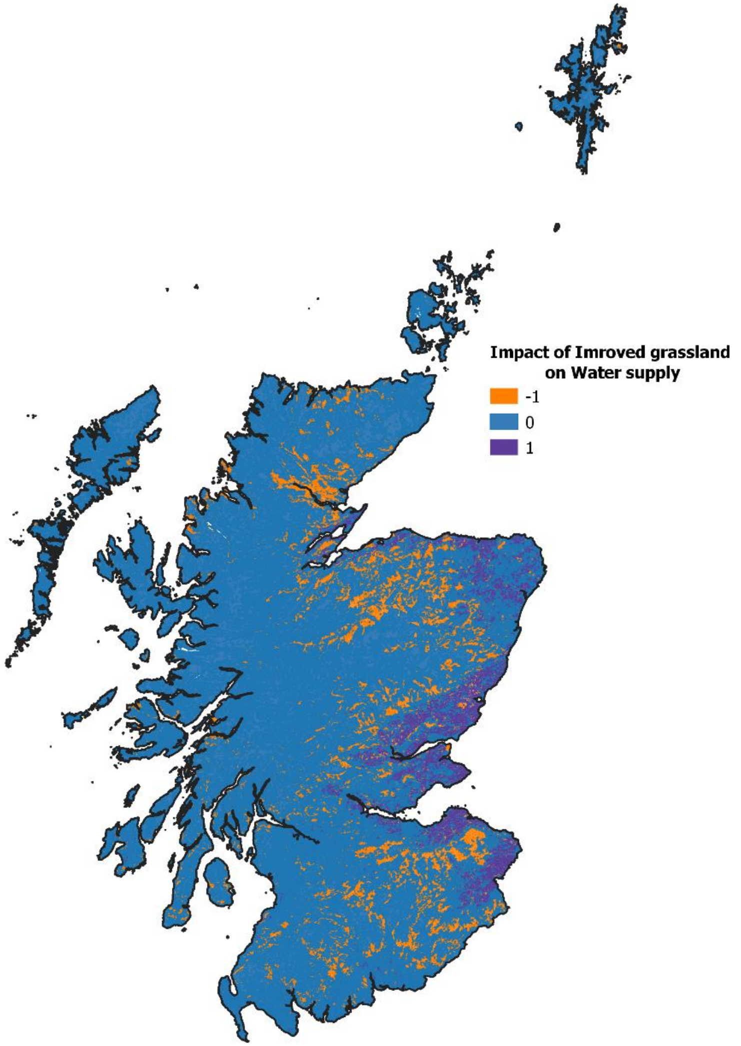


Figure 25. Predicted impact of a change to improved grassland on primary productivity in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

a)



b)

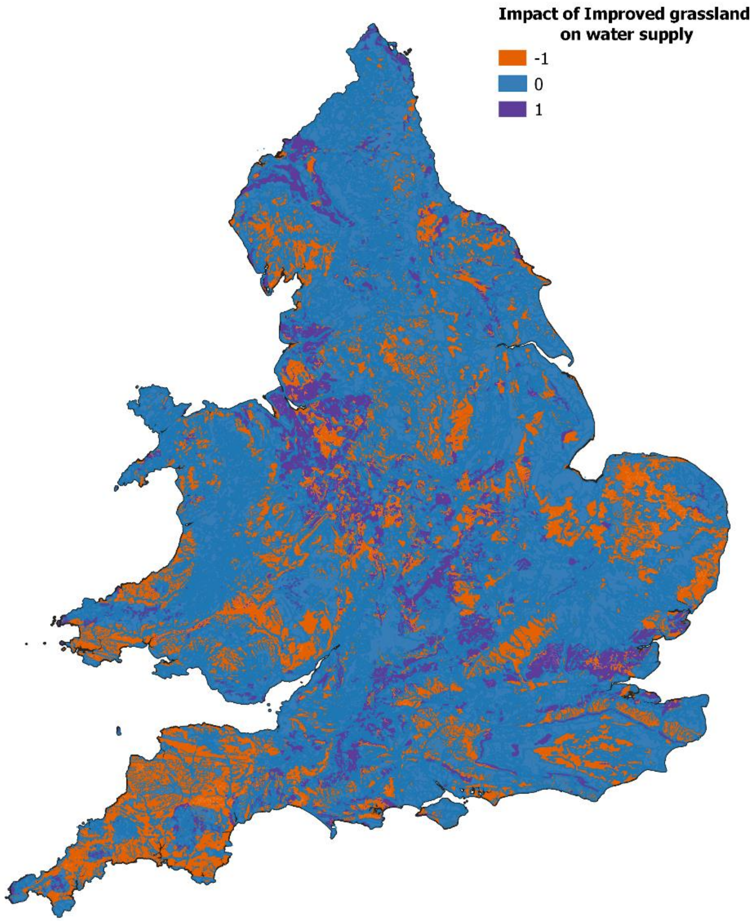
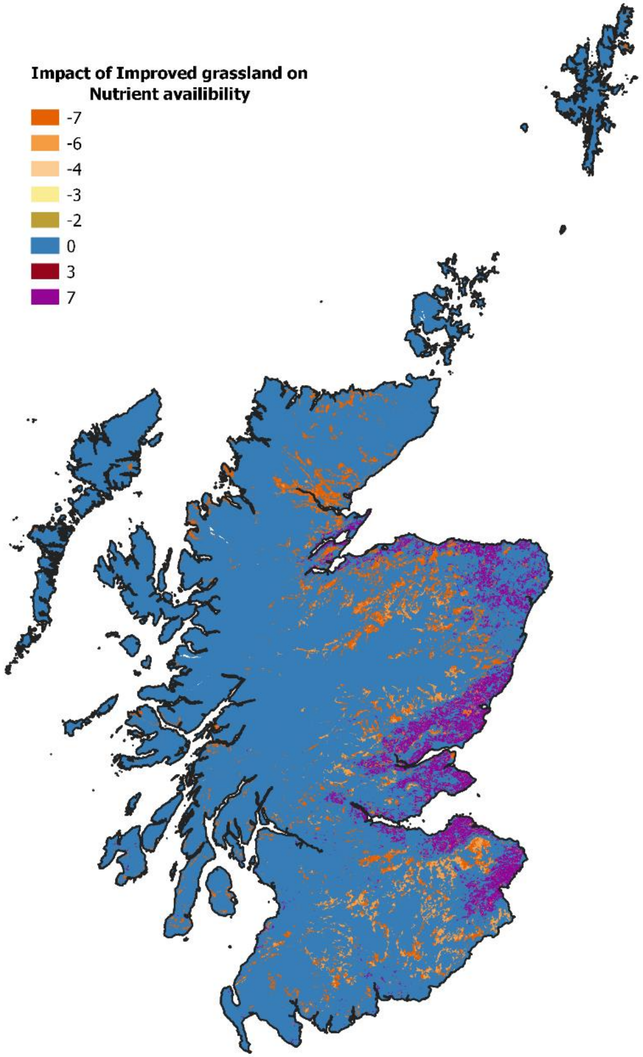


Figure 26. Predicted impact of a change to improved grassland on water supply in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

a)



b)

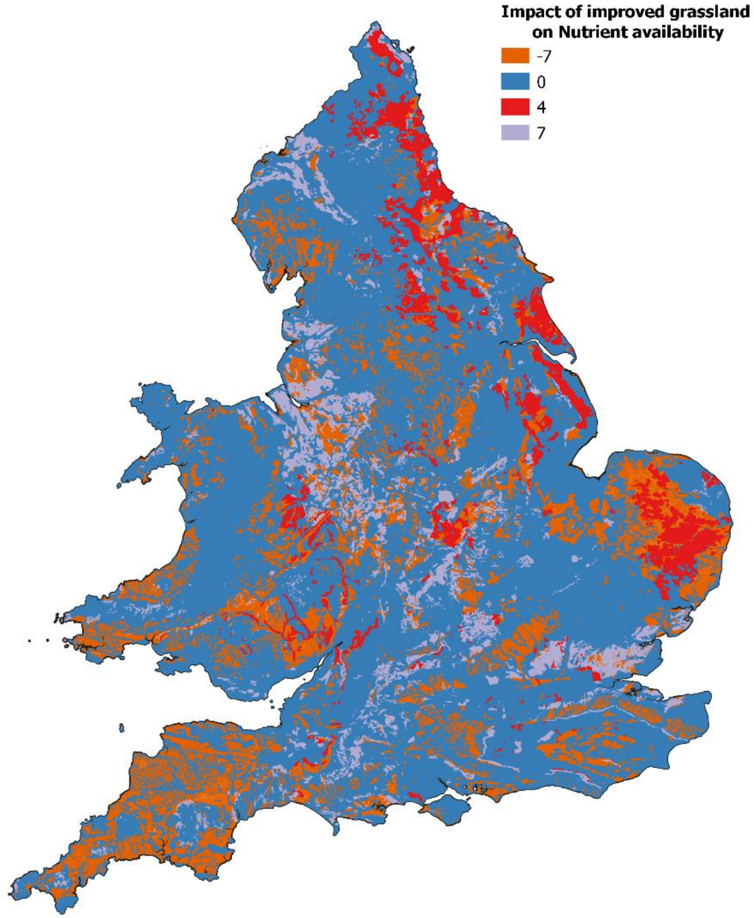
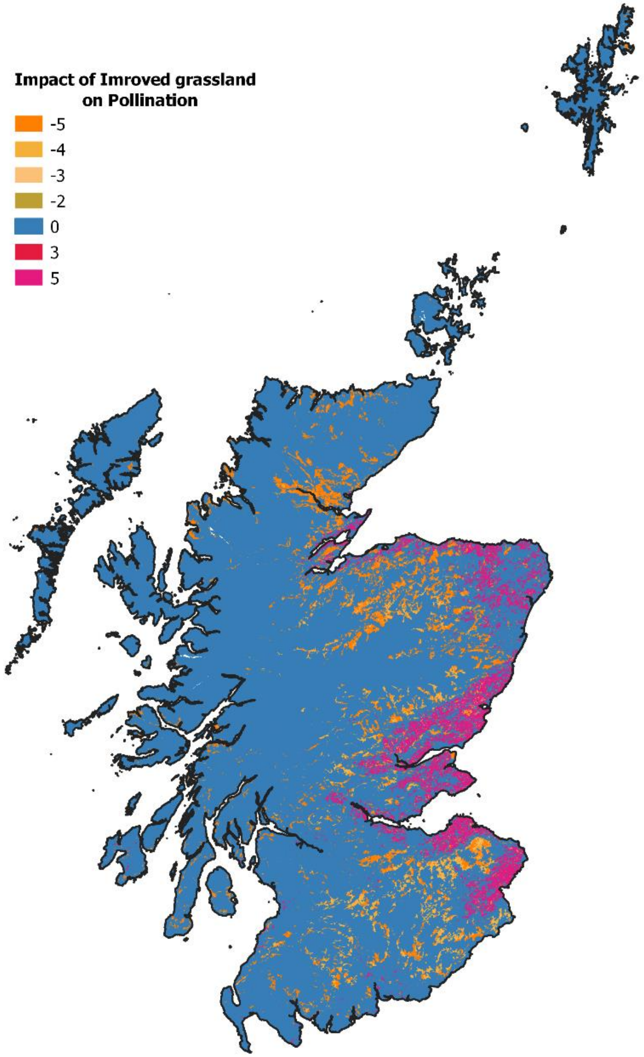


Figure 27. Predicted impact of a change to improved grassland on nutrient availability in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

a)



b)

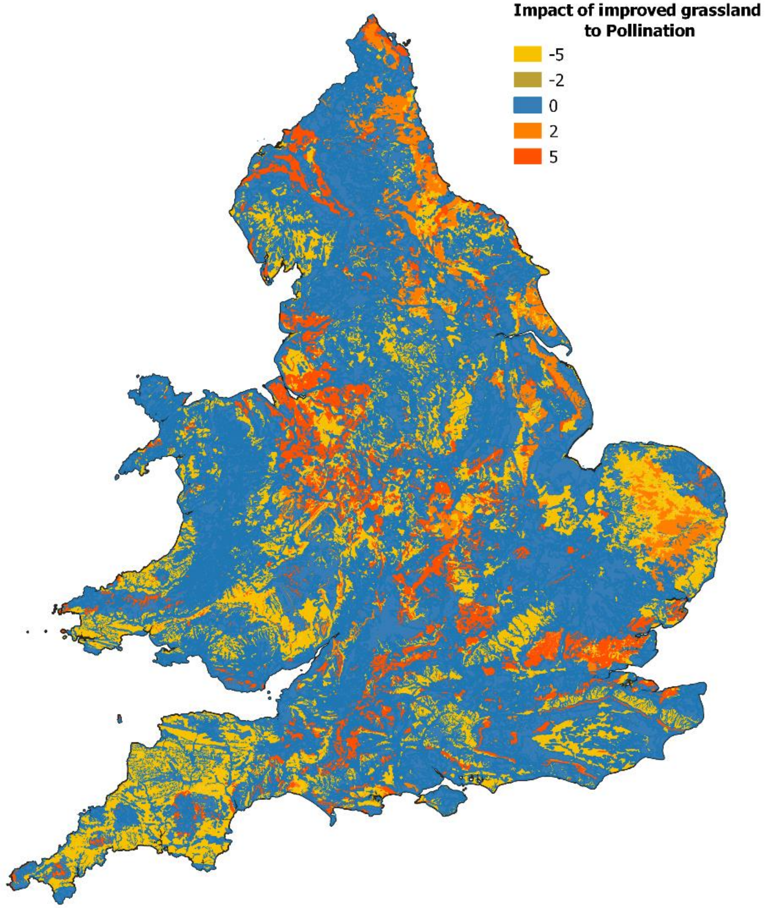
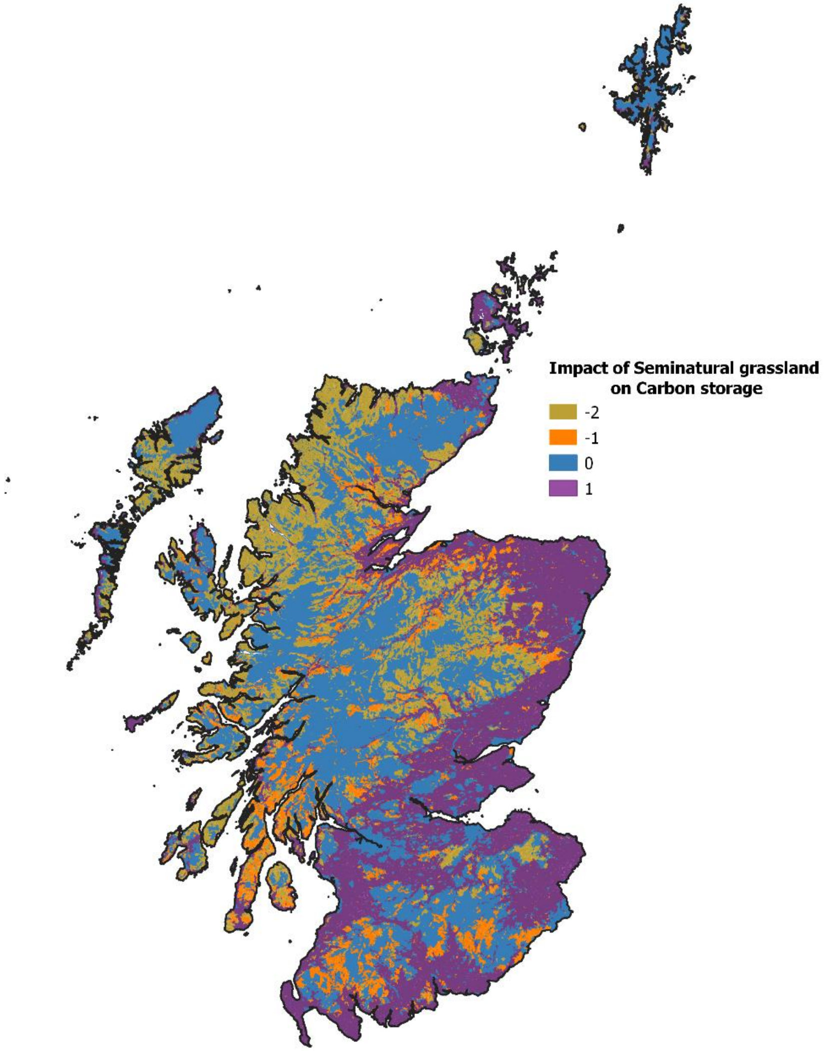


Figure 28. Predicted impact of a change to improved grassland on pollination in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

a)



b)

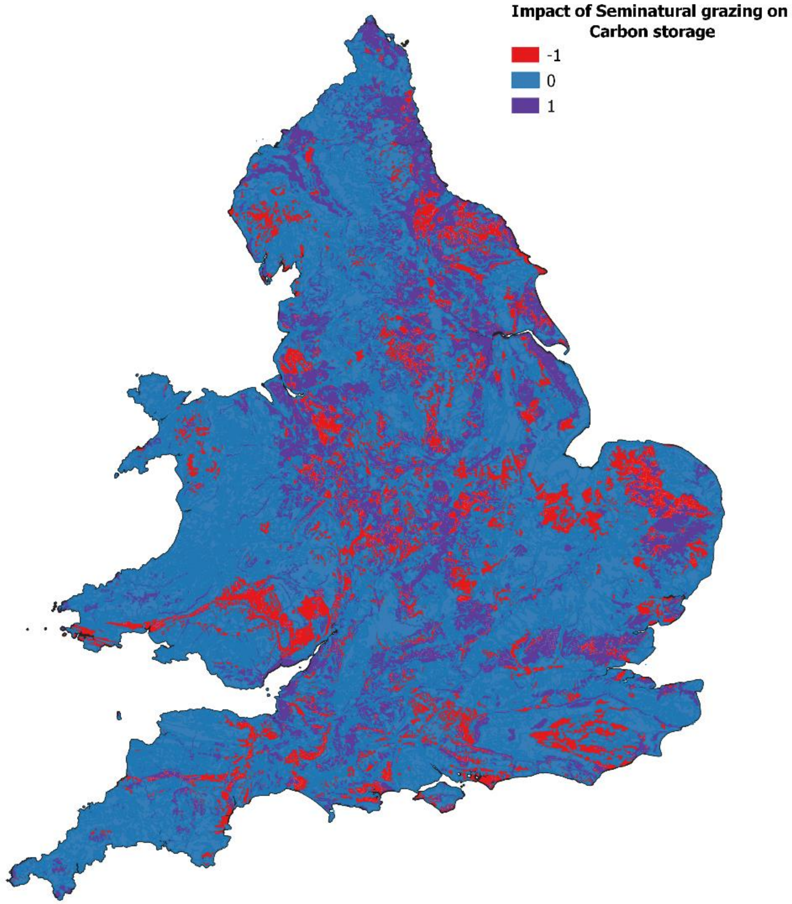
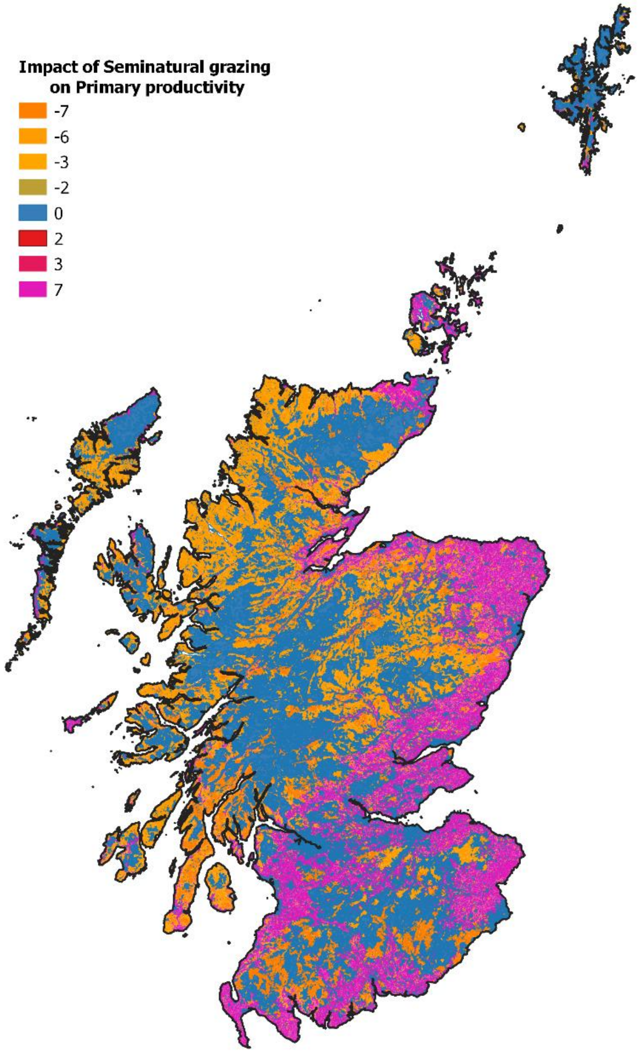


Figure 29. Predicted impact of a change to semi-natural grassland on carbon storage in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

a)



b)

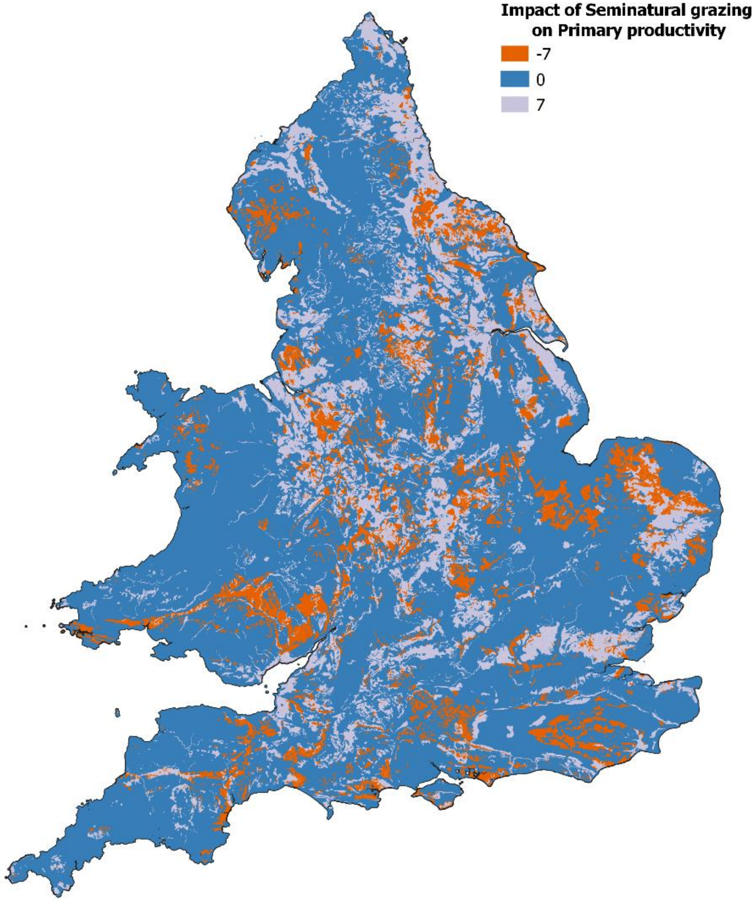


Figure 30. Predicted impact of a change to semi-natural grassland on primary productivity in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

a) b)

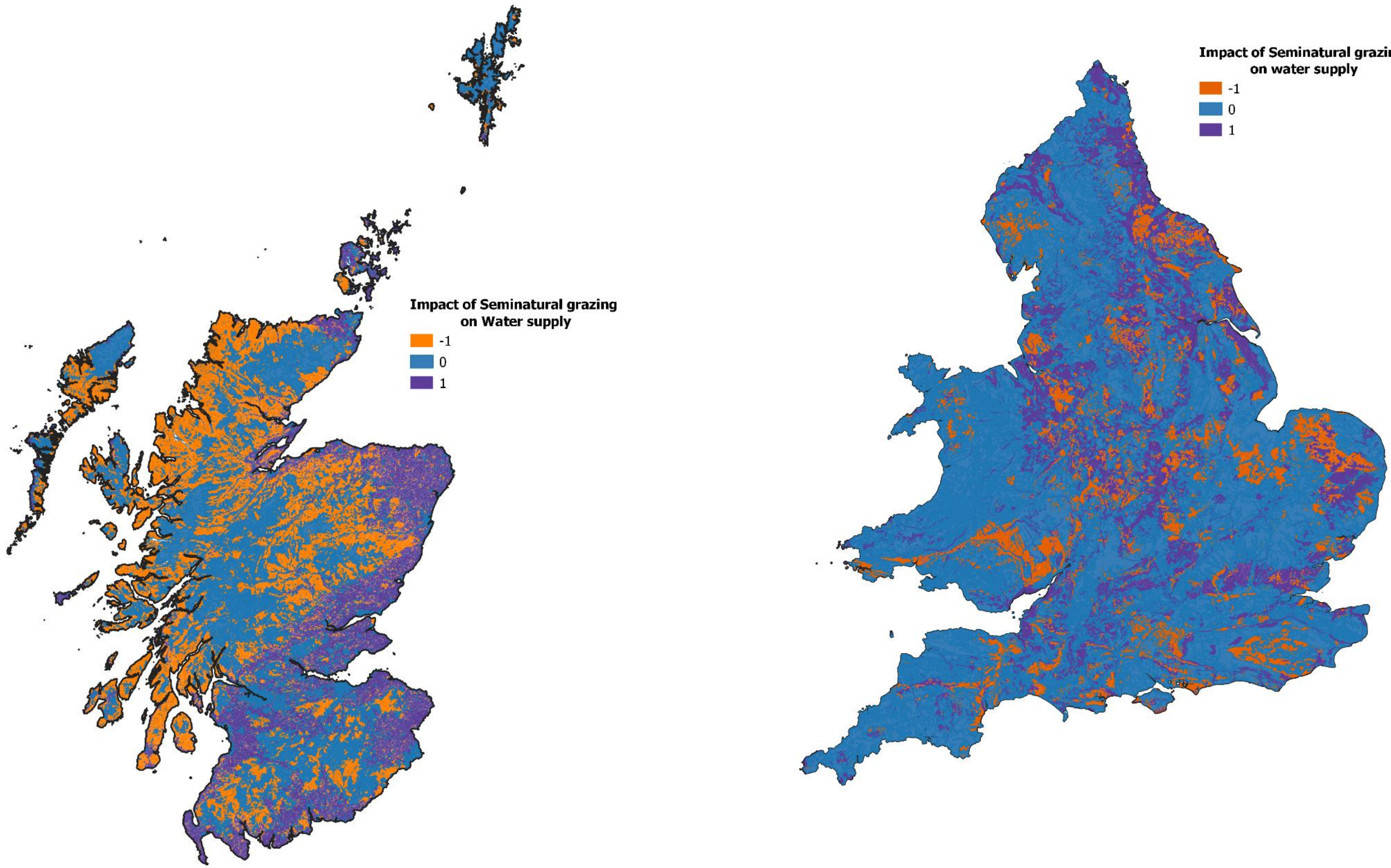


Figure 31. Predicted impact of a change to semi-natural grassland on water supply in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

a) b)

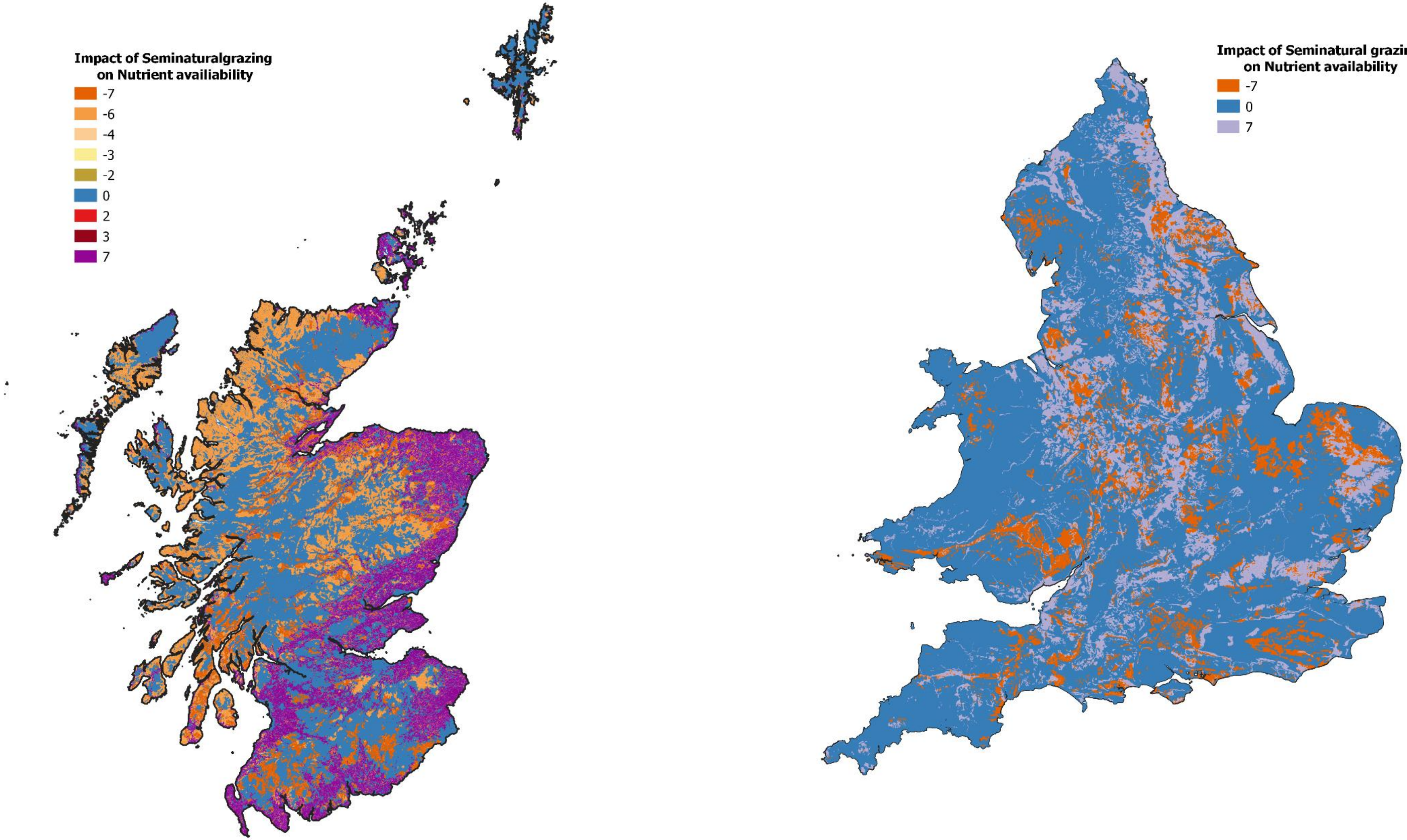
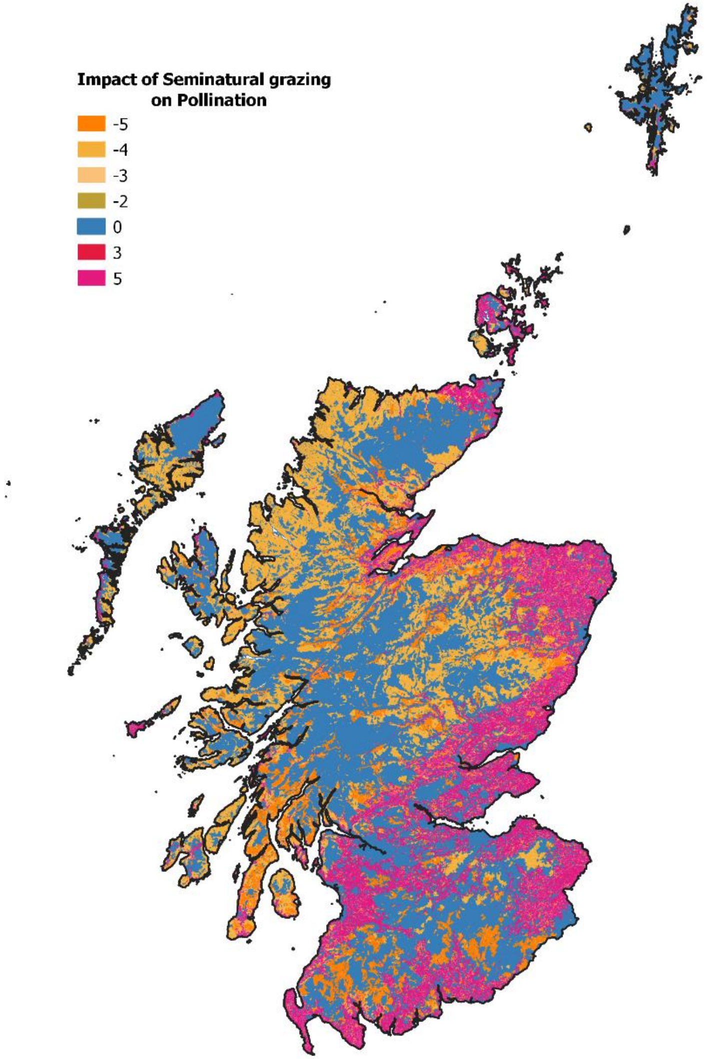


Figure 32. Predicted impact of a change to semi-natural grassland on nutrient availability in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

a)



b)

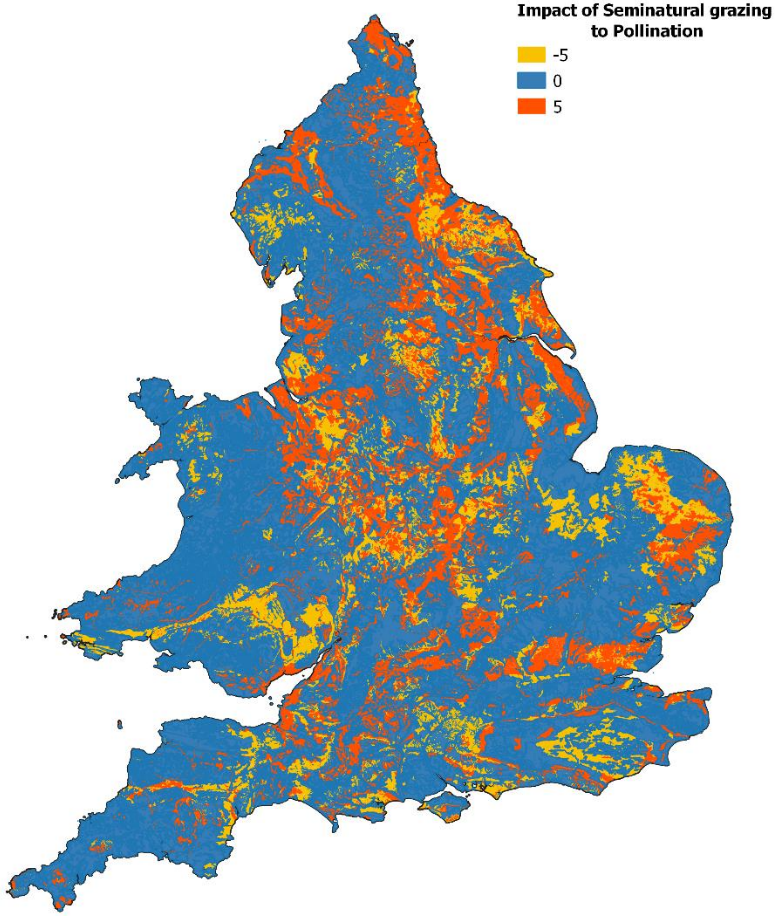


Figure 33. Predicted impact of a change to semi-natural grassland on pollination in a) Scotland, and b) England and Wales. Blue areas indicate areas where change is not possible.

Cranfield University

The James Hutton Institute