Environment and Rural Affairs Monitoring & Modelling Programme

ERAMMP Year 1 Report 12: ‘Quick Start’ Modelling (Phase 1)

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Version History

Version	*Updated By*	*Date*	*Changes*
1.0	PMO	30/9/2019	As published
1.1	CB	23/10/19	1. Corrected two of the author names/initials & 2. p.51 corrected error in units to be “£/ha changed/yr” in three bullet points
1.2	BJC	24/04/20	1. Versions 1.0 and 1.1 had two tables labelled as “2.1.7.4”. Rather than re-number all tables in the section, all references to “Table 2.1.7.3” were changed to “Table 2.1.7.3-A”, and all references to the first occurring “Table 2.1.7.4” were changed to “Table 2.1.7.3-B”. 2. Numbering of figures in section 2.1.7 (versions 1.0 and 1.1) begin with “Figure 2.1.4.4”. Rather than re-number all figures in section, this oversight is noted here, but figure numbers remain the same in version 1.2. 3. Figure 2.1.4.1 was replaced. The original figure was incomplete, and did not show all potential farm conversions. This only affects conceptual discussion, results were not changed. 4. Table 2.1.8.3 and related text was modified to replace the sector name “Beef” with the sector name “Grazers” when discussing potential conversions to non-agricultural uses. This only affects conceptual discussion, results were not changed. 5. All references to “Very Small Farms” were changed to “Part Time Farms” for consistency of definition based on Standard Labour Requirement. This only affects conceptual discussion, results were not changed. 6. Figures were reformatted where necessary to improve legibility of labels and legends, and font size of figure legends was increased and standardised. Information content was not changed. 7. Tables were reformatted where necessary for uniformity of font size, bolding and shading, and font size of table legends was standardised. Information content was not changed. 8. This version history table moved to up one page. Blank page inserted. Pages renumbered.

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Signed	

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Contents

Appendices referred to in this report can be found in Technical Annex (12TA1)

Abbreviations and some of the technical terms used in this report are expanded in the project glossary: https://erammp.wales/en/glossary (English) and https://erammp.cymru/geirfa (Welsh)

1 Summary

The potential impact of Brexit on the farming sector and wider environment is just one of the many challenges facing the Welsh Government. There are a range of decision and modelling tools which can be used to explore potential outcomes and the areas at risk where the environmental regulatory floor needs to be enhanced or social transition programmes put in place. The same tools can also be used to explore a range of 'what if' scenarios for different land management options which could be included in new Payment for Ecosystem Service (PES) schemes or in national land management payment schemes to replace CAP.

To meet this challenge in Wales, a partnership between the Welsh Government, their stakeholders and a consortium of research organisations led by the Centre for Ecology and Hydrology (CEH) was formed. This partnership, called ERAMMP, (https://erammp.wales/en) combined expert knowledge and a range of decision and modelling tools to examine potential changes in agricultural land use that might result from Brexit, and to explore potential benefits of new land management options.

Brexit Trade Scenarios

Three Brexit trade scenarios were developed in Welsh Government by the Brexit Roundtable convened by the Minister for Energy, Environment and Rural Affairs:

- EU Deal (EU based free trade agreement)
- No Deal (WTO rules apply)
- Multilateral Free Trade Agreements (MFTA).

(https://gov.wales/evidence-and-scenario-sub-group-roundtable-wales-and-brexit).

The Evidence and Scenarios Roundtable Sub-Working Group translated the trade scenarios into potential shifts within and between the principal livestock sectors in Wales (Dairy, Beef and Sheep) in response to changing market demand for dairy and meat products. The ERAMMP research consortium then converted the potential livestock shifts into the potential changes in agricultural land use needed to manage and support the livestock shifts.

The agricultural land use changes were mapped across Wales at field and farm scale and combined with other national data sources to drive a series of agricultural pollutant, woodland and ecological models exploring a range of potential "knock-on" consequences for environmental issues including woodland creation, agricultural pollutants, GHG emissions, water quality, air quality and bird biodiversity.

Some key findings from the Brexit work include:

- Potential change in animal numbers are between -36% (sheep sector; No Deal and MFTA) and +54% (Dairy; No Deal). The sheep sector is more negatively affected due to reliance on exports relative to the dairy and beef sectors.
- Total area potentially affected by the Brexit trade scenarios is 3 to 17% of current farmland depending on the scenario.
- Total area potentially changing to non-agricultural uses is 2 to 15% of current farmland depending on the trade scenario (with the sheep sector comprising 65 to 100% of this land). For the MFTA scenario, potential changes for all three livestock sectors is to non-agricultural use.

- The distribution of land area potentially affected is highly spatially variable depending on the trade scenario, the current distribution of farming sectors, the agricultural quality of the land affected, and proximity to farms in a similar sector (Figure 1.1). The results have been disaggregated by region to further illustrate this spatial variability.
- Whilst the total agricultural land area potentially affected does not differ markedly between the No Deal and MFTA scenarios, the change within and between livestock sectors is notably different (Figure 1.1).

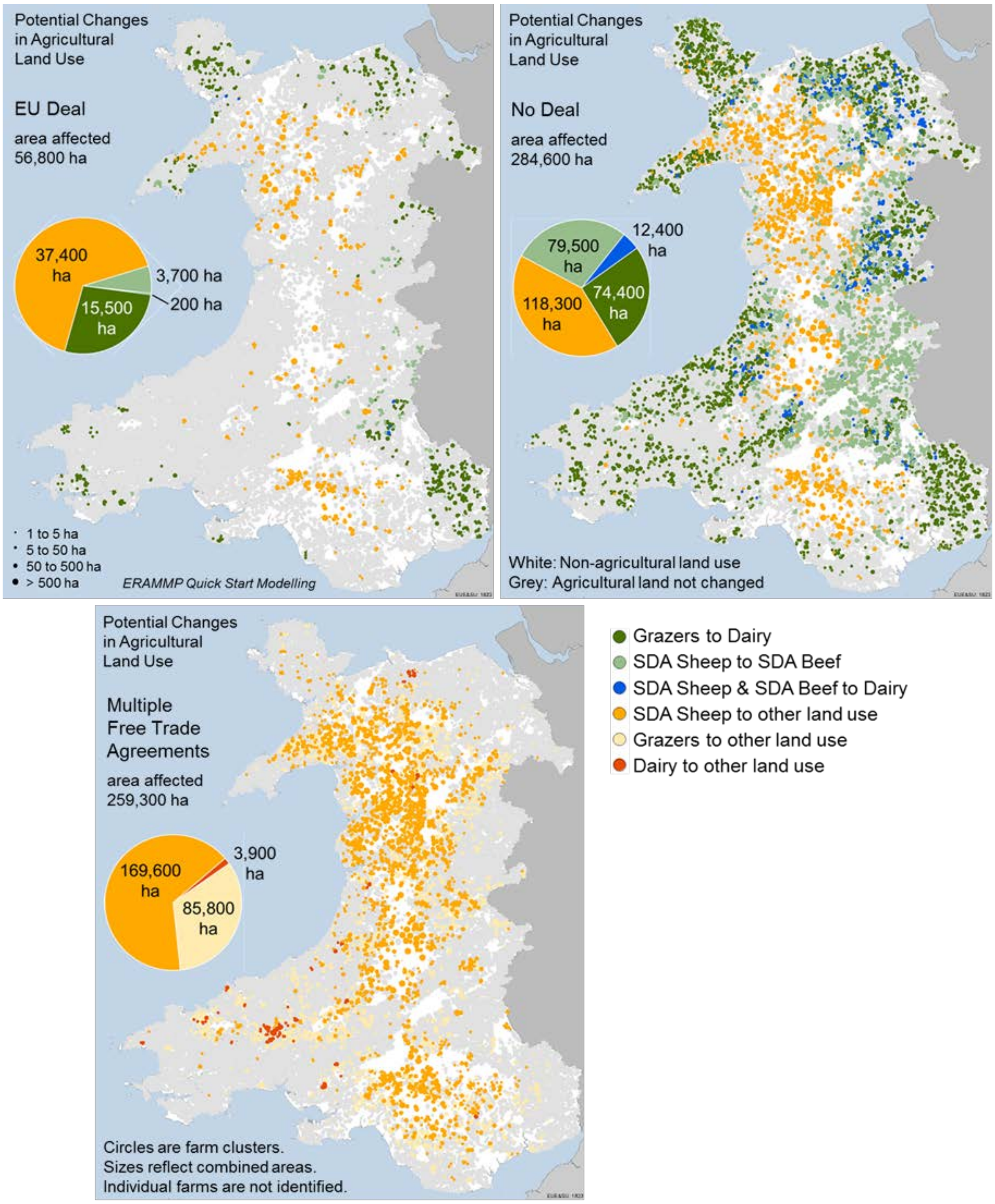


Figure 1.1. Potential agricultural land use change for the three Brexit trade scenarios. Farms that have potential for land conversion and are geographically close to each other have been combined into circles proportional to their combined area, such that individual farms cannot be identified. Grey areas are included in the simulation.

- The area with potential to change to non-agricultural use may not all be available for new woodland planting due to current constraints and sensitivities included in the Glastir Woodland Creation Rules (GWC-Wales, 2018).
- Environmental outcomes of the trade scenarios have been explored in terms of magnitude and spatial distribution across Wales for greenhouse gas (GHG) emissions, water quality, air quality and bird abundance and diversity. The results emphasize the improvement in environmental outcomes for some areas but risks of degradation in others (see Figure 1.2 for one example).

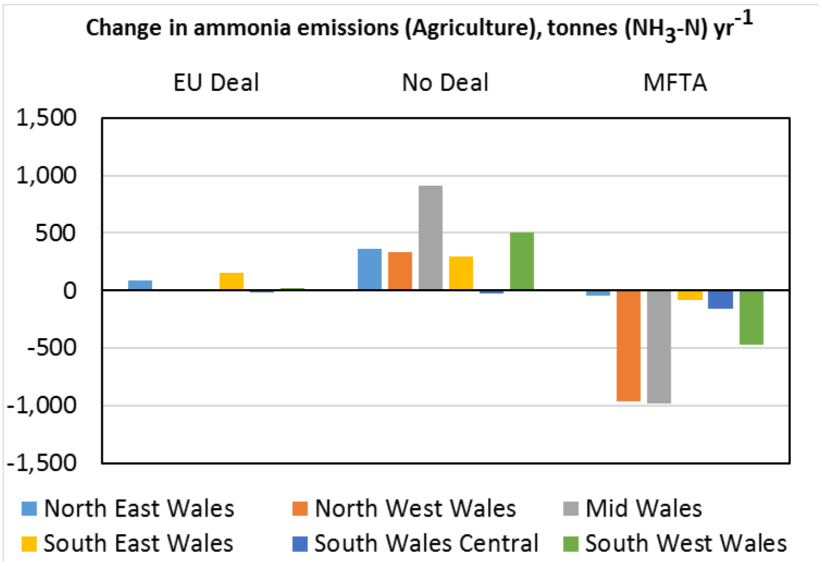


Figure 1.2. Potential change in ammonia emissions at a regional scale for the three Brexit trade scenarios.

Some specific issues which should be considered with respect to the Brexit trade scenario analyses include:

- Expert judgement and many assumptions have been taken in creating the Brexit trade scenarios and anticipated livestock sector responses. We are going into uncharted territory, expert knowledge will inevitably fall short, and unexpected and unpredictable outcomes may occur.
- Only the three dominant livestock sectors (sheep, beef and dairy) have been considered due to time constraints.
- Spatial patterns of the potential environmental impacts are highly variable largely because of the combined impact of the spatial distribution of environmental constraints (e.g. soil, climate) and their influence on current farming practices.

Finally it should be noted that, for transparency, effort has been made throughout this report to describe in detail the assumptions, limitations and uncertainties in the analyses. The language used throughout has been deliberately chosen to emphasise the highly speculative nature of the work. Predicting the behaviour and decision making of any sector has many pitfalls, especially when no comparable situation has been experienced before.

Land Management Scenarios

The ERAMMP Quick Start modelling team undertook an initial rapid assessment of the spatial distribution of partial monetary values attributable to a limited number of public goods potentially resulting from "what if" changes in land management practices. The assessment focused on test areas in three contrasting Welsh landscapes:

- The Conwy catchment.
- The Vale of Clwyd.
- A group of valleys in South Wales which include the Heads of the Valleys region (called "Heads of Valleys" for convenience in this report).

The land management options considered and the scenarios examined included:

- Woodland creation using five combinations of woodland type and management;
- Removal of agriculture from low quality land using two intensities of removal (based on Agricultural Land Class: ALC 5 only and ALC 4 & 5 combined);
- Removal of agriculture from peatlands.

Environmental changes potentially resulting from these land management scenarios were estimated and mapped in the study areas. Monetary values (and spatial variation by landscape type) were derived for a set of four 'public goods' resulting from the potential environmental changes:

- Climate mitigation from reduction in agricultural GHG emissions;
- Climate mitigation from C sequestration in new woodland;
- Public health benefits from removal of particulates (PM 2.5) by new woodland;
- Increases in peri-urban land available for recreation.

Between 1 and 87% of current farmland in the landscape study areas is potentially affected by the land management options depending on scenario and landscape study area. Key findings for each management option include:

- New woodland creation:
  - Climate mitigation benefits of new woodland are dominated by the reduction of GHG emissions due to removal of agriculture for planting trees (66 to 92% of total mitigation). Carbon sequestration in new woodland contributes the remaining mitigation benefit (8 to 34%).
  - Differences in woodland type and management affect carbon sequestration rates by a factor of 3.
  - Transfers of pollutants to water bodies are reduced by 7 to 50% depending on woodland scenario and landscape area. Similar reductions are estimated for agricultural ammonia emissions.
  - Additional peri-urban recreation land and GHG emissions reductions from agriculture are largest contributors to monetary value of new woodlands.
- Removal of agriculture from low quality land resulted in:
  - 45 to 83% increase in climate mitigation.
  - 44 to 88% reduction in pollutant loadings to water bodies.
  - 40 to 77% reduction in ammonia emissions.

- Removal of agriculture from peatlands resulted in:
    - 1 to 50% increase in climate mitigation.
    - 1 to 53% reduction in pollutant loadings to water bodies.
    - 1 to 46% reduction in ammonia emissions.

In terms of partial monetary value per hectare of land changed (partial because not all public goods were valued), the management scenarios had a range of outcomes depending on the test area. The ranges across the three study areas of additional partial annual values of public goods per hectare of land changed per year for each management scenario were:

- Removal of agriculture from peatland: £345 to £526.
- New woodland creation: £651 to £2,704.
- Removal of agriculture from low quality land: £384 to £5,150.

A combined scenario was developed which brought together all three management scenarios in a stepwise approach to allow monetary values to be added within each test area. The stepwise approach prevented double uses of changed land within individual management scenarios. The results again indicate there was a large range in the additional partial annual value of public goods delivered between the three test areas (Table 1.1) and in the relative contribution of different individual public goods to the total values in each test area (Figure 1.3).

Table 1.1 Additional partial annual monetary value of new public goods explored for each test area for the combined scenario; expressed as total value and total value as a rate of return per hectare of land changed.

Monetary value units	Conwy	Vale of Clwyd	Heads of Valleys
Total annual value (£m yr^{-1})	17	5.5	47
Total annual value corrected for area changed (£ (ha changed)$^{-1}$ yr^{-1})	418	2,257	918

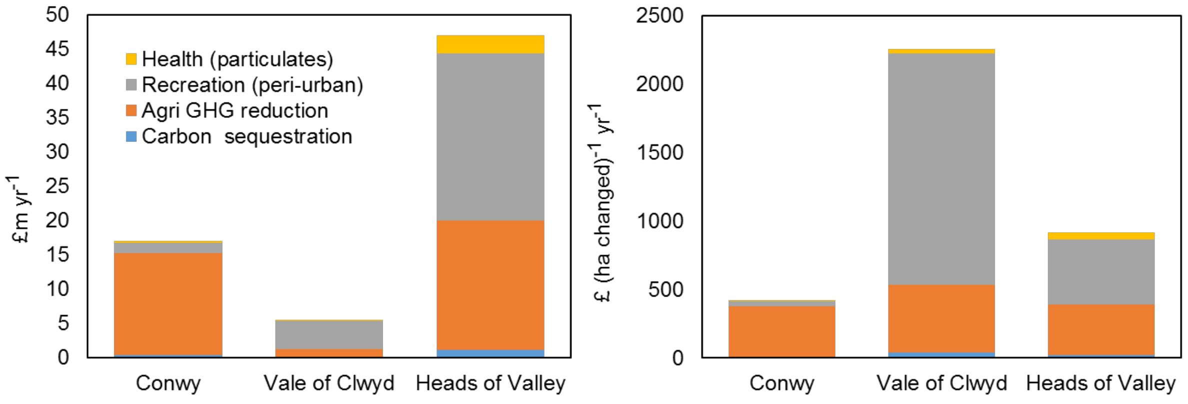


Figure 1.3 Additional partial annual monetary value of the combined scenario in each test area partitioned by individual public good valued. Left: total value (£m yr^{-1}). Right: standardised for area changed (£ (ha changed)$^{-1}$ yr^{-1}).

Some important issues which need to be recognized when considering the results of the land management scenario analyses include:

- What is recognised as a public good is still not universally agreed.
- Only four public goods have been considered here, and two of these represent only a partial valuation (i.e. recreation only includes peri-urban land; air quality only includes PM2.5 removal and the benefits for human health).
- It should be recognised that not all public goods can be valued (e.g. biodiversity).
- Environmental impacts and public goods associated with woodland and agriculture are both highly dependent on the sector and management type.
- In many cases, public goods delivered by removal of existing practices which produce negative impacts (e.g. agricultural pollution) have as much or more value as the positive public goods delivered by their replacement (e.g. woodland, recreation land).
- Some public goods such as recreation and air quality improvements are the most spatially variable in value due to their dependence on the size and proximity of surrounding human populations receiving benefit.

Recommendations from the Quick Start Project

1. WG should ensure the limitations and assumptions for the work are always included in any presentations and future uses of the work and data protection considered for all maps and results released.
2. WG should consult with the ERAMMP team on the best use of the Quick Start approach versus the Integrated Modelling Platform (IMP) for any future scenario work required.
3. WG should consult with the ERAMMP team as to additional environmental impacts and public goods which should be considered in any Quick Start work going forward.
4. WG should ensure future work regarding the potential impact of new woodland explicitly define: a) the type of agriculture land it is replacing; b) the location; and c) the woodland and management type. The environmental outcomes from these factors are as variable as when considering the impact of different agricultural livestock sectors. Quick Start work on substitution effects and the effect of improved management of current woodland should also be completed.
5. WG should ensure future work takes into account displacement or leakage of environmental impacts within Wales, UK and globally to ensure compliance with the Well Being of Future Generations Goal of ‘A Globally Responsible Wales’.

2 Programme of Work

This report provides a synthesis of rapid modelling work (Quick Start) carried out by ERAMMP for the Welsh Government over a 12 month period to provide early insight into two questions:

- What are the potential changes to the Welsh livestock sectors (sheep, beef and dairy) under three different Brexit trade scenarios? Where will these most likely occur across the landscape of Wales, and what agricultural land use changes will these entail? What will be the consequences for a range of for environmental issues including woodland creation, agricultural pollutants, GHG emissions, water quality, air quality and bird biodiversity.

- What are the potential outcomes of different major land management scenarios on a range of public goods in three contrasting Welsh landscape types? How variable are they spatially and what is the range in partial monetary value of four public goods per hectare of land changed?

The Quick Start (QS) work has involved close partnership between the ERAMMP team and the Welsh Government Evidence and Scenarios Roundtable Sub-Working Group. The Sub-Working Group is part of the Brexit Roundtable Group, a forum set up by the Welsh Government Cabinet Secretary for Energy, Planning and Rural Affairs of Welsh Government and stakeholders across the portfolio to support a collective approach to Brexit in Wales.

ERAMMP is a partnership of 20 organisations, funded by Welsh Government and the Centre for Ecology and Hydrology, designed to deliver a programme of monitoring and modelling which collects data across the Welsh landscape and links observed changes to their impacts on a wide range of benefits including their economic consequences. The programme undertakes modelling for the EU exit process and for the design and evaluation of programmes delivering to Natural Resources Policy.

This report contains two sections:

- Brexit trade scenarios
- Land management scenarios

A series of detailed Appendices are included in the Technical Annex that accompanies this report to provide more in-depth reporting on the methods, assumptions, uncertainties and spatial patterns of the outputs.

2.1 Brexit trade scenarios

Question: How might potential Brexit trade agreements affect key agricultural sectors in Wales, considering interdependencies and wider environmental impacts?

The aim of this work was to combine expert knowledge with decision support and modelling tools to identify potential changes in Wales' livestock sectors (sheep, dairy and beef) in response to three Brexit trade scenarios. The agricultural land use changes needed to support the new livestock activities for each scenario were mapped at field and farm scale across Wales and combined with other national data sources to drive agricultural, woodland and ecological models which provided estimates of impacts a range of environmental impacts and services (e.g. water quality, GHG emissions, carbon sequestration, afforestation, bird biodiversity and human health).

The modelling approach consisted of four stages:

1. Develop scenarios of anticipated livestock sector responses to different Brexit trade agreements (market driven changes in dairy and meat products).
2. Convert anticipated sector responses to national maps of potential agricultural land use changes, including change to other (non-agricultural) land uses.
3. Select woodland planting options for agricultural land potentially changed to other land uses, and add new woodlands to national land use change maps.
4. Estimate environmental impacts and consequences from potential changes in agricultural land use and woodland expansion (impacts and services).

Key features of the Quick Start approach were: interactivity (input from Welsh Government at policy relevant stages); transparency (access to intermediate modelling results); adaptability (ability to add or modify assumptions and rule-based decisions); and modularity (facility to add or modify environmental impact models).

Central to implementation of the approach was the CEH Land Use Change Toolbox (Appendix 3), a GIS-based modelling and analysis package which combined:

1. Anticipated changes in animal numbers in the Welsh livestock sectors in response to Brexit trade scenarios (provided by the Welsh Government Brexit Roundtable Sub-Working Group);
2. Field-scale national maps of current farm types in Wales (based on the Land Parcel Information System, LPIS);
3. Statistics describing current livestock farm characteristics and practices in Wales (from the 2017 June Agricultural Survey, JAS)
4. Rule-based decision trees specifying the type, likelihood and location of livestock farm changes that potentially could occur in response to Brexit trade scenarios (based on criteria developed and agreed with Welsh Government).

These inputs are discussed below. The outputs of the Toolbox were spatially explicit maps (and national/regional summaries) of potential livestock and agricultural land use changes. These land use change maps could be compared to other spatially explicit datasets (e.g., socioeconomic) and were provided to a suite of environmental impact models to examine the environmental consequences of agricultural land use change.

2.1.1 Scenario generation

Stage 1: Develop scenarios of anticipated livestock sector responses to different Brexit trade agreements (market driven changes in dairy and meat products)

The Brexit trade scenario work here is based on "Summary of the EU Exit Scenario Planning Workshop" published in 2018 by the Evidence and Scenarios Roundtable Sub-Working Group (https://gweddill.gov.wales/docs/drah/publications/180219-summary-of-eu-exit-scenario-planning-workshops-en.pdf). The purpose of the Sub-Working Group (SWG) report was to "draw together evidence and expert opinion around five possible scenarios for the UK leaving the EU. The report uses scenario planning as a tool to analyse the potential impacts on the agricultural, fishing, forestry and environment sectors, it explores some of the interdependencies to understand some of the complex changes that may be ahead".

Three basic trade scenarios were identified by the SWG, with additional variables of public funding and workforce constraints (therefore five scenarios in total), to help draw out the Welsh implications of EU Exit. The work was designed to test particular trade and market vulnerabilities in key sectors including fisheries, farming and timber while drawing out interdependencies across sectors and the wider impacts on the environment and communities.

For the purpose of their report, the SWG simplified the analysis on each sector to reflect three possible trading scenarios (which were analysed in this project):

- **EU Deal:** EU-UK FTA trading environment. Trade with the EU-27, non-tariff barriers are in place increasing transaction costs. This scenario is closest to business as usual. The EU will still want to access some UK goods, services and markets.
- **No Deal:** Trade under World Trade Organisation (WTO) rules. The UK-EU trade relationship is the same as with rest of the world. This scenario would be a major change for existing business models, causing economic disruption.
- **Multilateral Free Trade Agreements (MFTA):** UK Government aspiration: FTAs with the EU-27 (and other nations also having FTAs with the EU-27), and new FTAs with countries not previously traded with. This scenario assumes a broadly similar EU trade relationship as currently in place, enabling potential impacts of greater world market exposure to be examined.

The SWG report summarised the pressures and directions of change (expansion or contraction of markets) anticipated for each agricultural sector for each Brexit scenario. However, the SWG report did not speculate on the possible scales of the changes to the farming sectors or the magnitude of the interactions between the sectors. The SWG general consensus was that impacts from the three Brexit scenarios would be different for each sector and that this would be reflected in geographical differences across Wales, but the pattern and extent of impacts was unknown.

2.1.2 Livestock sector responses

Among the Key Findings of the SWG report are the following related to the livestock sectors (the focus of this Quick Start analysis)

- "The ***sheep*** sector faces severe challenges as it relies on export to balance seasonal production and to achieve carcass balance. The pressures from geographical constraints and workforce availability in abattoirs and processing mean lamb markets are likely to struggle in all scenarios."
- "The ***dairy*** and poultry sectors are most robust because of their focus on UK internal markets and lower reliance on export."
- "***Beef*** remains viable with a buoyant dairy industry to supply calves, with a better carcass balance and a lower dependency on export."

To examine the potential geographic extent and pattern of sheep, dairy and beef sector responses to the Brexit scenarios, the qualitative directions of change indicated in the SWG report were converted into estimates of changes in the numbers of animals needed on Welsh farms under each Brexit scenario to meet the new market demands. Using expert judgement and cross-checking with stakeholder groups, the SWG developed projections of market demand for meat and dairy products for each Brexit scenario and extrapolated these to estimated changes in animal numbers in the Sheep, Dairy and Beef sectors in Wales (Stebbings, 2018).

The SWG livestock sector analysis drew on the FAPRI-UK modelling work published (https://www.afbini.gov.uk/publications/afbi-report-post-brexit-trade-agreements-uk-agriculture) by the Agri-Food and Biosciences Institute (AFBI) and the analysis of changes to farm business income post-Brexit modelled in Agriculture and Horticulture Development Board (AHDB) reports (https://ahdb.org.uk/brexit).

The estimated changes in animal numbers for each Brexit trade scenario can be compared to baseline animal numbers in 2017 as a measure of the potential impacts of Brexit scenario Wales' livestock sectors (Table 2.1.2.1).

Table 2.1.2.1 Changes in livestock in Wales (relative to 2017) anticipated for the Sheep, Dairy and Beef sectors in response to the three Brexit trade scenarios.

	Change in Animal Numbers			**Change in Livestock Units (LU)**		
	EU Deal	**No Deal**	**MFTA**	**EU Deal**	**No Deal**	**MFTA**
Dairy	+43,000	+238,000	-14,000	+36,000	+199,000	-11,000
Beef	-2,000	+23,000	-131,000	-12,000	+5,800	-84,000
Sheep	-604,000	-3,230,000	-3,230,000	-39,000	-207,000	-207,000
	% Change in Animal Numbers			**% Change in Livestock Units (LU)**		
	EU Deal	**No Deal**	**MFTA**	**EU Deal**	**No Deal**	**MFTA**
Dairy	+10%	+54%	-3%	+10%	+54%	-3%
Beef	-0.3%	+5%	-26%	-4%	+2%	-30%
Sheep	-7%	-36%	-36%	-7%	-36%	-36%

2.1.3 Potential agricultural land use changes

Stage 2: Convert anticipated sector responses to national maps of potential agricultural land use changes, including change to other (non-agricultural) land uses.

To convert anticipated changes in animal numbers required under each Brexit trade scenario into agricultural land use changes across Wales, we used Robust Farm Type (RFT) categories to characterize the different agricultural sectors in Wales. For each RFT category (Table 2.1.3.1) summary statistics can be derived describing land use practices, livestock distributions, stocking rates, supporting land use areas and livestock cohorts, and sizes of labour and capital requirements. This project used data from the 2017 June Agricultural Survey to calculate these statistics which provide a comprehensive picture of current farm practice in Wales.

Table 2.1.3.1 Robust Farm Type (RFT) categories in Wales used to allocate agricultural land use changes in response to Brexit trade scenarios.

Robust Farm Types in Wales			
Category	**Description**	**Category**	**Description**
RFT-1	Cereals	RFT-6	Dairy
RFT-2	General Cropping	RFT-7	LFA Grazing Livestock
RFT-3	Horticulture	RFT-8	Lowland Grazing Livestock
RFT-4	Specialist Pigs	RFT-9	Mixed
RFT-5	Specialist Poultry	RFT-10	Non Classifiable

Using the known characteristics of current RFT's, a rule-based decision-tree was developed for specifying the land area requirements and farm properties needed to re-allocate livestock numbers in response to each Brexit trade scenario. For instance, to accommodate an increase in the Welsh dairy herd, the land use mix, livestock distributions and stocking densities on existing dairy farms (RFT-6) can be used to calculate the area of new dairy farms (with similar characteristics) needed to accommodate the additional animals and support the particular agricultural activities of a dairy.

However, land for the new dairy farms must be provided from some source. This land is assumed to be derived from another category of existing RFT (e.g. mixed livestock grazers RFT's 7 & 8), and in converting to a dairy enterprise the livestock maintained under the old RFT category must be accounted for. The procedure for identifying the new national distribution of agricultural land use in Wales under a Brexit trade scenario is thus a rule-driven iterative process of re-distributing existing RFT's until the total animal numbers in the national beef, dairy and sheep herds are the size required by market demand in the Brexit scenario under consideration.

As might be expected with declining overall animal numbers in some livestock sectors (as is the case in all three Brexit scenarios), at the completion of expansion and shifting amongst RFT's to accommodate the growing sectors, there will be a "surplus" of farms in the RFT categories of the declining sector(s). For these RFT's a further rule-base is established to take holdings in this category "out of agricultural use", providing areas for potential "other land use".

The geographical locations of RFT's across Wales were derived from the Land Parcel Information System (LPIS). This spatially explicit field scale database was linked to the June Agricultural Survey (JAS) to identify the locations and areas of individual farms (holdings) and the current RFT category for each.

2.1.4 Rule-based decisions for land use change

A simple approach for assigning and mapping potential agricultural land use change was required in Quick Start so that the outputs could be interpreted and easily communicated to ministers and policymakers. A conceptual approach and general rules using RFT's were developed in conjunction with the SWG to constrain and define the potential types of livestock sector changes that might occur in response to the Brexit scenarios. The assumptions and rules in this approach are easily stated and readily changed to examine potential alternate responses of the livestock sectors.

The potential holdings changing from an existing RFT category to a new RFT category (Figure 2.1.4.1), and thus the area of potential agricultural land use change across Wales, were selected in each Brexit scenario based on average Agricultural Land Classification (ALC) values for each holding. For potential conversion to a new RFT, all holdings within the “source” RFT category were ranked from best to worst average ALC. Holdings were then selected in descending order on the list until the required area of new RFT was reached. For conversion to dairy RFT, source RFT size and proximity to existing dairy were also taken into account. Holdings potentially converting to other (non-agricultural) use were ranked from worst to best average ALC, and holdings were selected in descending order from the list until the required total area of new non-agricultural land use was reached.

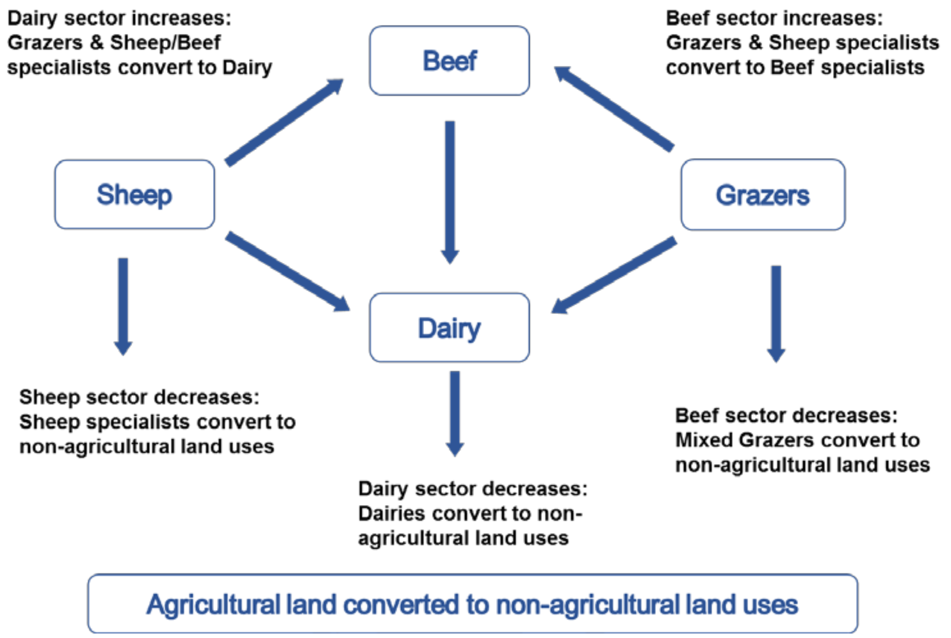


Figure 2.1.4.1 Conceptual approach for selecting farms from livestock RFT categories for potential change in response to Brexit scenarios. Changes are driven by target livestock numbers for each scenario. Whole farms change following rule-based decision trees. Farms assume average characteristics (land use and livestock) of the new RFT. Changes are complete when national animal numbers on newly distributed farm types match scenario targets (sheep, beef and dairy animals).

The following general rules for selecting farms among the livestock sectors in Wales with potential to change were agreed in discussions with the SWG:

- Farms converting to dairy: Select first from small farms of any type within 1km of an existing dairy, with additional farms taken from mixed grazers as needed. Farms selected had to conform to slope, elevation and ALC characteristics of existing dairy farms. Rank eligible farms using ALC from best to worst, with best selected first.
- Farms converting from dairy to other (non-agricultural) uses: Rank existing dairy farms using ALC from worst to best, with worst selected first.

- Farms converting from sheep to beef: Exclude sheep farms already converted to dairy. Rank remaining sheep farms using ALC from best to worst, with best selected first.
- Farms converting from grazers to other (non-agricultural) uses: Exclude grazing farms already converted to dairy. Rank remaining grazing farms using ALC from worst to best, with worst selected first.
- Farms converting from sheep to other (non-agricultural) uses: Exclude sheep farms already converted to dairy or beef. Rank remaining sheep farms using ALC from worst to best, with worst selected first.

These general rules can be developed into formal decision trees based on current (baseline) characteristics and farm practices of livestock farms in Wales once those characteristics and practices are derived for each of Wales' livestock RFT's.

Note: ALC data used in Quick Start were taken from the freely available version of the Predictive ALC map for Wales (PALC-Wales, 2018), which assigns ALC based on the most limiting factor for agricultural use. Data source and further information can be found here:

2.1.5 Options for woodland expansion

Stage 3: Select woodland planting options for agricultural land potentially changed to other land uses and add new woodlands to national land use change maps.

New woodland planting was considered an option for all areas identified as potentially changing to other (non-agricultural) land uses under each Brexit scenario, as long as those areas were not designated as unsuitable by the Glastir Woodland Creation Rules (GWC-Wales, 2018). Three options for defining areas "unsuitable" for woodland planting were examined. The least restrictive option only excluded land with physical *Constraints*, where data indicate woodland planting is impossible (lakes, existing forest). The second option excluded areas of Constraint as well as areas with *Sensitivities* which make woodland planting undesirable for biodiversity, environmental or cultural reasons (e.g. ground nesting bird habitats, SSSIs which may be damaged by woodland, or World Heritage sites). The most restrictive option excluded areas of Constraints and Sensitivities as well as areas with *Guidance* issues which must be considered before planting would be approved, or which may cause administrative issues (e.g. National parks, historic landscapes, common land).

After applying the appropriate level of Constraints, Sensitivities and Guidance, the remaining land was subject to a final assessment to determine if planting was deemed possible by Forest Research (FR) models based on soils, elevation, topography and climate. The assessments of areas for potential new woodland planting and the planting options and suitability were carried out on a 250 x 250 m grid.

Applying each of the three woodland planting options to each of the three Brexit trade scenarios produced 9 potential woodland planting scenarios. For each, we identified farms "suitable for new woodland planting" as holdings potentially changing to non-agricultural use under the Brexit scenario and having more than 10ha available for woodland planting under the applied planting option. The 10 ha requirement was suggested by Welsh Government as a threshold for economically viable planting. Suitable farms were then ranked according to their mean ALC and selected in order from best to worst ALC until the Welsh Government target of 100,000 ha of new woodland planting (http://www.assembly.wales/research%20documents/17-008-woodlands/17-008-web-english.pdf) was reached. For many of the 9 woodland planting scenarios, the total area available and suitable for new woodland planting was less than the target of 100,000ha.

2.1.6 Modelling environmental impacts

Stage 4: Estimate environmental impacts and consequences from potential changes in agricultural land use and woodland expansion (impacts and services)

The spatial changes in agricultural land use and woodland creation were passed to the ERAMMP impacts modelling team for application in a series of environmental impact models. The majority of impact models used were well-tested models which have previously been developed and applied at the national scale:

- Farmscoper developed by ADAS for agricultural pollutants (greenhouse gas emissions, diffuse pollution to water bodies and air ammonia emissions).
- Carbine developed by FR for carbon sequestration in woodlands and greenhouse gas emissions from forest management.
- ESC developed by FR for woodland species selection and estimation of woodland recreation and ecosystem services

New bespoke analytical tools were also developed specifically for ERAMMP:

- Bird abundance and diversity developed by BTO.

All models and data tools are needed to fully explore the full impacts for any individual scenario. A brief description of each model / analytical approach is provided below. Further details are provided in Appendix 1.

Farmscoper

Farmscoper (Farm Scale Optimisation of Pollutant Emission Reductions; Gooday et al., 2014) is a pollutant modelling framework that allows for the assessment of the impacts of multiple mitigation methods on multiple pollutants at both farm and catchment scale. Within this project, the following pollutants were considered: Nitrate, Phosphorus, Sediment, Ammonia, Nitrous Oxide, and Methane.

Farmscoper functions as a decision support tool that can be used to assess diffuse agricultural pollutant loads on a farm and quantify the impacts of farm mitigation methods on these pollutants. The farm systems within the tool can be customised to reflect management and environmental conditions representative of farming across England and Wales. The tool contains over 100 mitigation methods, including many of those in the latest Defra Mitigation Method User Guide.

Carbine

CARBINE is an analytical model developed to address questions about the carbon and GHG balances of forestry systems, and to inform the development of forest policy and practice, particularly with regard to the goal of climate change mitigation. The CARBINE model is applied to a wide range of research questions, with examples including exploring the potential impact of establishing new areas of forest on land-based carbon stocks and sequestration.

The inputs to the model include the areas of different types of forest (tree species and growth rates), tree age distribution, soil class, selected meteorological data, land use prior to tree establishment, management prescriptions for forest areas (e.g. no harvesting or harvesting on a specified rotation) and a specification for how any harvested wood is utilised.

The outputs from CARBINE include annual estimates of changes in carbon stocks (rates of carbon sequestration) in forest areas over time, levels of wood and timber production (which can be broken down into specific wood product categories if required), the development of forest age class distribution over time, and changes in the species composition of forests in response to management interventions (where relevant).

ESC

Ecological Site Classification (ESC) is a knowledge-based forest classification system that has been developed as a model to assist in forest tree species selection. ESC determines species suitability and potential stand yield (m^3 ha^{-1} yr^{-1}) at a given site location. The model evaluates six environmental factors (four climatic variables and two soil variables, Pyatt et al., 2001), with the limiting factor determining the suitability for each species at each site. Potential stand yield is calculated as the suitability score (value between 0 and 1) multiplied by the species' potential maximum yield class in Britain. Here we assessed suitability for nine species classes across Wales at a resolution of 250 m.

Suitability was calculated for 11 species and the most productive species for each 250m pixel selected for each of three woodland types; productive conifers, native broadleaves and short rotation forestry. In addition to the three forest types, the impact of five different management types are considered; two each for productive conifers and native broadleaves and one for Short rotation forestry: productive conifers (thinning/clearfell and continuous cover forestry), native broadleaves (amenity with no thinning or clearfell and production under continuous cover forestry) and short rotation forestry. The management type impacts the recreation and biodiversity indicators and carbon values.

The most productive species, modelled yield class, forest type and management type were used to look up values for recreation and biodiversity indicators, and, in addition to soil class and climate zone, to look up carbon values in CARBINE.

BTO bird abundance and diversity model

The BTO Bird model is based around modelled relationships between bird abundance captured with the BTO/JNCC/RSPB Breeding Bird Survey (BBS) and land use within 1km squares. Land use information includes data from all national data sources that were available and relevant to birds, including Landcover maps, Robust Farm Types, River Networks etc.

The model is a new development for the ERAMMP Quick Start requirements, based on previous similar approaches developed by BTO for use in other contexts. Models for 58 widespread species were developed and outputs include predicted changes in abundance and bird diversity, considering all species and subsets of species, such as those of conservation concern (i.e. red, amber).

2.1.7 Primary assumptions and uncertainties

Many unknowns and uncertainties surround the Brexit scenario questions resulting in a series of assumptions which had to be drawn for the work to proceed. These assumptions relate to the series of steps taken in creating the three Brexit trade scenarios, generating the anticipated responses of the livestock sectors in Wales, and translating the sector responses to spatially explicit agricultural land use change data which could be used to drive the Quick Start environmental impact models.

There were also issues involved in producing outputs which are accessible, informative and highlight important issues concerning interpretation of maps and units, while protecting personal privacy and respecting data protection agreements.

Assumptions and uncertainties in assigning land use changes

Generating the Brexit scenarios

Readers are referred to the SWG livestock sector report (Stebbings, 2018) for a thorough discussion of assumptions and uncertainties inherent in the development of the three Brexit trade-scenarios and their effects on livestock sectors in Wales.

Making land use change decisions

The rule-based decision trees for assigning agricultural land use changes were based on a limited set of assumptions concerning the current characteristics of livestock farms in Wales (as outlined in section 2.1.2). The limitation was intentional in order to provide transparent and easily understandable criteria of agricultural land use change. As implemented, the livestock sector changes were determined based solely on the current agricultural capacities and practices of livestock farms in Wales (e.g. what are the current capabilities of livestock farms to respond to trade scenario pressures).

With agreement from Welsh Government, and in order to complete this initial rapid assessment of potential for change, two obvious and important factors potentially affecting changes in farm enterprises were not included in the Quick Start decision-tree analyses:

- Socioeconomic factors, which strongly affect likelihood of change, were not taken into account except for exclusion of Part Time Farms (<1 FTE) from the analyses (the implicit assumption being that Pasrt Time Farms would be unlikely to respond other than randomly to socio-economic drivers, thus increasing the variability of potential response, but not affecting overall capacity for response);
- Human behavioural factors, which also strongly affect likelihood of change through farmer choice, were not taken into account (the implicit assumption being that famer choice will create random variation in the pattern of change but not affect overall capacity for response).

Using average farm characteristics and practices

In Quick Start, the area of land required to convert between farm types in order to match anticipated changes in livestock numbers for a Brexit trade scenario was calculated based on the average characteristics (e.g., land use patterns) and average practices (e.g., stocking densities) for each Robust Farm Type. While using averages is a straightforward method of deriving a first estimate of national capacity for agricultural change, it is useful to consider whether estimates based on averages are likely to be un-biased.

For instance, In the face of declining livestock numbers (in a given Brexit scenario) it may be the case that farms with stocking densities greater than average could adapt to the declining demand by reducing stocking numbers, while farms with stocking densities less than the average have less flexibility and would be more likely change to other (non-agricultural) land uses. If the threshold stocking density to remain in agriculture (not a characteristic that can be derived from available JAS data) is greater than the average for a farm type, there will be more farms likely to leave agriculture than to remain (fewer farms have stocking flexibility). As a result, estimates of agricultural area being changed to other (non-agricultural) uses based on average practices (as in this study) are likely to be underestimates.

Planting new woodland

We apply an assumption that the best (ranked by ALC) of land looking to transition out of agriculture would be selected first for woodland planting, for consistency with the methods used for other land use transitions (Appendix 3). Only holdings with over 10 ha suitable land were used, since this is considered an economic threshold for woodland planting. The assumptions on criteria preventing woodland planting were derived from the Welsh Government GWC as detailed in Appendix 3.

Assumptions and uncertainties in the environmental impact models

Farmscoper

For water borne pollutants, Farmscoper incorporates outputs from a suite of models including the phosphorus and sediment model PSYCHIC (Davison et al., 2008) and the nitrate model NEAPN (Lord and Anthony, 2000). Modelled pollutant loads from these source models compare favourably with available water quality datasets such as those from the Harmonised Monitoring Scheme (Defra Project WQ0223; with adjustments made to account for inputs from non-agricultural sectors such as sewage treatment works).

Gaseous emissions are derived from the methodologies used in the national inventories for ammonia (NARSES; Webb and Misselbrook, 2004) and nitrous oxide and methane (IPCC; Baggottt et al., 2006), except that indirect emissions of nitrous oxide are calculated from the modelled nitrate losses rather than using the inventory approach. With the exception of these indirect emissions, the gaseous emissions are not affected by the physical environment (i.e. climate and soil type).

Carbine

The general purpose of the CARBINE model is to address questions about the carbon and GHG balances of forestry systems, and to inform the development of forest policy and practice, particularly with regard to the goal of climate change mitigation. The CARBINE model is applied to a wide range of research questions, with examples including:

- What are the carbon stocks in a defined area of forest?
- What is the impact on land-based carbon stocks and sequestration of establishing new areas of forest on a defined area of land?
- What impacts do different silvicultural systems have on the development of carbon stocks and sequestration in a defined area of forest?

- What emissions and removals of GHGs should be reported for a defined area of forest, for the purpose of reporting GHG inventories under the UNFCCC?
- What contribution could a defined area of forest make towards meeting climate change mitigation targets (e.g. UK national targets)?
- What would be the impact on carbon stocks and sequestration of introducing a programme of regular harvesting for wood production in a forest area that previously was not subject to significant human intervention?
- What would be the impact on GHG emissions of changing the uses of harvested wood, for example, diverting the use of wood from use in timber products to use for bioenergy?

The CARBINE model also has the capacity to produce estimates of other variables not directly to do with forest carbon but of great relevance to decisions about forest management, for example:

- Levels of wood and timber production (which can be broken down into specific wood product categories if required)
- The development of forest age class distribution over time
- Changes in the species composition of forests in response to management interventions (where relevant).

ESC

ESC woodland suitability values were calculated for eleven species: *Alnus rubra*, *Betula pendula, Betula pubescens, Fagus sylvatica, Populus nigra, Populus tremula, Quercus robur, Quercus petraea, Picea sitchensis, Pinus sylvestris, Pseudotsuga menziesii.* When two species within the same genus (e.g. *Betula* (birch) and *Quercus* (Oak)) were present in a forest type the most suitable species was taken as indicative of site potential for the genus, on the basis that forest managers would make their silvicultural decisions according to similar principles.

For the three forest types we used the following tree species:

- Productive conifers: Sitka spruce (*Picea sitchensis*), Douglas fir (*Pseudotsuga menziesii*), Scots pine (*Pinus sylvestris*)
- Native broadleaves: oak (*Quercus*), beech (*Fagus*), aspen (*Populus*), birch (*Betula*)
- Short rotation forestry: Sitka spruce (*Picea sitchensis*), red alder (*Alnus rubra*), poplar (*Populus*)

For each 250 m pixel the most productive species from each forest type in 2020 was selected for the simulation for that and future time periods. In addition to the three forest types, we simulated five different management types, two each for productive conifers and native broadleaves and one for short rotation forestry:

- Productive conifers (thinning/clearfell)
- Productive conifers (continuous cover forestry / low impact silviculture system)
- Native broadleaves managed for amenity (no thinning/clearfell)
- Native broadleaves managed for production (continuous cover forestry/ low impact silviculture system)
- Short rotation forestry.

The outputs for the most productive species in 2020, yield class, forest type and management type were used to look up values for the recreation and biodiversity indicators and carbon values in CARBINE.

For the ERAMPP model pipeline, ESC provided a suitability index identifying the most productive species in each of three forest types and five management types for each 250m pixel. The tree species category (broadleaf/conifer), forest type, management type, yield class estimate, climate zone, soil class and species was were used to assign properties generated from CARBINE to index outputs over time.

BTO bird abundance and diversity model

Bird data were used from multiple years (2013-2017) to reduce between-year variability and to capture data for rarer species. Species were only selected if they occurred in at least 30 1km squares to ensure development of robust models.

All land-use changes are likely to benefit some species and to have negative effects on others. It is simplistic to refer to such changes as being “good” or “bad” for wildlife or biodiversity in general. Moreover, there are likely to be other effects of Brexit on wildlife that are not directly linked to changes in farm types; for example, following Brexit, some environmental legislation may be lost or weakened (e.g. implementation of legislation through agreements such as RAMSAR and the Habitats Directive) (Welsh Gov., 2018). As such, results presented here only provide crude predictions.

The woodland data used here combined coniferous and broadleaf cover, which have very different values for biodiversity in general and birds in particular. Specifically, many native species are supported by broadleaved woodland and very few by exotic conifers. Hence, predictions of effects of increases in woodland that, in practice, will comprise conifer planting, will be unrealistically positive, and predicted changes in natural succession or broadleaf planting will be unrealistically negative.

Diversity indices reflect patterns of relative abundance across species and can be increased by increases or reductions in particular component species, depending upon their initial dominance within the community. In addition, a lack of change in an index can mask turnover of component species whereby the balance of numerical abundances in an area changes less than the abundances of individual species. These points need to be considered while interpreting diversity index results.

The abundance and diversity estimates in this study are derived from raw BBS count data, which describe relative abundances within species and are not, strictly, comparable between species. This is because species vary in their detectability, both absolutely and in respect of the variation in detectability with distance from the observer. Hence, the estimates of bird population sizes provided do not represent total numbers but, rather, numbers detectable from BBS transect surveys through a 1-km square. This means that populations of more cryptic or quieter species, those with less detectable females and those found in habitats with poorer visibility and/or around transmission will have been under-estimated. However, given that most species are consistent in terms of habitat selection and proportion of populations that is detected can be assumed constant, this under-estimation will not cause bias in estimates of population change. It does, however, mean that the diversity indices that have been calculated here should only be regarded as indicative, because they depend upon estimates of absolute numbers, which are not equivalent between species (for example, a count of four mute swans is more likely to be close to the real, total number present than a count of four wrens, which is likely to reflect four singing males and an unknown number of females and birds that were more distant and not detected).

2.1.8 Brexit trade scenario results

Spatial distribution of baseline agricultural land uses in Wales

To convert anticipated changes in animal numbers required under each Brexit trade scenario (see Section 2.1.2) into agricultural land use changes across Wales, we used Robust Farm Type (RFT) categories to characterize the different agricultural sectors in Wales (Table 2.1.8.1).

Table 2.1.8.1. Robust Farm Type (RFT) categories in Wales.

RFT	Category	Deriving 2/3 of Standard Output (SO) from:
1	Cereals	Cereals, combinable crops and set-aside
2	General cropping	Arable crops including field scale vegetables
3	Horticulture	Fruit, nursery stock, glasshouse, market garden vegetables
4	Specialist pigs	Pigs
5	Specialist poultry	Poultry
6	Dairy	Dairy cows
7	LFA grazing livestock	Cattle, sheep and other grazing livestock (with 50% or more of holding area in LFA)
8	Lowland grazing livestock	Cattle, sheep and other grazing livestock (with less than 50% of holding area in LFA)
9	Mixed	Mixed crop-livestock farms, mixed pig-poultry farms (where neither accounts for > 2/3 of SOs)
10	Non classifiable	None of the above categories (fallow or buildings and other areas only)

For each RFT category, summary statistics were derived describing land use practices, livestock distributions, stocking rates, supporting land use areas and livestock cohorts, and sizes of labour and capital requirements. The data from the 2017 June Agricultural Survey in Wales defined the baseline for Quick Start and were used to provide a comprehensive picture of current farm practice in Wales.

Because Quick Start is focused on the livestock sectors in Wales, the project limited its analyses to potential land use changes occurring in three of the RFT categories: Dairy (RFT-6), LFA Grazers (RFT-7) and Lowland Grazers (RFT-8). The livestock RFT's (6, 7 and 8) manage 69% of the agricultural land and 97% of Sheep, Dairy and Beef animals (expressed as Livestock Units, LU) in Wales.

On the advice of the SWG, Part Time Farms (spare time and part time) using less than 1 full-time equivalent worker (FTE) were not included in the Quick Start analyses. Even though Part Time Farms account for 37% of agricultural land in Wales, they manage only 10% of livestock LU's, and contribute only 13% of economic value (as SO). The SWG did not consider that Part Time Farms would be influenced in a predictable manner (if at all) by the Brexit trade scenarios.

Focussing only on livestock RFT's (6, 7 and 8) and excluding Part Time Farms (<1 FTE) defines the population of farms analysed in the Quick Start (QS) project (called the QS RFT's). The QS RFT's comprise 20% of farm holdings in Wales, control 56% of agricultural land, manage 87% of livestock (as LU's), contribute 72% of economic value (as SO), and account for 76% of labour FTE's (Figures 2.1.8.1 and 2.1.8.2).

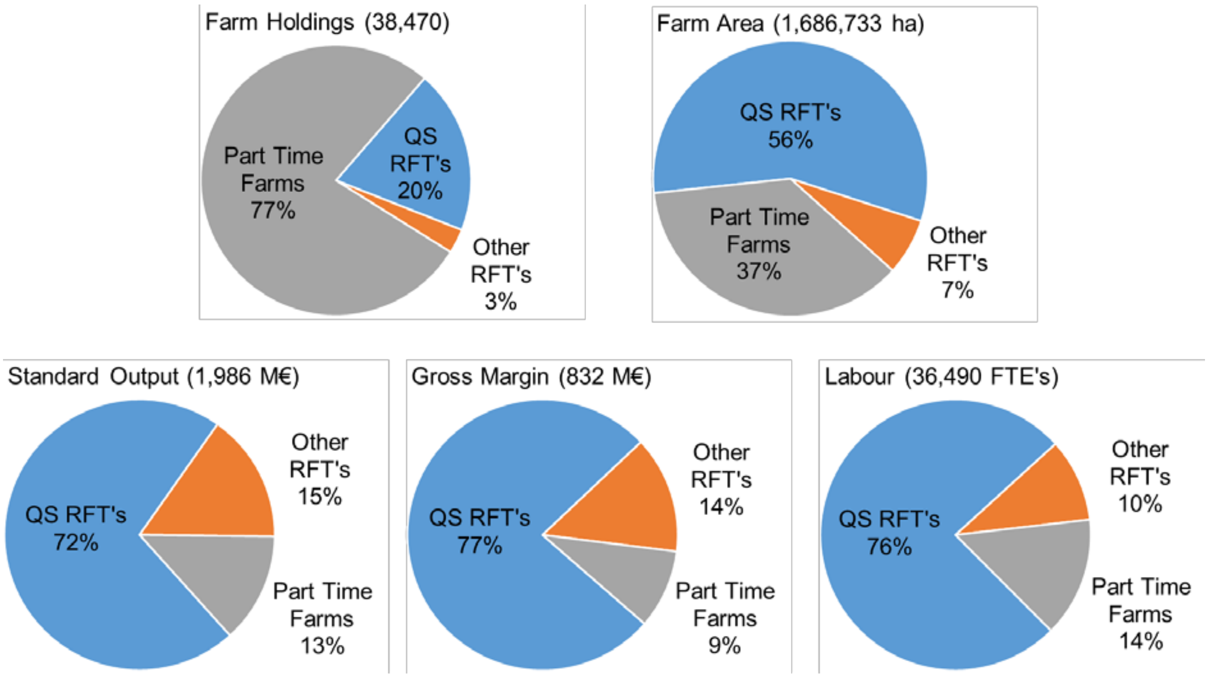


Figure 2.1.8.1. Distribution of baseline (2017) farm enterprise measures in Wales comparing Part Time Farms (< 1 FTE), Quick Start (QS) Livestock RFT's (6,7,8; Part Time Farms excluded) and all Other RFT's (1,2,3,4,5,9,10; Part Time Farms excluded). Data from 2017 June Agricultural Survey for Wales.

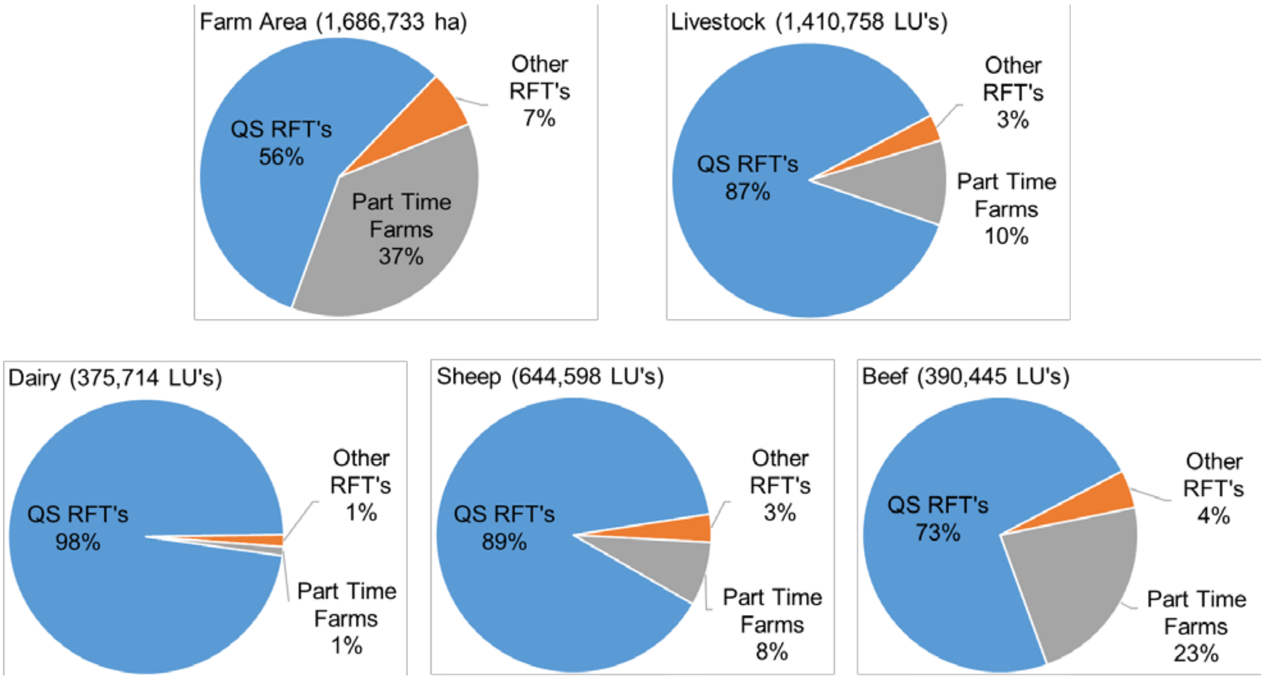


Figure 2.1.8.2. Distribution of baseline (2017) farmland and livestock in Wales comparing Part Time Farms (< 1 FTE), Quick Start (QS) Livestock RFT's (6,7,8; Part Time Farms excluded) and all Other RFT's (1,2,3,4,5,9,10; Part Time Farms excluded). Data from 2017 June Agricultural Survey for Wales.

Defining and mapping baseline (2017) Livestock Sectors for Brexit analysis

Due to the large area and number of farms included in the LFA grazing category (RFT-7), this category was sub-divided using Main Farm Type (MFT) categories which differentiate the LFA (Less Favourable Area) into Disadvantaged Areas (DA) and Severely Disadvantaged Areas (SDA) and identify sheep specialists, beef specialists and mixed grazers in each area (Table 2.1.8.2). A similar mapping into Lowland, DA and SDA was done for dairy (RFT-6). This differentiation on the landscape of Wales provides finer spatial resolution for mapping potential agricultural land use change aligned to the livestock sectors.

Table 2.1.8.2. Baseline (2017) agricultural areas for the four livestock sectors (Dairy, Sheep, Beef and Grazers) modelled in Quick Start. The livestock sectors are based on Robust and Main Farm type classifications (RFT's 6, 7 and 8; LFA divided into SDA and DA by MFT; full time farms >1 FTE labour).Based on 2017 June Agricultural Survey data.

	MFT	RFT-6 Dairy (ha)	RFT-7 LFA Grazing (ha)	RFT-8 Lowland Grazing (ha)	Total Areas (ha)
Dairy					178,638
RFT 6A	SDA Dairy	25,896			
RFT 6B	DA Dairy	75,206			
RFT 6C	Lowland Dairy	77,536			
Sheep					437,236
RFT 7A	SDA Sheep		437,236		
Beef					21,259
RFT 7B	SDA Beef		21,259		
Grazers					318,229
RFT 7C	SDA Grazing		135,080		
RFT 7D	DA Grazing		117,635		
RFT 8	Lowland Grazing			65,514	
All QS Farms					955,363
Total		178,638	711,210	65,514	

To simplify presentation and align the outputs with the SWG focus on the four livestock sectors (dairy, sheep, beef and grazers), the three groups of dairy (Lowland, DA and SDA) were combined into a single category called "Dairy", and three groups of grazers (Lowland, DA and SDA) were combined into a single category called "Grazers". The agricultural areas associated with the final Quick Start RFT categories are summarized by the grey entries in Table 2.1.8.2. More detailed tables of economic characteristics, livestock numbers and agricultural land uses for each of the QS RFT categories are available in Appendix 4.

Rule-base decisions for selecting farms with potential to change farm type

Once the relevant livestock sector farm types had been identified and characterised, a series of rule-based decision trees were developed to select farms with the potential to change in response to the Brexit trade scenarios. The conceptual approach and general rules for selecting farms with potential to change were agreed with the SWG and are described in section 2.1.4. Those rules were converted to formal decision trees based on current (baseline) characteristics and farm practices of Quick Start livestock RFT's identified and defined above.

An example for selecting farms for potential dairy expansion is presented in Figure 2.1.8.3. Details and rules for other farm conversions are provided in Appendix 3. Future changes in assumptions concerning livestock RFT conversions can be included in modified rule bases and the Agricultural Land Use Change Tool re-run.

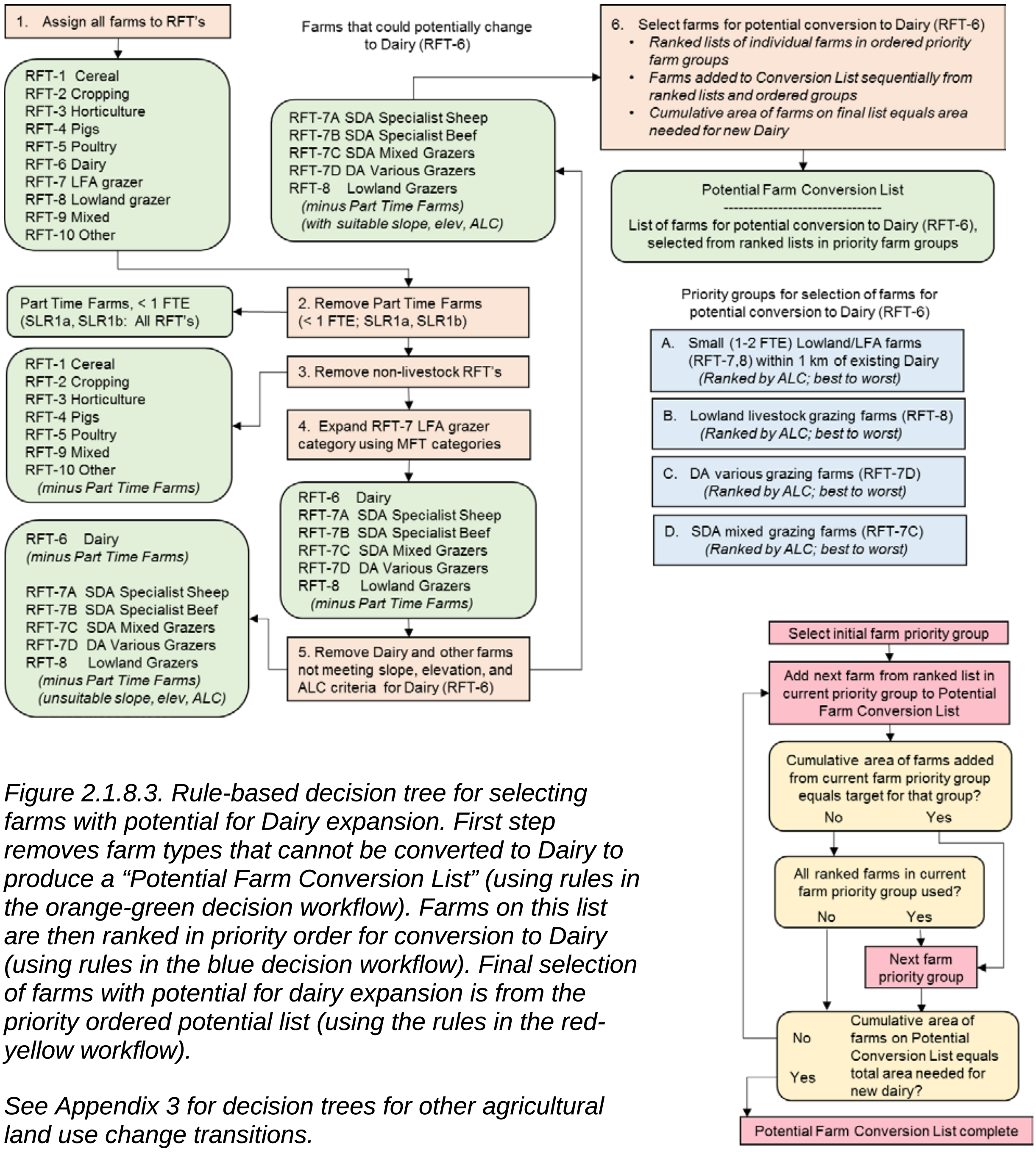


Figure 2.1.8.3. Rule-based decision tree for selecting farms with potential for Dairy expansion. First step removes farm types that cannot be converted to Dairy to produce a "Potential Farm Conversion List" (using rules in the orange-green decision workflow). Farms on this list are then ranked in priority order for conversion to Dairy (using rules in the blue decision workflow). Final selection of farms with potential for dairy expansion is from the priority ordered potential list (using the rules in the red-yellow workflow).

See Appendix 3 for decision trees for other agricultural land use change transitions.

Potential change in agricultural land use in response to Brexit trade scenarios

The potential agricultural land use conversions (following the rule based decisions above) vary in magnitude and location across Wales under the three different Brexit trade scenarios (Figure 2.1.8.4). Total agricultural land area potentially affected ranges from 56,779 to 284,592 ha depending on the scenario (Figure 2.1.8.5).

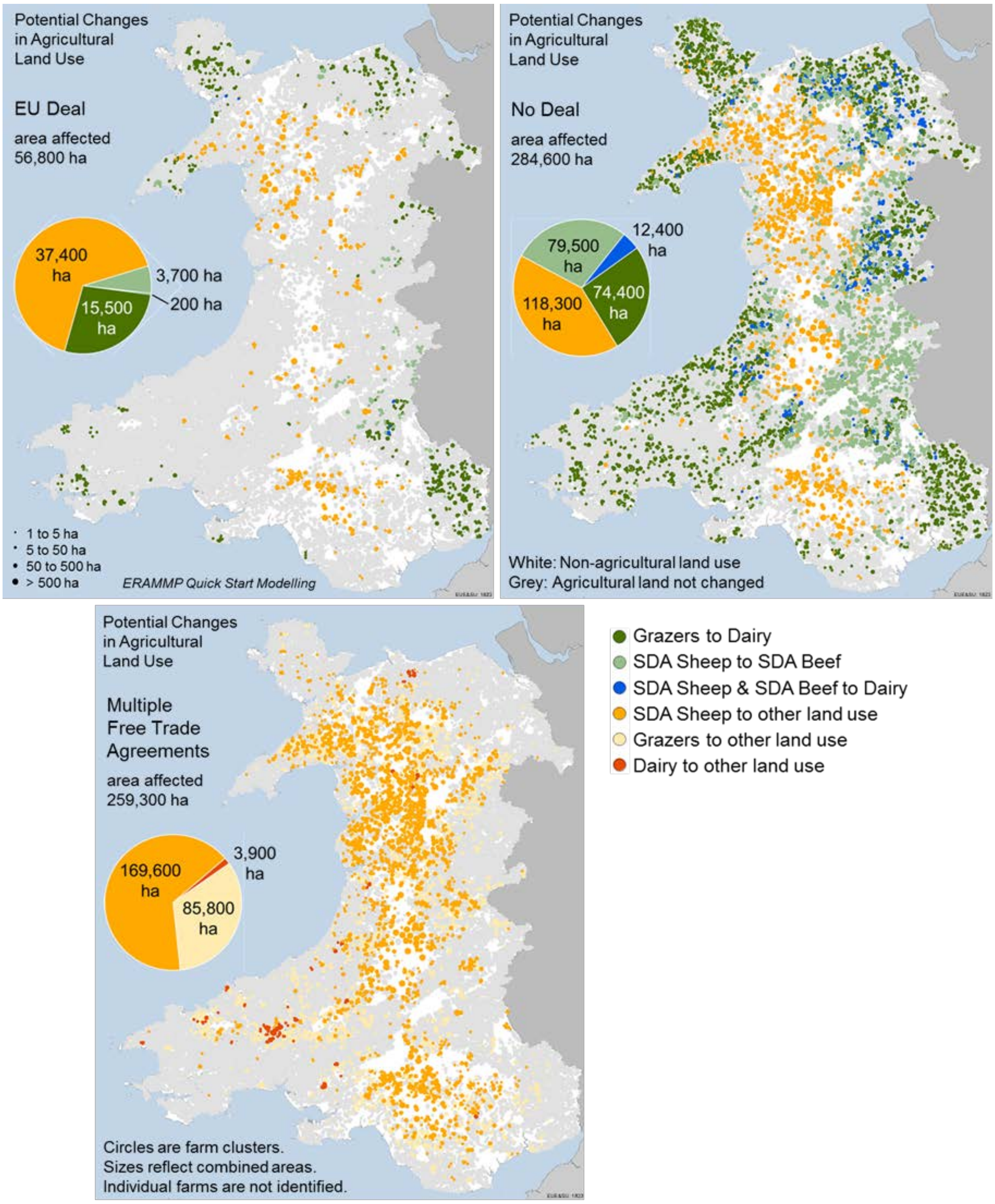


Figure 2.1.8.4. Potential agricultural land use change for the three Brexit trade scenarios. Farms that have potential for land conversion and are geographically close to each other have been combined into circles proportional to their combined area, such that individual farms cannot be identified. Grey areas are land included in the analyses.

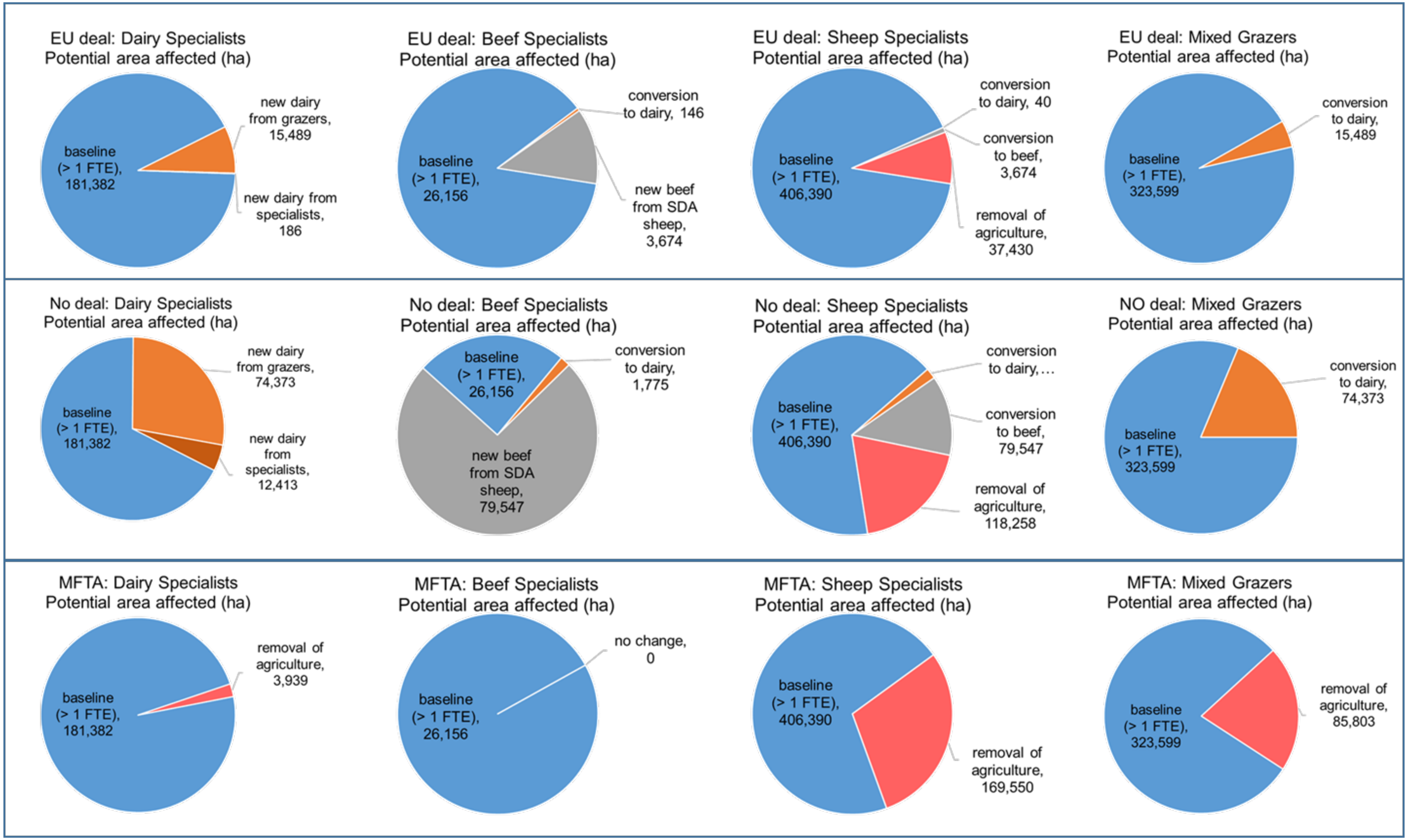


Figure 2.1.8.5. Potential changes in farm areas for each livestock sector (Dairy, Sheep, Beef and Grazers) for the three Brexit trade scenarios (EU Deal, No Deal and MFTA)

Total agricultural land area potentially affected is greatest for the No Deal trade scenario (17%) followed closely by the MFTA scenario (15%) with smallest potential change for the EU Deal trade scenario (Table 2.1.8.3). The scenario with most potential for conversion between livestock sectors is No Deal with 10% of livestock land potentially changing enterprise (and 7% potentially changing to non-agricultural use). The scenario with most potential for agricultural land changing to other, non-agricultural use is MFTA with 15% of current farmland moving to other uses (and no farms moving to new enterprises).

For all three Brexit trade scenarios, the sheep sector makes up the majority of farmland with potential for changing to other (non-agricultural) uses (100% in the EU Deal and No Deal scenarios, and 65% in the MFTA (Table 2.1.8.4). Further details in the form of maps, tables and pie charts for each Brexit trade scenario and each livestock sector are available in Appendix 4.

Table 2.1.8.3. Potential agricultural land use conversions under the three Brexit trade scenarios, the total areas affected (ha), and the proportion each represents of baseline (2017) farmland of all types in Wales (1,686,733 ha).

	EU Deal (ha)	No Deal (ha)	MFTA (ha)
Potential Conversions			
Grazers to Dairy	15,489	74,373	
SDA Beef to Dairy	146	1,775	
SDA Sheep to Dairy	40	10,638	
SDA Sheep to SDA Beef	3,674	79,547	
SDA Sheep to non-agricultural uses	37,430	118,258	169,550
Dairy to non-agricultural uses			3,939
Grazers to non-agricultural uses			85,803
Area Totals			
Total Area changed to new sector (% of baseline farmland)	19,348 (1.1%)	166,334 (9.9%)	0 (0%)
Total Area changed to non-agricultural uses (% of baseline farmland)	37,430 (2.2%)	118,258 (7.0%)	259,292 (15.4%)
Total Area affected by Brexit scenario (% of baseline farmland)	56,779 (3.4%)	284,592 (16.9%)	259,292 (15.4%)

Table 2.1.8.4. Farmland area (ha) in different livestock sectors potentially changing to other (non-agricultural) land uses for each of the three Brexit trade scenarios, and the percentage of each sector's contribution to the total area potentially changing.

Sector	EU Deal	No Deal	MFTA
Sheep	37,430 (100%)	118,258 (100%)	169,550 (65%)
Beef	0	0	85,803 (33%)
Dairy	0	0	3,939 (2%)
Total (ha)	37,430	118,258	259,292

Potential regional changes in agricultural land use and farm jobs

Potential changes in farm area and farm jobs were estimated for the QS livestock RFT's for each of the Brexit scenarios The results suggest strong regional patterns. In all trade scenarios, the potentials for most land use change, most land use change to non-agricultural uses and most jobs affected were in Mid Wales and North West Wales.

Maximum potential change by region:

- Potential agricultural area affected Mid Wales (121,250 ha) under No Deal
- Potential area changing to non-agricultural uses North West Wales (100,026 ha) under MFTA
- Potential jobs affected North West Wales (2,677 FTEs) under MFTA.

The baseline for farm area and farm jobs by region are available in Appendix 4 as are the potential changes for each Brexit trade scenario and region. A high level summary is shown in Figure 2.1.8.6.

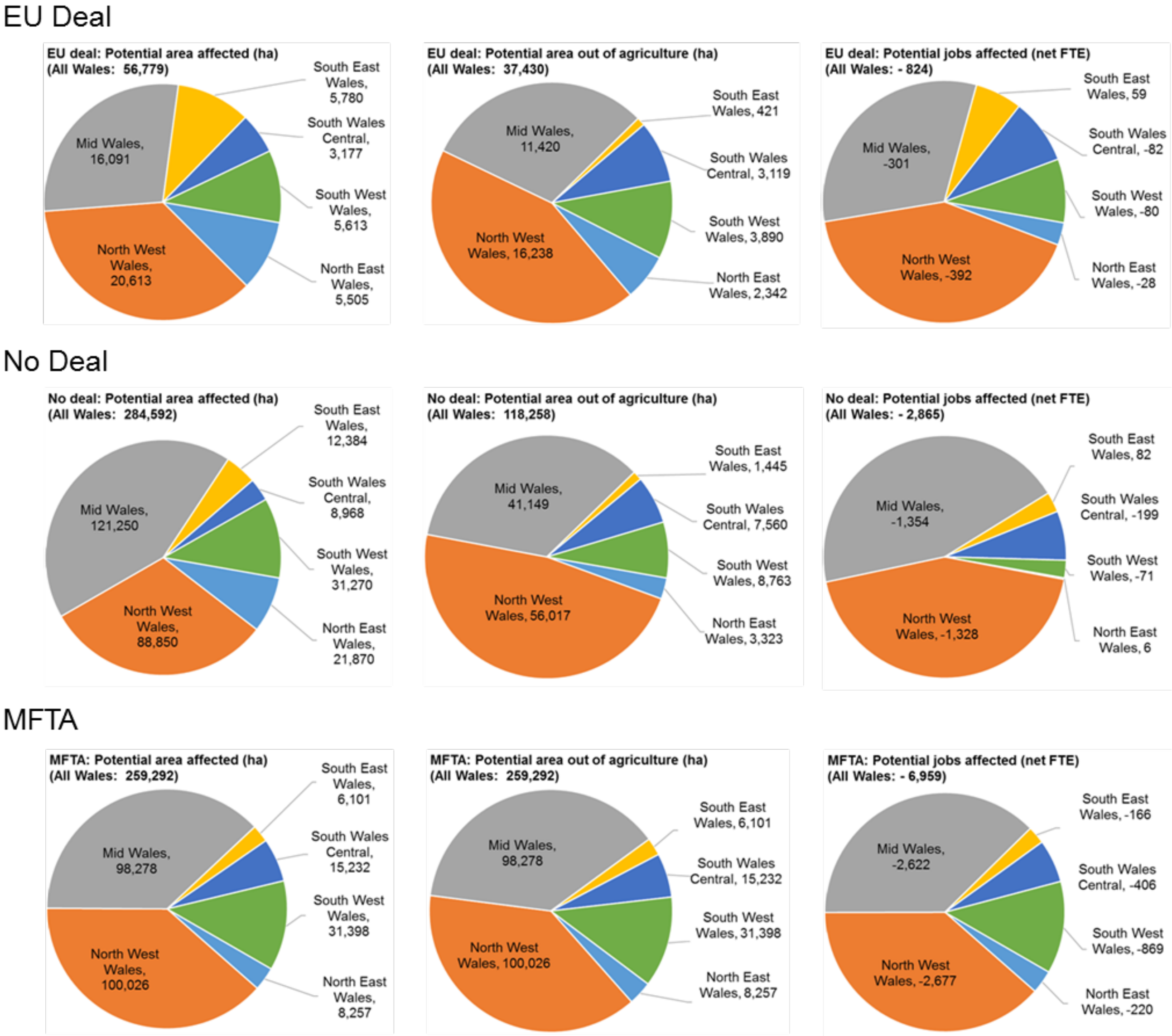


Figure 2.1.8.6. Potential area and farm jobs affected by region for the three Brexit trade scenarios: EU Deal, No Deal and MFTA.

Potential areas for new woodland planting

New woodland planting was considered an option for all areas identified as potentially changing to other (non-agricultural) land uses under each Brexit scenario, as long as those areas were not designated as unsuitable by the Glastir Woodland Creation (GWC) Rules (GWC-Wales, 2018). Three options for defining areas "unsuitable" for woodland planting were examined. The least restrictive option only excluded land with physical *Constraints*, where data indicate woodland planting is impossible (lakes, existing forest). The second option excluded areas of Constraint as well as areas with *Sensitivities* which make woodland planting undesirable for biodiversity, environmental or cultural reasons (e.g. ground nesting bird habitats, SSSIs which may be damaged by woodland, or World Heritage sites). The most restrictive option excluded areas of Constraints and Sensitivities as well as areas with *Guidance* issues which must be considered before planting would be approved, or which may cause administrative issues (e.g. National parks, historic landscapes, common land).

After applying the appropriate level of Constraints, Sensitivities and Guidance, the remaining land was subject to a final assessment to determine if planting was deemed possible by Forest Research (FR) models based on soils, elevation, topography and climate. The assessments of areas for potential new woodland planting and the planting options and suitability were carried out on a 250 x 250 m grid.

The results suggest that applying current GWC Constraints, Sensitivities and Guidance to new woodland creation may significantly reduce the land area potentially available for new woodland planting. For the EU deal and No Deal scenarios the percentage of land potentially released from agriculture that would be available for woodland planting under the full set of GWC restrictions is less than 1/10 of the land available for planting under Constraints alone (Table 2.1.8.5). Only for the MFTA scenario under GWC Constraints only can the full 100,000 ha of new woodland creation be realized. Maps of potential locations for woodland expansion under the three Brexit scenarios are available in Appendix 4.

Table 2.1.8.5. Potential limitations of current GWC Constraints, Sensitivities and Guidance for new woodland planting on land with potential to be released from agriculture under the Brexit trade scenarios.

		New area for woodland planting (ha) (also given as % of potential area) Total new area for planting is limited to 100,000 ha		
Brexit Trade Scenario	**Potential area out of agriculture (ha)**	**Observing GWC Constraints**	**Observing GWC Constraints & Sensitivities**	**Observing GWC Constraints, Sensitivities & Guidance**
EU Deal	37,430	21,647 (58%)	7,215 (19%)	1,985 (5%)
No Deal	118,258	83,783 (71%)	31,171 (26%)	6,820 (6%)
MFTA	259,292	99,982 (39%)	98,343 (38%)	44,671 (17%)

An example of the variability in potential area for new woodland creation across Wales is demonstrated by the results for the MFTA scenario (Figure 2.1.8.7). Strong regional variability in woodland creation opportunity relates to both the difference in land with potential to be released from agriculture and the difference in area of contributing variables which underpin the GWC Constraints, Sensitivities and Guidance. A full breakdown of regional results is available in Appendix 4.

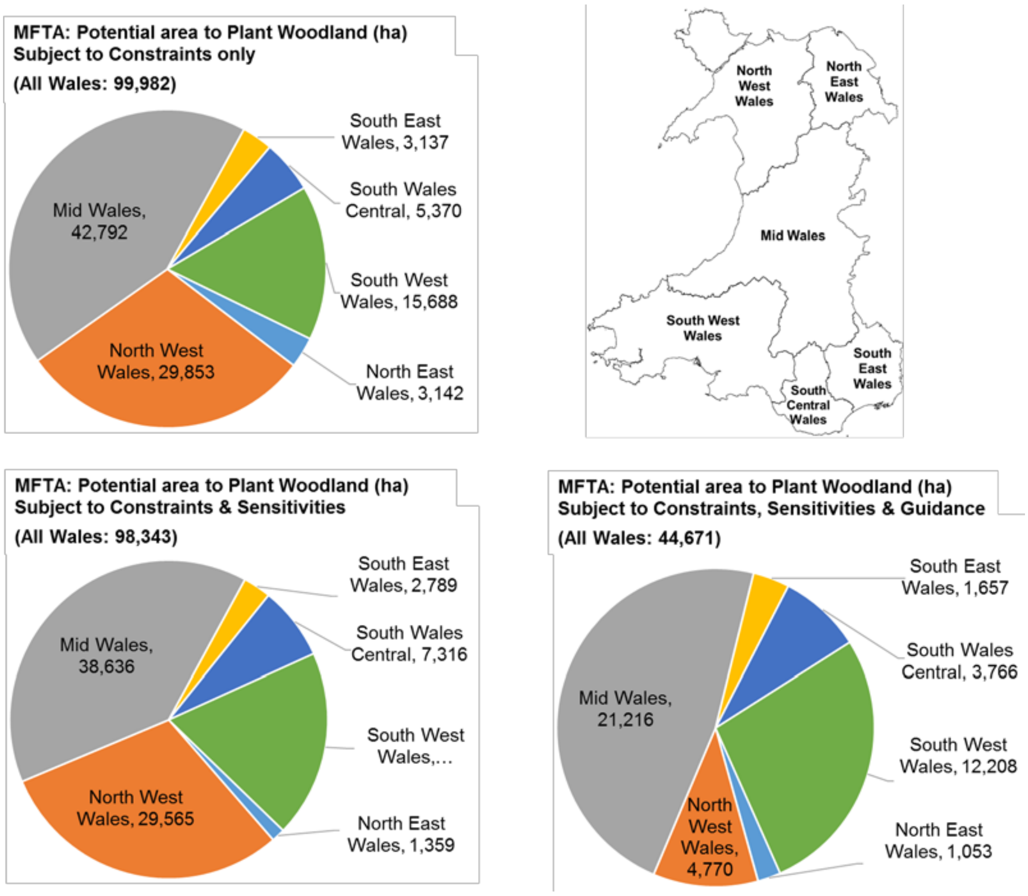


Figure 2.1.8.7. Potential areas for woodland expansion by region for the MFTA Brexit trade scenario under three different levels of GWC restrictions.

Environmental impacts of potential land use change in response to Brexit scenarios

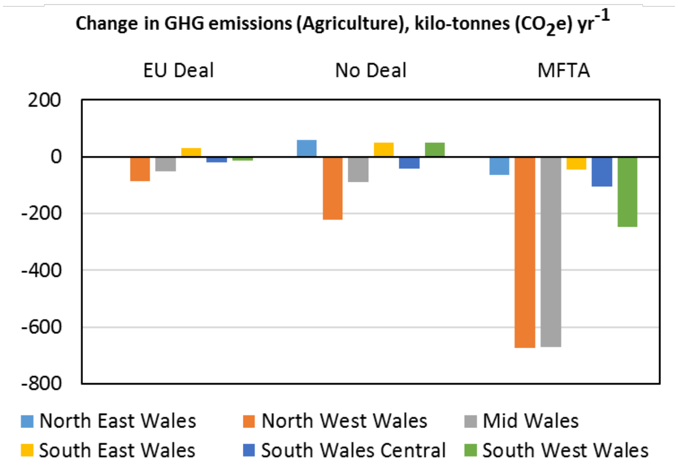
Greenhouse gases (GHG)

Outputs from Farmscoper modelling provide information regarding the potential change in agricultural greenhouse gas (GHG) emissions at national and regional scales. All three Brexit scenarios have the potential to reduce agricultural GHG emissions. National reductions range from -124 to -1,560 kilo-tonnes of CO_2e yr^{-1} depending on the scenario, which is equivalent to -1.5 to -18.5% reduction in national baseline 2017 emissions (Figure 2.1.8.8).

Highest baseline (2017) agricultural GHG emissions per hectare are located in the South West region, and small parts of Mid Wales, North East Wales and South East Wales. These map onto areas where most of the current Dairy sector is based. Areas of potential increases in GHGs are located near current Dairy due to the potential for dairy expansion in the EU Deal and No Deal scenarios (Figure 2.1.8.9).

Potential reductions in agricultural GHG emissions for all scenarios are greatest in Mid Wales and North West Wales where most potential for land coming out of agriculture is located. The greater potential impact of the MFTA scenario on reducing livestock and agricultural area is reflected in the highest potential reductions in GHG associated with that scenario (Figure 2.1.8.8 and 2.1.8.9).

Figure 2.1.8.8. Potential change in agricultural GHG emissions by region for the three Brexit trade scenarios.



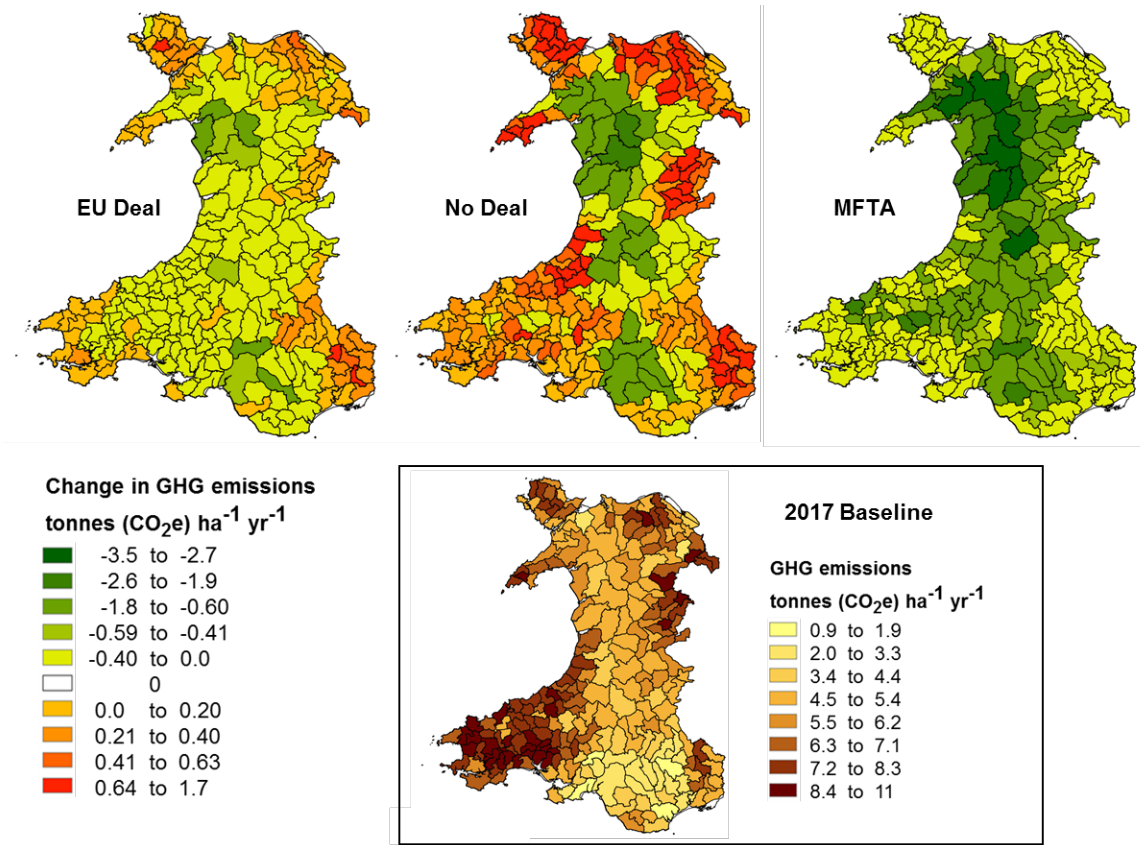


Figure 2.1.8.9. Spatial patterns of potential changes in agricultural GHG emissions across Wales for the Brexit trade scenarios. Changes are relative to 2017 baseline values (inset). Maps are based on Welsh Agricultural Small Areas containing 100 to 200 farms.

Note the importance of expressing results as *per hectare* when comparing regional results or mapping areas. Without this, areas of relatively low intensity farming but large total area would appear to be responsible for most of GHG emissions.

Water quality

Outputs from Farmscoper modelling provide information regarding the potential change in nitrogen load, total-phosphorus and suspended sediment load to water bodies. The potential changes to nitrogen loads to waterbodies are given as an example (Figure 2.1.8.10). A high degree of regional variability is apparent in current nitrogen loads to water bodies, with greatest loads related to the spatial patters of current farming sectors (Figure 2.1.8.11).

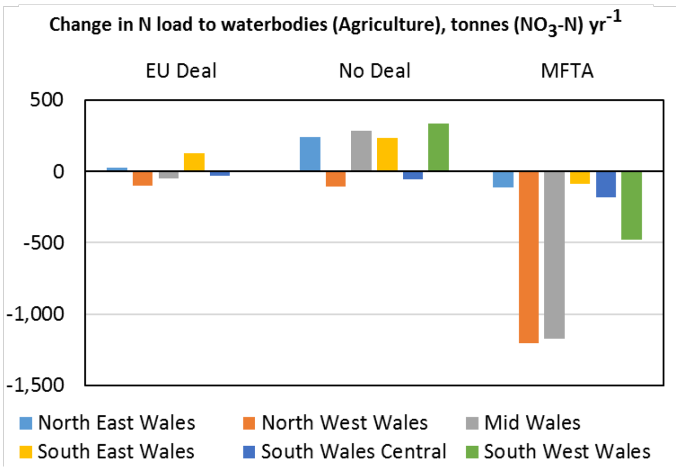


Figure 2.1.8.10. Potential change in agricultural Nitrogen load to water bodies by region for the three Brexit trade scenarios

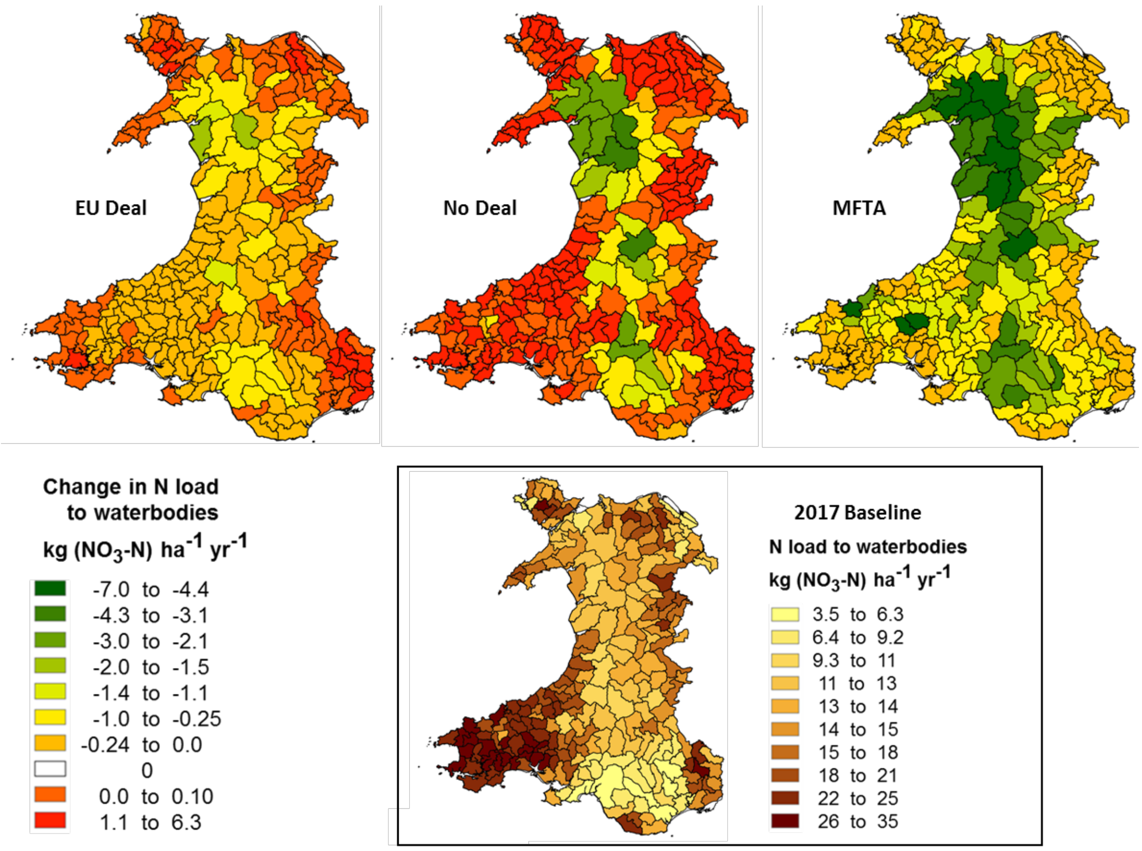


Figure 2.1.8.11 Spatial patterns of potential changes in agricultural Nitrogen loads to waterbodies across Wales for the Brexit trade scenarios. Changes are relative to 2017 baseline values (inset). Maps are based on Welsh Agricultural Small Areas containing 100 to 200 farms.

The potential change to nitrogen loads range from +598 to - 2,759 tonnes nitrate-N yr^{-1}. As a percentage of current loads the changes are equivalent to - 0.1%, +2.7% and -12.7% changes for the EU Deal, No Deal and MFTA scenarios respectively The greater potential impact of the MFTA scenario on livestock numbers and agricultural area is reflected in the higher potential reductions in diffuse pollution for this scenario, whilst increases are generally seen for No Deal.

For all scenarios, potential reductions in loads are greatest in Mid Wales and North West Wales due to the potential for land coming out of agriculture. This is the same pattern as seen for GHG emissions and ammonia emissions. Using nitrogen load as an example, small increases in nitrogen loads are seen for some areas for the EU Deal and No Deal scenarios due to a switch to different farming sectors primarily associated with the potential for an increase in Dairy. Dairy is generally associated with more nitrogen fertiliser use and leakage on a per hectare basis.

Results for all diffuse pollutants for all Brexit scenarios are available Appendix 4.

Air quality

Outputs from Farmscoper modelling provide information regarding the potential change in ammonia emissions, an important precursor for formation of particulates (e.g. PM2.5's) and also a contributor to nitrogen enrichment (eutrophication) of the wider countryside. Potential changes in emissions range from +1912 to -2,284 tonnes ammonia-N yr^{-1}. Changes are equivalent to a +1%, +12% and -14% reduction in current ammonia emissions for the EU Deal, No Deal and MFTA scenarios respectively (Figure 2.1.8.12). The greater potential impact of the MFTA scenario on livestock numbers and agricultural area is reflected in the higher potential reductions in diffuse pollution for this scenario, whilst increases are generally seen for No Deal.

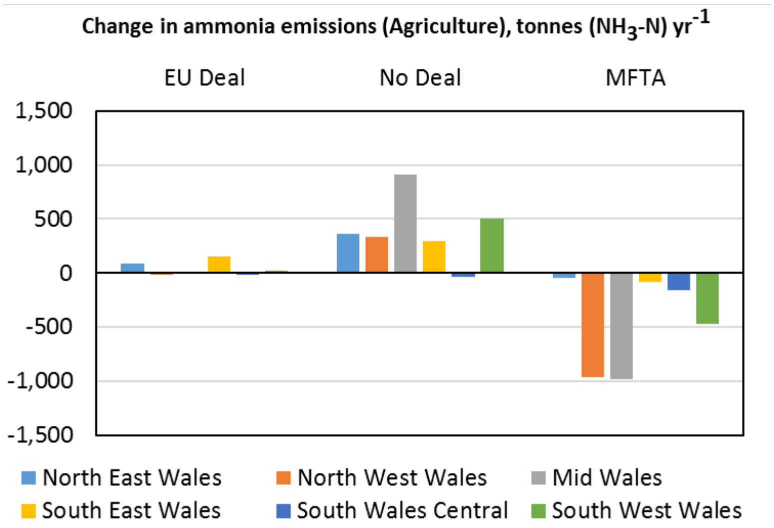


Figure 2.1.8.12 Potential change in agricultural Ammonia emissions by region for the three Brexit trade scenarios.

After correcting for the difference in regional areas, the relationship to current and potential land use change can be explored. A high degree of regional variability is apparent in current ammonia emissions associated with spatial distribution of different farming sectors as for GHG and nitrogen load emissions. In all scenarios, potential reductions are greatest in Mid Wales and North West Wales due to the potential for land coming out of agriculture. Small increases are seen for some areas for the EU Deal and No Deal due to a switch to different farming sectors primarily associated with the potential for an increase in Dairy. Dairy is generally associated with more nitrogen fertiliser use and leakage on a per hectare basis (Figure 2.1.8.13).

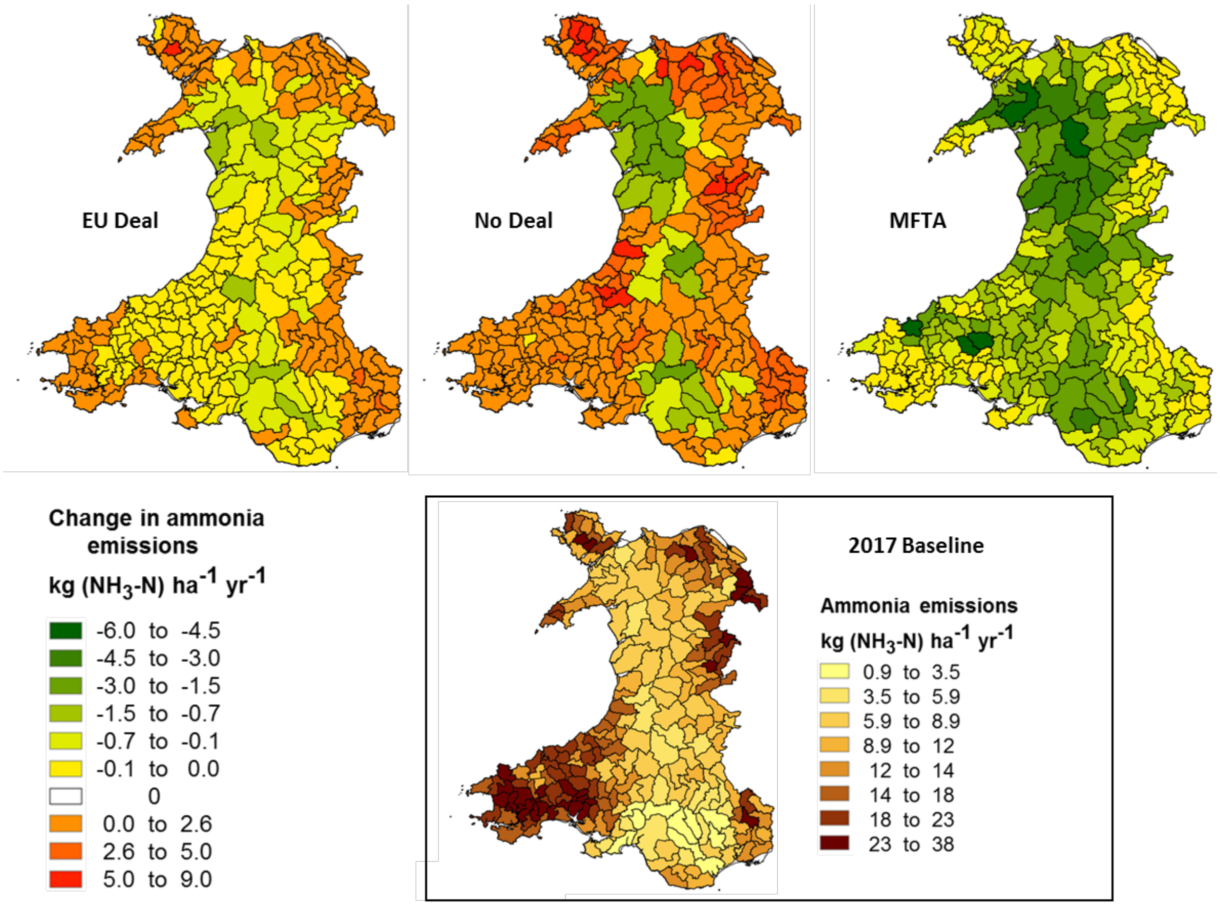


Figure 2.1.8.13 Spatial patterns of potential changes in agricultural Ammonia emissions across Wales for the Brexit trade scenarios. Changes are relative to 2017 baseline values (inset). Maps are based on Welsh Agricultural Small Areas containing 100 to 200 farms.

Note the importance of expressing these results per hectare due to the difference in size of regional areas. Without this correction, areas of relatively low intensity farming but large total area would appear to be responsible for most of ammonia emissions.

Bird Diversity

Potential change in abundance of the 58 bird species modelled was highly variable between species. For farmland species, the range was from -5% (Greenfinch) to +31% (Starling). For woodland species, model projections were from -26% (spotted flycatcher) to +13% (Dunnock). For Wetland and Water species, the range was -14% (Mallard) to +70% (Sedge Warbler). For other species, the projections ranged from -12% (Pheasant) to +55% (Whinchat). There was no consistent difference in ranges between the three Brexit trade scenarios in direction or magnitude of potential change (Figure 2.1.8.14). Woodland birds appeared to be most sensitive to changes, which is not unexpected as a proportion of “land with the potential coming out of agriculture” is planted with new woodland in this scenario.

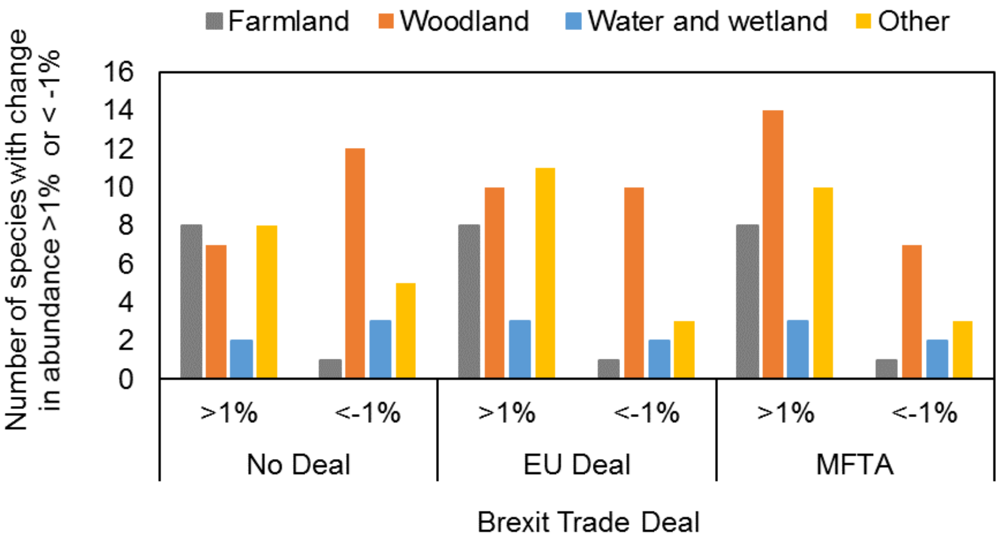


Figure 2.1.8.14 Projected change in number of bird species by habitat type. Only species with more than 1% change in numbers (positive or negative) are included. Note all 'land with potential to come out of agriculture' has been planted with new woodland (100% conifer) up to a pro rata limit of 100,000 ha new woodland target.

With respect to bird diversity, absolute predicted changes in the diversity index were very small: between +0.04 and -0.05 (Figure 2.1.8.15). The closer the index is to 1, the higher the species diversity. This was equivalent to a change of between -5% and +6%. Water and Wetland species and 'Other' species (i.e. those not listed as indicator species) appeared to be most sensitive to land use changes associated with the Brexit trade scenarios and new woodland planting scenario, although the changes were still very small in absolute terms. This probably reflects the habitat-specialism of some species in these groups, whereby their occurrence is more sensitive to the loss or gain of particular habitat patches than that of more generalist species or those associated with common habitats.

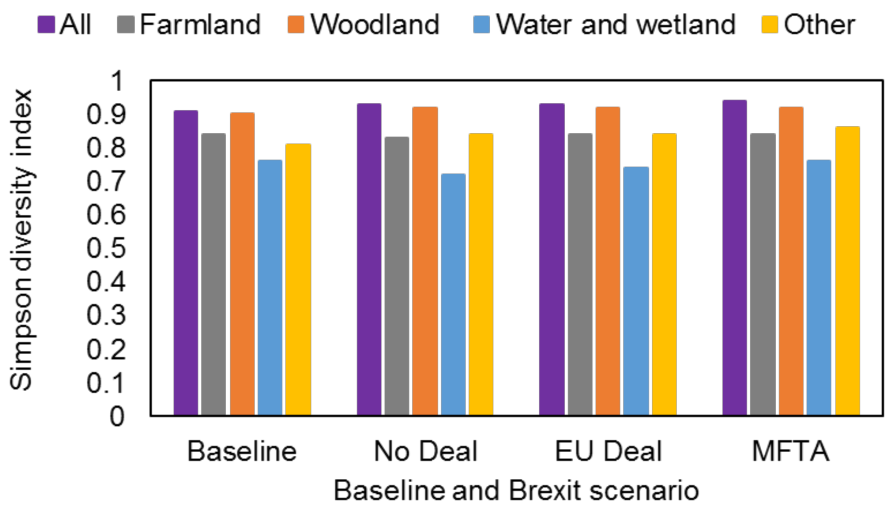


Figure 2.1.8.15 Projected change in bird diversity by habitat type. Note all 'land with potential to come out of agriculture' in each scenario has been planted with new woodland, up to a pro rata limit of 100,000 ha. The closer the index to 1, the higher the species diversity.

Percentage changes in farmland and woodland species were limited to -2% to +1%. Overall, it is clear that species' abundances are predicted to be far more responsive and sensitive to land-use change than composite indices of diversity. This is probably because increases in one species are commonly associated with decreases in another, due to variation in habitat requirements. Clearly, a simple diversity index does not discriminate between species, so there is no consideration of effects on priority versus other species. Further, effects on diversity may be larger with changes in the presence or abundance of rare species, but monitoring and analysis using Breeding Bird Survey (BBS) data preclude consideration of many such species although results for some red and amber species of conservation value are available.

Full bird diversity model outputs including results for species of conservation concern are available (Kettel and Siriwardena, 2018a).

2.2 Land management scenarios

ERAMMP has undertaken an initial rapid assessment of the spatial distribution of values attributable to a limited number Public Goods (PGs) resulting from a series of 'what if' major land management changes. These changes could arise from intended or unintended changes resulting from e.g. Payment for Ecosystem Services (PES) schemes, new public support schemes and / or Brexit trade deals. WG defined the management changes of interest and asked for three contrasting areas to be explored as it was thought national maps could mask important spatial patterns.

2.2.1 Test areas

The land management scenario assessment focussed on three test areas of contrasting land use and proximity to urban centres (Figure 2.2.1.1).

- The Conwy catchment which has mixed land use with large areas of upland peat and woodland.
- The Vale of Clwyd dominated by agricultural land.
- A group of valleys in South Wales which include the Heads of the Valleys region (referred to "Heads of Valleys" in this report) with mixed land use, relatively low intensity management practices and is located near urban centres.

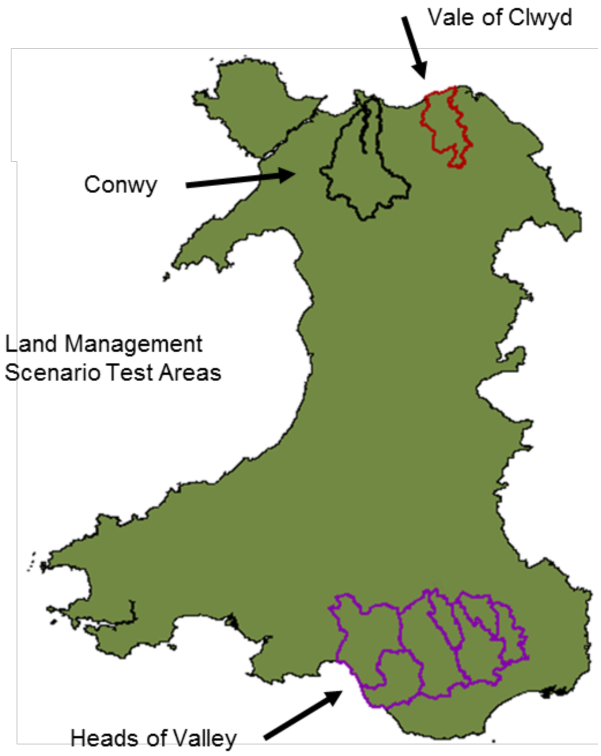


Figure 2.2.1.1. Location of test areas for the land management scenarios.

The test areas are made up of multiple catchments and include a highly variable amount of farmland which is in the Land Parcel Identification System (LPIS) (Table

2.2.1.1). LPIS is used for verification for payment and compliance purposes and is a fundamental part of the Integrated Administration and Control system (IACS) and part of the technical implementation of the Common Agricultural Policy (CAP). It is therefore land likely to be most affected by any future change in land management payments schemes.

Table 2.2.1.1. Total area, area of farmland and amount which is Land Parcel Identification Systems (LPIS) land within the three ERAMMP Land management scenario test areas.

Test Area	Area (ha)	Farmland area (ha)	% of area which is LPIS farmland	% of total Welsh farmland (1,236,557 ha)
Conwy	58,009	45,741	79	3.6
Vale of Clwyd	22,405	15,076	67	1.2
Heads of Valleys	175,564	60,190	34	4.9
Totals	255,978	121,007	47	9.7

2.2.2 Land management interventions

Five intervention options were included in the assessment:

1. New Woodland Creation with GWC: Three new woodland types under four management practices limited by current new woodland planting WG Glastir Woodland Creation (GWC) policy constraints (GWC-Wales, 2018).
2. New Woodland Creation with GWC plus 100,000 ha target limit: Three new woodland types under four management practices limited by current new woodland planting WG GWC policy constraints, and limiting total area planted to a target of 100,000ha for Wales (calculated pro-rata for the test study area size).
3. Removal of agriculture from peatlands.
4. Removal of agriculture from lowest quality agricultural land (Agricultural Land Classification (ALC) 5 soils).
5. Removal of agriculture from lower quality agricultural land (Agricultural Land Classification (ALC) 4 & 5 soils).

2.2.3 Scenario generation

The following methodology was taken to generate the five scenarios.

New woodland creation with GWC

In this first woodland creation scenario, new woodland planting was simulated on land removed from agriculture considering issues of planting restriction under the current Glastir Woodland Creation (GWC) scheme. Three options for defining areas “unsuitable” for woodland planting based on GWC rules were examined to explore the effects of GWC restrictions on area available. The least restrictive option only excluded land with physical *Constraints*, where data indicate woodland planting is impossible (lakes, existing forest). The second option excluded areas of Constraint as well as areas with *Sensitivities* which make woodland planting undesirable for biodiversity, environmental or cultural reasons (e.g. ground nesting bird habitats, SSSIs which may be damaged by woodland, or World Heritage sites). The most restrictive option excluded areas of Constraints and Sensitivities as well as areas with *Guidance* issues which must be considered before planting would be approved, or which may cause administrative issues (e.g. National parks, historic landscapes, common land). See Appendix 5 for more details.

The variability in carbon sequestration resulting from different woodland types and management was also explored. Five combinations of forest type and management were considered:

- Native broadleaf with low impact silviculture
- Native broadleaf with no thinning or felling
- Production conifer with low impact silviculture
- Production conifer with thinning and felling
- Short rotation forestry

New woodland creation with GWC plus 100,000 ha target limit

In this second woodland creation scenario, new woodland planting was also simulated subject to GWC restrictions, but the total area planted (if possible) was limited to maximum of pro rata 100,000 ha according to the test study area. Exactly matching the 100,000 ha target was not an optimisation criteria, since this would not accurately reflect real world controls on land use change. Land was selected by prioritising farms where new planting would connect existing broadleaved woodland, calculating cumulative area and then filtering out the portion of the dataset with cumulative area >100,000 ha. As a result, the final area simulated as new woodland will always be slightly under the target. See Appendix 5 for more details.

As for woodland creation scenario 1, five combinations of forest type and management were considered:

- Native broadleaf with low impact silviculture
- Native broadleaf with no thinning or felling
- Production conifer with low impact silviculture
- Production conifer with thinning and felling
- Short rotation forestry

For both woodland creation scenarios, the benefits from woodland creation explored are:

- Recreations benefits derived from the proximity to urban centres (peri-urban) and are capped at a limit of 20% of current value of recreation land in each test area.
- Air quality emission reductions for ammonia due to reduction in agriculture have been calculated and are presented but not valued.
- Air quality reductions of PM2.5s are calculated and their benefit for health valued.

- Biodiversity benefits modelled are limited to bird abundance and diversity but the increase in woodland area will benefit many woodland species however the benefit will depend on the woodland type, management and connectivity to other woodlands. Biodiversity associated with farmland by definition will also potentially decline where farmland has been converted to woodland.
- Water quality benefits calculated are limited to the benefits associated with removal of agriculture diffuse pollution. Other impacts of woodlands on water quality are not assessed.

Removal of agriculture from peatland

The peatland scenario was to explore the impact of removing livestock from fields located on peatlands as defined by the new Unified Wales Peatland Map (Evans et al., 2014).

The impacts for greenhouse gas emissions will have two components:

1. Reduction in emissions from livestock and any associated fertiliser applications
2. Potential change in peatland emission factors for accounting, if the land changes IPCC emission factor category. Whilst this has been explored the potential interactions with the emissions calculated from the Farmscoper model has never been explored before and needs more in depth analysis.

There is no evidence base for the potential recreation benefits of peatland which has been removed from agriculture therefore no monetary valuation has been attempted.

Air quality emission reductions (ammonia) have been calculated and are presented but not valued. Change in particulates have not been calculated.

There will be specific biodiversity and conservation benefits over time which are represented only by area released. Biodiversity benefits will depend on the condition and connectivity of new woodlands created. Management for restoration to full peatland systems is likely to require actions such as rewetting and nutrient inflow reductions.

Water quality benefits calculated are limited to the benefits associated with removal of agriculture.

Removal of agriculture from lowest quality agricultural land (ALC 5)

Farms were taken out of agriculture if the majority area of the farm was on non-agricultural land, urban land or was ALC grade 5. This was determined using ALC data from the freely available version of the predictive ALC map for Wales (PALC-Wales, 2018). These data replace the previous “Provisional” map withdrawn in 2017. This assigns agricultural land class based on the most limiting factor for agricultural use. See Appendix 5 for more details.

The rationale was that lower quality land is likely to be less agriculturally profitable, and thus there may be opportunity to explore different management options.

Benefits expected to be derived are:

- Recreations benefits are derived from the proximity to urban centres (peri-urban) and are capped at a limit of 20% of current value of recreation land in each test area.

- Air quality emission reductions (ammonia) have been calculated and are presented but not valued. Reductions in particulates have not been calculated.
- There will be specific biodiversity and conservation benefits over time which are represented only by area released with potential for restoration to semi-natural vegetation. It should be noted this potential will only be realised in many cases if there is active management to e.g. reduce nutrient stored in soils and/or maintenance of conservation levels of grazing,
- Water quality benefits calculated are limited to the benefits associated with removal of agriculture diffuse pollution.

Removal of agriculture from lower quality land (ALC 4 and 5)

Using the same ALC data, farms were taken out of agriculture if the majority area of the farm was on non-agricultural land, urban land and was ALC grade 4 or 5.

The rationale was that land with lower quality (ALC) is likely to be less agriculturally profitable, and therefore may be more likely to have intended or unintended changes in land management going forward and/or be open to PES or public payment scheme opportunities.

Benefits expected to be derived are as above in the ALC-5 scenario.

Combined scenario

The environmental impacts and monetary values for individual scenarios cannot be added within a test areas as there is overlap of land used for different scenarios e.g. land subjected to the scenario ‘Removal of land from lowest quality land (ALC 5) may also have been included in the scenario(s) for new woodland creation.

A combined scenario was therefore constructed which captured land for a subset of scenarios in the following sequence:

1) Remove agriculture from peatlands
2) On remaining land, include any new woodland creation with GWC (for native broadleaf, no thin/fell) scenario
3) Finally, include any land from ‘Remove agriculture from lower quality land (ALC Grade 4 and 5) scenario which is not included in 1 or 2 options above.

2.2.4 Environmental modelling

Outputs from the land management scenarios were passed to environmental impact models to explore the environmental consequences and where possible estimate monetary value of change in public goods. The models are summarised in Table 2.2.4.1, and detailed descriptions are available in Appendix 1. Assumptions and limitations are as described for Brexit scenarios (see Section 2.1.7) where these overlap. Where new models or data tools are used or approaches vary significantly from the Brexit scenarios, these are described below.

Table 2.2.4.1. Role of different model and data tools for evaluating environmental impact of Land Management Scenarios

		Land Management Scenario				
		New Woodland		Removal of agriculture		
Environmental impact	**Public Good (PG)**	**GWC constraints & sensitivities**	**GWC constraints & sensitivities + 100,000 ha pro rata limit**	**Peat land**	**ALC 5**	**ALC 4&5**
Greenhouse gas emissions	Climate mitigation	Farmscoper				
Carbon sequestration	Climate mitigation	ESC + Carbine				
Nitrogen, phosphorus and sediment load to rivers	*not evaluated*	Farmscoper				
Ammonia emissions	Air quality	Farmscoper				
Particulate emission reductions (PM2.5)	Air quality & health	EMEP4UK and Alpha Risk Poll				
Land available for public use (peri-urban)	Recreation	Orval				
Bird diversity and abundance	Biodiversity	BTO Bird model				

BTO bird model

The BTO Bird models is based around modelled relationships between bird abundance captured with the BTO/JNCC/RSPB Breeding Bird Survey (BBS) and land use in 1km squares using a range of national sources of data. The model is a new model developed to meet the ERAMMP Quick Start requirements although similar approaches have been developed before by BTO (Kettel and Siriwardena, 2018b).

The impact of new woodland on PM2.5 removal and health benefits

The modelling approach is based on calculated removal rates of the pollutant PM2.5 by woodland based on outputs from a large-scale atmospheric chemistry transport model called EMEP4UK using an approach developed for the UK (Jones et al., 2017). These removal rates are then converted to total health value based on a reduction in exposure to PM2.5 concentrations involving estimates of change in Respiratory Hospital Admissions, Cardiovascular Hospital Admissions and Life Years Lost (and the associated monetary values) using the Alpha Risk Poll model (see Appendix 1 for details).

Recreation and the ORVal model

Recreation values are based on modelling of known patterns of recreation in England and Wales, through the ORVal tool (http://www.exeter.ac.uk/leep/research/orval/). The modelling uses long-term Government survey data, and established welfare valuation approaches.

It should be noted that work in other parts of the UK suggests that cost savings to the NHS as a result of the physical activity supported through this recreation are usually at least ¼ of the magnitude of these welfare values.

The recreation resource for each test area is measured in terms of public footpaths and accessible open space. The ORVal tool uses national survey data (GOV.UK, 2014) to model households' behaviour in terms of their choices to visit there recreation areas. The visits are valued based on the value of individuals' time spent participating in the outdoor recreation. This cost of time approach is the same as that used by the Department for Transport to value time savings from transport projects (DOT, 2017), as part of assessments as to whether those projects should be supported by Government.

ORVal sums the value of all recreational visits estimated by the model to estimate the value of each footpath or accessible open space. The values of these recreational areas are summed by the tool according to administrative boundaries (e.g. Local Authorities). These values are used to estimate the baseline value in the land management scenario test areas.

2.2.5 Valuation of Public Goods

Partial additional monetary valuation was calculated for four public goods (PGs).

1. Climate mitigation, emissions reduction (tonnes (CO_2e) yr^{-1})
2. Climate mitigation, sequestration (tonnes (CO_2e) yr^{-1})
3. Recreation, new land available for public access to peri-urban areas (i.e. <2km from an urban area) (ha)
4. Health benefits from particulate removal (tonnes PM2.5 yr^{-1})

Intervention delivers multiple benefits, for example creation of new woodlands adjacent to urban centres provide recreation, improves air quality and sequesters carbon. To understand the full public good of an intervention the combined value must be applied on an area basis. Valuation methods are described in Appendix 1.

No valuation was attempted for Biodiversity as there is no acceptance of either the validity or utility of valuation of this fundamental ecosystem property.

Valuation was carried out for changes in water quality but there is currently no acceptance of water quality as a public good rather than an issue best tacked as a regulatory issue. The results have therefore not been included here.

Monetary valuation carbon

The expected changes in carbon emissions have been valued according to latest Government Guidance, adopting the non-traded price of carbon (BEIS, 2013), which escalates from £68 in 2020 (the baseline year) to £319 per tonne in 2095. Values are in 2020 prices, and present values are calculated over 75 years using HM Treasury recommended discount rates. This is an established valuation approach across the public sector in the UK, and is widely used in policy analysis and decision-making across Government departments.

2.2.6 Primary assumptions and uncertainties

Assumptions and uncertainties for the environmental models remain as for the Brexit scenario models (Section 2.1.7). With the respect to the land management scenario generation key uncertainties and assumptions are highlighted below.

Scenario creation

Woodland creation

- We assumed that farms could be incentivised to plant new woodland on all land not subject to constraints and sensitivities, regardless of its agricultural value.
- We did not exclude farms<10ha, on the grounds that woodland planting may be incentivised by payments, so thresholds for profitability did not apply.
- For the pro-rata scenario, woodland planting was prioritised as outlined in Appendix 5 according to opportunity to increase existing woodland. Use of a single criteria to rank suitable land had a large influence on where planting took place (since guidance areas were not ruled out, meaning that suitable land generally greatly exceeded the pro rata target).

Removal of agriculture from lower (ALC 5) and lowest (ALC 4&5) quality land

- Land was taken out of agriculture based on majority ALC at farm level i.e. including land outside of the study area boundary.
- Modelling of impacts only used land on fields which were at least partly inside the boundary
- We retained urban and non-agricultural classes here to account for the proportion of farm taken up by these when selecting farms for change- it should be noted that applying a linear scaling to non-linear categories affects the influence of these areas.
- Socioeconomic factors which cannot be mapped may be more important than ALC in guiding whether farms are likely to be persuaded to stop agriculture for AES payments.

Removal of agriculture from peatland

- Spatially- there are numerous maps of peat locations- we used the new Wales Unified Peat Map (note, licensing for ERAMMP still being agreed). Peat is likely to only occupy a portion of a field, but we apply an assumption that the whole field would be removed from agriculture, for practical reasons
- Although transitions between land use will take place over a period of time, the temporal aspect is not accounted for here.
- Changes in peat emissions were calculated only for the portion of the field which is peat, and within the study area.

Air quality PM2.5 removal and health benefits due to new woodland

- Removal rates of PM2.5s vary between test study sites due to initial pollution concentrations, the spatial location of woodland in relation to pollution concentrations, as well as interactions among other pollutants and meteorology in the original model runs which were run at a 5x5 km resolution.
- It should be noted the greatest monetary health value (90%) is associated with Life Years Lost.
- The test study areas do not map exactly to local authority boundaries. The calculations used the closest one or two local authorities for each test study area.
- It is assumed that pollution removal due to the action of vegetation within a local authority is greater than the effects of vegetation outside of the local authority.
- Spatial variation in pollution concentrations, woodland and benefitting population within a local authority are not explicitly accounted for in this approach. Methods are available to do this sub-test area analysis but insufficient time was available for this initial rapid assessment.

Additional finer-scale modelling will help to better understand optimum locations for woodland planting. In the short-term, this can be achieved using a 1x1km version of EMEP4UK. In the longer-term, development of a nested, finer grid model suitable for application in urban areas would be needed.

Recreation value of new peri-urban land and the ORVal tool

- This is one of the most location dependent benefit of all benefits valued to date but is driven by the focus on peri-urban values only for now. Note values do not relate to new woodland area only. Value is derived from any land (except peatland) assumed to be made available for public access. The variation between study areas is related to the urbanisation of the case study area.
- This public good relates to new publicly accessible land (peri-urban only) taken out of agriculture within 2km of urban areas but with no current footpaths or access points (potential for recreation with investment). It assumes land no longer in agricultural use is not put to other productive use and becomes accessible for recreation (either by default or deliberate intervention).
- Its additional value will depend, inter alia, on the size of the nearby population, and the extent of existing recreational areas that population has access to, and other characteristics of the land (e.g. surrounding land, habitat type, slope, ease of access, local culture around using land for recreation). These factors can only be thoroughly investigated with more detailed modelling.
- The marginal impact of additional recreational space would be expected to have diminishing returns. This has been reflected by the use of a cap of +10-20% of current value: a) new area 0-100% of OrVal RA, new area value = 10% OrVal RV; b) new area > 100% OrVal RA, new value = 20% OrVal RV.

- The value of the trips is based on the cost of time for those participating in the recreation. Note: the UK Government Office of National Statistics current approach to valuing recreation for the national accounts only uses transport and entrance fee expenditures. Since most recreational activity is free, the ONS method therefore results in significantly lower values than those estimated in ORVal.
- These visitor/value figures include visits by adult local residents and non-local UK residents. It excludes visitors from overseas and children (so are an underestimate). The cost of time does not vary with income.
- Note that even though we are controlling for proximity to urban areas, the local distribution of the new resource (especially in a large area like Heads of Valleys) will matter but there has been insufficient time to explore this.
- Any newly accessible land is unlikely to be evenly spatially distributed. Area which becomes accessible can be greater than land use change in the scenario since sub-field level changes are assumed to make the whole field accessible.

Bird abundance and diversity

See discussion of BTO model assumptions and uncertainty in Section 2.1.7.

Valuation of Public Goods

There are significant limitations with respect to partial monetary valuation of public goods. These include:

- Some PGs cannot, or some consider should never be valued e.g. biodiversity.
- Some valuation approaches could be considered to under value the true risks for future generations (e.g. climate mitigation)
- The current status of some natural resources as either a public or private good is not agreed (e.g. water quality)
- Some natural resources contribute to a range of both public and private goods e.g. landscape aesthetics contribute to e.g. well-being; recreation; tourism and double accounting could be a concern.

The cumulative effect of these limitations mean that total value is always incomplete and should never be used in isolation to inform decision making. It is just one source of evidence which can help inform the discussions between government, industry, the third sector/NGOs and the public.

Issues regarding reporting units and maps

To enable high level reporting, some simplifications have been made to model outputs. These include:

- Presentation of spatial outcomes at field/farm scale can breach personal data legislation. The alteration of maps to solve this issue inevitably reduces their accuracy.
- Management scenarios may use the same land and therefore benefits are not additive. The combined scenario provides one solution to resolve this issue

however the rule base to create this scenario is very dependent on priorities and rule base to create the scenario. The potential number of combined scenarios are numerous.

- Multiple actions which contribute to a single benefit e.g. stopping of agriculture for woodland creation which could be conflated to the single action of woodland creation.
- Conversion of outputs from absolute values per test area to standardised area unit e.g. outcome per total land area and outcome per total land area changed.
- Using the midpoint of ranges for woodland scenarios in some tables and figures for a high level summary.

2.2.7 Land management scenario results

Land Use change

The area of land converted within the different test areas for each scenario is highly variable due to the variable presence of:

- Area of land which passes current GWC constraints and sensitivities and area of test area for pro rata limit for new woodland creation.
- ALC 4 and 5.
- Peatland.

For the Conwy and Heads of Valleys, removal of agricultural from low quality land impacts the most land whilst woodland creation affects most land in the Vale of Clwyd. These differences reflect the relatively high quality of agricultural land in the Clwyd but also the lack of many features which currently constrain new woodland creation such as designated and protected areas for biodiversity and landscape. Areas are shown in Table 2.2.7.1.

Table 2.2.7.1. Area of LPIS land in each test area and the area of land converted in each test area for each scenario. The shaded cell for each test area highlights the scenario which affects the most land area within each catchment. The area of land changed as a % of current farmland is also shown.

<table>
<tr><th colspan="2">Scenario</th><th>Conwy
ha (%)</th><th>Vale of Clwyd
ha (%)</th><th>Heads of Valleys
ha (%)</th></tr>
<tr><td colspan="2">LPIS Farmland</td><td>45,741</td><td>15,076</td><td>60,190</td></tr>
<tr><td rowspan="2">Woodland creation</td><td>GWC constraints and sensitivities</td><td>12,914
(28%)</td><td>6,237
(41%)</td><td>29,633
(49%)</td></tr>
<tr><td>GWC constraints and sensitivities plus pro rata 100,000 ha limit</td><td>2,863
(6%)</td><td>1,049
(7%)</td><td>8,206
(14%)</td></tr>
<tr><td rowspan="2">Remove agriculture from low quality land</td><td>ALC 5</td><td>30,658
(67%)</td><td>449
(3%)</td><td>28,199
(47%)</td></tr>
<tr><td>ALC 4 & 5</td><td>39,747
(87%)</td><td>1,223
(8%)</td><td>49,145
(82%)</td></tr>
<tr><td>Remove agriculture from peatland</td><td>All LPIS land with peat</td><td>24,061
(53%)</td><td>223
(1%)</td><td>8,676
(14%)</td></tr>
</table>

New Woodland

Climate mitigation benefits of woodland creation

Overall, variability in climate mitigation benefits due to new woodland creation varies between the three test areas due to the:

- area of land taken out of agriculture within the test catchments which affects reduction in agricultural reductions in GHG emissions from animals, and fertiliser use;
- type of farming sector which is removed for new woodland as GHG emission density varies by sector;
- type of woodland planted and management option which affects the rate of carbon sequestration.

These three issues are explored further below.

The area of new woodland created within the three test areas is variable due to the different size of the test areas and the rule-base for creating new woodlands. The Heads of Valleys is the largest test area and proportionally has the greatest percentage of new woodland created within both scenarios (Table 2.2.7.2).

Table 2.2.7.2. Farmland (LPIS) land in the three test areas and area converted to new woodland under the two scenarios (ha) and as a percentage LPIS land (%).

Test area	LPIS land (ha)	New woodland with GWC ha (% LPIS land)	New woodland with GWC and pro rata 100,000 ha limit ha (% LPIS land)
Conwy	45,741	12,914 (28%)	2,863 (6%)
Vale of Clwyd	15,076	6,237 (41%)	1,049 (7%)
Heads of Valleys	60,190	29,633 (49%)	8,206 (14%)

Removal of agriculture to allow for new woodland creation was responsible for:

- -8.7 to -175.1 kilo-tonnes (CO_2e) yr^{-1} emission reductions.

This is between 2 to 11 times greater than the amount of climate mitigation delivered by the carbon sequestered by trees planted after 100 years of the applied forest management scheme used in the scenarios.

Woodland type and management also contributes to the variation in climate mitigation benefit observed as these impact on the rate of carbon sequestration in the soil, trees and litter and the GHG emissions associated with management practices. The variability affects rates by a factor of 3. Values were:

- -1.4 to - 17.6 kilo-tonnes (CO_2e) yr^{-1} for New Woodland with GWC and 100,000ha limit
- -7.0 to -52.8 kilo-tonnes (CO_2e) yr^{-1} for New Woodland with GWC.

Native Broadleaf woodland type has the greatest C sequestration value over the 100 management horizon selected for presentation here closely following by short rotation woodland. This is due to the GHG cost of management practices in production coniferous forestry. Note here the substitution effects of the biomass and wood produced for the energy sector and building sector are not included.

In summary, GHG reduction due to removal of agriculture represents 66%-92% of climate mitigation for new woodland creation scenarios. The remaining mitigation (i.e. 8%-34%) is due to C sequestration rates in new woodland.

When converted to partial annualised monetary value* using recommended HM treasury discounted rates (3.5% declining over time), total climate mitigation (Agriculture GHG reduction plus C sequestration) values vary from £0.6m yr^{-1} for Vale of Clwyd with GWC and 100,000 ha limit to £14m yr^{-1} for the Heads of Valleys New Woodland with GWC (Figure 2.2.7.4).

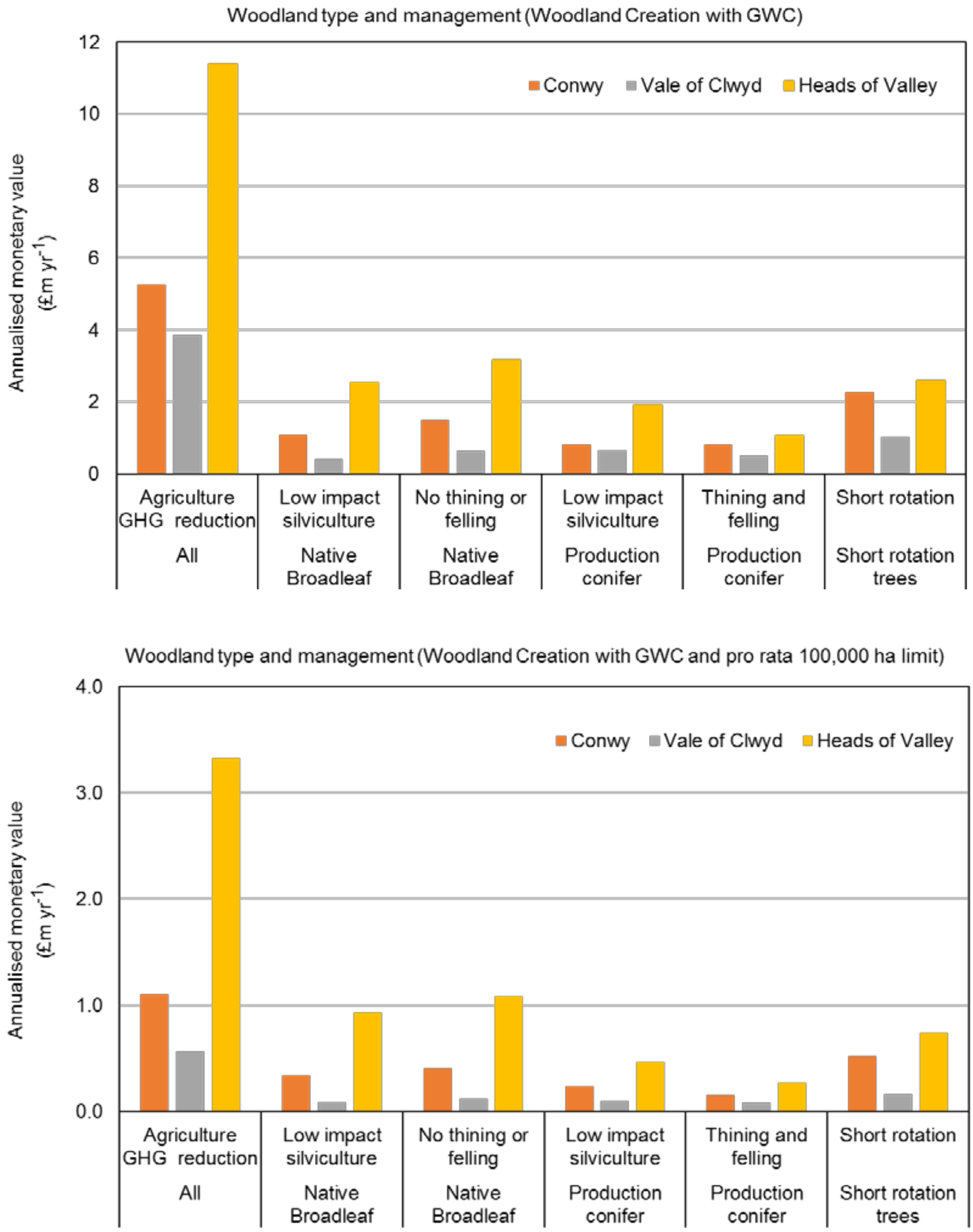


Figure 2.2.7.4. Annualised monetary value (£m yr^{-1}) of climate mitigation relating to new woodland creation in the three test areas illustrating the difference between woodland type and management for the two scenarios: upper) New woodland with GWC; and lower) New woodland with GWC and pro rata 100,000ha limit.

<u>Climate mitigation benefits of woodland creation corrected for area of land converted to new woodland within test areas</u>

When comparing between sites, an adjustment needs to be made to take account of the variable area of land converted to woodland within the three test areas.

When corrected for area of land changed, the higher density of greenhouse gas emissions within the Vale of Clwyd per hectare due to more intensive agriculture and greater presence of dairy can be seen (Table 2.2.7.3-A). Values range from 5.9 to 9.5 tonnes (CO_2e) (ha changed)$^{-1}$ yr^{-1}.

Table 2.2.7.3-A. Annual greenhouse gas reductions due to agriculture removal (tonnes (CO_2e) (ha changed)$^{-1}$ yr^{-1}) for new woodland creation scenarios corrected for area of land converted following the rule-base for New Woodland creation scenarios in the three test locations.

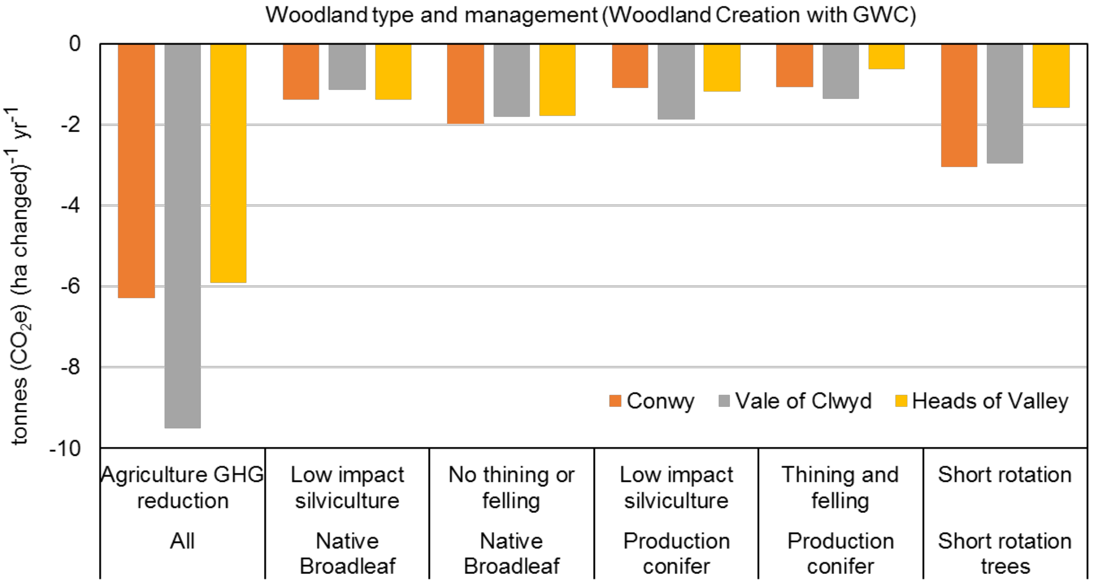
Test area GHG emissions changes	New woodland with GWC, tonnes (CO_2e) (ha changed)$^{-1}$ yr^{-1}	New woodland with GWC and pro rata 100,000 ha limit, tonnes (CO_2e) (ha changed)$^{-1}$ yr^{-1}
Conwy	-6.3	-5.9
Vale of Clwyd	-9.5	-8.3
Heads of Valleys	-6.2	-5.9

There is also a variable potential growth rate per hectare changed of the woodland within each scenario. This is illustrated in Table 2.2.7.3-B where for a common woodland type and management option (Native Broadleaf with low impact silviculture), carbon sequestration rates vary from 1.1 to 1.9 tonnes (CO_2e) ha^{-1} yr^{-1} due to difference in soil and climate type alone of land selected both within and between catchments.

Table 2.2.7.3-B. An example of the variability in annual carbon sequestration rates per unit area of land planted (tonnes (CO_2e) (ha changed)$^{-1}$ yr^{-1}) due to Woodland creation (Native Broadleaved / Low impact silviculture option) in the three test locations. Note this excludes the GHG reductions due to removal of agriculture.

Test area C sequestration rates	New woodland with GWC, tonnes (CO_2e) (ha changed)$^{-1}$ yr^{-1}	New woodland with GWC and pro rata 100,000 ha limit, tonnes (CO_2e) (ha changed)$^{-1}$ yr^{-1}
Conwy	-1.9	-1.4
Vale of Clwyd	-1.4	-1.1
Heads of Valleys	-1.8	-1.4

Rates of carbon sequestration for all woodland types and management options are generally lowest in the Vale of Clwyd perhaps due to lower rainfall. The combined effect of both reduced GHG emissions from agriculture and variable rates of carbon sequestration rates per hectare of land changed is shown for the two scenarios in Figure 2.2.7.5.



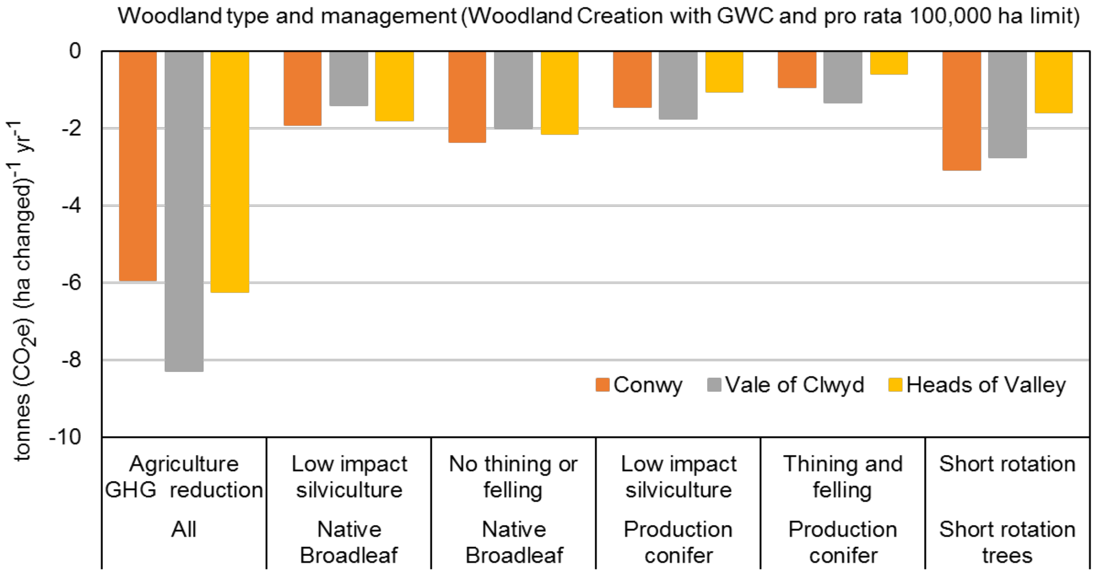
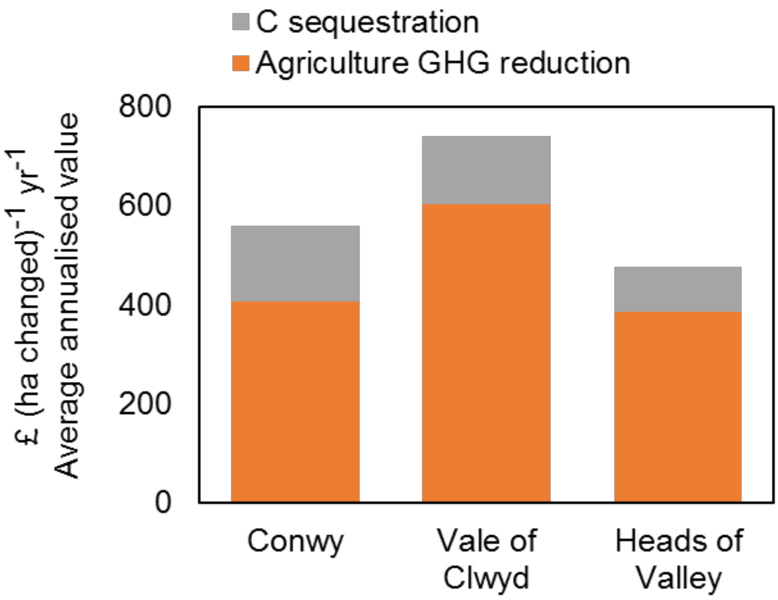


Figure 2.2.7.5. Annual climate mitigation relating to new woodland creation in the three test areas illustrating the difference between woodland type and management for the two scenarios corrected for area of land changed which differs between the three test areas (CO_2e (ha changed)$^{-1}$ yr^{-1}): upper) New woodland with GWC; and lower) New woodland with GWC and pro rata 100,000ha limit.

When GHG reductions from agriculture and carbon sequestration are combined for area of land converted to new woodland, and a midpoint selected for woodland type and management option calculated, the different monetary value of climate mitigation per area changed per year can be more clearly seen (Figure 2.2.7.6). Rates vary from:

- 558 £ (ha changed)$^{-1}$ yr^{-1} in the Conwy
- 741 £ (ha changed)$^{-1}$ yr^{-1} in the Clwyd
- 476 £ (ha changed)$^{-1}$ yr^{-1} in the Heads of Valleys



**Annualised Present Values of public goods (£m yr^{-1}) calculated over 75 years using HM treasury recommended discount rates (0-30 years, 3.5%; 31-75 years 3.0%). Monetary value of carbon from BEIS non-traded price of carbon over 75 years; £68 tonne^{-1} in 2020 (baseline year); £319 tonne^{-1} in 2095.*

Figure 2.2.7.6. The monetary value of climate mitigation benefits (£ (ha changed)$^{-1}$ yr^{-1}) from new woodland creation scenarios corrected for the difference in area between the three test areas.*

The greater mitigation value per hectare change in the Clwyd is due primarily to the greater reduction in agriculture GHG emissions (Table 2.2.7.3-A&B) as carbon sequestration rates in the new trees are generally lower than for the Conwy and Heads of Valleys.

Clearly when considering the potential climate mitigation benefits of new woodlands, the type of agriculture it is replacing and the types of woodland and management need to be explicitly stated as values vary by as much as 3.6 and 0.8 tonnes (CO_2e) (ha changed)$^{-1}$ yr^{-1} respectively.

It should be noted, these values are all for new woodland planted. Options to explore management of *current* woodland are not covered here but runs have been completed and additional time is needed to explore the outputs. The potential contribution of substitution effects for the energy or construction industry have been calculated but are not included here.

<u>Air quality benefits of woodland creation</u>

Reduction in ammonia emissions were between 33%-50% of currents emissions for new woodland creation with GWC between the three test areas. This was reduced to 6-16% with the pro rata planting to the 100,000ha limit (Table 2.2.7.4).The magnitude of change generally increased from Conwy < Vale of Clwyd<Heads of Valleys.

Table 2.2.7.4. Annual reductions in ammonia emissions to the atmosphere (tonnes NH_3-N) and the % reduction of baseline loads in the three test areas.

New Woodland scenario	Test Area	Ammonia emissions tonnes NH_3-N yr^{-1} (% baseline)
with GWC	Conwy	-198 (33%)
	Vale of Clwyd	-214 (48%)
	Heads of Valleys	-407 (50%)
with GWC and pro rata 100,000 ha limit	Conwy	-38.3 (6%)
	Vale of Clwyd	-28.5 (6%)
	Heads of Valleys	-129 (16%)

As for climate mitigation and water quality, the magnitude of these reductions are influenced by the area of land taken out of agriculture in preparation for new woodland. When standardised for area of land converted, the magnitude of change are very similar for the Conwy and Heads of Valleys (Figure 2.2.7.7).

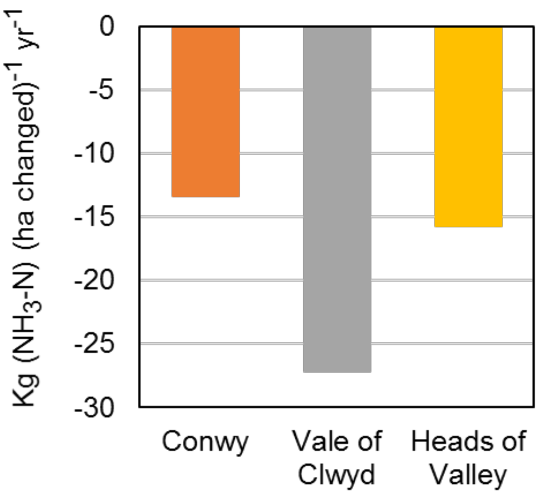


Figure 2.2.7.7. Annual reductions in ammonia emissions (kg NH_3-N) in the three test areas corrected for area of land changed (ha changed) in the three test areas.

The reduction in annual emissions of ammonia (as for nitrogen load to water bodies) in the Clwyd was greatest at more than 45% more than the average across all three test areas. This is again likely due to the presence of more intensive agriculture, specifically dairy in the Clwyd.

Air quality and health benefits of woodland creation

The results from the modelling work indicates the greatest PM2.5 removal rates under current baseline conditions are located in the Heads of Valleys test area. This is due to the greatest PM2.5 concentrations. The greatest monetary value (due to a reduction in adverse health impacts) is also seen in the Heads of Valleys, due to the much larger benefitting population in this test study site (Table 2.2.7.5).

Table 2.2.7.5. Baseline rates of PM2.5 pollution removal and the monetary value per hectare of woodland due to the associated reduction in adverse health impacts.

Test study area	Pollution removal rates per ha of woodland (kg ha^{-1})	Monetary value per ha of PM2.5 removal by woodland (£ ha^{-1})
Conwy	5.52	63.37
Vale of Clwyd	6.35	77.66
Heads of Valleys	7.77	329.80

The increase in pollutant removal rates under the two new woodland scenarios suggest that an additional 15,000 to 63,000 kg of PM2.5 can be removed, depending on the case study area, and in the All available area scenario, this increases to 71,000 to 230,000 kg of PM2.5. In terms of health value, this equates to £180,000 to £2,700,000 for the Woodland creation with GWC and pro rate 100,000 ha limit scenario, rising to £818,000 to £9,700,000 for the Woodland creation with GWC scenario (Table 2.2.7.6).

The much greater values for Heads of Valleys are partly due to the larger area allowing more woodland, partly to the greater pollution concentrations there, but is primarily due to the much greater population benefitting from the reductions in pollutant exposure.

Table 2.2.7.6. Quantity of PM2.5 pollution removed (kg per year) and monetary value (£ per year) for the two Woodland creation scenarios.

Test study area	Woodland with GWC		Woodland with GWC and pro rata 100,000 ha limit	
	Quantity of PM2.5 removed (kg per year)	Value of PM2.5 pollution removed (£ per year)	Quantity of PM2.5 removed (kg per year)	Value of PM2.5 pollution removed (£ per year)
Conwy	71,293	£818,419	15,805	£181,441
Vale of Clwyd	39,575	£484,337	6,656	£81,461
Heads of Valleys	230,242	£9,772,932	63,758	£2,706,330

**Annualised Present Values of public goods (£ yr^{-1}) calculated over 75 years using HM treasury recommended discount rates (0-30 years, 3.5%; 31-75 years 3.0%).*

The higher partial monetary benefit per unit area of woodland, and the higher pollutant concentrations in Heads of Valleys suggest that new woodland creation in that area would achieve the greatest health benefit.

However, woodland creation in other areas will also benefit populations further away, and ongoing work will help understand the relative importance of woodland close to and further away from a particular population.

Recreation benefits of woodland creation

We consider newly created peri-urban woodland (within 2 km of urban areas) for potential new recreation benefits. The amount of new peri-urban woodland is a variable portion of the total new woodland created within each test area due to the variable nature of land converted, proximity to urban centres and also current location of recreation land (Table 2.2.7.7).

Table 2.2.7.7. Area of current public-accessible, peri-urban land in the three test area, the area changed due to woodland creation scenarios, and the area and monetary value of this land converted to new woodland which is assumed to contribute to new recreation (peri-urban only) benefits.

New Woodland scenario	Test Area	Baseline peri-urban recreation land (ha)	Area of new woodland (ha)	New peri-urban recreation land (ha)	Value of new per-urban recreation land (£k yr^{-1})
with GWC	Conwy	2,616	12,914	4,660	1,518
	Vale of Clwyd	895	6,237	5,697	4,060
	Heads of Valleys	11,600	29,633	36,713	24,400
with GWC and pro rata 100,000 ha limit	Conwy	2,616	2,863	1,412	759
	Vale of Clwyd	895	1,049	895	2,030
	Heads of Valleys	11,600	8,206	10,552	12,200
Note: For area of new peri-urban recreation land between 0 and 100% of baseline, new value is capped at 10% of baseline value. For area of new peri-urban recreation land greater than 100% of baseline, new value is capped at 20% of baseline value.					

**Annualised Present Values of public goods (£m yr^{-1}) calculated over 75 years using HM treasury recommended discount rates (0-30 years, 3.5%; 31-75 years 3.0%).*

Biodiversity benefits of woodland creation

Biodiversity benefits from new woodland creation scenarios beyond bird populations have not been explicitly explored due to time constraints. However, models are available and have been deployed before in Wales in the linked GMEP project to explore the potential benefits of e.g. of woodland expansion for woodland plant species (Emmett et al., 2014, 2017). The key finding from the work was the potential long lag times (i.e. decades) for habitat conditions to become suitable for species to be present at target levels. It should be noted, for many species, active management is likely to be required to enable species to create suitable tree and ground flora for the species / habitat of interest. Removal of agriculture alone may result in a nutrient-enriched soil open to invasion by an array of species potentially far removed from biodiversity or conservation targets.

Water quality benefits of new woodland

The water quality benefit of new woodland modelled here is limited to the change due to removal of agriculture not the planting, management and harvesting of the new woodland. It is therefore an incomplete analysis.

In summary, likely improvements in water quality linked to removal of agriculture for new woodland creation include reduced:

- leakage of fertiliser
- runoff of animal wastes
- sediment transfer
- release of control chemicals

Likely risks associated with new woodland creation are increased:

- risk of acidification on poorly buffered soils due to the scavenging effect of tree canopy of acidifying nitrogen and sulphur compounds;
- erosion / sediment events linked to ground preparation and harvesting
- release of control / biocide chemicals

Here the change in nitrogen, phosphorus and sediment load to water bodies has been explored due to the removal of agriculture only prior to woodland creation.

Reduction in pollutant loads to water bodies relative to baseline were between 28%-50% of currents loads of nitrogen, phosphorus and suspended sediments for new woodland creation with GWC between the three test areas. This reduced to 6-15% with the pro rata planting to the 100,000ha limit (Table 2.2.7.8).The magnitude of change increased from Conwy < Vale of Clwyd<Heads of Valleys (Figure 2.2.7.8).

Table 2.2.7.8. Annual reductions in nitrogen (NO_3-N), phosphorus (total-P) and suspended sediment (SS) loads to water bodies in the three test areas (tonnes yr^{-1}) and the % reduction of baseline loads in the three test areas.

New Woodland scenario	Test Area	N load; tonnes (NO_3-N) yr^{-1} (% baseline)	P load; tonnes (Total-P) yr^{-1} (% baseline)	Sediment load; tonnes (SuspSolids) yr^{-1} (% baseline)
with GWC	Conwy	-259 (30%)	-7.4 (29%)	-2,539 (28%)
	Vale of Clwyd	-208 (46%)	-4.1 (44%)	-1,032 (42%)
	Heads of Valleys	-554 (50%)	-16.8 (49%)	-5,490 (49%)
with GWC and pro rata 100,000 ha limit	Conwy	-53.4 (6%)	-1.6 (6%)	-528 (6%)
	Vale of Clwyd	-29.5 (7%)	-0.6 (7%)	-168 (7%)
	Heads of Valleys	-164 (15%)	-4.8 (14%)	-1,523 (14%)

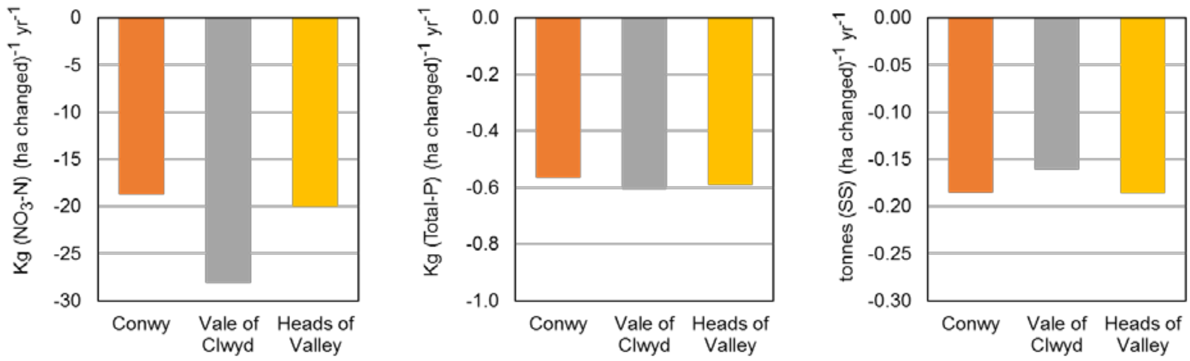


Figure 2.2.7.8. Annual reductions in nitrogen (kg NO_3-N), phosphorus (kg total-P) and suspended sediment (tonnes SS) loads to water bodies in the three test areas corrected for area of land changed (ha changed) in the three test areas.

As for climate mitigation, the magnitude of these reductions are influenced by the area of land taken out of agriculture in preparation for new woodland. When standardised for area of land converted, the magnitude of change are very similar across the three test areas for phosphorus and sediment loads. However for nitrogen loads, there was 26% more reduction in emissions per hectare changed in the Vale of Clwyd than the average across all three test areas. Note this is also true for nitrogen emitted to the atmosphere as ammonia where reductions in the Vale of Clwyd (see above). This is likely due to the presence of more intensive agriculture, specifically dairy in the Clwyd.

<u>Partial total monetary value of new public goods which have been assessed for woodland creation</u>

It has only been possible to value four public goods:

- Climate mitigation split into:
  - GHG reductions from agriculture
  - carbon sequestration in woodland
- Recreation
- Health benefit from reduction in PM2.5s

These values can be combined to indicate a partial monetary value for each test area but with the major caveat this excludes other public goods such as biodiversity not valued. Total value ranges from £6m to 33.5m per year with the Heads of Valleys having the greatest partial monetary value (Table 2.2.7.9; Figure 2.2.7.9). However again this is dependent on the size of the test areas and the area of land changed. When values are standardised by area of land changed, the Clwyd and Heads of Valleys have very similar partial monetary annualised value (Table 2.2.7.9; Figure 2.2.7.9).

Table 2.2.7.9. Additional annual monetary value of selected public goods in the three test areas resulting from the midpoint impact of the two new woodland scenarios and 5 woodland / management combinations.

Public Good	**£m yr^{-1} [£ (ha changed)$^{-1}$ yr^{-1}]**		
	Conwy	**Vale of Clwyd**	**Heads of Valleys**
Climate mitigation (GHG reduction)	3.2 [406]	2.2 [604]	7.3 [386]
Climate mitigation (C sequestration)	1.2 [152]	0.5 [137]	1.7 [90]
Health value of PM2.5 reduction	0.5 [63]	0.3 [82]	6.2 [328]
Recreation (peri-urban)	1.1 [139]	3.0 [823]	18.3 [967]
Total	6.0 [761]	6.0 [1647]	33.5 [1771]

**Annualised Present Values of public goods (£m yr^{-1}) calculated over 75 years using HM treasury recommended discount rates (0-30 years, 3.5%; 31-75 years 3.0%). Monetary value of carbon from BEIS non-traded price of carbon over 75 years; £68 tonne in 2020 (baseline year); £319/tonne in 2095.*

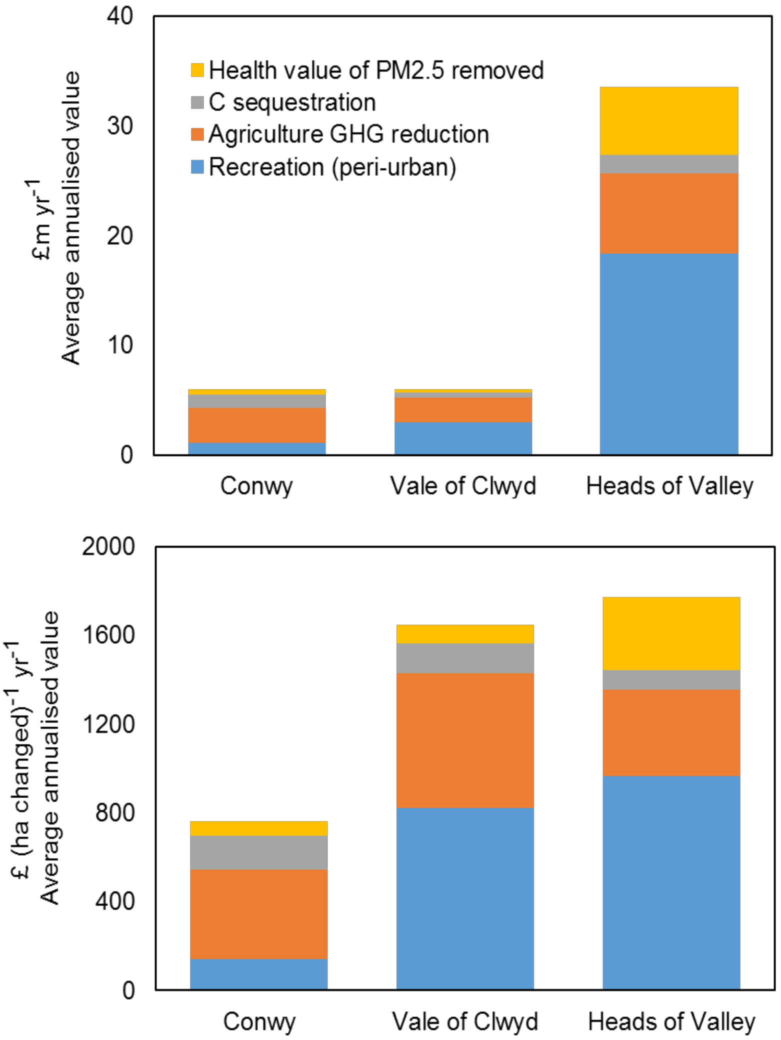


Figure 2.2.7.9. Additional partial annual monetary value of selected public goods in the three test areas resulting from the midpoint impact of the two new woodland scenarios and 5 woodland / management combinations. Values are shown are: a) total value, and b) value standardised for area of land changed.*

**Annualised Present Values of public goods (£m yr^{-1}) calculated over 75 years using HM treasury recommended discount rates (0-30 years, 3.5%; 31-75 years 3.0%). Monetary value of carbon from BEIS non-traded price of carbon over 75 years; £68 $tonne^{-1}$ in 2020 (baseline year); £319 $tonne^{-1}$ in 2095.*

Removal of agriculture from low quality land

The area of land involved in the scenario involving removal of agriculture from low quality land (ALC 5 and ALC 4&5) is the scenario which affects most land in the Conwy and Heads of Valleys. This is reflected in the large percentage changes in many environmental impacts modelled for this scenario relative to baseline values (Table 2.2.7.10) e.g.:

- 45-83% increase in climate mitigation
- 44-88% reduction in pollutant loadings to water bodies
- 40-77% reduction in ammonia emissions

In contrast, changes in the Vale of Clwyd are only 3-9% of baseline values for all these environmental issues.

Land removed from agriculture could have some value for biodiversity / conservation purposes although appropriate management would be needed for this to be realised in some cases and long lag times may occur. Land could also be converted to new woodland and / or made available for recreation purposes. These are not all mutually exclusive potential future uses of land.

Table 2.2.7.10. Impact of the removal of agriculture from low quality land (ALC5 and ALC 4&5) on area of land changed and a range of environmental issues expressed in absolute terms and as a percentage of baseline values.

	Conwy		**Vale of Clwyd**		**Heads of Valleys**	
LPIS Farmland (ha)	45,741		15,076		60,190	
Scenario	**ALC5**	**ALC4&5**	**ALC5**	**ALC4&5**	**ALC5**	**ALC4&5**
Area changed (ha)	30,658	39,747	449	1,223	28,199	49,145
Area changed (%)	67	87	3	8	47	82
Climate mitigation						
tonnes (CO_2e) yr^{-1}	-169,514 (63%)	-223,144 (83%)	-4,335 (3%)	-8,977 (7%)	-157,051 (45%)	-275,281 (78%)
Water quality						
tonnes (NO_3-N) yr^{-1}	-530 (62%)	-699 (82%)	-15.5 (3%)	-30 7%)	-490 (44%)	-862 (78%)
tonnes (Total-P) yr^{-1}	-16.7 (65%)	-21.9 (85%)	-0.3 (3%)	-0.7 (8%)	-15.6 (46%)	-27.5 (81%)
tonnes (SusSol) yr^{-1}	-5,839 (68%)	-7,520 (88%)	-80 (3%)	-217 (9%)	-5,341 (48%)	-9,291 (83%)
Air Quality						
tonnes (NH_3-N) yr^{-1}	-343 (57%)	-465 (77%)	-16 (4%)	-27 (6%)	-326 (40%)	-592 (73%)
Recreation						
Area, ha	1,315	3,398	231	588	19,321	35,858

When converted to monetary values, the results are dominated by the impact of the large area of the Heads of Valleys and its proximity to urban centres for recreation (Figure 2.2.7.10). When corrected for land area changed, the Vale of Clwyd has greatest monetary value per hectare change in this scenario for the public goods valued.

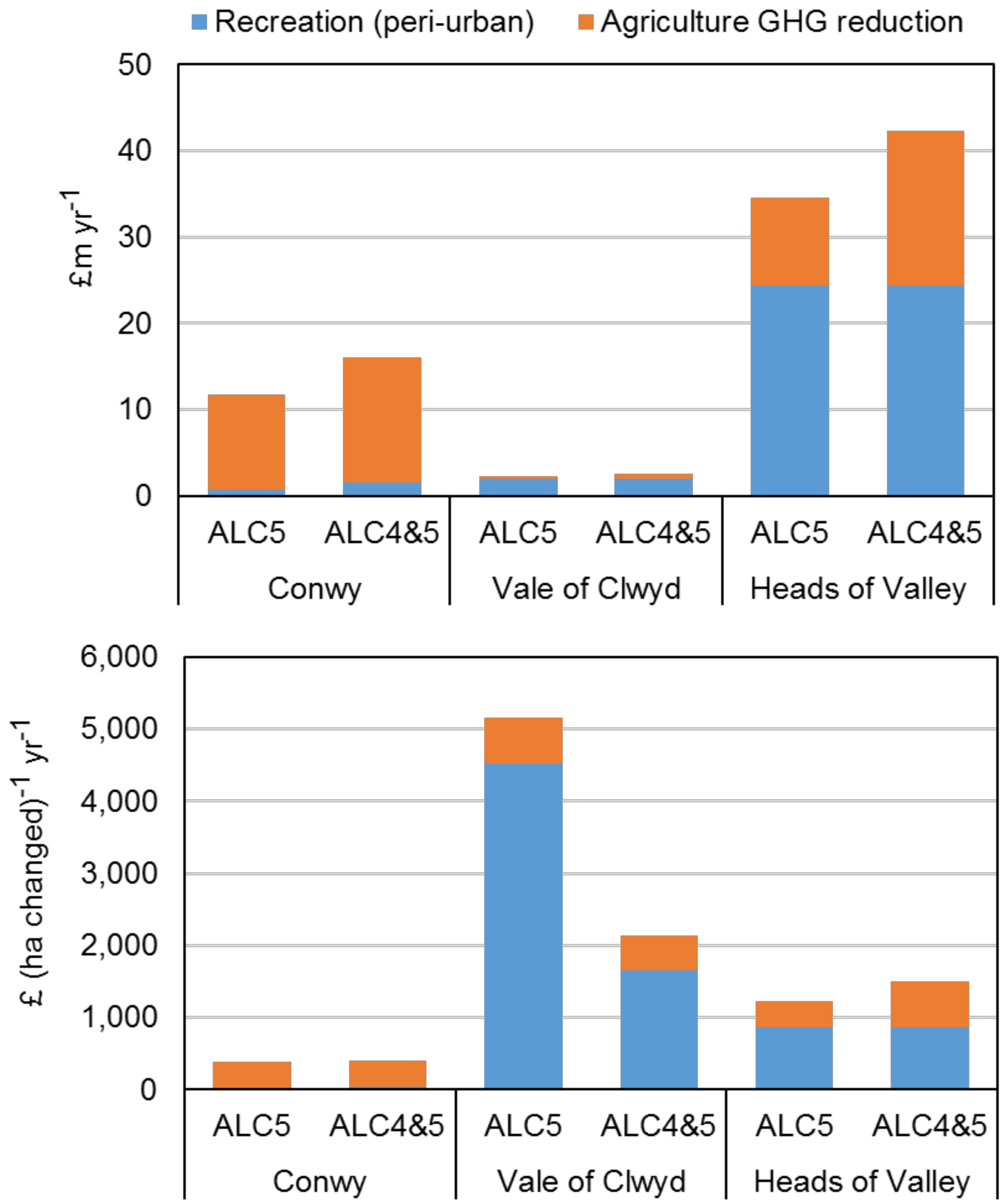


Figure 2.2.7.10. Additional partial annual monetary value of two public goods in the three test areas resulting from the removal agriculture from low quality land (ALC5 and ALC4&5). Values are shown are: a) total value, and b) value standardised for area of land changed. Note: There is no carbon sequestration benefit from this scenario calculated although natural succession could provide some depending on protection from wild grazers and fire. Removal of particulates (PM2.5s) as reported for new woodland creation.

Removal of agriculture from peatland

The area of land involved in the scenario involving removal of agriculture from peatland affects most land in the Conwy due to large presence of peat in the catchment. This is reflected in the large percentage changes in many environmental impacts modelled for this scenario relative to the baseline (46-53%) (Table 2.2.7.11). In contrast, changes in the Vale of Clwyd and Heads of Valleys are ca. 1% and 20% respectively of baseline values for these environmental issues. In summary across all test areas, impacts relative to baseline were:

- 1 - 50% increase in climate mitigation
- 1 - 53% reduction in pollutant loadings to water bodies
- 1 - 46% reduction in ammonia emissions

Table 2.2.7.11. Impact of the removal of agriculture from peatland on area of land changed and a range of environmental issues expressed in absolute terms and as a percentage of baseline values. Note that removal of particulates and recreation are not considered for this scenario.

	Conwy	**Vale of Clwyd**	**Heads of Valleys**
LPIS Farmland (ha)	45,741	15,076	60,190
Area changed (ha)	24,061	223	8,676
Area change (% LPIS Farmland)	53	1	14
Climate mitigation			
tonnes (CO_2e) yr^{-1}	-134,390 (50%)	-1,808 (1%)	-46,082 (13%)
Water quality			
tonnes (NO_3-N) yr^{-1}	-421 (50%)	-6.1 (1%)	-142 13%
tonnes (Total-P) yr^{-1}	13.2 (51%)	-0.1 (1%)	-4.7 (14%)
tonnes (SS) yr^{-1}	-4,580 (53%)	-36 (1%)	-1,652 (15%)
Air Quality			
tonnes (NH_3-N) yr^{-1}	-275 (46%)	-6 (1%)	-88 (11%)

Additional climate mitigation may be realised if peats are rewetted but there was insufficient time to consider this issue in full and it is known values will be very small relative to those arising from the removal of livestock and associated agricultural practices. This omission therefore will not impact significantly on comparisons between test areas or between scenarios.

Peatland which has agriculture removed will have some value for biodiversity / conservation purposes although appropriate management would be needed for this to be realised in some cases and long lag times may occur. Conversion to recreation land has not been considered or valued here as no known case studies are available. Particulate (PM2.5) removal is also not associated with this scenario. Only the climate mitigation values can be monetised and when corrected for land area changed, the Vale of Clwyd has greatest additional partial annual monetary value per hectare change in this scenario (Figure 2.2.7.11).

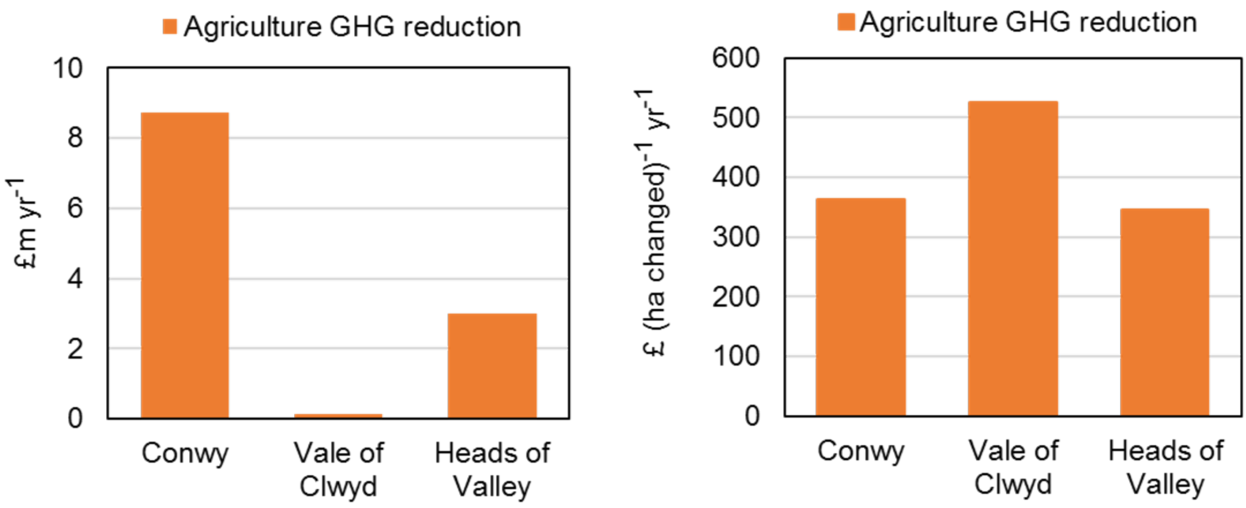


Figure 2.2.7.11. Additional annual partial monetary value of climate mitigation in the three test areas resulting from the removal of agriculture from peatland. Values are shown are: a) total value, and b) value standardised for area of land changed.

Comparison of monetary value between management scenarios

In terms of monetary value per area of land changed, the management scenarios had a range of outcomes depending on the test area (Table 2.2.7.12). Thus, the range of for additional partial annual value public goods per hectare of land changed per year for each management scenario was:

- Removal of agriculture from peatland: £345 – £526
- New woodland creation: £651 – £2,704
- Removal of agriculture from low quality land: £384 – £5,150

Table 2.2.7.12. The range of monetary annual values of goods for the three management scenarios corrected for area of land changed.

Management scenario	**£ (ha changed)$^{-1}$ yr^{-1}**		
	Conwy	**Vale of Clyd**	**Heads of Valleys**
Removal of agriculture from peatlands	363	526	345
Woodland creation	651 - 997	1,414 – 2,704	1,573 – 2,354
Removal of agriculture from low quality land	384 - 403	2,137 – 5,150	1,227 – 1,500

Combined scenario

Construction of the combined scenario avoids double accounting of land which is used by more than one management scenario and allows for a potential total partial value to be calculated for each test area. Land is selected according to the following criteria in the following order:

1) Remove agriculture from any peatlands
2) On remaining land, include any land captured in plant native broadleaf (100k ha target pro rata; no thin/fell; only on acceptable land) scenario
3) Finally, include any land from ‘Remove agriculture from ALC Grade 4 and 5’ scenario which is not included in 1 or 2 options above

Total area changed is indicated in Table 2.2.7.13. Four of these environmental outcomes were converted into monetary value on an annualised basis using methods described previously. The large area of the Heads of Valleys provides the most total partial value of public goods but per hectare of land changed, the Vale of Clwyd provides the most efficient rate of return (Table 2.2.7.14).

Table 2.2.7.13. Impact of the combined scenario on area of land changed and a range of environmental outcomes.

	Conwy	Vale of Clwyd	Heads of Valleys
LPIS Farmland (ha)	45,741	15,076	60,190
Area changed (ha)	40,593	2,428	51,211
Area change (% LPIS Farmland)	89	16	85
Climate mitigation (tonnes (CO_2e) yr^{-1})			
GHG reduction	-228,801	-19,069	-291,249
C sequestration	-6,726	-2,097	-17,587
Water quality (tonnes yr^{-1})			
Nitrogen load (NO_3-N)	-716	-64	-916
Phosphorus load (Total P)	-22	-1	-29
Sediment load (Suspended Solids)	-7,673	-409	-9,658
Air quality (tonnes (NH_3-N) yr^{-1})			
Ammonia emissions	-479	-60	-643
Particulate removal (tonnes (PM2.5) yr^{-1})			
PM2.5s	-13.1	-6.6	-60.0
Recreation (ha)			
Publicly accessible peri-urban	3,919	1,600	39,758

Table 2.2.7.14 Additional annual monetary value of new public goods valued expressed as a total for each test area and as a rate of return per hectare of land changed in the combined scenario.

Monetary value units	Conwy	Vale of Clwyd	Heads of Valleys
Total annual value (£m yr^{-1})	17	5.5	47
Total annual value corrected for area changed (£ (ha changed)$^{-1}$ yr^{-1})	418	2,257	918

Total value for the three test areas are shown in Figure 2.2.7.12. The contribution from the different public goods within each test area is also very different for the three test areas within this combined scenario. This can been seen as a proportion of total value for each test area in Figure 2.2.7.13.

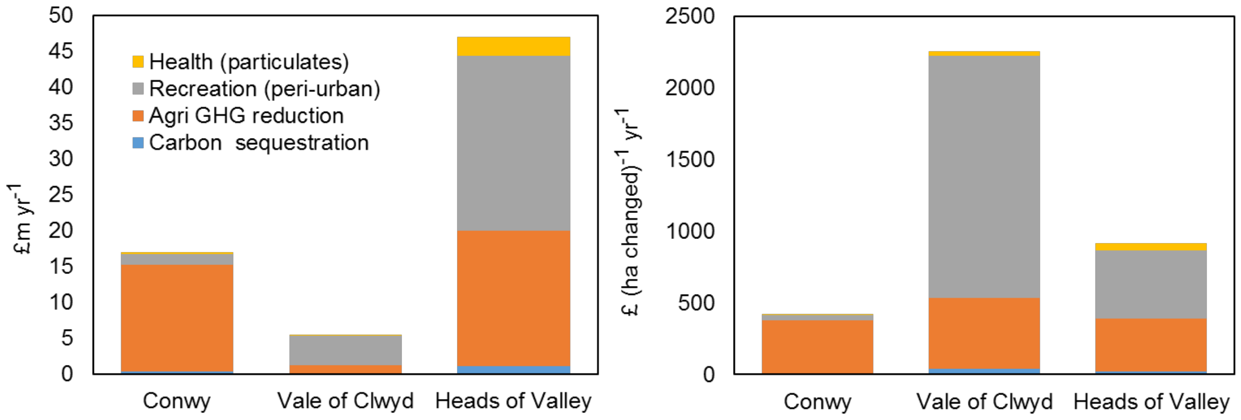


Figure 2.2.7.12. The additional partial annualised monetary value of the combined scenario as: a) total value and b) standardised for area changed within each test area.

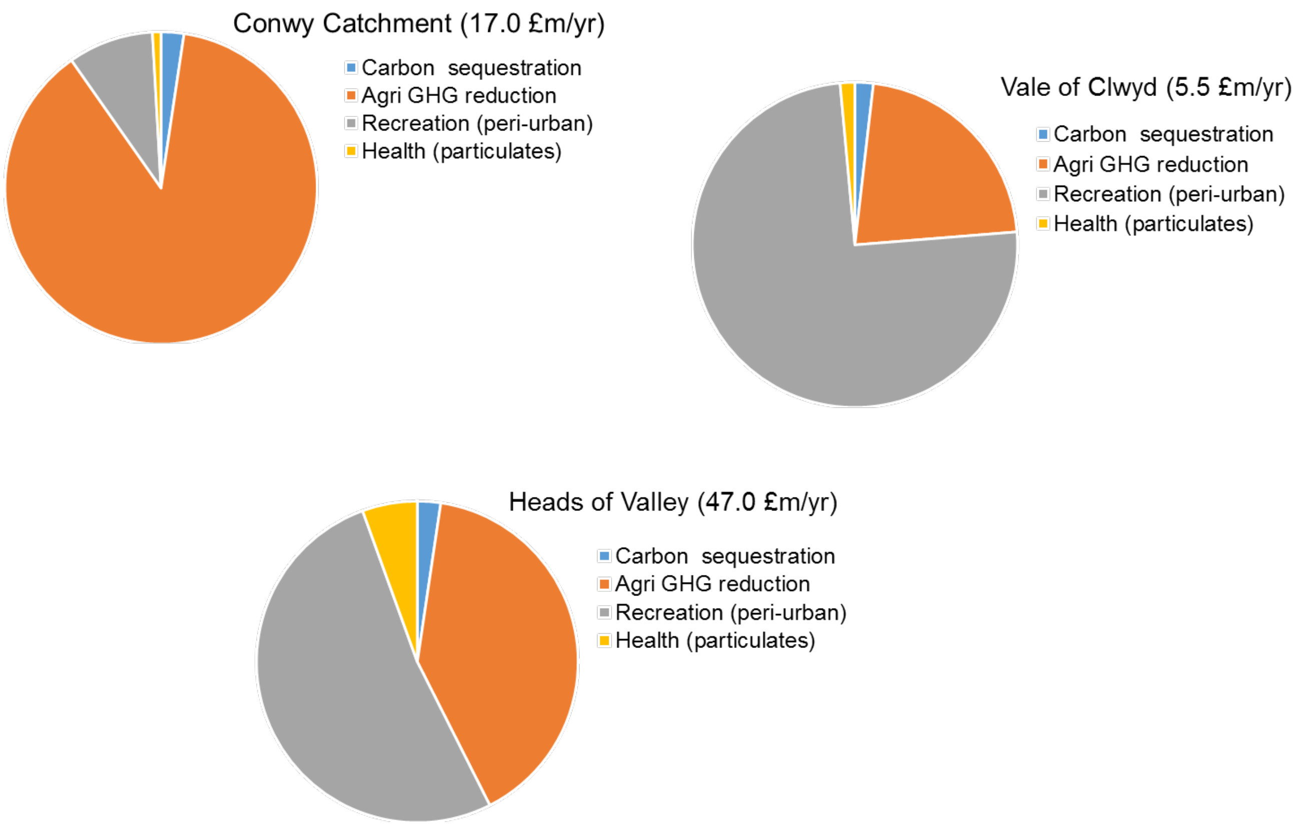


Figure 2.2.7.13. The proportional total additional partial annualised monetary value (£m yr^{-1}) of the combined scenario for each test area for the four public goods.

Overall the partial monetary value of public goods assessed per test area for the combined scenario increased in the order: Heads of Valleys > Conwy > Clwyd. However, total value expressed as value per hectare of land which was projected to have changed land use was highest for Clwyd > Heads of Valleys > Conwy. Clearly the public goods prioritised and the unit used to express change is critical for any future assessment of the potential for the delivery of public goods.

It should be noted, all the land area identified as being subject to change could be made available for biodiversity / conservation purposes, new woodland or recreation depending on the local priorities and proximity to relevant parcels of land which could enhance the success of any such conversion.

2.2.8 National maps for maintaining or enhancing public goods

Welsh Government requested some examples of national maps which could illustrate where public goods could be supported going forward and the range of monetary values they could deliver. Three examples are presented:

- New woodland creation
- Peatland
- Biodiversity

Woodland

Figure 2.2.8.1 illustrates the potentially large area of land across Wales which could be available for new woodland planting depending on the level of masks which exclude land to either reduce risks or protect other resources / benefits. The potential additional annual monetary value of public goods delivered by new woodland was found to vary from £651 – £2,704 per hectare of land changed per year in the three contrasting test areas explored in Quick Start (See Section 2.2.7).

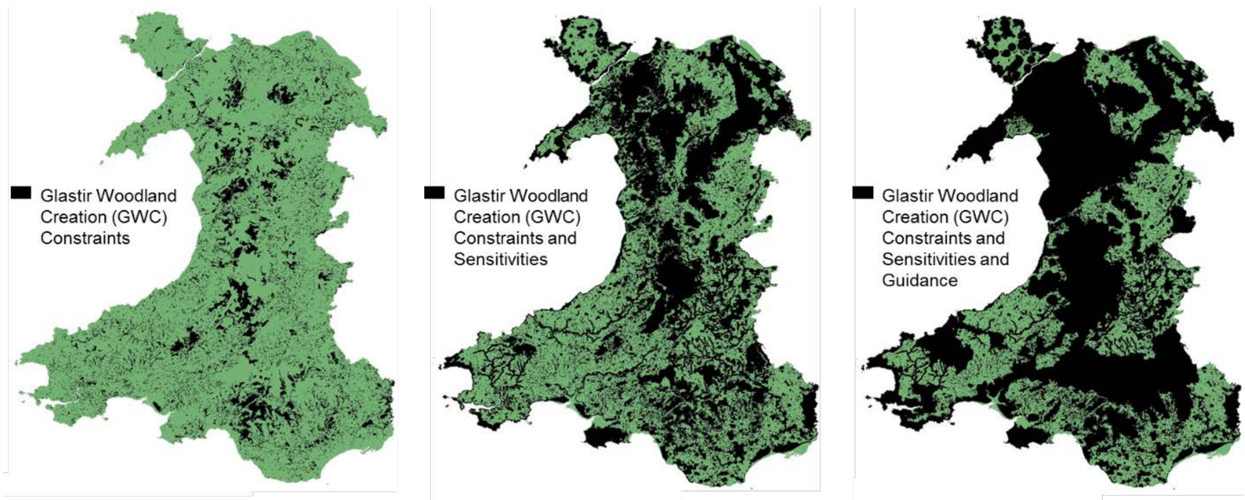


Figure 2.2.8.1 Land potentially suitable for new woodland creation (indicated as green) depending on the levels of constraints, guidance and sensitivities applied from the Glastir Woodland Creation maps (GWC-Wales, 2018).

Peatland

Figure 2.2.8.2 indicates the presence of peatland across Wales. This includes upland and lowland peats and peatlands currently used for a wide range of uses including conservation, recreation, agriculture and woodland production. The potential additional annual monetary value of public goods by removing agriculture from peatland was reported to vary from £345 – £526 per hectare of land changed per year in the three contrasting test areas explored in Quick Start (see Section 2.2.7).

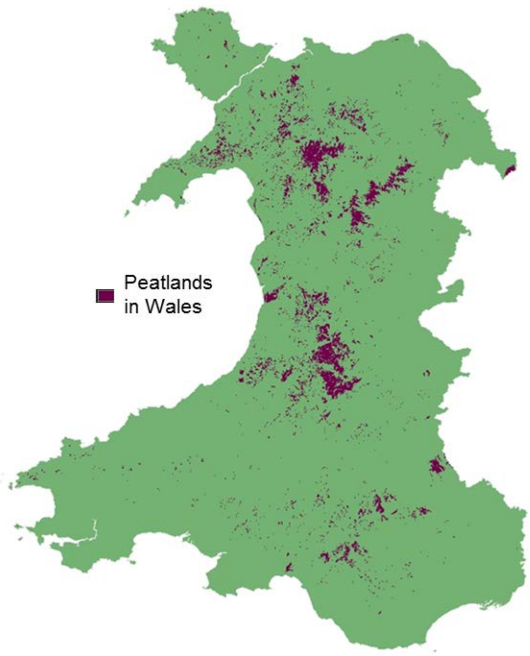


Figure 2.2.8.2 Peatland distribution (dark areas) across Wales

Biodiversity

A wide range of biodiversity data sources are available which could illustrate the potential for either protecting or enhancing different elements of the public good 'Biodiversity' across the Welsh landscape. Here we provide just three to illustrate the wide-ranging nature of the options (Figure 2.2.8.3). Methods for the habitat diversity and plant diversity were by the CEH Biodiversity Tool (Appendix 1). Methods for the lizard and slow worm data from the Local Environment Records Centre (LERC) data are embedded within the ERAMMP Year 1 report "A Review of the Contribution of Species Records held by Local Environmental Record Centres in Wales to ERAMMP Evidence Needs". No monetary value is calculated for biodiversity as there are no agreed methods and generally it is usually undesirable.

It should be noted, novel methods for integrating the large number of data sources for biodiversity for 'priority' species (i.e. section 7) and 'priority plus common' species using structured data such as that derived from the ERAMMP field survey and unstructured data is provided in other ERAMMP Year-1 reports. This could provide a simplified, integrated map to inform selection of areas for payments for either protection for enhancement of biodiversity.

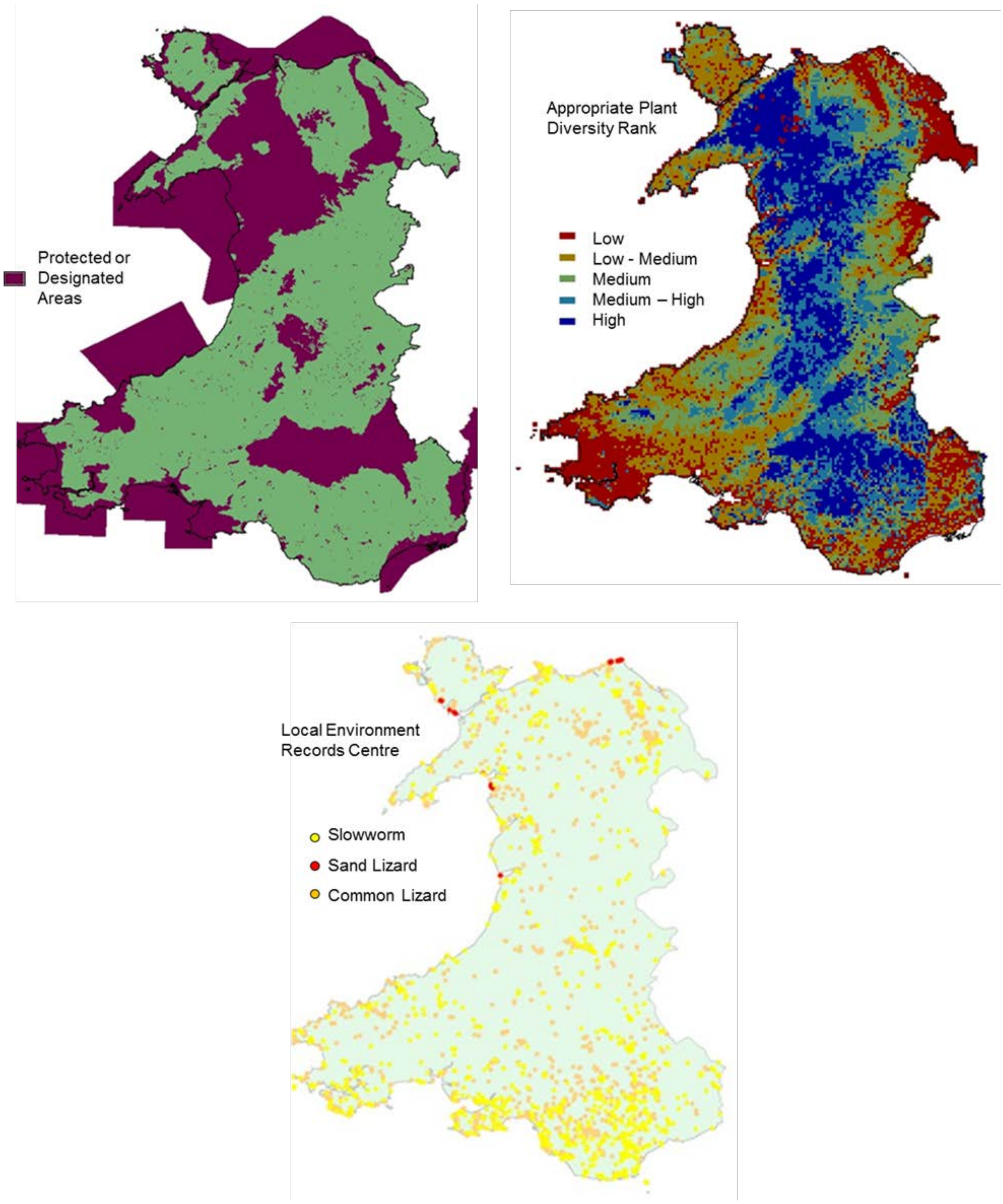


Figure 2.2.8.3 Spatial maps of just three examples illustrating the distribution of different components of biodiversity within the Wales landscape: (upper left) The distribution of protected or designated areas; (upper right) appropriate plant diversity where a high rank indicates species presence which are indicative of the particular habitat; (lower) Lizard and slow worm 1km resolution of records in the Local Environment Records Centre (LERC) for 2010-2018.

3 Conclusions

The Quick Start modelling work has been a challenging piece of work, which had an extremely tight deadline for delivery, and relied on close cooperation and joint working within the ERAMMP modelling team, and between the ERAMMP team, WG staff and the Evidence and Scenarios Roundtable Sub-Working Group of the Brexit Roundtable. We would like to express our thanks to the WG staff and Sub-working group for their contribution without which this report would not have been possible.

With respect to the Brexit scenarios work, the outputs have highlighted the highly variable magnitude of the potential risks and benefits which may arise from the different Brexit trade scenarios with respect to environmental outcomes. The application of the models, albeit with many brave assumptions also described the highly spatially variable nature of these potential outcomes. This information may be used to both highlight where the regulatory floor may need enhancing and / or transition schemes put in place to support communities heavily reliant on the agricultural livestock sector.

For the management scenario work, the outputs have highlighted a range of issues when applying monetary valuation of public goods. In summary, the work has emphasised that the approach does not provide a ‘solution’ but can only contribute to the political and public debate. There are many uncertainties and caveats which mean results can be easily mis-interpreted and inevitably all valuations are only ever a partial valuation as methods are not available for all public goods. Furthermore, the variability in partial monetary values depending on location as illustrated by the contrasting results from the three test areas selected have been illustrated.

The large number of assumptions, limitations and uncertainties have been described in detail for transparency purposes and a language used throughout the report to emphasise the highly speculative nature of the work. Predicting the behaviour and decision making of any sector has many pitfalls, not least when no comparable situation has been experienced before.

Overall, despite these limitations the results provide a significant contribution to the debate concerning the trade-offs / risks and benefits we can all derive from the agriculture, woodland and recreation sectors. Some past assumptions of delivery of public goods by different sectors and where these occur in our Welsh landscape have perhaps been challenged through the work. We hope this report will contribute to an informed, collective discussion about how we all can all secure a more sustainable future for Wales’ primary production industries and natural resources going forward.

4 Recommendations

1. WG to ensure the limitations and assumptions for the work are always included in any presentations and future uses of the work and data protection considered for all maps and results released;
2. WG to review the outcomes from this work and identify if additional work could further support policy development taking into consideration the planned launch of the prototype Integrated Modelling Platform (IMP) in July 2019. The benefits of some continued Quick Start work is in the new development of rapid new scenarios or issues which have not been hard-wired into the IMP where timing is a critical issue and/or to explore additional benefits not currently included in the IMP.
    - Leisure
    - Tourism
    - Water resources / flow
    - Flood mitigation
    - Other Public health benefits e.g. green space
    - Other biodiversity options
3. WG to decide if additional Quick Start results not included in this report due to time constraints are required. These include:
    - Substitution effects of the woodland creation scenario for the energy and building sectors
    - The potential benefits of improved management of our current woodland stock
    - Reporting on the climate mitigation benefits of rewetting of peatlands
    - Impact on bird diversity for the management scenarios in the test areas
4. WG to ensure future work regarding the potential impact of new woodland defines the type of agriculture land it is replacing, location and woodland and management type as the environmental outcomes are as variable as when considering the impact of different agricultural livestock sectors. Quick Start work on substitution effects and the effect of improved management of current woodland should also be completed.
5. Displacement or leakage of environmental impacts within Wales, UK and globally needs to be taken into account to ensure the Well Being of Future Generation Goal of e.g. ‘A Globally Responsible Wales’ is represented in future work.

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