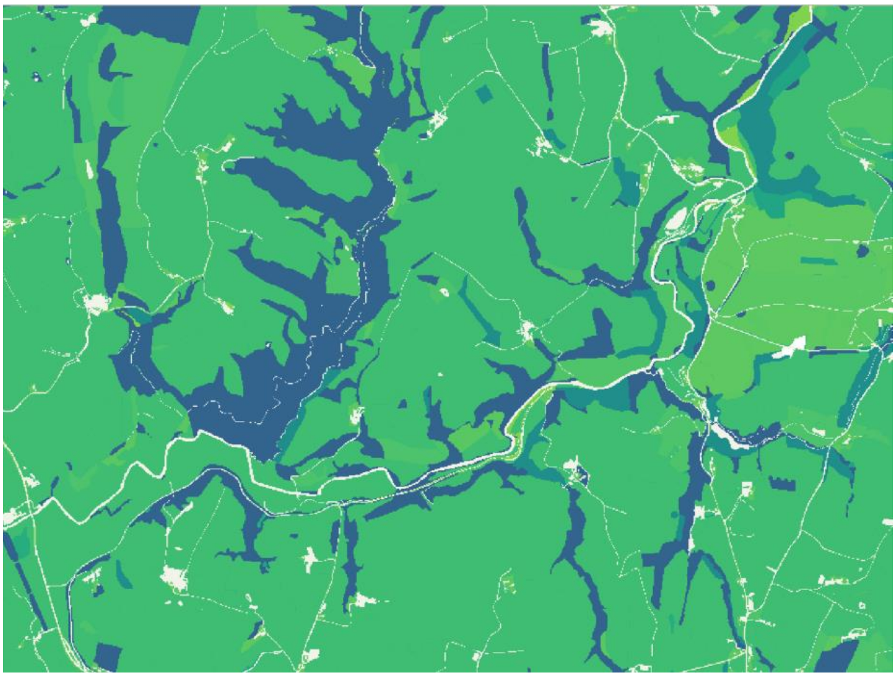

ECOSERVR: A NATURAL CAPITAL MAPPING TOOL FOR MEASURING PUBLIC GOODS

T&T 074 – UPPER DANE TEST AND TRIAL

Report presented to DEFRA on 29th September 2020
Updated with additional evidence 22nd January 2021

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EXECUTIVE SUMMARY

Context and objectives

The targets set out by the government's 25-year environment plan are calling for a shift in policy and practice, putting natural capital and biodiversity in the spotlight and recognising the multiple ways in which a thriving environment benefits society and the economy. In the context of the new Environmental Land Management (ELM) scheme, landowners will receive "public money for public goods". This will require delivery of agri-environmental interventions and monitoring of their impact. With many emerging frameworks and methods, the need for an evidence-based, rigorous, widely applicable yet adaptable toolkit is becoming obvious.

Our test and trial sought to develop a natural capital mapping tool and test its real-life potential using a group of upland farms in Cheshire as a case study. Our test and trial is directly relevant to the Land Management Plans theme, and explored aspects of the Spatial Prioritisation, Collaboration, and Innovative Delivery themes.

Our primary and complementary research questions were:

1. **Can a natural capital mapping tool provide a habitat register (environmental baseline) and measure the delivery of public goods at scales meaningful to ELM?**
    a. How accurate is the mapping tool in assigning habitat codes to field parcels?
    b. How sensitive is the mapping tool in detecting changes at various geographic scales (farm to catchment)?
2. **What are the benefits and limitations of the tool for developing whole-farm plans, as perceived by land advisors?**
    a. When, where and by whom should the tool be used to inform land management plans?
    b. What skills are required to use the tool?
3. **What are the benefits and limitations of the tool for developing whole-farm plans, as perceived by farmers?**
    a. Are farmers already using, or interested in using, a spatial approach to deliver agri-environmental interventions?
    b. Would the tool help farmers make land management decisions, and what other information is required to make these decisions?

Overview of activity

Developing a natural capital mapping tool

We developed a natural capital mapping tool based on the existing, open access toolkit Ecoserv-GIS (originally developed by Durham Wildlife Trust, 2013). Ecoserv-GIS integrates a range of nationally available datasets to produce an **environmental baseline** which details the extent and spatial distribution of habitats. This map, alongside other accessible spatial datasets, then feeds into evidence-based, spatial models that map both capacity and demand for a set of ecosystem services. **Ecosystem services** are the direct and indirect benefits we derive from nature, and six have been identified as "public goods" that will be supported under the ELM scheme: clean and plentiful water, clean air, protection from environmental hazards, mitigation of climate change, thriving plants and wildlife, and beauty, heritage and engagement (Defra 2018). The Ecoserv approach assigns scores to each habitat type based on empirical values from the scientific literature, and the models calculate indicators based on our scientific understanding of the processes driving each ecosystem service. The approach goes beyond simply assigning a value to a habitat and multiplying it by the extent of this habitat, but also considers the spatial context and interaction with other features, as well as socio-economic and environmental properties of the landscape and communities within it. The process is transparent and automated to provide standardised habitat classifications and ecosystem service measurements across Great Britain, facilitating comparisons across time and space.

Unfortunately, despite its merits and proven usefulness in natural capital assessments and policy making, Ecoserv-GIS is no longer maintained and no longer function due to its reliance on an outdated version of proprietary software (ESRI ArcGIS). We therefore took the opportunity of re-writing the toolkit in the R programming language. The result is **EcoservR**, a new toolkit benefiting from the following considerations:

- R is free and open-source, with a large and active support community that can contribute to developing the tool further in the future.
- We made sure that the tool, initially designed for use at county scale, has a sufficient level of detail to work at farm scale (for instance by incorporating hedgerow data).
- We incorporated new datasets in the baseline process (such as the Crop Map of England).

Measuring the benefits of agri-environmental interventions

With EcoservR, we generated an environmental baseline for the whole Dane river catchment in Cheshire. The habitat classification was based on the following datasets:

- MasterMap Topography (Ordnance Survey)
- Greenspace and Open Greenspace (Ordnance Survey)
- Priority Habitat Inventory (Natural England)
- CORINE Land Cover (European Environment Agency)
- Crop Map of England (Rural Payments Agency)
- Terrain data (Ordnance Survey)
- Hedgerows (Rural Payments Agency)

We used the habitat baseline as a canvas to plan a suite of interventions likely to be available to farmers under the new ELM scheme. The interventions were mapped around a group of 14 farms and revolved around:

- Water quality management and restoration of wetlands for wading birds
- Native woodland creation and restoration
- Pollinator habitat creation and restoration
- Hedgerow planting

We measured the difference in scores for various ecosystem services before and after these interventions (335 ha of land use change), both at farm scale and in the wider surrounding landscape. The tool identified gains of up to 21% in capacity scores at the landscape scale (ca. 2000 ha area) around the 14 participating farms, and of up to 241% at the farm scale. Trade-offs and synergies between different services could be identified, demonstrating the potential of EcoservR for informing spatial prioritisation of certain public goods depending on the local context.

Assessing real-life usefulness of EcoservR

During the tool development process, we held a workshop with nine land advisors working in the Cheshire region. Advisors saw the advantage of having a robust way of quantifying public goods that works nationwide while producing scores reflecting the local, spatial context. They thought that maps are a good medium of communication between them and farmers. However, in order to use an approach like ours on a regular basis to help farmers produce land management plans, the tool would need to be very user-friendly and ideally embedded within a portal where interventions can easily be edited, and where ecosystem service scores can be translated into payments.

We visited five farms to ground-truth the habitat classification, and three farmers were interviewed to assess their interest in the approach. Ground-truthing revealed issues in classifying grasslands into their management types (improved, semi-improved, unimproved), highlighting the importance of validating the map through a farm walk before generating a public good assessment. Still, we were able to revise the classification rules to rectify systematic misclassifications, increasing the out-of-the box accuracy from 54% to 78% in our sample. We are confident that this can be improved further in the future, but a system that allows farmers to verify and correct habitats at the field parcel system would probably be the best way to ensure that farm plans and associated public goods projections are representative of the reality on the ground.

The farmers interviewed had an overall good understanding of ecosystem services and could identify those they are already delivering. They could interpret our score maps when they aligned with their intuitive understanding of the underlying biophysical processes. They identified limitations of the current models in terms of their inability to detect small, sub-field parcel level features and to account for land management regime. However, they saw the value of the overall approach in measuring goods across their land, which they would like to see reflected in payments. They thought that ELM payments would need to at least match what they were getting for productive agriculture to be viable, and need to consider the long-term nature and ongoing maintenance costs of some agri-environmental interventions. They recognised that land management needs to embrace technology and were willing to use an online platform, especially if it could streamline the application workflow and reduce the amount of paperwork.

Key findings

Our mains findings were:

1. EcoservR can be used to produce a detailed natural capital register with over 200 possible habitat types, and had an accuracy of 78% in our farm group after revisions.

2. EcoservR provides a rigorous, standardised method to measure the change in delivery of public goods associated with a range of common agri-environmental interventions. A simulation of strategic interventions in the landscape around the farm group saw environmental gains of up to 21% from the baseline at the landscape scale, and of over 200% at individual farm level.

3. Farmers and land advisors saw the value of an evidence-based quantification of public goods that has a spatial element and works nationally. However, to make use of it, the process would have to be simplified and embedded within the application process, all the way through to producing a projection of available funding.

4. A given intervention may generate a mix of gains and losses across the seven different ecosystem services supported by EcoservR. Having a separate assessment for each service can help identify interventions that align with spatial priorities, favouring certain interventions where they are most needed (e.g. enhancing water purification near a stream) whilst also highlighting potential synergies and trade-offs. Combined with local knowledge and context, opportunities may therefore be identified to fill service gaps, and potentially connect to regional or national schemes.

5. Interventions designed with the aim of achieving wider landscape benefits (strategic approach) resulted in uneven impacts on different farms, some being more solicited or impacted than others based on existing spatial features and suitability. EcoservR is able to model and measure these impacts, lending well itself to collaboration. However, this raises questions about how to handle payments fairly within farm groups when individual contributions may be uneven.

Conclusion

The novel aspect of the Ecoserv approach, compared to other emerging tools with a similar scope, is a spatially explicit approach that lends itself ideally to both site-level assessment and to strategic planning across larger areas (**Figure 1**). By measuring simulated impacts of different interventions across a landscape, EcoservR could facilitate collaboration among farms, identify areas delivering multiple benefits, and support decisions aligned around local priorities. These themes are all key considerations likely to be important under the new ELM scheme, and our tool could provide a bottom-up mechanism to demonstrate projected outcomes for farms and farm groups. The models are data-driven and evidence-based, with standardised outputs that would enable fair comparisons nationally and could therefore be linked to payments. Other functions of the tool that fell outside the scope of this report, such as the ability to identify "pinch points" based on societal demand and landscape capacity, could help policy makers set regional priorities and target certain grant schemes and ELM tiers, especially if used in conjunction with other national resources such as the Natural Capital Atlases (Natural England 2020).

EcoservR, or indeed any technological product supporting ELM, needs to be user-friendly to encourage uptake. We developed EcoservR as a stand-alone tool that has applications outside ELM (such as urban planning), but we can imagine the models being used behind the scenes of a larger online "one-stop-shop" portal where advisors and landowners can view, verify and edit maps of their holdings, generate public good assessments, and preview available payments for various intervention options. We have identified possible collaborations within the next round of ELM Test and Trials that could harness the power of the Ecoserv approach while providing a more seamless and streamlined planning experience.

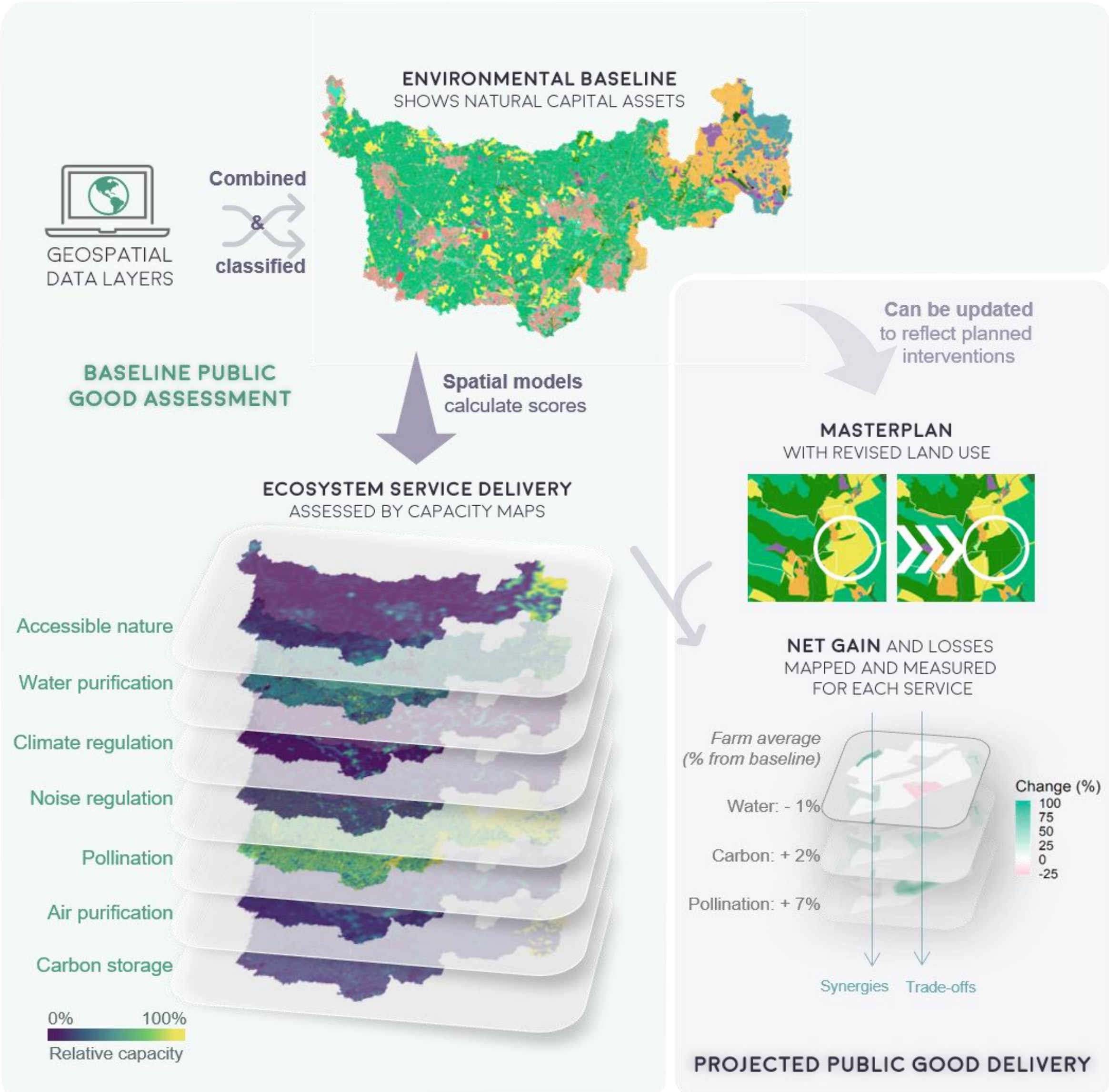

Figure 1. The environmental baseline generated by EcoservR can be used to generate a public good assessment for seven ecosystem services. It can also be updated to measure the projected impacts of agri-environmental interventions, supporting decision-making and providing nationally standardised metrics. *Contains OS data © Crown copyright and database right 2020*.

DEFINITIONS AND ACRONYMS

Word or Acronym	Description or Definition
CS	Countryside Stewardship, a scheme from the Rural Payments Agency
CWT	Cheshire Wildlife Trust
ELM	Environmental Land Management
GIS	Geographic Information System
HLS	Higher Level Stewardship, a scheme from the Rural Payments Agency
OS	The Ordnance Survey, Britain's mapping agency
R	A programming language and open-source software used to develop the tool
T&T	Test and Trial

INTRODUCTION

Project background

The need for a natural capital mapping tool

The new Environmental Land Management (ELM) scheme is calling for a shift in how farms are managed, moving the focus from food production to the production of multiple outputs. This includes the provision of environmental services that deliver public benefits throughout the wider landscape and the communities within it. The ELM scheme is proposing to introduce payments for these "public goods", and farmers are aware that they will need to diversify their land management plan to deliver outputs that are eligible for funding.

A **land management plan** is likely to be a key working and planning document under the new ELM scheme. This should at least include an **environmental baseline** (current type/condition of field parcels) and a **public good delivery assessment** (the services the land delivers as a result), possibly alongside wider business goals and aspirations for the farm (Defra LMP Thematic Working Group 2020). This document could support the application process by evidencing how proposed agri-environmental interventions could enhance the delivery of one or more public goods.

There are a growing number of tools for assessing natural capital and ecosystem services in the UK, which vary in their ease of use, scale at which they can be applied, data requirements, and outputs produced (see e.g. Ecosystems Knowledge Network Tool Assessor for a comprehensive list). Several of these tools can generate useful information to support the ELM scheme, and include:

- The Eco-metric is a framework for measuring ecosystem services designed to be used alongside the Defra biodiversity metric (ENCA 2020). It relies on a matrix of scores assigned to each habitat for 18 different ecosystem services. It has the advantage of providing a standardised metric (units) reflecting gains and losses, and comes as an Excel workbook that does not require advanced IT skills. However, in its current form it is time consuming to enter all the information manually (surface and condition of each habitat type), and does not explicitly consider the spatial context of these habitats (although it incorporates a multiplier that considers location).
- The new Natural Capital Atlases (Lear et al. 2020) map natural assets at the regional scale, presenting at a $5km^2$ resolution the quantity (extent) and quality (condition) of these assets compared to the national range. This is too coarse a scale to be of use in designing land management plans, but may help to identify gaps and opportunities for collaborative work and to set regional priorities.
- ASSIST E-planner (https://assist-e-planner.ceh.ac.uk/) is a web-based tool designed to facilitate the targeting of new agri-environmental interventions based on the suitability of the landscape to support four different management interventions, and additionally indicates the relative priority for the chosen service compared to the national average.
- InVEST and Ecoserv-GIS are spatial tools that use environmental data layers to map ecosystem services (18 services for InVEST, 9 for Ecoserv-GIS). Ecoserv-GIS additionally generates an environmental baseline using widely available datasets, while InVEST supports economic valuation.

Practitioners want outputs that lend themselves well to discussion with a range of stakeholders (Vorstius and Spray 2015), and early evidence from the Spatial Prioritisation Working Group (Defra, June 2020) suggests that farmers respond well to maps and visual outputs. Spatial data also facilitate decision-making involving strategic and collaborative planning across larger areas, a necessary consideration for meaningful environmental benefits (POST PN627 2020). We therefore wanted our tool to be spatially explicit and generate easily interpretable maps as an output, while also making it easy to derive robust, evidence-based scores for measuring public good delivery consistently across the country. We also wanted the tool to be able to produce both an environmental baseline and a public good delivery assessment, two key parts of a land management plan. Finally, we wanted the tool to be simple to use.

None of the tools above met all these requirements, but rather than creating a whole new tool from scratch, we identified Ecoserv-GIS as meeting most of them, and chose to update it to simplify its workflow further and produce outputs usable at farm scale.

The Ecoserv approach

Originally developed at the Durham Wildlife Trust in 2013, Ecoserv-GIS is a natural capital mapping toolkit that measures ecosystem services from a habitat map generated from easily accessible national datasets. The models calculate scores for a range of ecosystem services, based not only on the intrinsic capacity of these habitats to deliver services but on their spatial arrangement (e.g. with larger or more connected patches providing a higher level of service), and on our scientific understanding of the biophysical processes driving them. It is a fairly intuitive and user-friendly toolkit designed for practitioners with intermediate GIS skills (Vorstius and Spray 2015).

The strongest feature of the Ecoserv approach with respect to ELM is its ability to quantify change in ecosystem service delivery by comparing an intervention scenario to the environmental baseline. Projected gains (or losses) can be quantified for each service, and because the tool relies on nationally harmonised datasets, the scores could eventually be linked to payments (although payments were outside the scope of this T&T). The Ecoserv approach has a proven track record of real-life applications, informing policy and greenspace strategies in national parks and other natural areas (Rouquette and Holt 2016; South Downs National Park Authority 2016) as well as in urban areas such as the Liverpool City Region (Liverpool City Region Natural Capital Working Group 2019; Busdieker et al. 2020).

However, there are barriers to a wider uptake of Ecoserv-GIS, as it relies on an outdated version of the software ArcGIS and no longer function properly. Additionally, while the toolkit itself is free to use, ArcGIS is a proprietary software with a costly license. Therefore, we decided to rewrite the tool workflows in the R software, which is free and open source. The resulting EcoservR tool therefore benefits from the extensive evidence base underpinning Ecoserv-GIS, but also from updated workflows designed with ELM and farm-scale land management in mind.

The T&T team

This Test and Trial is a partnership between Liverpool John Moores University and the Cheshire Wildlife Trust, and additionally benefited from the expertise and support of Natural Capital Solutions and Forest Research.

Liverpool John Moores University provided expertise on the natural capital elements of the trial and developed the mapping tool at the core of the trial. C. Bowe has experience in spatial analysis of natural capital and metrics underpinning ecosystems services, and S. Angers-Blondin led the conversion of Ecoserv-GIS into the R language.

Cheshire Wildlife Trust managed and coordinated the work with farm advisors and land owners. They have been working in the area for several years and have an excellent knowledge of the study area habitats and environmental priorities. This came in extremely useful when the work with farmers had to be dramatically reduced because of COVID-19. Instead of supporting farmers in producing 14 separate farm plans, J. Pimblett and M. Varley developed a holistic, strategic set of hypothetical interventions, which spanned the Dane Headwater Farm Group footprint, part of Natural England’s Facilitation Fund network. The interventions were based on their intimate knowledge of the area and where they felt there was realistic scope for the delivery of environmental improvements.

C. Bellamy is one of the original authors of Ecoserv-GIS and provided support and guidance in adapting and modernising the toolkit. J. Rouquette and A. Holt are the directors of Natural Capital Solutions, a consultancy that has been using the Ecoserv approach for over five years. They provided further advice on improving the baseline mapping process and ecosystem service models, and tested several versions of the scripts for external work in other parts of the country and at site- to county-scale, which helped identify and fix a great number of bugs and performance issues.

Project location

We used the Dane river catchment as a study area (**Figure 2**), focusing on the upper part which covers 7500 hectares of upland fringe landscape dominated by livestock farming. At the highest elevations, such as that around Axe Edge, open moorland is dominant. This gives way to steep cloughs and more gently sloping fields with fast flowing upland river systems and scattered clough woodlands.

The area forms one of Cheshire Wildlife Trust's (CWT) strategic focus areas, known as Living Landscapes. In 2017, the trust established the Dane Headwater Farm Group, as part of Natural England's Facilitation Fund scheme. The group is composed of 14 landowners, farming a contiguous area of 2640 ha within the upper Dane catchment. Trust staff are working particularly closely with these landowners to deliver natural capital works on their holdings, hosting training events and workshops, and providing support with agri-environmental applications.

Figure 2. The Dane River catchment (blue outline) in Cheshire, with the Dane Headwater Farm Group footprint (dark red) located in the upper part of the catchment. The white window outlines the core area ("landscape scale") where interventions were designed, and for which results are presented in the report (ca. 4 x 5 km; 2080 ha) unless stated otherwise. *Contains OS data © Crown copyright and database right 2020*.

Research questions

Our test and trial sought to develop a natural capital mapping tool and test its real-life potential using a group of upland farms in Cheshire as a case study. Our test and trial is directly relevant to the Land Management Plans theme, and explored aspects of the Spatial Prioritisation, Collaboration, and Innovative Delivery themes. Our research questions were:

1. **Can a natural capital mapping tool provide a habitat register (environmental baseline) and measure the delivery of public goods at scales meaningful to ELM?**
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Themes

In addition to our main research questions, this test and trial sought to answer programme-level questions belonging to four of the six themes and outlined in the T&T Monitoring and Evaluation document.

Land management plans

- What types of information, knowledge or skills have been applied to develop an LMP?
- What tools and mechanisms are used to produce LMPs (e.g. data format, stakeholders involved)?

Spatial prioritisation

- In what ways have T&Ts addressed synergies, competing priorities and conflicts in needs at a local scale?

Collaboration

- How, if at all, have tools and mechanisms supported collaboration?

Innovative delivery solutions

- To what extent have T&Ts identified and used innovative tools and mechanisms (e.g. apps) to contribute to the development of LMPs and delivery of anticipated outcomes?

METHODOLOGY

Developing the natural capital mapping tool

The toolkit will be available to download as an R package towards the end of October: information will be posted on the EcoservR website (https://ecoservr.github.io/EcoservR). The toolkit currently contains 10 baseline processing steps (scripts) and 13 ecosystem service modelling scripts. All maps and outputs can be produced from two highly automated and annotated master scripts (one for the baseline and one for ecosystem services), reducing the need for interacting with code to specifying data inputs.

The toolkit also includes built-in datasets which are pre-formatted and called when necessary (such as socio-economic data for demand models, and lookup tables to join score values to habitat types), and a stylesheet with symbology styling for the habitat map (to visualise the outputs simply and consistently using the free QGIS software). The general workflow of the toolkit is illustrated in **Figure 3**.

The tool was developed and tested on consumer-grade computers and should work on most modern computers operating Windows or MacOS. Detailed system requirements and instructions for installing the toolkit can be found in the EcoservR user guide, which will be released along with the toolkit.

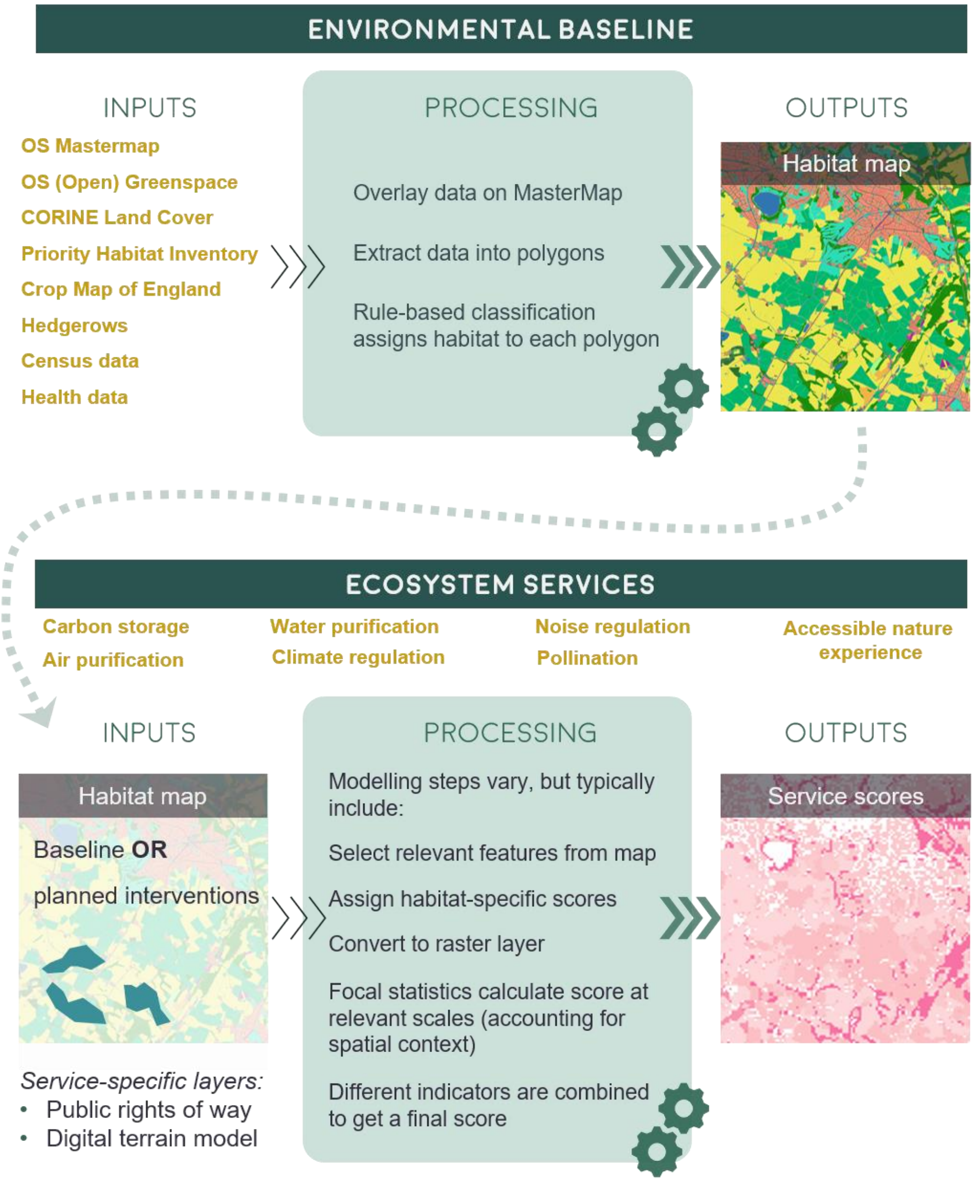

Figure 3. Simplified workflow of the EcoservR toolkit with current data inputs and outputs and supported ecosystem services. *Contains OS data © Crown copyright and database right 2020.*

Table 1. Datasets required (bold) and recommended for producing an environmental baseline and public goods assessment. The white rows indicate datasets that are not integrated in the baseline map but are called upon by certain ecosystem service models.

Dataset	Source	License	Use in toolkit
OS MasterMap Topography	Ordnance Survey	Available under Public Sector Geospatial Agreement (PSGA) or educational licence	Main mapping source; habitat classification
OS Greenspace *(and/or)*	Ordnance Survey	Available under PSGA or educational licence	Habitat classification; public access
OS Open Greenspace	Ordnance Survey	Open Government Licence	Habitat classification; public access
CORINE land cover 2018	European Environment Agency (Copernicus)	Open Licence	Habitat classification
Priority Habitat Inventory	Natural England	Open Government Licence	Habitat classification
Crop Map of England 2019	Rural Payments Agency	Open Government Licence	Habitat classification
OS Terrain 5m	Ordnance Survey	Available under PSGA or educational licence *(OS Terrain 50m available under Open Government Licence)*	Habitat classification, some service models
Hedgerows	Rural Payments Agency	Not publicly available *(CEH's Woody Linear Features may be used as an alternative; paid licence)*	Adds polygons to the map; habitat classification
OS VectorMap District	Ordnance Survey	Open Government Licence	Identify roads and other features in some service models
Designated sites (National Parks, LNR, NNR, SSSI, etc.)	Varied	Open Government License	Identify publicly accessible greenspaces
Public Rights of Way	Local councils	Open Government License	Identify publicly accessible greenspaces
Census 2011 (average house population)	Derived from Office for National Statistics *(built into tool)*	Open Government License	Societal demand in service models
Index of Multiple Deprivation 2019 (HDD score)	*(built into tool)*	Open Government License	Societal demand in service models

Producing an environmental baseline

We produced the baseline map for the Dane river catchment using the datasets listed in **Table 1**. All datasets were accessed in February or March 2020, apart from the Crop Map of England whose 2019 version was released in May 2020 and subsequently added to the map. Most datasets are available under an Open Government Licence and directly downloadable from open data portals. We contacted local councils (Cheshire East and West, Staffordshire, Derbyshire) for up-to-date public rights of way data, and the hedgerow data for our study area was kindly provided by the Rural Payments Agency.

Using several datasets help refine the classification, but a map could theoretically be produced using only OS Mastermap (the only required dataset that is not freely available), and OS Open Greenspace. Adding Natural England's Priority Habitat Inventory data will unlock several more habitat codes that cannot be differentiated otherwise and is highly recommended. Some licenced datasets can further improve the classification: OS Greenspace is highly recommended in urban and peri-urban areas, which are not covered by OS Open Greenspace.

The baseline map processing involves a series of 10 modules which progressively update OS MasterMap polygons with additional information from the other data layers (**Figure 3**), and finishes with a rule-based classification that considers all available data to assign a habitat code (**Appendix 1**). These codes are derived from the Phase 1 habitat classification system (JNCC 2010) and are therefore readily interpretable by most land advisors.

EcoservR workflows are largely the same as the original Ecoserv-GIS and we refer the reader to the Ecoserv-GIS user guide (Winn et al. 2018) for specific details on geoprocessing steps. The main additions to EcoservR are new modules incorporating hedgerows and the Crop Map of England data, with the aim of increasing detail and accuracy of habitat classification at the farm scale.

Modelling ecosystem services

We translated the Ecoserv-GIS ecosystem service models that most closely align with the public goods defined in the 25-year environment plan (**Table 2**; Defra 2018). Future development of the tool will include carbon sequestration, biodiversity and flood risk mitigation. The Ecoserv approach produces, for each ecosystem service, a capacity and a demand model. Capacity models map the ability of the landscape to deliver a service, while demand models identify the parts of the landscape that have need for a service (because of the health or density of people living there, or the presence of features that generate a need). In the context of this report, we focus on **capacity models** as they can be used to measure delivery of public goods in the context of ELM.

Real-world testing and feedback

Workshop with land advisors

We held a two-hour online workshop with 9 land advisors working in the Dane river catchment area on March 25th, 2020 (**Appendix 2**). We demonstrated the EcoservR tool and gathered feedback about the relevance of the outputs in the context of ELM, data governance and tool usability in land management planning. Land advisors' comments and suggestions were taken into consideration when revising the tool.

Table 2. Each public good set out in the 25-year environment plan can be measured by at least one EcoservR ecosystem service model.

Public goods	Ecosystem services in EcoservR
Clean and plentiful water	Water purification
Clean air	Air purification
Protection from and mitigation of environmental hazards (flooding, drought)	*Water flow (flood risk) model in development*
Mitigation & adaptation to climate change	Local climate regulation, carbon storage
Thriving plants & wildlife	Pollination *(Biodiversity model in development)*
Beauty, heritage, and engagement with the natural environment	Accessible nature experience

Land management plan for the farm group

Initially, this test and trial was set to produce 14 individual land management plans in collaboration with the farms in the Dane Headwater Facilitation Fund group (**Table 3**). However, due to COVID-19 preventing face-to-face research, we instead decided to create a strategic land management plan for the whole farm group footprint, using the expert knowledge of the Cheshire Wildlife Trust in the area. It was unfortunate that we had to reduce farmers' contributions to our project so drastically, but mapping interventions at a landscape rather than individual farm scale allowed us to explore questions around collaboration that we had not planned to examine.

We designed a set of interventions totalling 335 ha and revolving around the following environmental priorities (see **Appendix 1** for description of target habitats):

- **Woodland creation**: planting of new native broadleaved woodland (107 ha; target A11)
- **Woodland restoration**: removal of invasive species, or conversion of coniferous plantation to native broadleaved woodland (59 ha; target A11)
- **Pollinator habitat creation**: Sowing a semi-natural meadow community (19 ha; target Bu2) or sowing legume- and herb-rich leys on temporary grasslands. (18 ha; target B4)
- **Pollinator habitat restoration**: adjusting grazing regimes and/or introducing seeds/plugs to diversity the sward (32 ha; target Bu1)
- **Wetland creation**: digging of scrapes and rewetting to improve habitats for wading birds (99 ha; target D/E)
- **Hedgerow creation**: planting of hedgerows (1 ha; target J21)

Table 3. Characteristics of the 14 farms (anonymised) participating in the Cheshire Wildlife Trust facilitation fund group. Shaded rows indicate the farms visited for interviews and/or ground-truthing.

Farm ID	Farm size	Farm description
Farm 1	70 ha	Sheep & beef suckler herd. Existing HLS agreement. Tenant.
Farm 2	147 ha	Sheep. Existing mid-tier CS agreement. Landowner.
Farm 3	57 ha	Sheep & beef suckler herd. Existing mid-tier CS agreement. Tenant.
Farm 4	41 ha	Dairy farm. Existing mid-tier CS agreement. Landowner.
Farm 5	83 ha	Sheep & dairy. Existing HLS and woodland creation agreement. Tenant.
Farm 6	151 ha	Sheep. Existing HLS agreement. Landowner.
Farm 7	124 ha	Sheep & beef suckler herd. Existing HLS agreement. Landowner.
Farm 8 & 9	208 ha	Dairy farm. Existing HLS agreement. Landowner.
Farm 10	955 ha	Sheep. Existing HLS agreement. Landowner.
Farm 11	50 ha	Sheep. Existing HLS and woodland creation agreement. Landowner.
Farm 12	72 ha	Sheep & beef suckler herd. Existing HLS agreement. Landowner.
Farm 13	250 ha	Sheep & beef suckler herd. Existing HLS agreement. Landowner/tenant.
Farm 14	75 ha	Sheep & dairy. Existing HLS agreement. Landowner.

The current Ecoserv approach relies heavily on assigning scores to specific habitat types, and therefore improvement of a field parcel that does not result in a change of habitat code will not result in a change in delivery score. This was the case for ca. 3 ha (5%) and 17 ha (34%) of areas assigned for woodland restoration and pollinator habitat creation or restoration, respectively. Therefore, our models likely slightly underestimated the environmental gains achieved by these interventions. We could not design a rigorous method to account for habitat condition within the time frame of this Test and Trial, but it is a priority for future development of EcoservR.

The scenario we simulated for our catchment-wide land management plan (**Appendix 3**) is based on realistic land management interventions of the kind currently eligible for funding under Countryside Stewardship agreements. These opportunities have been identified by the Cheshire Wildlife Trust over the last two or three years and therefore represent a genuine vision for the area, rather than having been designed for the tool to showcase environmental benefits. Some of the mapped interventions are based on ongoing work in the Facilitation Fund and are therefore representative in terms of extent and suitability of interventions carried out in the area.

Farm visits and engagement with farmers

We had to reduce the number of farm visits to a strict minimum because of COVID-19. In August 2020, we visited five farms in the group to ground-truth the environmental baseline, surveying over 200 field parcels. When the map classification was erroneous, we annotated the map with the correct Phase 1 habitat code. We used this information to refine the habitat classification rules and improve the accuracy of the tool.

We experienced difficulties engaging with farmers and getting them to provide feedback on the approach. In the end, three farmers (from farms 4 & 5; **Table 3**) agreed to discuss the tool and general ELM scheme framework in semi-structured interviews in August 2020.

After a request from Defra to let farmers experience the tool for themselves and with the aim of eliciting more answers to our questions about the usefulness of the tool, we developed a web app (**Appendix 5**) which lets farmers explore their environmental baseline and create "ELM-style interventions" interactively. A new public good assessment is generated seamlessly (using the EcoservR models in the background), and the app displays heatmaps of public good distribution and a change analysis (showing gains or losses in delivery of four public goods). Users can generate an automated PDF report of the interventions they applied and projected public good scores, a document which could form the basis of a Land Management Plan within an ELM portal (**Appendix 6**).

In December 2020, all farmers were sent the link to the app, detailed instructions, and a link to a survey to collect feedback. Unfortunately, despite being given a month to respond and sent several reminders, only one person responded to the survey.

The discussion during interviews revolved around the following themes and questions:

1. Baseline map and using spatial information

- Do you use maps or other data to manage your farm?
- How does the EcoservR environmental baseline compare?

2. Public goods and land management priorities

- What parts of your farm do you think provide which services/public goods?
- Of the public goods identified by Defra, or any other land management targets, which do you think are the most important (should be prioritised) for the Dane catchment? On your farm?
- Are you surprised by anything you see in the EcoservR ecosystem service score maps? Does it align with what you think your farm already delivers?

3. Planning land management interventions

- How are you achieving / would you achieve the targets you identified as environmental priorities?
- How do you decide where to create an intervention?
- What resources and incentives would you require from an ELM scheme to carry out these interventions?
- Would the EcoservR tool and maps help you shape your ELM whole farm plan?

The interviews were audio-recorded, and farmers comments reported in our findings have been slightly edited for clarity or to preserve anonymity. Survey questions sent with the app revolved around the same themes but were more direct (agree/disagree or multiple choice) so they could be answered online rather than conversationally. They are detailed in **Appendix 7**.

RESULTS AND DISCUSSION

Natural capital mapping tool outputs

Environmental baseline

The environmental baseline map for the Dane River catchment covers an area of 417 km^2 (41 675 ha) dominated by farmland, transitioning to less intensively managed grazing land in the East, with a fringe of moorland and bog on the edge of the Peak District National Park (**figure 4**). The program took 94 minutes (1.5 hours) to produce a map containing 493k polygons[1], and a third of this time was devoted to the computationally intensive step of integrating hedgerows into the map. We estimate that producing a similar baseline map with the old Ecoserv-GIS tool would have taken over 4 hours, not including hedgerows. EcoservR is therefore an improvement over the old toolkit, and we estimate that producing a basemap and seven ecosystem service capacity models could be achieved in less than one to two working days, once the input datasets had been collated and depending on the size of the study area and computing power available.

An application of the baseline is to produce a natural capital asset register for a site (**Table 4**), summarising the spatial information contained in the map and allowing a detailed breakdown of land use on a given farm. This register can be generated dynamically every time the extent or habitat type of a polygon is edited to reflect changes in land management practices.

Table 4. Example of a natural capital asset register (habitat list) for a farm within the study area (Farm 3 in Table 3).

Habitat code	Description	Area (ha)	Cover (%)
Bu or Bu2	Grassland, semi-improved	47.0	82.6
D5	Mosaic: acid grassland, dry heath	5.8	10.2
Bu1	Grassland, unimproved	2.2	3.8
A12/A2	Woodland, coniferous	0.7	1.2
A2	Scrub	0.3	0.5
J21	Hedgerows	0.3	0.5
B5/E3/F/H2	Marshy Grassland/Fen/Swamp/Saltmarsh	0.2	0.3
A31	Scattered trees, broadleaved	0.2	0.3
A11	Woodland, broadleaved	0.1	0.2
A11/A2	Woodland, broadleaved (with scrub)	0.1	0.2
J511	Road, surfaced	0.1	0.1
J37	Sealed surface	< 0.1	< 0.1
G1u	Standing water	< 0.1	< 0.1
J360	Domestic buildings	< 0.1	< 0.1
J362	Shed/Garage/Farm building	< 0.1	< 0.1
A12	Woodland, coniferous	< 0.1	< 0.1
J12v	Road verge	< 0.1	< 0.1
A13	Woodland, mixed	< 0.1	< 0.1
G2u	Running water	< 0.1	< 0.1
J56	Private garden	< 0.1	< 0.1

[1] Run on a consumer-grade Windows 10 laptop with Intel Core i7 processor (4 x 2.50 GHz) and 12 GB RAM.

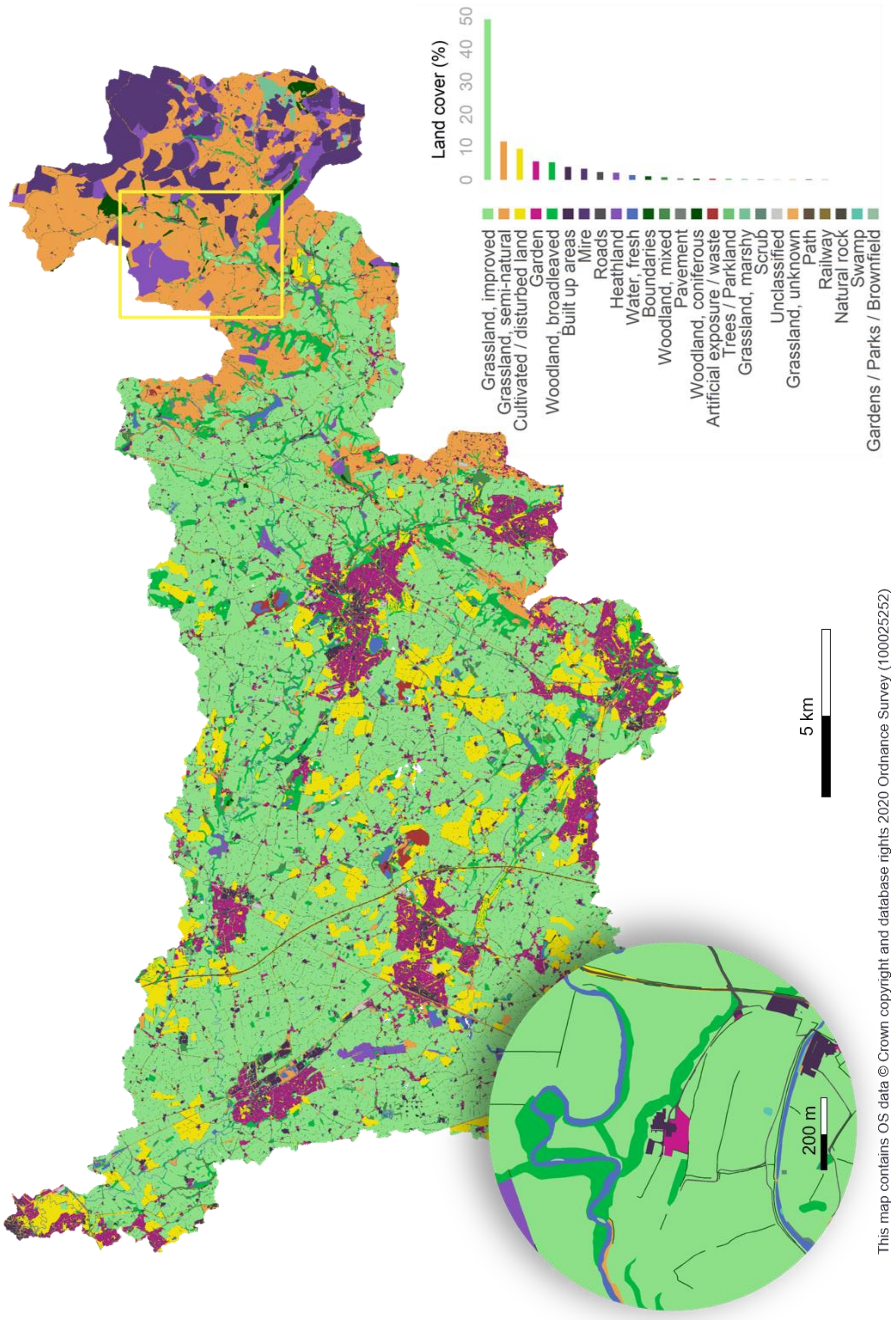

Figure 4. Environmental baseline for the Dane River catchment, an area of 417 km^2 (41 675 ha) in Cheshire. The map contains 72 different habitat types, grouped into broader land use groups for visualisation purposes. The legend displays the proportion of land cover occupied by each group. The inset shows the level of detail of the map at a finer scale, including hedgerows. The yellow window outlines the core area ("landscape scale") where interventions were designed, and for which results are presented in the report (ca. 4 x 5 km; 2080 ha) unless stated otherwise. *Contains OS data © Crown copyright and database right 2020*.

How accurate is the mapping tool in classifying habitats?

The first version of our environmental baseline proved accurate in 54% (120 out of 221)[2,3] of the polygons surveyed (**figure 5a**). Of the polygons incorrectly classified, the major issue by far (77 polygons; 35%) was semi-improved grasslands being classified as improved grasslands. This is likely a reflection of the particularities of upland farming, where land is managed less intensively. Additionally, the Crop Map of England 2018 was initially used to distinguish between arable land and pastures; however, the 2018 version of the dataset is very noisy (identifying arable crops in pixels that should be grass) and likely contributed to several misclassifications. The tool performed extremely well in classifying other types of land use such as woodlands (**figure 5**).

Because misclassifications were partially systematic, we were able to update the rules in the toolkit to reduce the prevalence of these mismatches (**figure 5b**). To acknowledge the different land management practices in the uplands, we introduced rules based on elevation and slope, so that above a certain threshold, a parcel of unknown agricultural land would be assigned as a semi-improved grassland rather than improved or cultivated land. We also updated the baseline with the Crop Map of England 2019 dataset.

After these revisions, accuracy increased to 78%, and the broad habitat type was correct 85% of the time (compared to 56% in the first map) due to the improved detection of semi-improved grazing land. This new classification remains to be tested more widely outside the study area. It is important to note that the tool does not eliminate the need for farm walks, and formal public good assessments should only be conducted once the baseline has been verified by the landowner or a land advisor. However, it does provide a base map which can be easily amended and updated.

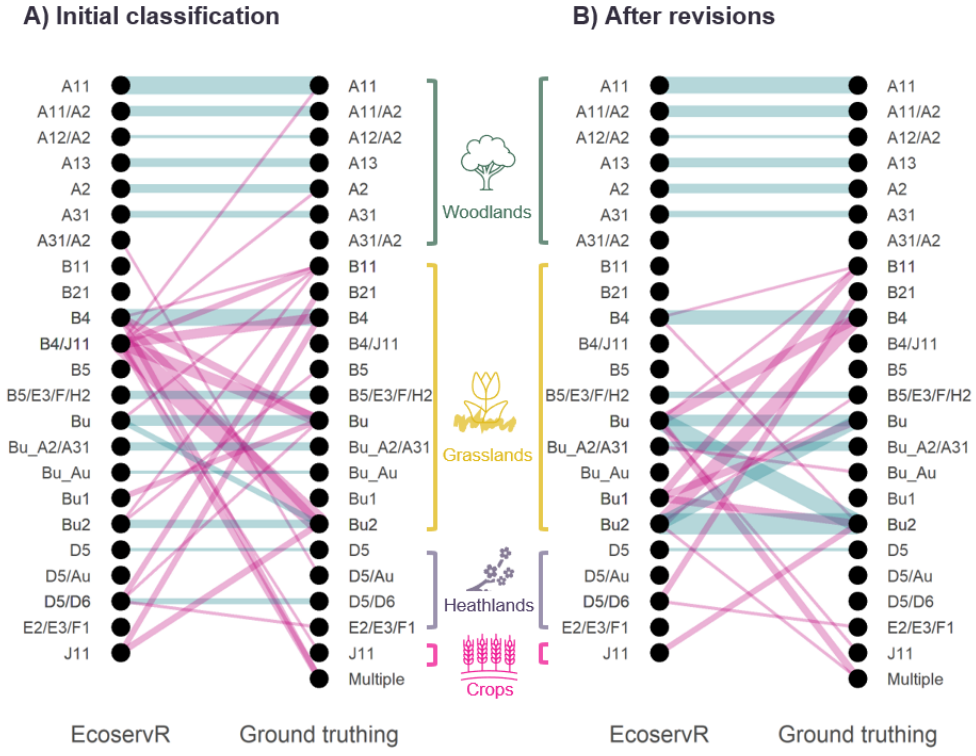

Figure 5. Validation of the EcoservR baseline map for 221 polygons on five upland farms in Cheshire. The accuracy of the initial baseline (A) was 54%, increasing to 78% after revising the rules (B). Green lines are correct classifications, and pink lines are incorrect classifications. The thickness of the line is proportional to the number of occurrences for a given habitat code pair.

2 We assumed that the codes Bu (rough grassland, probably semi-improved) and Bu2 (rough grassland, semi-improved) were equivalent and thus rightly classified, as they simply denote a different degree of confidence in the assignment.

3 The overall accuracy of the tool is likely to be higher than reported, as roads and buildings are straightforward to classify, and were not verified as part of our ground-truthing exercise.

Ecosystem services

Baseline public goods assessment

We produced catchment-wide capacity maps for the seven different ecosystem services supported by EcoservR. Capacity maps can help inform spatial priorities at local to regional scale by identifying areas providing multiple benefits (areas to protect) and gaps where capacity is low or lacking (opportunities). Within the farm group core area (ca. 2000 ha), there was heterogeneity in landscape capacity, with woodland areas generally scoring highest and delivering multiple benefits (**Figure 6**). This is a part of the Dane catchment that has high value: its capacity to deliver air purification, noise regulation and carbon storage was around 10-13% higher than the catchment as a whole, and 75% higher for accessible nature experience (due to the vast amount of Crown land and the edge of the Peak District National Park). It scored slightly below average (-5%) for water purification, potentially indicating that this is a priority service to target in the area. These maps can be a tool for communication and collaboration within farm groups, allowing to target interventions where they would bridge existing gaps, and possibly benefit several participants in return.

How sensitive is the tool in measuring change at various scales?

The agri-environmental interventions we designed covered 335 ha (**Appendix 3**), and resulted in net changes at the landscape extent ranging from roughly 0 (pollination) to gains of 21% (climate regulation) for the different services (**Table 5**; see **Appendix 4** for farm maps). Most farms showed gains in several services, sometimes slightly at the expense of another service (**Table 5**; **Figure 7**). For example, the slight decrease in pollination on Farm 2 is likely the result of woodland creation on a parcel that was previously semi-improved grassland. However, woodland creation generates multiple benefits and is associated with moderate to large gains for every other service. This exemplifies how EcoservR outputs can be used to choose interventions that align with local or regional priorities. Competing sets of interventions could even be assessed against each other to select the most profitable scenario.

It is important to note that the interventions were designed strategically to benefit the wider area, but not tailored to any individual farm. Therefore, the farm-level gains are in most cases likely underestimating what could be achieved if interventions were designed on a site-by-site basis with the aim of increasing services on-farm. This raises more questions about how collaboration might work under the new ELM scheme, especially when some farms in a group might be more solicited than others based on their existing natural capital assets or strategic locations. For instance, under a landscape-scale collaborative plan, farm A might be required to provide a large intervention to “bridge a gap” in pollination (enhance connectivity). Meanwhile, a neighbour farm B might not the most suitable location for this intervention (i.e. adding habitats would not improve connectivity). Under single farm plans, different interventions may have been selected, such as two small patches of pollinator habitat in each farm which may not have provided the same benefits, however both farmers would receive payments for services generated. Under a collaborative plan, should both farmers receive payment for this outcome? Which is the fairest and optimum outcome? These questions are beyond the scope of our T&T, but the spatial outputs generated by EcoservR could help explore them further.

Finally, a current limitation of our models is that they do not consider the habitat condition or current management of the land, such as fertiliser or pesticide inputs or grazing regime. These can all have significant impacts on ecosystem service delivery at fine scales, and we are working to include aspects of condition and management in future versions of the tool. For this reason, we also could not fully measure environmental benefits arising from some more subtle interventions (i.e. in the 20 ha / 335 ha where the intervention did not result in a change of habitat code). This partially explains low pollination capacity gains[4] despite the interventions creating (37 ha) or improving (32 ha) significant extents of pollinator habitats. These interventions did not usually change the habitat code of field parcels, which were generally semi-improved (Bu2) or temporary grazing (B4) grasslands and designed to remain so, but with a change in management practices aimed at improving biodiversity (sowing or plug planting, grazing reduction, etc.). Many agri-environmental interventions revolve around management change

[4] There is also a known issue with the pollinator model, which is too permissive in selecting pollinator habitats from the map and therefore generally scores very high (Vorstius and Spray 2015). Future versions of the model will include elevation constraints and a distance decay function to account for decreasing pollinator visits at higher distances from core habitats.

rather than land use change, especially in more intensively farmed land. This was an important discussion point in our workshop with land advisors, and we are exploring ways to integrate a condition assessment that could be used as a multiplier in the models to account for this.

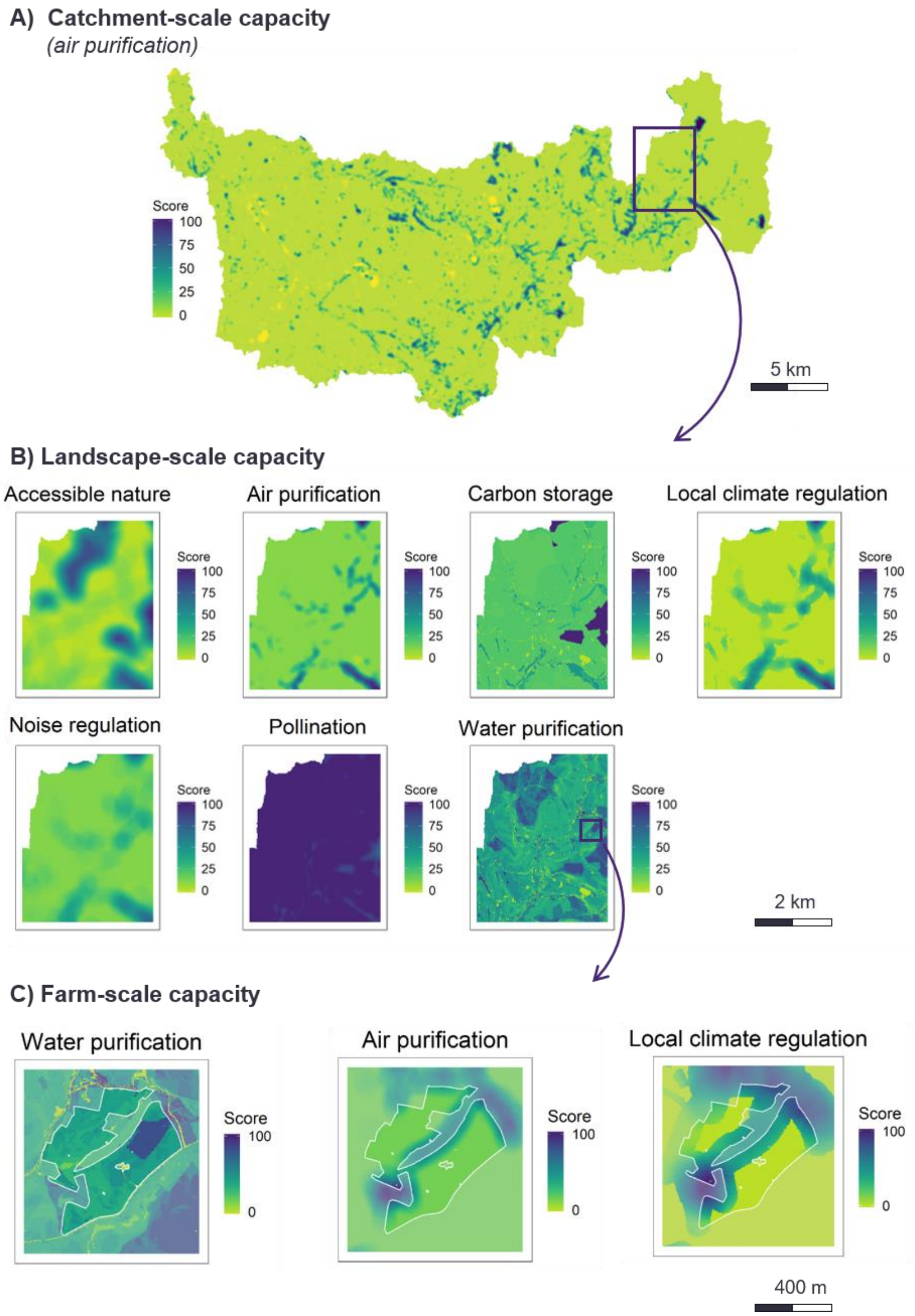

Figure 6. Catchment- (A), landscape- (B) and farm- (C) level capacity to deliver public goods in the Dane river catchment in Cheshire. The seven services measured by EcoservR are presented at the landscape scale; a selection has been chosen at other scales to simplify the figure. Score units are specific to each service model, but scores have been rescaled to a common range to facilitate visualisation and identification of areas that provide high benefits. A score of 100% represents the highest capacity delivered by the piece of landscape seen in the frame.

Table 5. Ecosystem service capacity generally increased as a result of simulated agri-environmental interventions (335 ha) within the farm group (presented as % change from baseline). We measured these impacts at three scales: farm scale (for 14 farms), landscape scale (the 2080 ha core area around the farm group), and for the whole Dane river catchment (41 675 ha; see Figure 4).

Boundary	Access. nature	Air purification	Carbon storage	Climate regulation	Noise regulation	Pollination	Water purification
Farm 1	0.54	13.48	6.13	56.63	11.57	-0.03	5.17
Farm 2	5.74	3.43	0.80	30.46	6.37	-0.38	5.68
Farm 3	0.30	0.51	0.00	7.81	0.56	0.00	0.00
Farm 4	0.13	0.06	0.95	6.67	0.10	0.08	-0.40
Farm 5	0.53	0.27	0.31	2.24	1.54	0.21	0.18
Farm 6	4.10	5.13	1.81	10.17	3.89	-0.03	1.39
Farm 7	0.00	2.06	0.76	71.97	3.49	0.00	0.63
Farm 8	0.02	2.87	0.66	12.95	4.97	0.02	0.80
Farm 9	0.45	2.27	1.47	40.35	3.97	0.00	1.11
Farm 10	0.01	-0.02	-0.02	6.39	0.14	0.00	0.26
Farm 11	0.13	0.63	0.02	1.28	2.44	0.00	0.09
Farm 12	0.26	-0.77	0.00	4.39	0.96	0.00	0.00
Farm 13	0.96	15.00	3.77	241.42	16.80	-0.03	3.94
Farm 14	2.82	3.37	-0.36	15.08	8.33	0.52	2.54
Landscape	**2.50**	**5.15**	**1.00**	**21.51**	**6.51**	**-0.02**	**3.36**
Catchment	**0.23**	**0.69**	**0.26**	**2.92**	**0.88**	**0.00**	**0.27**

Real-world use of EcoservR

Feedback from land advisors

The nine land advisors who participated in our workshop were aware of the upcoming need to recognise natural capital assets as part of a farm business and to evidence the delivery of public goods. Most of them agreed that they could see the potential of our ecosystem services maps as a conversation tool with the farmers, in order to identify the most suitable and beneficial interventions to be applied on a farm. The general consensus from the group was that farmers, especially the new generation, are receptive to scientific evidence and willing to base some decisions on it.

An advisor mentioned, supported by all, that hedgerows are a very important habitat on farms and should be part of the environmental baseline to capture fine-scale benefits. After the workshop, we sourced and integrated hedgerow data into our baseline map to incorporate this suggestion.

Another key discussion point was the current inability of the tool to take into account land management practices (e.g. organic farming, stocking densities, rotations, etc.). Our models therefore work well at landscape scale when a broad assessment needs to be carried out quickly, but require further fine-tuning to reflect the particularities of farming practices. Advisors also pointed out that it would be interesting to test the tool in a more intensive farming context (rather than upland farms), where interventions are most likely to be focused around improving the condition of existing land rather than creating new habitats. One advisor put forward the idea that some collaborations under ELM could rely on some productive farms "offsetting" their intensive use of the land, with interventions instead being created on more marginal land on other (e.g. upland) farms.

Finally, another important point raised by the advisors is that although they would like to be responsible for conducting baseline and public good assessments, they don't have much time or resources to learn new methods, and require a system that is easy to use. A certain level of IT skills is required to use the toolkit as it is currently script-based. The annotated master scripts and user guide make it straightforward for the user to specify parameters and launch the program without previous knowledge of the R language, but we are aware that even this can be daunting for a new user. We are hoping to create a user interface for EcoservR once the scripts have been more widely tested and are stable, and we also envision that a simpler version of the models, tailored for farm use, could be embedded within existing (e.g. Land App) or future portals.

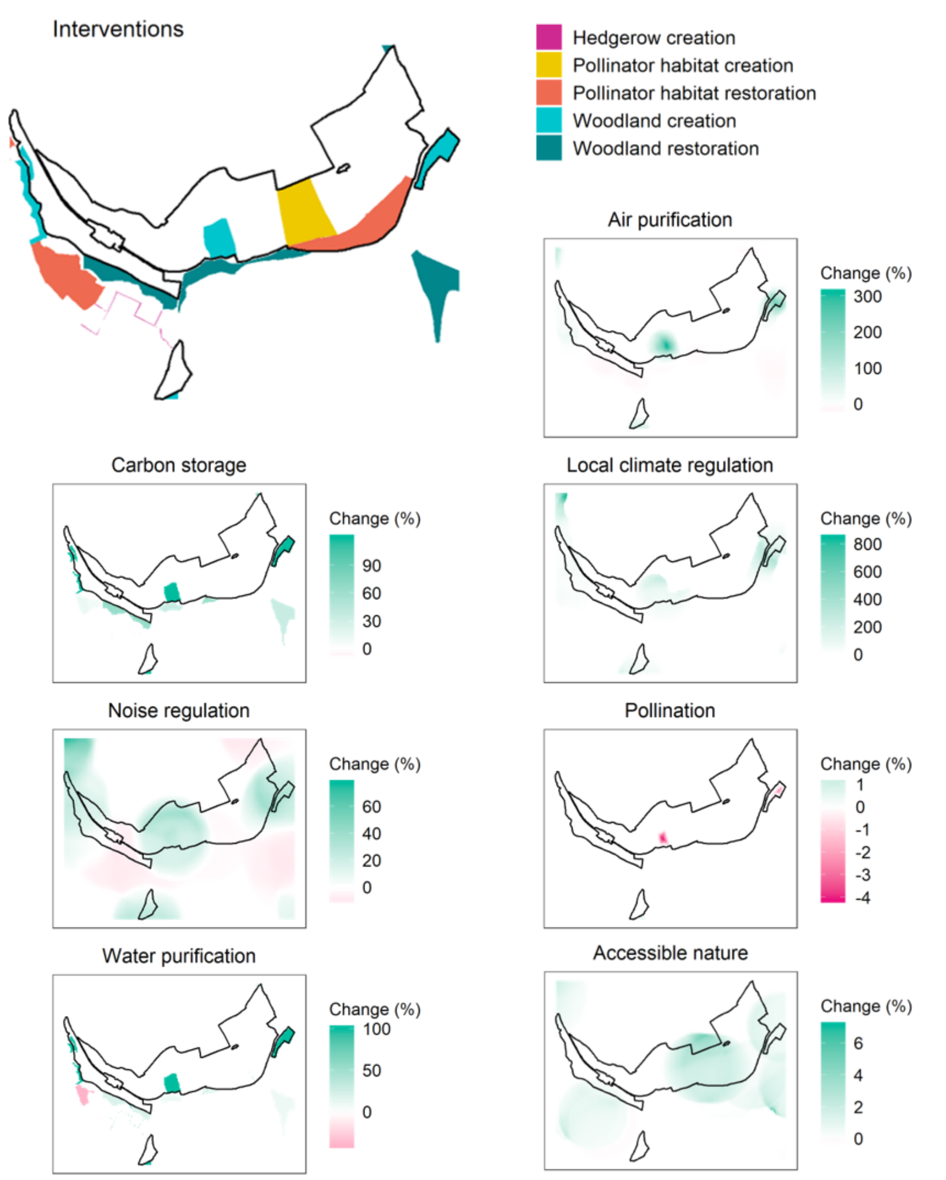

Figure 7. Simulated interventions on and around a farm (top-left panel; Farm 1 in Table 5) resulted in overall gains and minor losses in the projected delivery of seven ecosystem services, represented as percent change from baseline (note the different scale for each plot). NB: Interventions were created for the wider landscape, and therefore do not strictly respect farm boundaries (black outline).

Feedback from farmers (interviews and survey)

The lack of engagement from farmers (with one no-show and a cancelled interview, and only one survey response) was disappointing. It was however not wholly surprising according to our expert land advisor, given the circumstances (COVID-19) and type of farmers (mostly traditional upland sheep farmers, perhaps less interested in and comfortable with technology). We have gathered here the responses which we did receive for two farms who accepted to discuss the maps during an interview, and the person who trialled the app and provided feedback.

Understanding natural capital

The three farmers (from two farms) interviewed had no problem understanding and interpreting the baseline map. They all stated that they already use similar maps to manage their land under Country Stewardship agreements, and other maps too (e.g. topography maps). However, they had more difficulty interpreting some of the ecosystem service score maps. They could relate some services such as carbon storage or water purification to the baseline features quite well (amount of vegetation for carbon; terrain and vegetation for water purification). Other services like air purification, noise regulation and climate regulation were less easy to interpret, and farmers therefore seemed less trusting of the results. This emphasises the need to have clear and simple definitions of these terms in the new scheme.

When asked which environmental benefits they thought their farm provided, farmers first responded by listing habitats (natural capital assets) rather than their associated services. However, they understood the distinction quickly and could then identify the benefits provided by their assets (e.g. air quality from woodland, water purification from woodland on steep slopes, public access from footpaths). Farmer 1 identified carbon and biodiversity as priorities for the region. All identified water quality and erosion management as other priorities. The region experiences significant rainfall, and steep-sided valleys can lead to significant runoff: this agrees with the results of our models, which identified below average water purification capacity in the area compared to the full Dane river catchment.

Usefulness of the tool

Farmer 1 picked up on several classification errors and thought the mapping approach would have to be refined to be of use in informing a land management plan. A baseline map should include sub-fields features such as small ponds, field margins, etc. He also stated the importance of contextual elements such as ease of access, which the map alone cannot necessarily identify. He gave the example of a parcel crossed by an overhead powerline where woodland creation would not be practical even if it filled a capacity gap. Farmer 2 was more positive about the outputs produced by our models, and could see their value in providing a measure of environmental benefits. He thought that not taking the land management type into account was a limitation and would like to see this implemented for more accurate and useful outputs. This is a known challenge in the field of ecosystem service research, and one that will need to be addressed to ensure that farmers are rewarded fairly for good agricultural practices.

All three farmers were most interested in how our scoring system (and general measures of public good delivery) could tie in with payments: “It all comes down to: what is the [environmental] benefit [of planting trees], how much will they pay you for it, and is it more or less than what they pay for cows?”

When asked about how they would feel about going online to submit interventions and apply for funding, farmers at Farm 1 stated that broadband access is still an issue in the region, but recognized that these practices are the future of land management and did not seem daunted by it. “Technology will improve and things will go that way [digital platforms]. We can already register points and update them, the technology is there. I know it will get more simple and intuitive to use. I’m all for it.”

The farmer who trialled the app (full survey answers in **Appendix 7**) agreed that the maps were useful to understand the distribution of public goods on their farm and could help decide which interventions would be best. They could see themselves using the tool but noted that they would need help to do so, and would prefer this help to come in the form of face-to-face or phone conversations with a trusted advisor.

General ELM feedback

Farmer 2 had some strong concerns that the ELM scheme would not recognise the benefits that farms are already delivering and would only be rewarded for change rather than for existing good practices. He thought that it would "be better focusing on what's already there, and improving it over large areas, than saying 'we'll do a bit here'."

There are also high hopes that the scheme will recognise the long-term nature of ambitious agri-environmental interventions, and spread the payments accordingly. "I'd also say [my vision for ELM payments is] a long enough term, and you'd want it factored in for management. These schemes tend to pay for starting costs, but you need to consider ongoing costs like fence repairs, and have ongoing payments [to support them]." Farmer 2 could see a role for advisors in ELM, doing "boots-on-the-ground type of work, not a box-ticking exercise", and would want to be able to monitor the benefits that are being invested in, for example by surveying biodiversity to assess the success of a certain intervention.

The survey responder left the following comments:

"Payment rates need to be more competitive than they currently are so as to better incentivise a shift from current land management practices. Currently, environmental conservation does not compete financially with agriculture.

The ELM scheme would benefit from assistance from local advisors."

CONCLUSION

Our Test and Trial developed EcoservR, a natural capital mapping tool, and tested its use by developing a landscape-scale land management intervention scenario. We gathered feedback from nine land advisors and three farmers (from two farms), identifying the current strengths of the tool and areas of improvement that we are keen to continue addressing beyond this T&T. We also developed a demonstration app which forms a proof of concept of our approach. Here we answer our three main research questions, provide insights into other programme-level questions relating to four of the six T&T themes, and additional learning and future priorities resulting from our use of EcoservR within and outside ELM.

Key findings

1. Can a natural capital mapping tool provide a habitat register and measure the delivery of public goods at scales meaningful to ELM?

Yes: we used the evidence-based, spatial approach of the existing Ecoserv-GIS to create a new tool that performs better and produces outputs usable at farm scale. The tool is free to use and no longer relies on proprietary software, which should ensure a longer-lasting legacy and wider impact by simplifying the tool maintenance and encouraging uptake by practitioners. Most datasets required to run the tool are also free, or available to many practitioners under the Public Sector Geospatial Agreement.

The habitat classification was 78% accurate, with potential to refine further as high-quality national datasets become available. The spatial models allow to quantify the delivery of public goods in a robust and nationally standardised way, and are sensitive enough to detect change resulting from even modest, small-scale interventions and at different extents (farm, landscape, catchment). For instance, the 166 ha of simulated woodland interventions represented only 0.4% of the total catchment area, but led to an almost 3% increase in the climate regulation service for the catchment (**Table 5**).

A current limitation of the tool is its inability to modulate scores in response to changes in land management practices (e.g. reduced inputs or grazing regime) when the habitat type remains unchanged (only habitat condition changes). This point was raised as a concern by all land advisors and farmers interviewed and is a priority for future work.

EcoservR is not meant to replace on-the-ground work, but could save time by providing an automated way of generating a baseline map that can be checked for accuracy and built upon by farmers or advisors, rather than requiring a full habitat survey to be carried out. This baseline map can then become a working document that the farmer can update depending on planned management changes: our vision of how the tool could sit within the development of a land management plan is illustrated in **Figure 8**.

2. What are the benefits and limitations of the tool for developing whole-farm plans, as perceived by land advisors?

The nine land advisors consulted were impressed by the outputs generated by EcoservR and saw the merits of the approach and its potential role in producing a land management plan for the ELM scheme. They identified limitations to the approach that we are working to resolve with respect to considering land management practices. Most could see themselves using the Ecoserv approach to help farmers identify the most suitable and lucrative interventions for their land, provided that the tool sat behind a simple user interface. Land advisors could help farmers interpret the outputs, and where conflicts (trade-offs) between ecosystem services occur, advise on the most suitable intervention given the local context and the farmer’s overall goals for the farm business.

Land advisors raised concerns about the new scheme potentially introducing many new systems and platforms requiring training for which advisors have little time or resources to spare. We envision the EcoservR approach could be embedded within a larger platform where advisors and farmers could easily access data, add interventions, and preview projected payments all in one place.

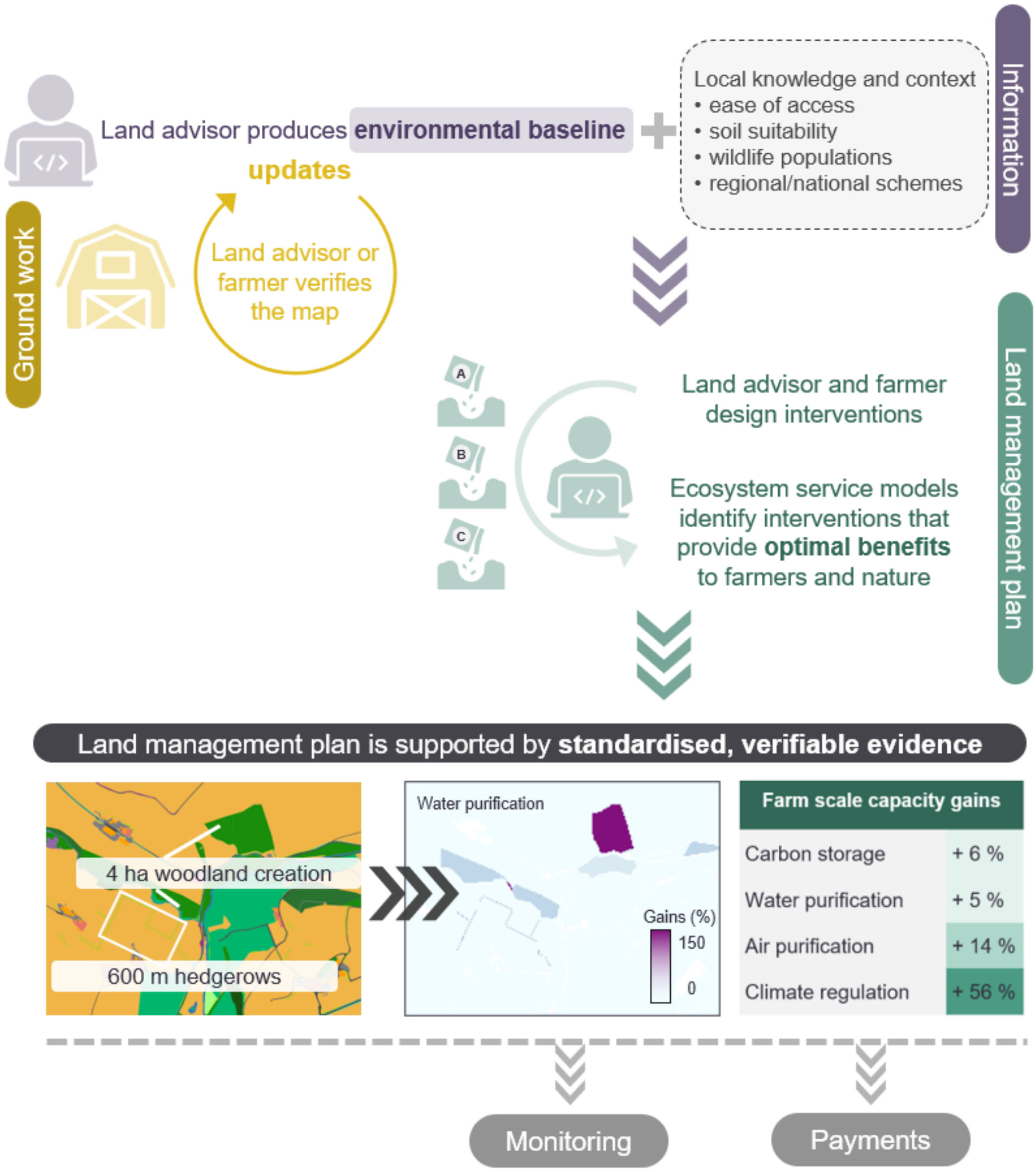

Figure 8. Proposed role of a natural capital mapping tool within a Land Management Plan workflow. The tool does not replace the need for on-farm work, but rather complements local knowledge by providing additional information, standardised nationally. Interventions can be modelled iteratively to find the scenario that delivers the largest benefits. Projected scores could be tied to payments, and monitoring could be conducted to assess the actual delivery against projected gains modelled by the tool. *Contains OS data © Crown copyright and database right 2020*.

3. What are the benefits and limitations of the tool for developing whole-farm plans, as perceived by farmers?

While we were concerned that the outputs and the overall mapping process might sound complicated to farmers, they readily understood the environmental baseline, quickly learned to make a distinction between natural capital assets and ecosystem services, and understood the public good score maps relatively well given that they were not given prior information or detailed explanations about the process. They did not shy away from technology and are willing to use an online platform to design their land management plan – but would probably require help from a trusted advisor to do so. They thought the score maps produced by the tool were useful but not enough in themselves to make management decisions, and were more interested in how these scores might tie in with payments.

Additional answers to programme-level questions

Land management plans

- *What types of information, knowledge or skills have been applied to develop an LMP?*

The environmental baseline produced by EcoservR uses a range of nationally available datasets, which are mostly free but need to be sourced separately to the toolkit by the user.

The strategic land management plan for the farm group was developed using the habitat baseline produced by EcoservR and the expertise of a local land advisor. The advisor had the necessary GIS skills to draw interventions to be integrated into the “masterplan” map, although we acknowledge that IT skills vary considerably among land advisors. For simpler interventions (that do not change the boundaries of a parcel), manual editing of a polygon’s attributes is a straightforward way to create the masterplan. Our demo app (**Appendix 5**) lets the user do this interactively from a web browser. We only received feedback from one farmer on this, who indicated that help from an advisor would be necessary to generate a land management plan in that way. A trained advisor would probably be best placed to ensure that a public good assessment is done correctly and transparently.

- *What tools and mechanisms are used to produce LMPs (e.g. data format, stakeholders involved)?*

We used a range of national geospatial data layers (vector and raster data) to produce the environmental baseline, which was then used as the canvas for the LMP. Were it not for COVID-19 restrictions, we would have used the map as a communication tool between the land advisor and farmers to develop interventions collaboratively. Instead, interventions were planned strategically by using the environmental baseline and the Cheshire Wildlife Trust’s extensive knowledge of the area to identify opportunities. The interventions were mapped as a separate vector layer and then merged into the baseline map to reflect the simulated changes.

The semi-automated workflows of EcoservR could help an experienced user (such as a trained advisor) produce detailed and informative maps rapidly and reproducibly. Habitats could then be verified by the advisor or the farmers themselves, making the assessment an iterative and evolving process. Our demo app (**Appendix 5**) is a first step towards giving users the power to simulate their own interventions, and automating the resulting public good assessment. The app can even generate an automated report (**Appendix 6**) which could form part of a land management plan.

Spatial prioritisation

- *In what ways have T&Ts addressed synergies, competing priorities and conflicts in needs at a local scale?*

The baseline provides information on the spatial distribution and extent of habitats and the services flowing from them. Combined with local knowledge, interventions can be designed optimally to consider:

Opportunities, such as protecting habitats for known sensitive wildlife, or connecting to regional or national schemes like Nature Recovery Networks, the B-Lines pollinator network, etc.

Constraints, as arising from the existing condition of the land or practical reasons (e.g. access)

We generated score maps for seven different ecosystem services, allowing to identify conflicts (trade-offs) or multiple benefits arising from a given set of interventions. For instance, woodland creation is generally associated with high scores in most services, but can decrease pollination capacity if a pollinator habitat such as a flower-rich meadow is replaced by woodland. These multiple benefits and trade-offs can be examined alongside complementary evidence to make a decision that also considers suitability (e.g. by using the E-Planner tool) and/or aligns with regional or national priorities (e.g. by consulting the Natural Capital Atlases). Ultimately, from comments received during our interviews, it is likely that farmers will opt for the most lucrative intervention for their farm. Payment rates might therefore need to take into account which local and regional environmental outcomes are most desirable, to incentivize farmers to choose the most beneficial interventions for them and for nature.

It also became clear from our interviews that achieving high ecosystem scores will not be a priority to farmers if it appears to conflict with the farm business and food production. We discussed win-win strategies with land advisors: these are interventions that can benefit both food production and ecosystem services. For instance, hedgerows not only deliver a number of public goods (air purification, biodiversity, carbon storage) but can also provide shelter to livestock and host wildlife that provides natural pest control for crops. More research on these win-win scenarios could help the ELM scheme offer a menu of interventions that deliver multiple benefits and are complementary to the core farm business.

Collaboration

- How, if at all, have tools and mechanisms supported collaboration?

Because of COVID-19, we ended up designing one strategic, catchment-wide management plan rather than individual farm plans. This made us realise that designing interventions with the wider landscape in mind can affect farms differently: some farms were not assigned any interventions and others received several. Meaningful environmental outcomes are more likely to be achieved by fostering collaboration and action over large areas (POST PN627 2020), but doing so raises more questions about how farmers can share the responsibility and costs of these interventions, and make sure that farms that are not identified as a strategic asset for a collaboration are still offered opportunities and funding for other outcomes.

Innovative delivery solutions

- To what extent have T&Ts identified and used innovative tools and mechanisms (e.g. apps) to contribute to the development of LMPs and delivery of anticipated outcomes?

We developed EcoservR as a more efficient, accessible, and, in the long run, user-friendly software than Ecoserv-GIS. The tool is meant to support other applications beyond ELM, some of which require more advanced programming skills. However, for the sole purpose of generating an environmental baseline and a public good assessment, our models could easily integrate within a wider portal (e.g. a web app, see demo in **Appendix 5**) supporting ELM. If farmers or land advisors had the capacity to access and modify their farm plans online, new assessments and projected changes could be produced seamlessly, and ideally linked to available payments.

Additional learning and recommendations

For the ELM scheme to succeed, the underpinning methods and tools must be easy to use. Farmers and land advisors found that EcoservR has potential to inform land management plans under ELM. EcoservR's outputs are both visual (maps) and quantifiable in a standardised way that could make measuring public goods country-wide very robust. However, EcoservR is still a tool in development, and there are a few key limitations that we are hoping to address in the near future. Our work within and outside this test and trial in the last nine months has also helped us identify wider applications and avenues for future development, including collaborations that could benefit ELM.

Applications outside ELM

The EcoservR tool can be applied not only to measure projected gains from agri-environmental interventions, but can also inform urban developments and greenspace strategies. For instance, the tool has been used to measure environmental net gain/loss from planned developments in the Liverpool City Region (Busdieker et al. 2020). A translation to UKHab habitat classification is in preparation for the next release of the tool, and should help the tool fit in coherently with existing approaches such as biodiversity net gain assessments.

Recommendations for future work

Consider habitat condition and time lags

Aspects of land management such as grazing density, inputs used (fertilisers, pesticides), tillage system, etc. can impact the services (e.g. biodiversity, carbon storage, water quality and flow) delivered by a farm. The current toolkit cannot consider this information at the moment, but we are planning on adding management and condition attributes to fine-tune model outputs and give a more accurate picture of services delivered at farm scale.

Additionally, the toolkit assigns scores to habitats under the assumption that they are an optimal example of the type. In the case of long-term interventions such as woodland planting, this means that the scores reflect the projected end gains (of a woodland at maturity) rather than immediate gains. This is not necessarily a limitation: land advisors, and other practitioners working in urban developments, have reflected that with other tools such as the Eco-metric, planting trees is not an attractive option as the time to reach maturity has a negative impact on the score. It is however an important question that needs to be clarified if more ambitious schemes are to get uptake.

Test the tool more widely

Our case study considered upland farms in Cheshire where the land is not farmed very intensively. Given that EcoservR uses national datasets as inputs, outputs are theoretically directly comparable, and it would be highly interesting to contrast public good assessments from a range of farms with different habitats and management types around the country (especially when the above considerations on habitat condition have been taken into account). Additionally, we are hoping to build UK-wide capacity by adding alternative workflows for Scottish and Welsh datasets.

Integrate EcoservR models within an online ELM portal

We would like to see our models embedded within a “one-stop-shop” portal that would make it easy for farmers to view their land holdings, add or edit information, generate a public good assessment, and preview eligible payments. Our demo app is an example of how this might work (**Appendix 5**).

The Land App is a platform that is used in other Tests and Trials, and which seems to be intuitive for farmers to use. It provides an environmental baseline and allow landowners to upload timestamped, georeferenced photos to validate the information or evidence the delivery of interventions. It also gives a projection of currently available payments (e.g. Countryside Stewardship) for these interventions. However, it does not currently link natural capital assets to the services they provide, which a major missing link in the new ELM context. We have initiated discussions to use our Ecoserv approach within the Land App to generate ecosystem service scores, which could then be converted to payment rates – the main aspect that interested the farmers we interviewed. We recommend that Defra explore possibilities for merging some of the most successful features of individual T&Ts to provide farmers with the most seamless land management planning platform possible.

Simplify data governance and encourage open access

Practitioners in the environmental sector prefer using a free tool with free and/or readily accessible data inputs (Howard et al. 2016). Ecoserv-GIS focused on using as much open data as possible, and we have continued that trend, for instance by favouring CORINE land cover data over the CEH Land Cover Map, and incorporating new free datasets such as the Crop Map of England. The data layers used by EcoservR are therefore almost all free and available to download online, but sourcing this amount of data from several different sources (**Table 1**) is a time-consuming task (likely 1-2 working days), and not necessarily easy for someone with no or basic GIS skills. If the EcoservR or a similar spatial approach was selected to power the ELM land management plan workflow, we recommend that all required data be made available to farmers and advisors from a central location, where they could be queried spatially (e.g. by the outline of the farm) to optimise time and data management. Given the importance of hedgerows in agri-environmental schemes, we also recommend that the national hedgerow dataset compiled by OS for the Rural Payments Agency be made available, for instance under the Public Sector Geospatial Agreement.

Concluding remarks

The Ecoserv approach has a proven track record in supporting ecosystem service assessments, for instance in the Liverpool City Region and in Cheshire. This Test and Trial demonstrated that EcoservR can generate maps of natural capital assets and public good assessments at farm- to catchment scale. Farmers and land advisors saw the potential for EcoservR to be used regionally and even nationally as a standardised, evidence-based tool to support the delivery of the ELM scheme. We look forward to continuing the development of the tool, notably by incorporating habitat condition and farm management to refine the quantification of ecosystem services. Ultimately, a land management plan should be flexible enough to recognise the local context of a farm business, but also robust enough to enable fair payments across the country. EcoservR could provide key information to support claims in this respect, and its multi-scale approach may help identify opportunities for collaboration in the wider landscape to deliver more impactful interventions.

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Appendix 1. Habitat codes used by EcoservR

The habitat codes were developed for the original Ecoserv-GIS toolkit and are adapted from Phase 1 habitat codes. Our team is currently exploring a conversion to the UKHab classification system.

Habitat type	EcoservR code	Description
Woodland and scrub	A1	Woodland
	A11	Woodland, Broadleaved
	A11/A2	Woodland, Broadleaved, with scrub
	A111	Woodland, Broadleaved, Semi-natural
	A111/A2	Woodland, Broadleaved, Semi-natural/ with scrub
	A112	Woodland, Broadleaved, Plantation
	A112/A2	Woodland, Broadleaved, Plantation/ with scrub
	A11-O	Woodland, Broadleaved, Plantation, (orchard)
	A112o_T	Woodland, Broadleaved, Plantation, (orchard), Traditional
	A112o	Woodland, Broadleaved, Plantation, (orchard)
	A12	Woodland, Coniferous
	A12/A2	Woodland, Coniferous / with scrub
	A121	Woodland, Coniferous, Semi-natural
	A121/A2	Woodland, Coniferous, Semi-natural / with scrub
	A122	Woodland, Coniferous, Plantation
	A122/A2	Woodland, Coniferous, Plantation/ with scrub
	A13	Woodland, Mixed
	A13/A2	Woodland, Mixed / with scrub
	A131	Woodland, Mixed, Semi-natural
	A131/A2	Woodland, Mixed, Semi-natural/ with scrub
	A132	Woodland, Mixed, Plantation
	A132/A2	Woodland, Mixed, Plantation/ with scrub
	A2	Scrub
	A21	Scrub, Dense/continuous,
	A22	Scrub, Scattered
	A2m	Scrub, (mountain)
	A3	Parkland/scattered trees
	A31	Parkland/scattered trees, Broadleaved
	A31/A2	Parkland/scattered trees, Broadleaved / with scrub
	A32	Parkland/scattered trees, Coniferous
	A32/A2	Parkland/scattered trees, Coniferous / with scrub
	A33	Parkland/scattered trees, Mixed
	A33/A2	Parkland/scattered trees, Mixed / with scrub
	A41	Recently felled, Broadleaved
	A42	Recently felled, Coniferous
	A43	Recently felled, Mixed
	J14	Cultivated/disturbed land, Introduced shrub
Grassland and marsh	B/C31	Grassland / with Tall ruderal (rail verge)
	B11	Grassland, Acid, Unimproved
	B11a	Grassland, Acid, Unimproved
	B11m	Grassland, Acid, Unimproved (moorland)
	B12	Grassland, Acid, Semi-improved
	B21	Grassland, Neutral, Unimproved
	B22	Grassland, Neutral, Semi-improved

	B31	Grassland, Calcareous, Unimproved
	B32	Grassland, Calcareous, Semi-improved
	B4	Grassland, Improved
	B4/Bu	Pastures
	B4f	Grassland, Improved, (floodplain/grazing marsh)
	B4Urb	Grassland, Improved, [urban]
	B5	Grassland, Marshy
	B5/B(u)	Grassland, Marshy / or Grassland
	B5/E3/F	Grassland, Marshy /Fen/Swamp/Saltmarsh
	B5/E3/F/H2	Grassland, Marshy /Fen/Swamp/Saltmarsh
	B5/E3/F/H2_Bu	Grassland, Marshy /Fen/Swamp/Saltmarsh and Rough grassland
	B6	Grassland, Poor, Semi-improved
	B6/J3	Grassland, Poor, Semi-improved/Ephemeral/short perennial
	B6/J3Urb	Grassland, Poor, Semi-improved/Ephemeral/short perennial[urban]
	Bu	Grassland, rough (probable semi-improved)
	Bu/A11(A2)	Grassland with broadleaved trees or scrub
	Bu/A112	Grassland with broadleaved woodland
	Bu/A12	Grassland with coniferous trees
	Bu/A122	Grassland with coniferous woodland
	Bu_A1/A2	Grassland with woodland or scrub
	Bu_A11	Grassland with broadleaved trees
	Bu_A11/A2	Grassland with broadleaved trees or scrub
	Bu_A112	Grassland with broadleaved woodland
	Bu_A12	Grassland with coniferous trees
	Bu_A2/A3	Grassland with scrub trees
	Bu_A2/A31	Grassland with scrub trees
	Bu_A31	Grassland with scrub trees
	Bu_A32	Grassland with scrub trees
	Bu_Au	Grassland with wood, scrub or trees
	Bu1	Grassland, Unimproved
	Bu1/A11(A2)	Grassland, Unimproved with broadleaved trees or scrub
	Bu1/A11,A2	Grassland, Unimproved with broadleaved trees or scrub
	Bu1/A112	Grassland, Unimproved with broadleaved woodland
	Bu1/A12	Grassland, Unimproved with coniferous trees
	Bu1/A122	Grassland, Unimproved with coniferous woodland
	Bu1/A2	Grassland, Unimproved with scrub
	Bu1/A2,A3	Grassland, Unimproved with scrub, trees
	Bu1/Bu2	Grassland, (semi-improved or unimproved) (rough grassland)
	Bu1/Bu2Urb	Grassland, (semi-improved or unimproved) (rough grassland)[urban]
	Bu2	Grassland, semi-improved (good quality)
	Bui	Grassland, (probably improved)
	BuiUrb	Grassland, (probably improved)[urban]
	Buu	Grassland, [urban]
	Buu/C31	Grassland with tall ruderal (rail verge)[urban]
Cultivated / disturbed land	B4/J11	Grassland, Improved /arable (probable)
	B4/J11Urb	Grassland, Improved /arable (probable)[urban]
	J11	Cultivated/disturbed land, Arable
	J11a	Cultivated/disturbed land, Arable
	J11/Bu	Land principally occupied by agriculture
	J11t	Cultivated/disturbed land, Arable, (Allotments)
	J12	Cultivated/disturbed land, Amenity grassland

	J12Urb	Cultivated/disturbed land, Amenity grassland, [urban]
	J12v	Cultivated/disturbed land, Amenity grassland, (road verge)
	J13	Cultivated/disturbed land, Ephemeral/short perennial
	J13Urb	Cultivated/disturbed land, Ephemeral/short perennial, [urban]
	J1u	Cultivated/disturbed land
	J1uUrb	Cultivated/disturbed land, [urban]
Heathland and Mire	D	Heath
	D/E	Heath or Mire
	D/E/Bu/I	Sparsely vegetated areas
	D/I	Dry dwarf shrub heath with Natural rock
	D/I1	Dry dwarf shrub heath with Natural rock
	D_B5/E3/F/H2	Heath, marshy grassland
	D11	Dry dwarf shrub heath, Acid
	D12	Dry dwarf shrub heath, Basic
	D1u	Dry dwarf shrub heath
	D2	Wet dwarf shrub heath
	D3	Lichen/bryophyte heath
	D4	Montane heath/dwarf shrub
	D5	Mosaic: acid grassland, dry heath
	D5/Au	Mosaic: acid grassland, dry heath with Woods, Trees, Scrub
	D5/D6	Mosaic: acid grassland, (heath type unknown)
	D5_Au	Mosaic: acid grassland, dry heath / with Woods, Trees, Scrub
	D5_Bu_Au	Mosaic: acid grassland, dry heath / rough grassland with Woods, Trees, Scrub
	D5h	Mosaic: acid grassland, dry heath
	D5h_A2	Mosaic: acid grassland, dry heath with Scrub
	D6	Mosaic: acid grassland, wet heath
	Du	Heath
	E161	Bog, Sphagnum, Blanket bog
	E162	Bog, Sphagnum, Raised bog
	E17	Bog, Wet modified bog
	E18	Bog, Dry modified bog
	E1u	Bog
	E1u (Au)	Bog, with trees or scrub
	E2/E3/F1	Upland flushes, fens and swamps
	E21	Flush and spring, Acid/Neutral
	E22	Flush and spring, Basic
	E3/F1	Fen, (lowland fen)
	E31	Fen, Valley mire
	E32	Fen, Basin mire
	E33	Fen, Flood-plain mire
	E3u	Fen
	E4	Bare peat
Swamp and marginal	F1	Swamp
	Fu	Swamp/marginal/inundation
Water	G	Water (inland)
	G16	Standing water, Brackish / saline lagoons
	G1u	Standing water
	G26	Running water, Brackish / Tidal
	Gt	Tidal water
	G2u	Running water
	G3	Sea

Coastal	H11	Intertidal, Mud/sand
	H12	Intertidal, Shingles/cobbles
	H13	Intertidal, Boulders/rocks
	H1	Intertidal
	H1u	Intertidal
	H1ua	Intertidal
	H24	Saltmarsh, Scattered
	H26	Saltmarsh, Dense/continuous
	H2u	Saltmarsh, Unknown type
	H3	Shingle above high tide
	H3/H5	Shingle above high tide / Strandline vegetation
	H3/H6u	Shingle above high tide, or Sand dune
	H3/H5/H6	Sand dunes or vegetated shingle
	H4	Boulders/rocks above high tide
	H64	Sand dune, Dune slack
	H65	Sand dune, Dune grassland
	H66	Sand dune, Dune heath
	H67	Sand dune, Dune scrub
	H68	Sand dune, Open dune
	H6u	Sand dune
	H8	Maritime cliff and slope
	H81	Maritime cliff and slope, Hard cliff
	H82	Maritime cliff and slope, Soft cliff
	H84	Maritime cliff and slope, Coastal grassland
	H85	Maritime cliff and slope, Coastal heathland
Boundaries	J21	Boundaries, Intact hedge
	J22	Boundaries, Defunct hedge
	J23	Boundaries, Hedge and trees
	J24	Boundaries, Fence
	J25	Boundaries, Wall
	J26	Boundaries, Dry ditch
	J28	Boundaries, Earth bank
Gardens / Parks / Brownfield	J55	Other habitat, Probable garden/brownfield or park
	J55Urb	Other habitat, Probable garden/brownfield or park, [urban]
	J56	Other habitat, Private garden
	J56Urb	Other habitat, Private garden, [urban]
Infrastructure	J511	Other habitat, Road, Surfaced
	J512	Other habitat, Road, Unsurfaced
	J52	Other habitat, Roadside/Pavement
	J53	Other habitat, Railway
	J54	Other habitat, Path, sealed
Montane	Montane	Montane habitats
Rock, exposure and waste	I/J	Dump sites
	I1	Natural rock
	Ib	Boulders
	I11	Natural rock, Inland cliff
	I111	Natural rock, Inland cliff, Acid/neutral
	I112	Natural rock, Inland cliff, Basic
	I12	Natural rock, Scree
	I121	Natural rock, Scree, Acid/neutral
	I122	Natural rock, Scree, Basic

	I13	Natural rock, Limestone pavement
	I14b	Natural rock, Other exposure, boulders
	I14u	Natural rock, Other exposure
	I21	Artificial rock/exposure/waste, Quarry
	I22	Artificial rock/exposure/waste, Spoil
	I23	Artificial rock/exposure/waste, Mine
	I24	Artificial rock/exposure/waste, Refuse-tip
	I2u	Artificial rock/exposure/waste
Urban	J34	Built-up area, Caravan site
	J35	Built-up area, Sea wall
	J360	Built-up area, Buildings, (domestic)
	J361	Built-up area, Buildings, Business or Industry
	J362	Built-up area, Buildings, Shed/Garage/Farm building
	J363	Built-up area, Buildings, Structure
	J364	Built-up area, Buildings, Glasshouse
	J36x	Built-up area, Buildings, Glasshouse
	J36	Built-up area, Buildings
	J36u	Built-up area, Buildings
	J3x1	Built-up area, Sealed surface
	J37	Built-up area, Sealed surface
	J37/J12/J55	Discontinuous urban fabric
	J3u	Built-up area
	J4u	Bare ground
Mixed / other / uncertain	C11	Bracken, Continuous
	C12	Bracken, Scattered
	C31	Other, Tall ruderal
	C32	Other, Non-ruderal
	C3u	Other
	Au_SN	Woods/Trees/Scrub, with semi-natural habitats
	J4	Bare ground
	Linear	Linear habitats
	Unclassified	Unclassified
	Unclassified, not greenspace	Unclassified
	Unclassified, in development	Unclassified

Appendix 2. Agenda for workshop with land advisors

The workshop took place on the 25th of March 2020. The workshop was originally meant to be in-person and include a demonstration of the tool with interactive, participatory mapping from the advisors, but was converted to an online discussion / focus group because of COVID-19.

Agenda

10:00 Introductions

10:10 Overview of work in the Dane River catchment (*Joe Pimblett, CWT*)

10:20 Discussion around your goals for the catchment

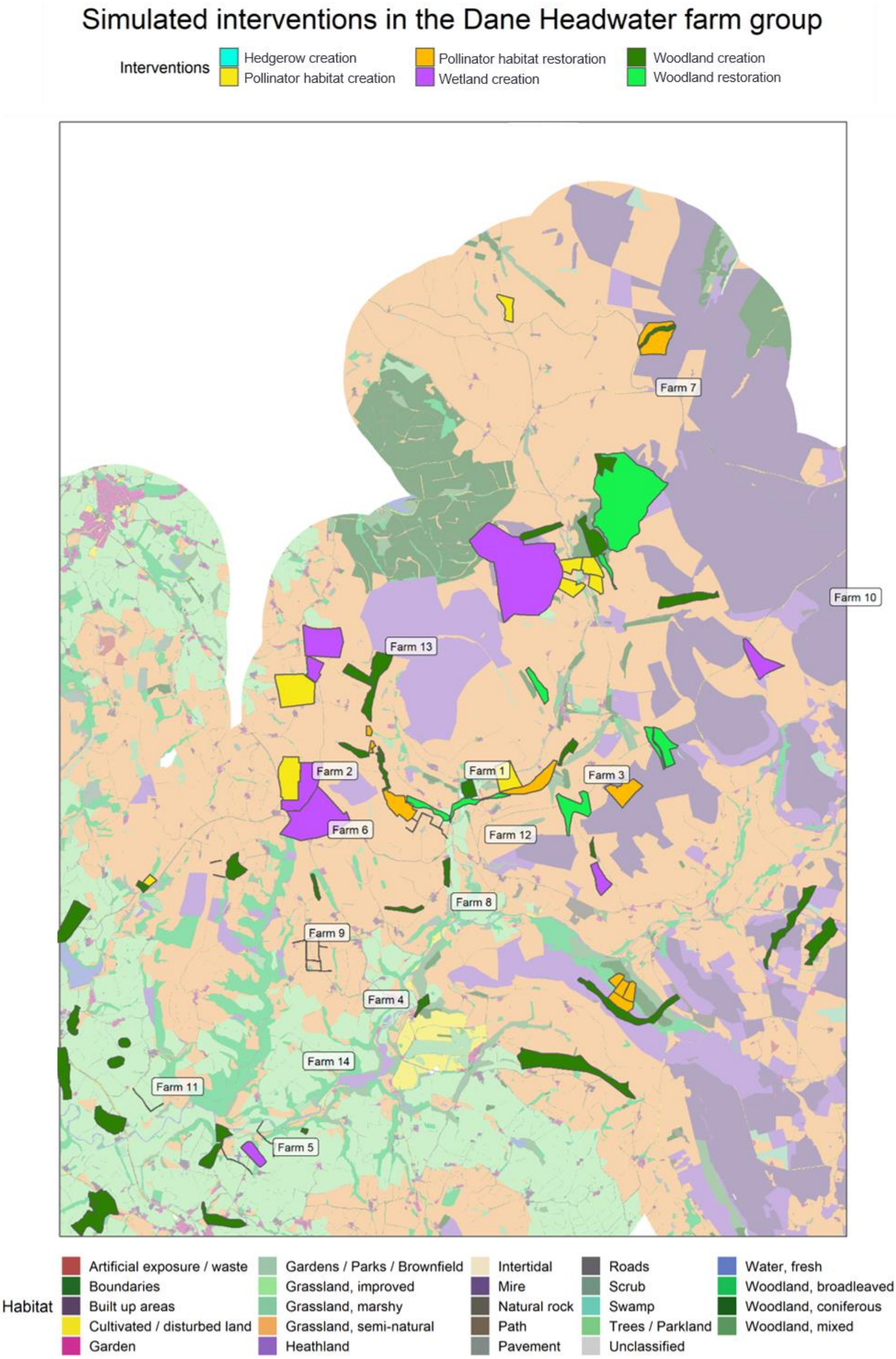
10:45 Overview of the Dane Test and Trial & demonstration (*Sandra Angers-Blondin, LJMU*)

11:00 Discussion around the natural capital mapping tool

12:30 End of meeting

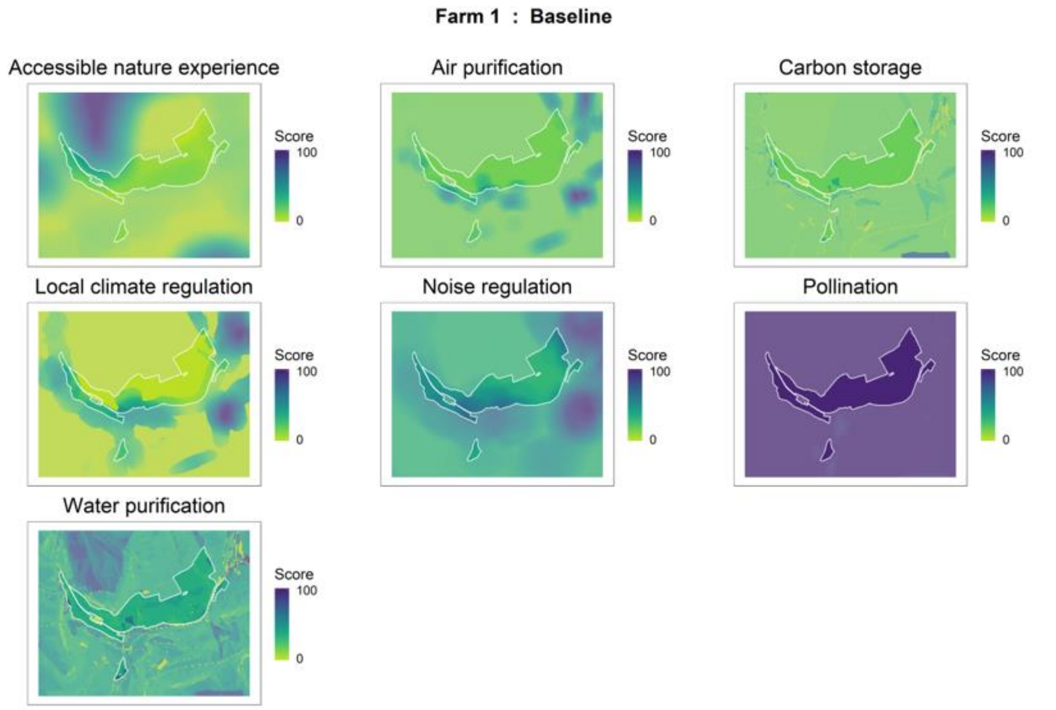
Appendix 3. Intervention map for the Dane Headwater farm group

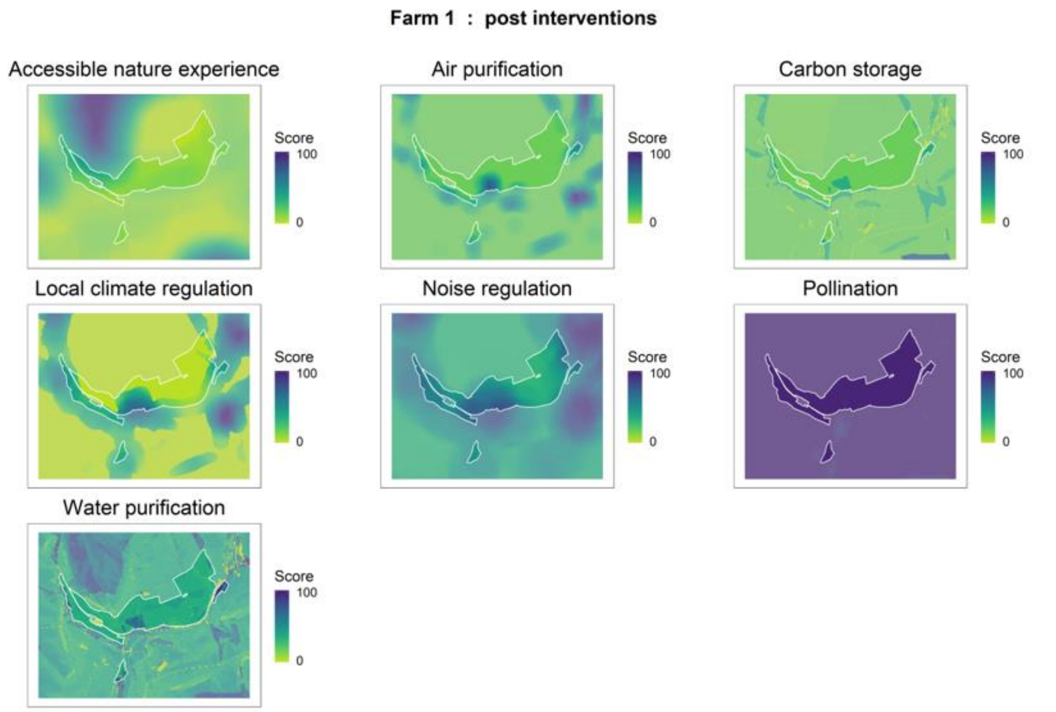
A set of fictional strategic interventions (saturated colours) were designed for the upper Dane catchment around 14 farms partaking in the Facilitation Fund led by the Cheshire Wildlife Trust (labels represent the center point of each farm).

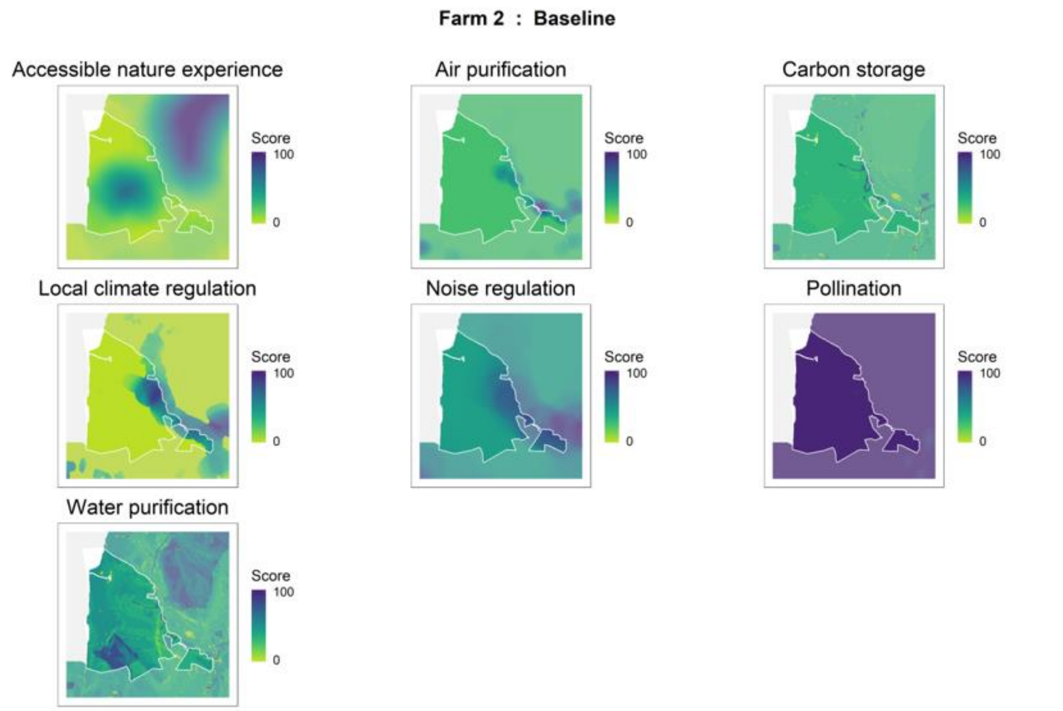


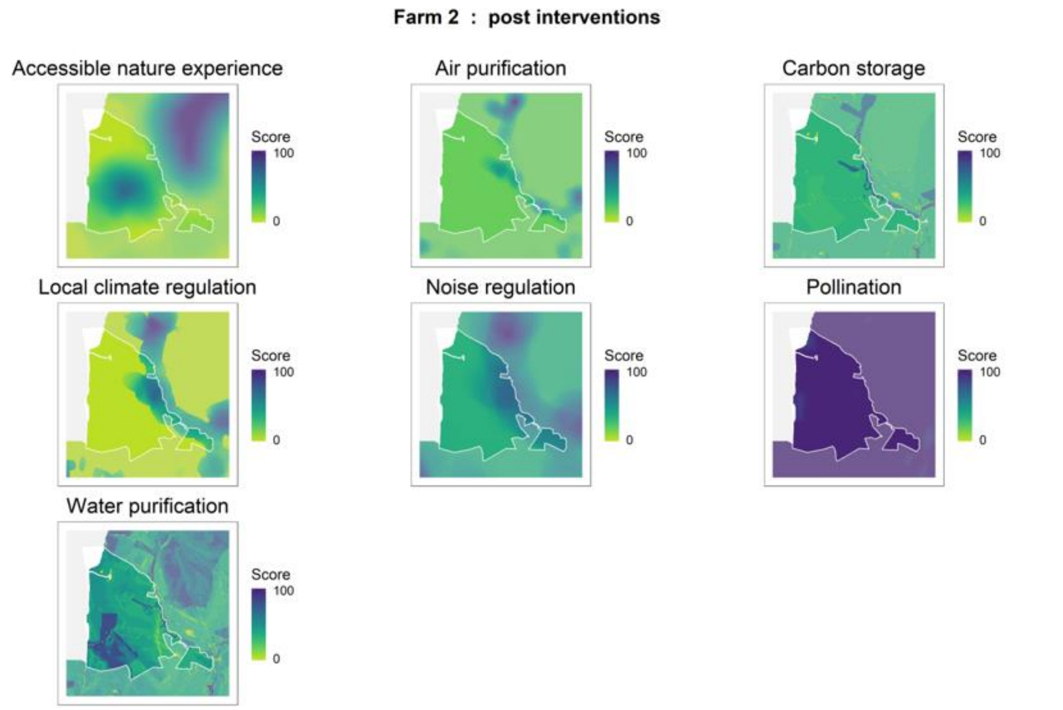
Appendix 4. Ecosystem service score maps for five farms

The seven ecosystem services measured by EcoservR before and after applying simulated agri-environmental interventions in the catchment (see Appendix 3). Maps are presented for five of the farms (white outlines) in the catchment (farms 1-5 in Tables 3 & 5). Score units are specific to each service model, but scores have been rescaled to a common range to facilitate visualisation and identification of areas that provide high benefits. A score of 100% represents the highest capacity delivered by this portion of the map (farm extent).

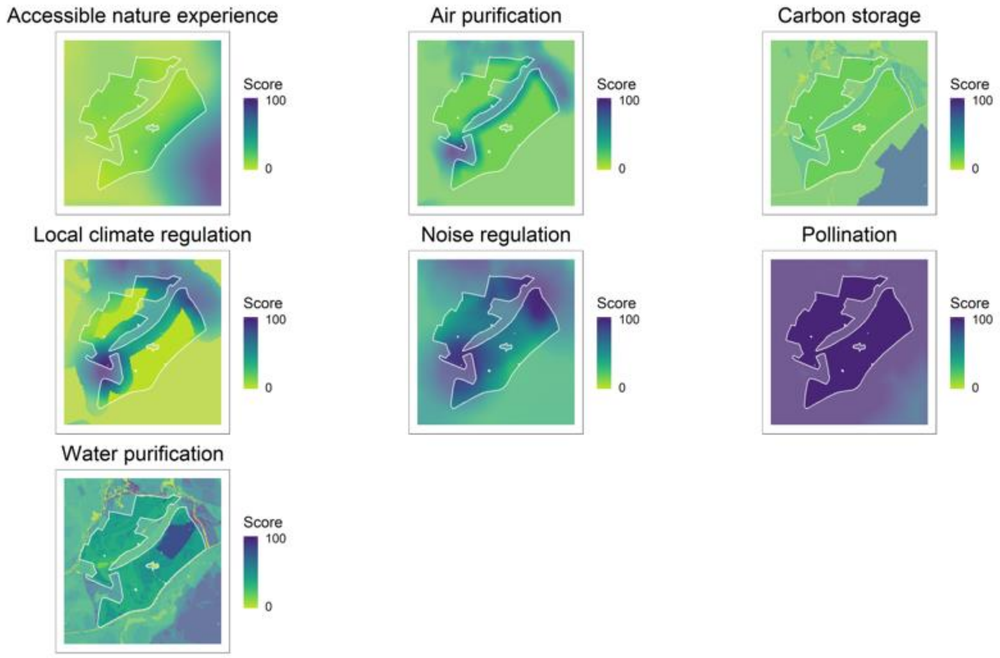




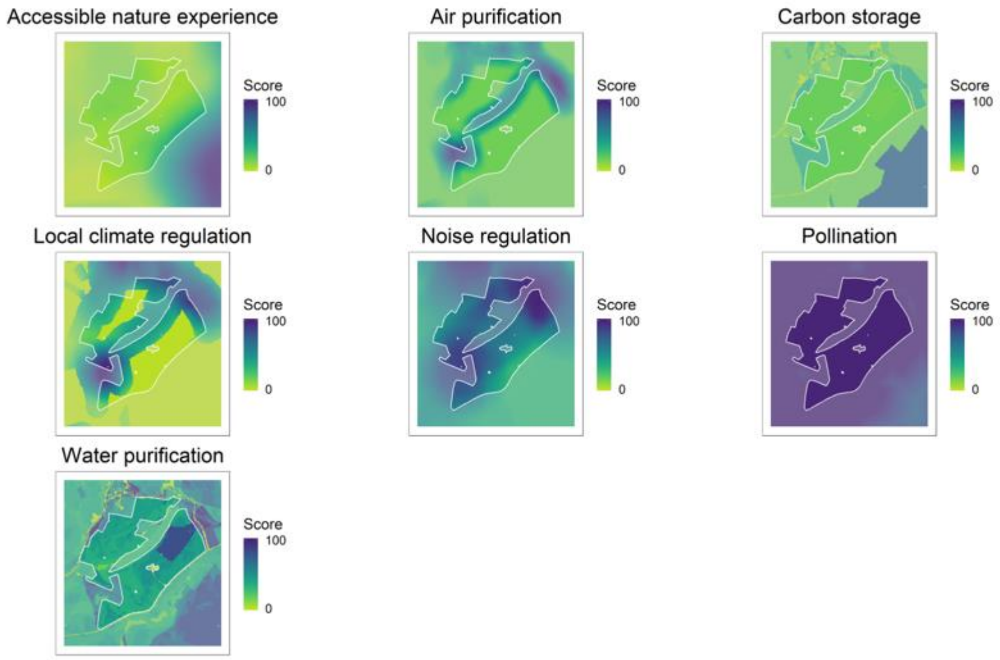

Farm 2 : Baseline
Accessible nature experience
Air purification
Carbon storage
Local climate regulation
Noise regulation
Pollination
Water purification
Score
100
0

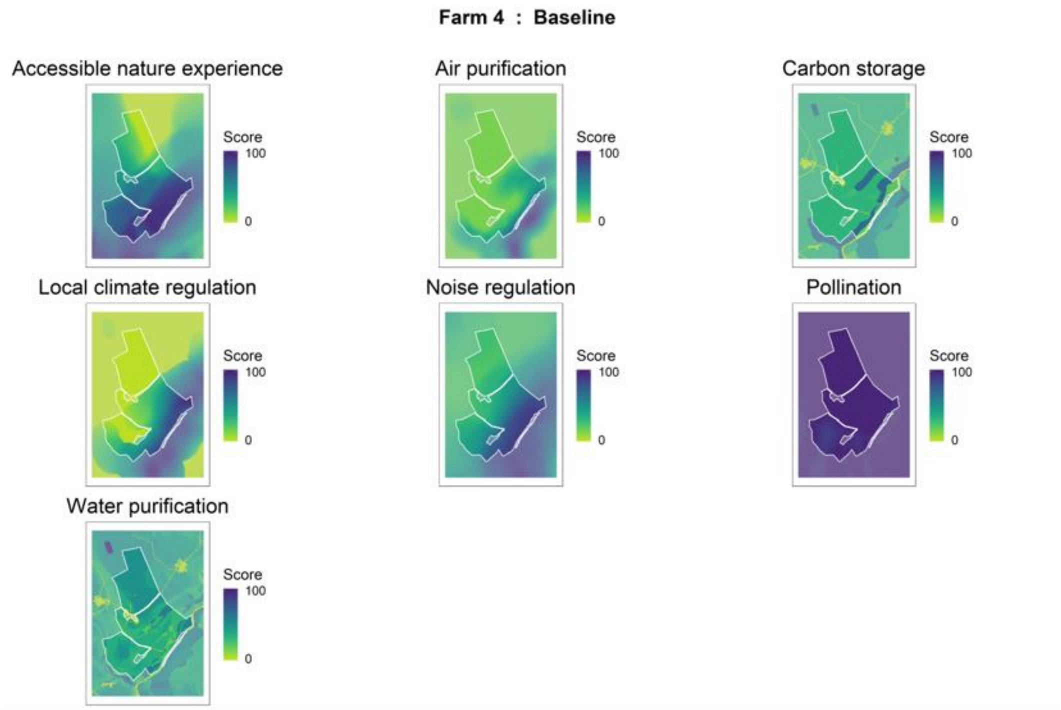

Farm 2 : post interventions
Accessible nature experience
Air purification
Carbon storage
Local climate regulation
Noise regulation
Pollination
Water purification
Score
100
0

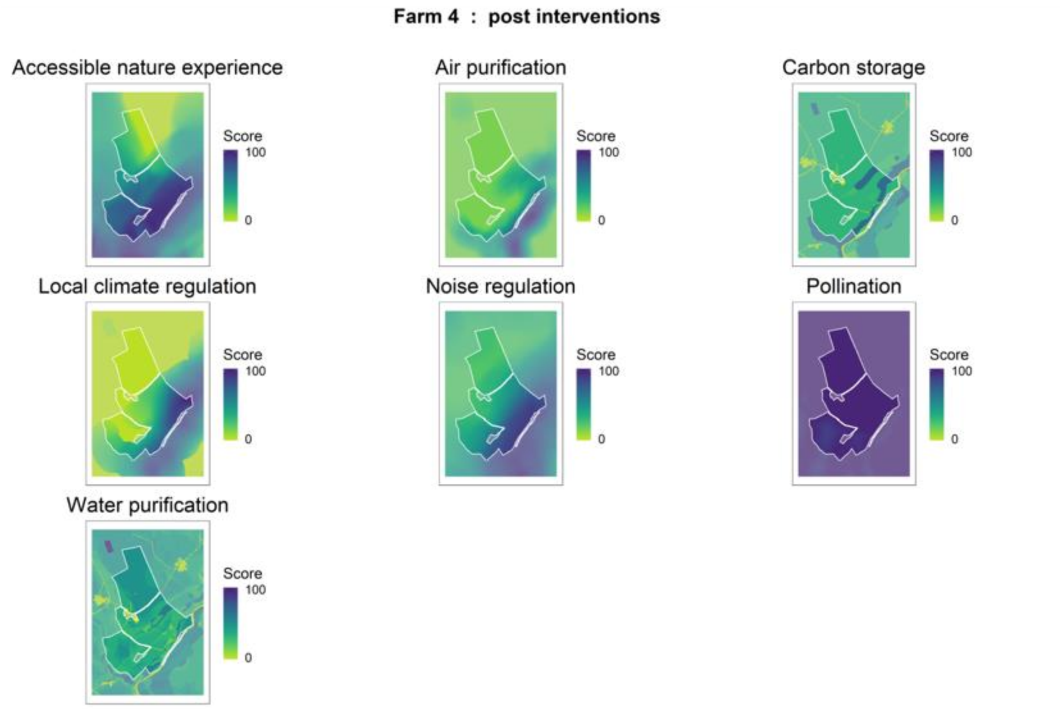
Farm 3 : Baseline

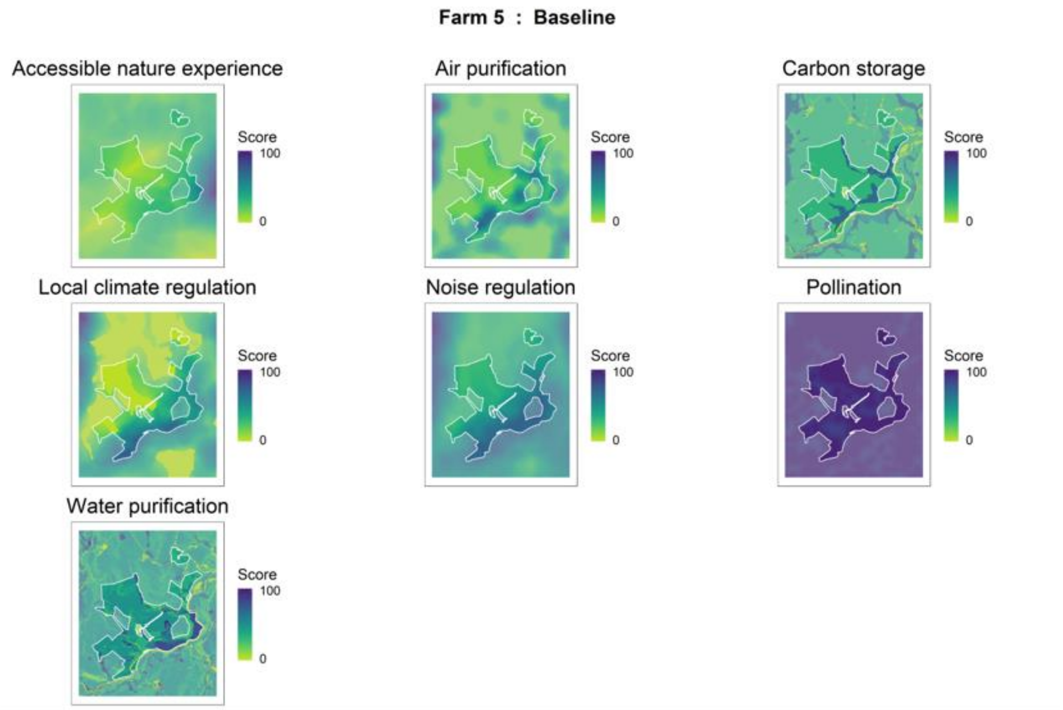


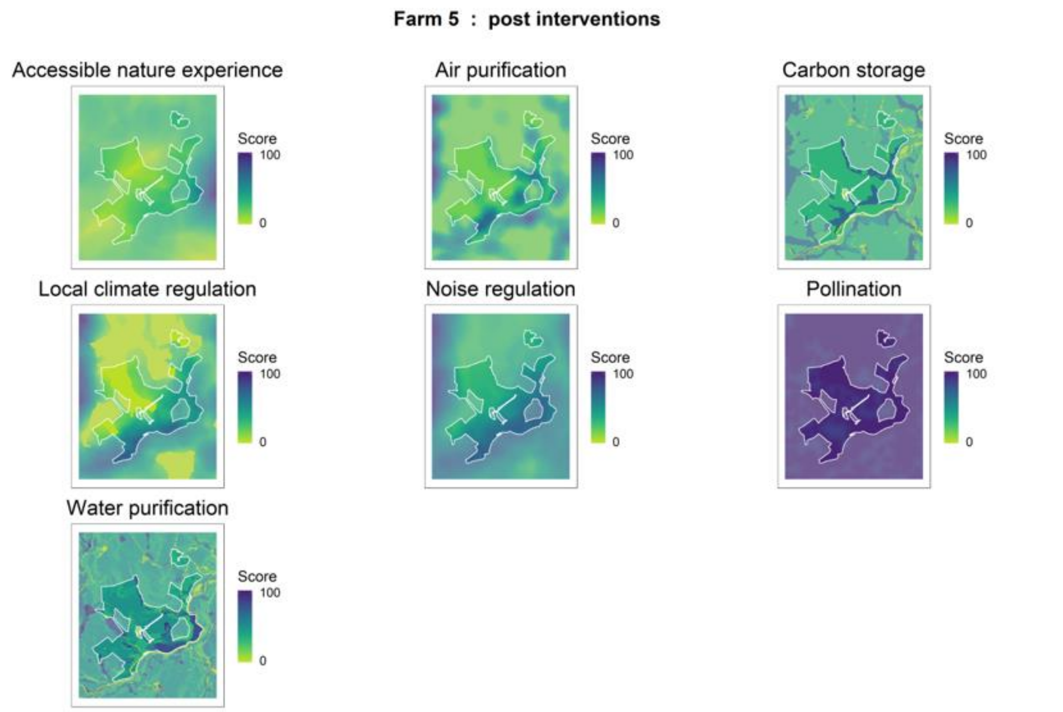
Farm 3 : post interventions




Farm 4 : Baseline
Accessible nature experience
Air purification
Carbon storage
Local climate regulation
Noise regulation
Pollination
Water purification
Score
100
0

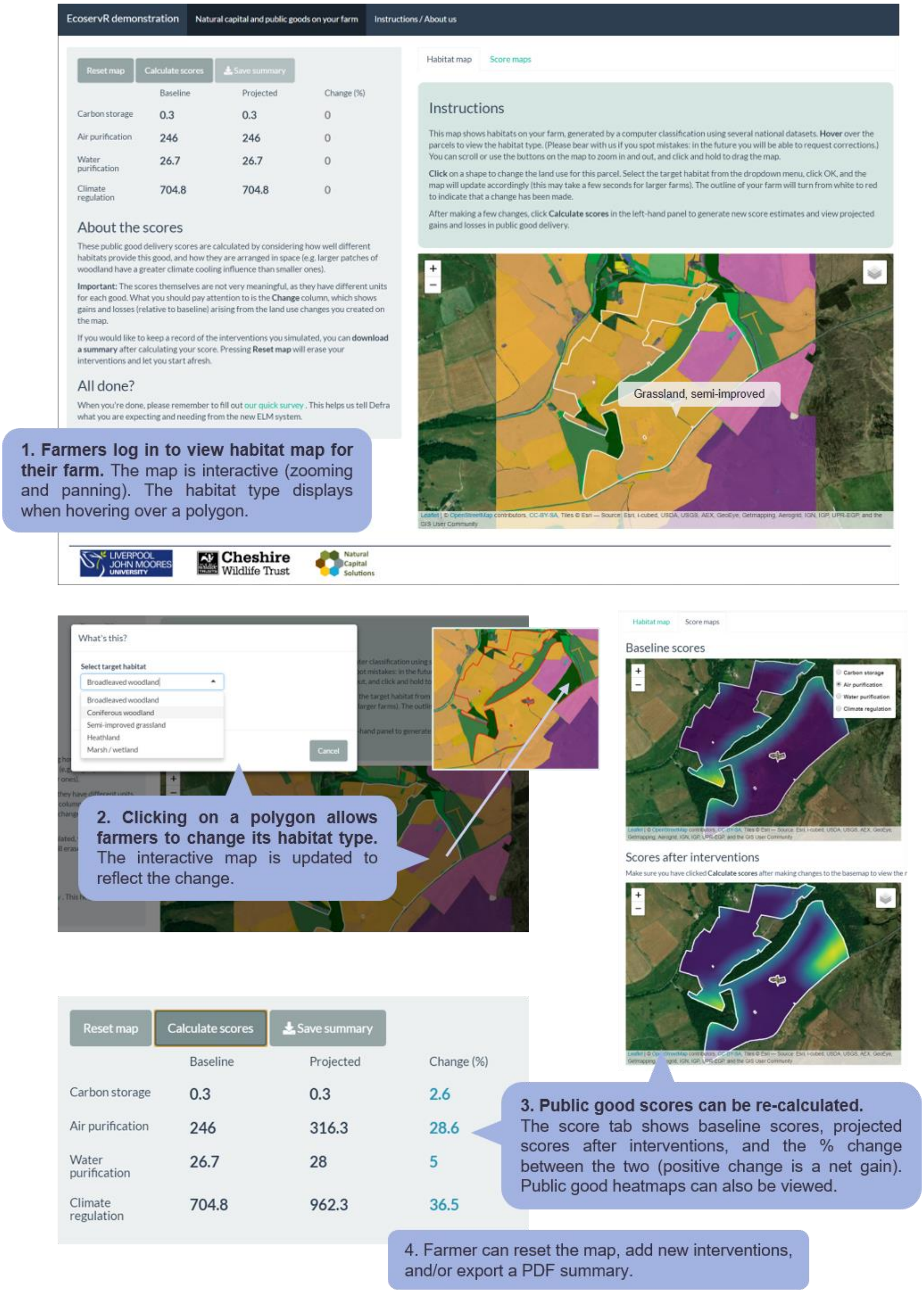

Farm 4 : post interventions
Accessible nature experience
Air purification
Carbon storage
Local climate regulation
Noise regulation
Pollination
Water purification
Score
100
0


Farm 5 : Baseline
Accessible nature experience
Score
100
0
Air purification
Score
100
0
Carbon storage
Score
100
0
Local climate regulation
Score
100
0
Noise regulation
Score
100
0
Pollination
Score
100
0
Water purification
Score
100
0


Farm 5 : post interventions
Accessible nature experience
Score
100
0
Air purification
Score
100
0
Carbon storage
Score
100
0
Local climate regulation
Score
100
0
Noise regulation
Score
100
0
Pollination
Score
100
0
Water purification
Score
100
0

Appendix 5. Interactive web app interface

We created an interactive web app as a demonstration of the EcoservR tool in the context of ELM. Farmers were invited to access a map of their farm, which can be edited by clicking on field parcels to change the habitat type (to simulate ELM-style interventions such as woodland planting). The app calculates the change in public goods arising from these interventions, potentially serving as a decision-making tool to help farmers select the most beneficial and profitable interventions. A summary report can be generated automatically (see Appendix 6) as a record of the exercise. *Contains OS data © Crown copyright and database right 2020*.



Appendix 6. Example summary report for a farm

Sample report generated automatically by the EcoservR demo app (see Appendix 5). The report contains a map of the farm highlighting the field parcels on which an intervention has been simulated, as well as a summary table reporting the original and target habitats and the size of the parcel. A public good assessment summary is also produced and could be converted to payment rates once these have been decided upon. This document could form the basis of a Land Management Plan.

LIVERPOOL JOHN MOORES UNIVERSITY

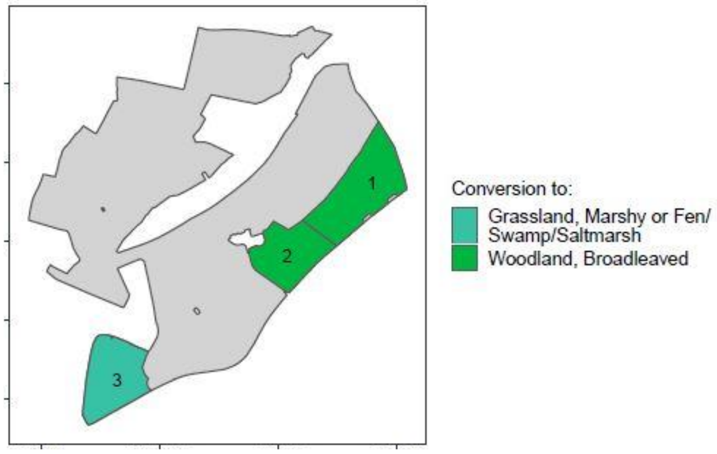
Environmental Land Management Test and Trial

Summary of simulated interventions in Ecoserv app

Liverpool John Moores University

The following is a summary of the interventions you generated for [redacted] Farm through the Ecoserv app. A map and a detailed breakdown of land use change like this could potentially form part of your land management plan and funding application under the new ELMS.

Interventions



ID	Baseline habitat	Target habitat	Area (ha)
1	Grassland, rough (probable semi-improved)	Woodland, Broadleaved	4.34
2	Grassland, semi-improved (good quality)	Woodland, Broadleaved	2.84
3	Grassland, semi-improved (good quality)	Grassland, Marshy or Fen/Swamp/Saltmarsh	3.25

Public good assessment

Public good assessment

These interventions are projected to deliver the following changes in capacity, presented as percentage change from what the baseline currently delivers. (Positive change indicates gain; negative change indicates loss.)

Public good	Capacity change (%)
Carbon storage	16.28
Air purification	37.51
Water purification	15.95
Climate regulation	62.03

Summary generated by the Ecoserv app on Thu Jan 21 17:11:07 2021

NB: These results are a projection of the potential delivery of public goods on your farm, based on the interventions you selected in the app. The Ecoserv app was developed by LJMU in the context of an ELM Test and Trial. Defra has not yet selected a method for assessing public goods, and there is no guarantee that this assessment will be valid under the new ELM system. We look forward to hearing your views on the method and any suggestions for improvement.

Appendix 7. Survey response

One participant responded to the survey after testing our web app. This is the full list of questions and the answers given.

1 It is useful to see the public good scores presented as a map

2 The maps help me understand which services are provided by the environment on my farm

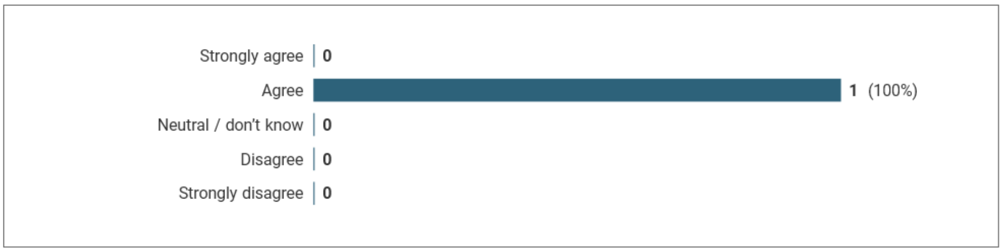
3 The score calculator could help me decide which interventions to go for

4 The score maps could help me decide where to apply my interventions

5 I would need help to use the tool to produce a public good assessment

6 This tool could facilitate collaboration with my neighbours for larger schemes if they had access to it as well

7 I can see myself using a similar tool for developing an ELM land management plan

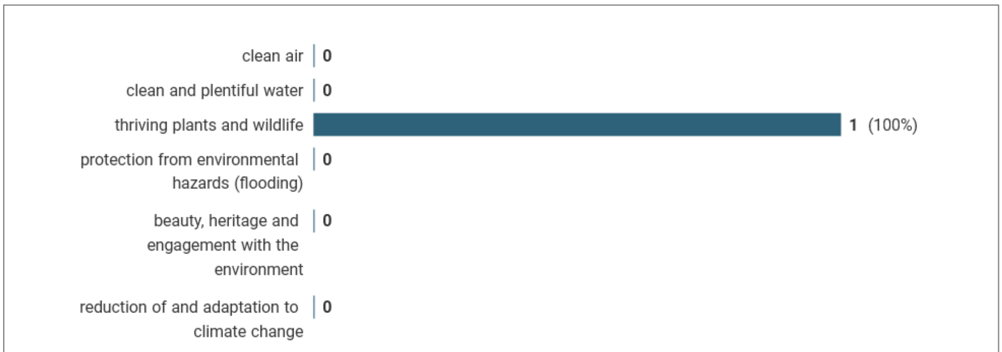


8 The score change could be used to inform a payment rate

9 Do you have any more comments about your experience using the tool? Please feel free to suggest features that would be useful to you in developing a land management plan.

No responses

10 Of the following public goods, which would you rank as highest priorities for Cheshire?



Multi answer: Percentage of respondents who selected each answer option (e.g. 100% would represent that all this question's respondents chose that option)

Appendix 7 (continued)

11 Which of these considerations will be most important to you in selecting interventions for a land management plan under the new scheme?

Multi answer: Percentage of respondents who selected each answer option (e.g. 100% would represent that all this question's respondents chose that option)

11.a If you selected Other, please specify:

No responses

12 What kind of resources, if any, would you want to use to learn more about public goods? (tick all that apply)

Multi answer: Percentage of respondents who selected each answer option (e.g. 100% would represent that all this question's respondents chose that option)

12.a If you selected Other, please specify:

No responses

13 Do you have any more comments about the new ELM system? This is a chance to express your views, and your (anonymous) feedback will be passed on to Defra.

Showing 1 response	
Payment rates need to be more competitive than they currently are so as to better incentivise a shift from current land management practices. Currently, environmental conservation does not compete financially with agriculture. The ELM scheme would benefit from assistance from local advisors.	671296-671287-70141143