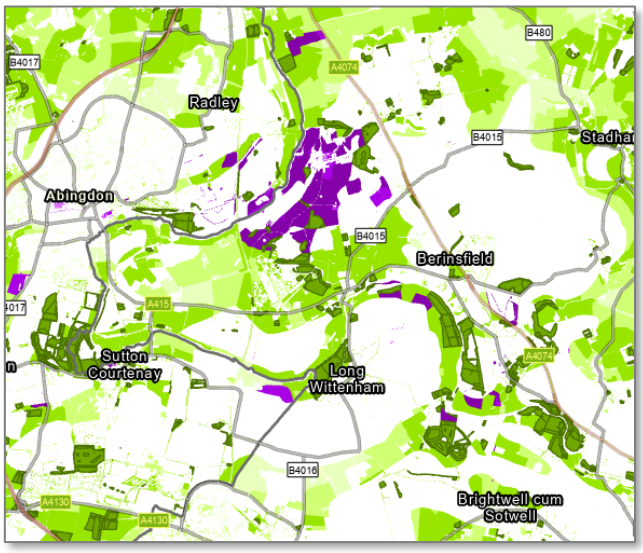
The Agile Initiative at the Oxford Martin School

Sprint 3: Scaling up Nature-based Solutions in the UK

AGILE NATURE RECOVERY AND NBS OPPORTUNITY MAPS: DESCRIPTION



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Introduction

This document describes the Agile Initiative system for generating and using maps of nature recovery and Nature-based Solution (NbS) opportunities anywhere in England. We are also working on adapting the system for use in the other UK nations.

This is one of a set of documents supporting the maps. The other documents are:

- **Agile NbS Opportunity Maps: Description (THIS DOCUMENT)**. Introduces the maps, describes how they are created and offers guidance on how they can be used and interpreted.
- **Agile NbS Opportunity Maps: User guide**. How to set up and display the maps if they are supplied ready-made as a GIS dataset for a specific area.
- **Agile NbS Opportunity Maps: Data sources.** A list of data sources used to create the maps.
- **Ground-truthing the NbS Opportunity Maps**: A guide on how to ground-truth the maps prior to using them to inform any on-the-ground interventions.
- **Creating Agile NbS Opportunity Maps: Software user guide:** How to use the python software to create your own maps anywhere in England using widely available datasets.

In addition, if you have been provided with a ready-made map for a specific area, you may have been given a set of **Release Notes** detailing issues specific to your map, such as the dataset versions used and (if applicable) changes since any previous versions.

What is the Agile Initiative?

The Agile Initiative is a five-year programme based at the Oxford Martin School which aims to respond to specific social and environmental policy questions with fast-paced solution-focused 'Sprints' that deliver demand-led new research. The NbS sprint works with policymakers and practitioners to help provide tools and guidance for tackling the challenges around scaling-up high-quality nature-based solutions in the UK. This includes mapping NbS and nature recovery opportunities, as well as guidance on governance, funding and monitoring NbS, with a map of case study examples.

What are the Agile opportunity maps?

We have developed open-source software to create maps of opportunities for Nature-based Solutions and nature recovery options for any area in England. The maps show areas which are potentially suitable for specific types of interventions, such as creating woodlands, grasslands, wetlands and ponds, and restoring peatlands, based on a series of simple rules. They are intended to encourage the siting of interventions in the most suitable locations to maximise benefits and minimise trade-offs.

The Agile opportunity maps are intended as a **decision-support tool** as part of a process of participatory engagement with stakeholders (see our separate Recipe for Engagement), and should always be used in conjunction with **ground-truthing and consultation with local experts** (see the separate ground-truthing guidance document).

The maps provide the following information:

- Habitat, based on information from OS Mastermap, Natural England's Priority Habitat Inventory, CROME crop map of England and OS Greenspace data.

- Agricultural land classification, Designations and Public accessibility
- Scores from 0 to 10 for 18 ecosystem services, and a similar score for biodiversity
- Estimates of carbon stored and sequestered per hectare (which can be used to estimate totals for the area)
- Opportunities for nature recovery and nature-based solutions: woodland & scrub, grassland, heathland and wetland creation or restoration; peatland restoration; agroforestry opportunities (silvoarable or silvopasture), community orchards, erosion prevention and natural flood management.

The maps can be used for several purposes (Figure 1). They can provide a baseline habitat map (1), then following the addition of extra data (2) they can identify areas that are currently delivering high levels of ecosystem services (3), and identify opportunities for enhancements (4). The ecosystem service scores can be exported to a spreadsheet, and this can then be used to assess the outcome of different interventions in terms of changes to ecosystem service scores, and hence benefits for people (5). This last step is not fully automated but we can provide guidance.

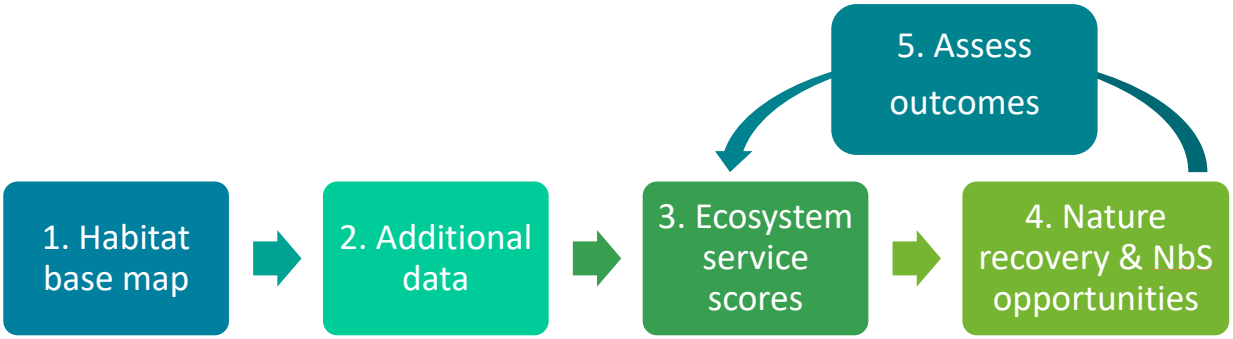

Figure 1. The Agile Opportunity Maps can be used to produce a baseline habitat map, assess baseline ecosystem service delivery, identify opportunities, and assess the benefits or trade-offs of proposed interventions.

The key features of the maps are:

1. Complete, detailed coverage with no gaps or overlaps – allows full habitat inventory and assessment of 'white space' options in areas in-between designated areas, including urban areas.
2. Matches OS Mastermap boundaries but also includes smaller habitat patches
3. Includes constraint and opportunity layers (ALC, designations, public access, flood zone, slope, soil type, peat status) all in one layer for rapid assessments
4. Shows opportunities for nature recovery (woodland & scrub, grassland, heathland, wetland, ponds, wood pasture, community orchards, agroforestry) and nature-based solutions (flood and erosion protection)
5. Open-source code can be used to generate the maps anywhere in England
6. Maps can be updated easily:
    - Download zip files from the LNRS data viewer and elsewhere to a specified directory
    - Run the python code (takes 3-4 days for a typical county)
7. Flexible – we can respond to user requests for changes and new features.

How can I get these maps?

The maps are continuing to evolve in response to user feedback, and we are currently inviting expressions of interest from partners looking to apply these maps in their local area. We can either provide maps for you to explore (there may be a waiting list for this) or we can provide you with the software to create the maps yourself. The application form for expressing your interest can be found in the Mapping section on the Agile Initiative Nature-based Solutions Knowledge Hub website. The maps and software are free to use with appropriate attribution, if you agree to provide feedback so that we can continue to improve the maps.

Licensing and software requirements

While the software to generate the maps is freely available, users will need:

- **A license to use OS Mastermap**. This is free for public sector organisations and academics. Other users can also apply for licenses for non-commercial use under specific conditions.
- Standard versions of the map use only freely available national habitat data. However if the map contains local habitat data such as from a Local Environmental Record Centre you may also need a license to use that.
- Sufficient **space on your hard drive**. A map for a whole county could be about 1 Gb.
- **A GIS package**. The data is supplied as ArcGIS Geodatabase datasets. If you need it as shapefiles please contact us. Shapefiles can be used by other GIS packages such as QGIS but they are larger, and attribute names will be truncated to 10 characters. You will also not be able to use the symbologies that we provide for the habitat legend and other attributes, as unfortunately they cannot be exported from ArcGIS to other formats.
- For creating the maps yourself, you will need **a license to use ArcGIS,** because the software is written in Python and uses many ArcPy functions. This is not required to use maps that have been generated by someone else (such as by ourselves).

Attribution

Please always display this copyright statement prominently with any output maps, whether presented online, in reports or papers, in presentations, or printed. You may need to modify this if your map includes Local Records Centre data. See the User Guide for more detail.

About the maps

Stage 1: The habitat baseline map

The habitat baseline incorporates the following datasets.

- **OS Mastermap Topography Layer**. The maps are based on OS Mastermap, a highly detailed map of the UK. This is a vector map, i.e. it contains polygons mapping the shape of fields, buildings, etc., rather than a raster map comprised of pixels. Hence the resolution is extremely precise - it shows individual buildings, roads, verges, gardens, waterbodies and field boundaries (Figure 2). It also includes a certain amount of useful habitat information, e.g. it distinguishes different combinations of coniferous, broadleaved and mixed woodlands, scattered trees, scrub, rough grassland, heath, marsh, rock and boulders. It is regularly updated by OS.

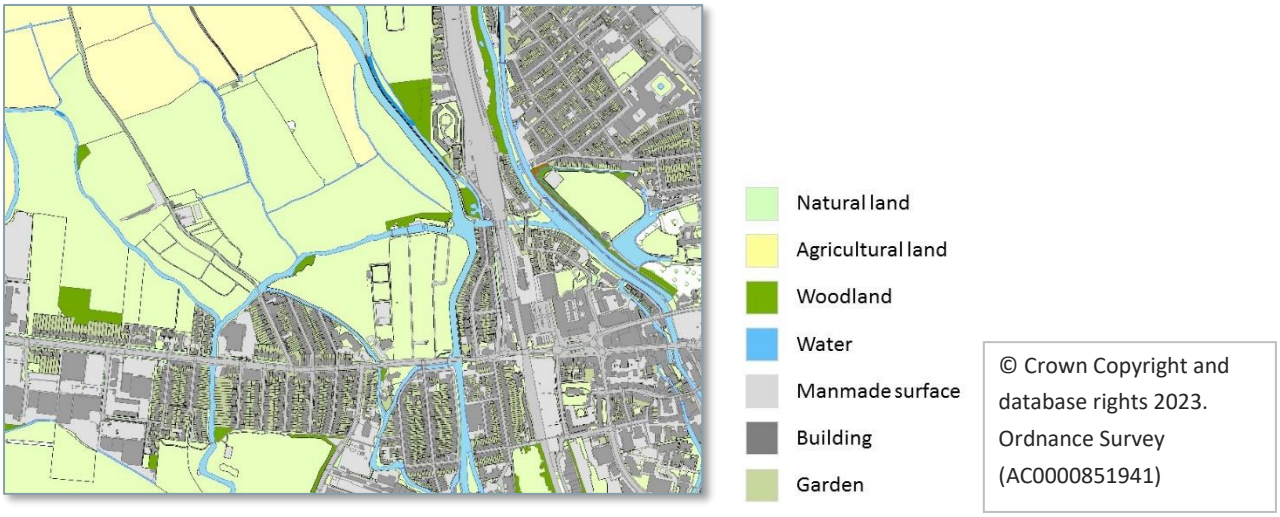

Figure 2. An extract from Ordnance Survey Mastermap, which has accurate mapping of buildings, gardens, roads, field boundaries etc plus some information on habitats

- **Habitat data**. The software merges in a choice of supplementary habitat data:
- The default option is **Natural England Priority Habitat Inventory**, freely available but quite old.
- Alternatively, **local habitat data** can be used if available, such as a Phase 1 or UK Hab survey. This may require a license, e.g. from a Local Environmental Record Centre (Figure 3).
- **The Rural Payment Agency's Crop Map of England** (CROME) is used to determine whether agricultural land is arable or improved pasture.

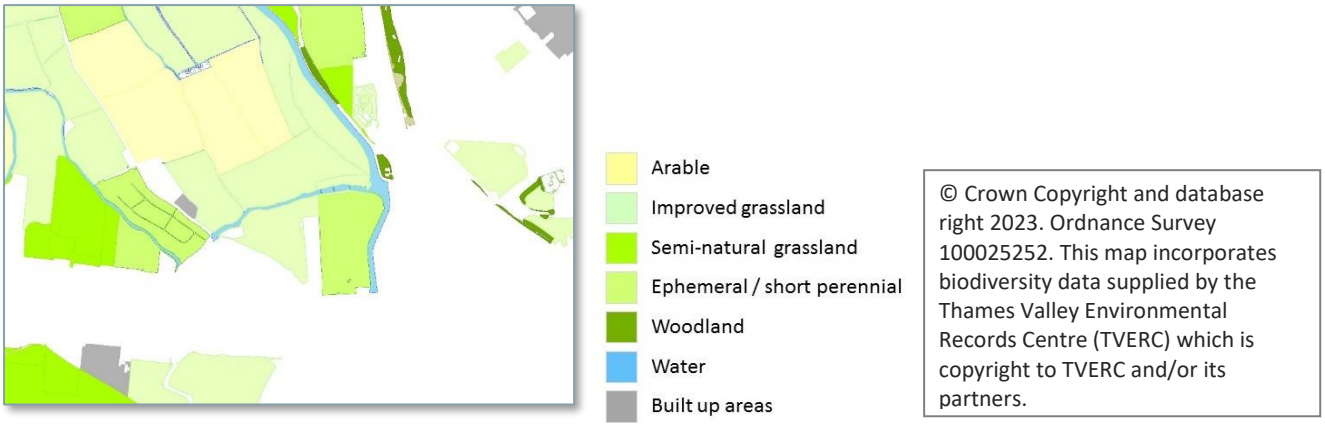

Figure 3. An extract from a local habitat dataset, showing good detail of semi-natural habitats but no data for urban areas, roads, etc.

- **OS Greenspace Data** is used to identify greenspace (allotments, playing fields, playgrounds, golf courses, cemeteries and churchyards and amenity grassland). We use both OS Open Greenspace, which covers all areas, urban and rural, and OSMM Greenspace, which only covers larger urban areas (not villages) but contains more detail (e.g. it identifies amenity grassland) (Figure 4).

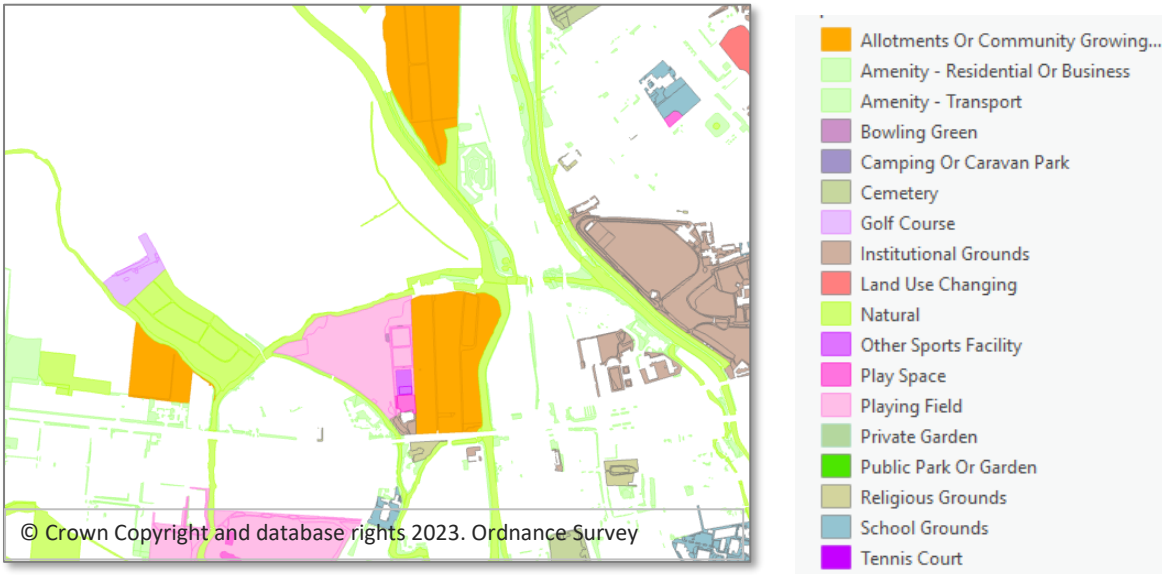

Figure 4. Extract from Ordnance Survey Green Space maps

All the datasets are merged into a single layer to form the final habitat base map, which has complete and detailed coverage of the area with no overlaps or gaps (Figure 5). One challenge when merging these datasets is that often the boundaries do not exactly match OS Mastermap boundaries. Therefore a straightforward intersect operation, when performed at county scale, creates millions of tiny extra polygons ('slivers') along the main polygon edges, where the boundaries overlap slightly, which makes the dataset unmanageable. The Agile Python software overcomes this challenge using a novel process (designed by Martin Besnier, a visiting researcher from the Université Paris Sud) that can merge 'messy' non-matching boundaries while staying faithful to the OSMM base map (Figure 6).

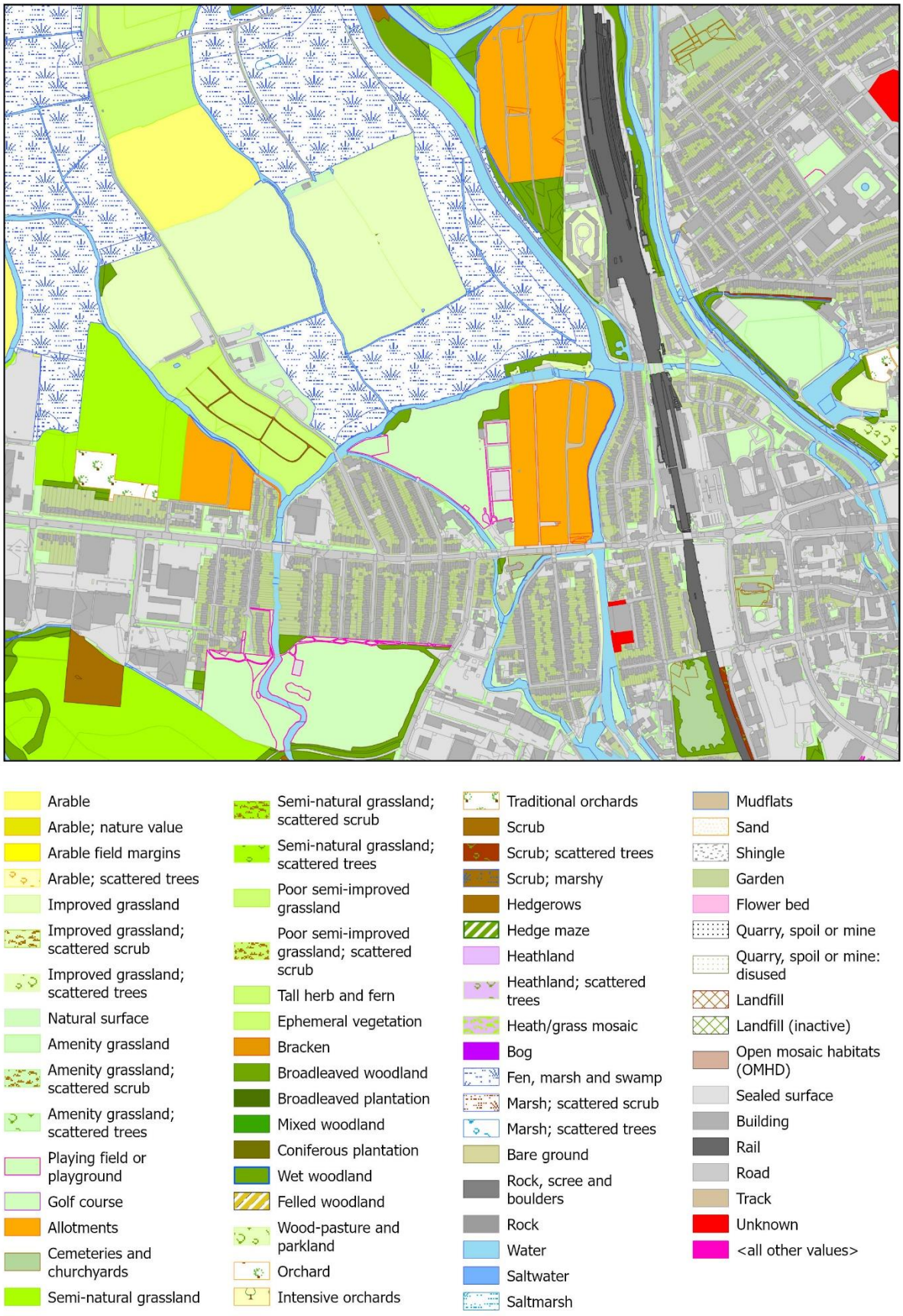

Figure 5. Extract from an Agile habitat baseline map showing complete and detailed coverage including greenspace

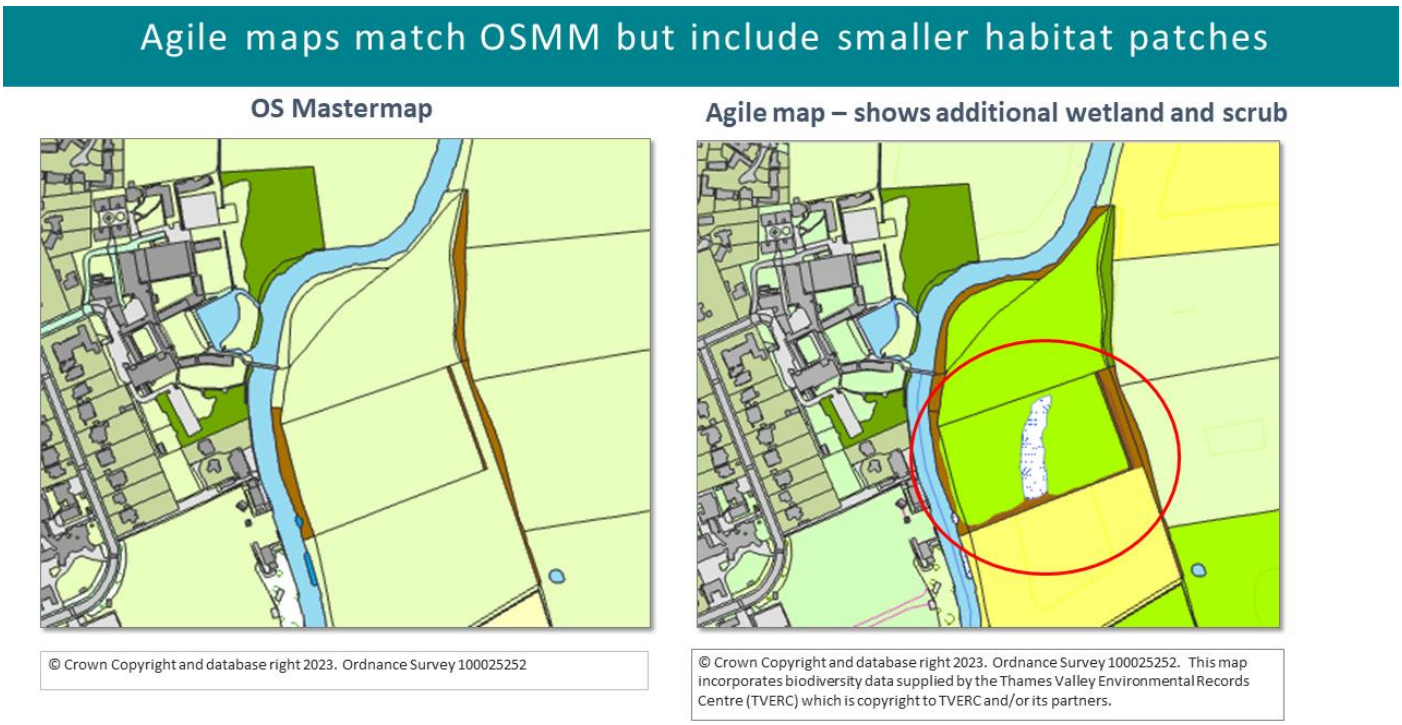

Figure 6. Agile map generation software merges messy datasets with non-matching boundaries, staying faithful to the original OS Mastermap boundaries but merging in new habitat patches where needed.

Stage 2: Adding extra data to inform ecosystem service scores and nature recovery opportunities

In order to inform the ecosystem service scores and also the constraints for the opportunity mapping, the following additional datasets are then merged in to the habitat base map.

- **Agricultural Land Class:** used to assess the capability of the land to produce food and to inform selection of nature recovery and NbS opportunities that minimise trade-offs with food production (see Stage 3).
- **Nature and cultural designations.** We aim to incorporate all the relevant designations, e.g. National Nature Reserves, Local Nature Reserves, SSSIs, Scheduled Ancient Monuments, National Trust Land, Green Belt, National Landscapes (formerly AONBs), etc. Currently we use a standard list of around 20 designations, all freely available. Users can add local datasets, e.g. Local Wildlife Sites.
- **Public accessibility** information is incorporated in order to assess the capability of the land to provide opportunities for nature-based recreation. This is based on CROW open access land, assumptions about the accessibility of certain types of greenspace, plus 50 m buffers around public footpaths. There is also an option to incorporate additional footpath and open space accessibility data from Open Street Map: this requires running some R code.

Stage 3: Estimating ecosystem service scores

We map the potential for each habitat to deliver benefits for people. This is done using a table of scores (from 0 to 10) that reflect the capability of each habitat to deliver each of 18 ecosystem services (Figure 7, Table 1). The matrix of scores is provided as a spreadsheet, for reference. The scores for some services are adjusted using multipliers to reflect Agricultural Land Class (for food production), designations (for cultural ecosystem services), and public accessibility (for recreation).

We can export a summary of the average scores per hectare for the area, and the area of high-scoring habitats. This information can also be used to explore the possible outcome of future interventions on ecosystem service delivery.

This section first describes the scores, then the multipliers, then presents important caveats to use when interpreting the ecosystem service maps.

SCORES

The scores have been developed over several years of research and testing, drawing on the following sources (a publication describing the rationale underpinning the scores is in preparation):

- A literature review of 780 papers.[1]
- A comparison exercise with similar scoring systems and other evidence sources, as part of the development of Natural England's Environmental Benefits from Nature tool (EBNT), which can be used alongside the Biodiversity Metric for assessing the ecosystem service outcomes of land-use change.
- A series of expert review consultations as part of the EBNT project.

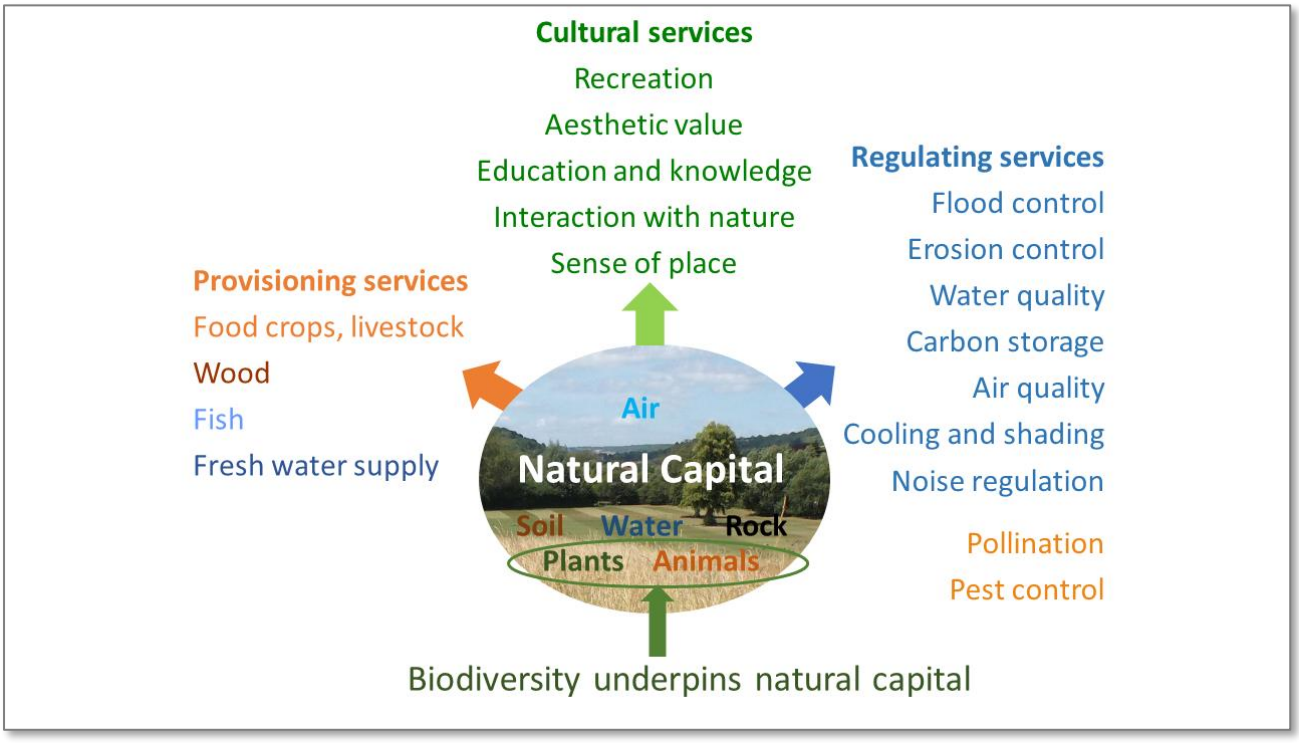

Figure 7. The 18 ecosystem services mapped by the Agile maps. These flow from natural capital and are all underpinned by biodiversity.

[1] Smith, A.C., P.A. Harrison, M. Pérez Soba, F. Archaux, M. Blicharska et al. (2017) How natural capital delivers ecosystem services: a typology derived from a systematic review. *Ecosystem Services 26:* 111–126.

Table 1. Definitions of each of the 18 ecosystem services

Provisioning	**Food production**	**Arable crops, horticulture, livestock, orchards, allotments, urban food, wild food (e.g. gathering berries or mushrooms).**
	Wood production	Timber, wood production for paper, woody biofuel crops, coppice wood or wood waste used for biofuel.
	Fish production	Aquaculture, commercial fishing, recreational fishing (recreational fishing is also a cultural service, but the habitat conditions match those for fish production).
	Water supply	Impact of soil and vegetation on rainwater runoff and infiltration, and thus on groundwater recharge or surface water flow.
Regulating	**Flood protection**	Reduction of surface runoff, peak flow, flood extent and flood depth through canopy interception, evapotranspiration, soil infiltration and physical slowing of water flow.
	Erosion protection	The ability of vegetation to stabilise soil against erosion and mass wastage by protecting the soil from the erosive power of rainfall and overland flow, trapping sediment, and binding soil particles together with roots.
	Water quality regulation	Direct uptake of pollutants by terrestrial or aquatic vegetation; interception of overland flow and trapping / filtration of pollutants and sediment by vegetation before it reaches watercourses; breakdown of pollutants into harmless forms e.g. by denitrifying bacteria that convert nitrates into nitrogen gas. Also infiltration into the ground, allowing pollutants to be filtered out by the soil and preventing pollution of watercourses – though pollutants could enter groundwater supplies.
	Carbon storage	Carbon stored in vegetation and soil. In the context of land use change (with complete loss of habitats and often major soil disturbance), this is more relevant than carbon sequestered annually. The 'time to reach target condition' reflects the time taken for a new habitat to reach a typical carbon sequestration rate for a mature habitat.
	Air quality regulation	Removal of air pollutants by deposition, absorption and/or breakdown by vegetation. Fine particles ($PM_{2.5}$) are the most damaging type of pollution, but vegetation can also remove ozone and nitrogen oxides (by absorption into pores).
	Cooling and shading	Shade, shelter and cooling effect of vegetation and water, especially urban trees close to buildings, green roofs and green walls, which can reduce heating and cooling costs, or trees in urban parks which can provide shade on hot days.
	Noise reduction	Attenuation of noise by vegetation.
	Pollination	Pollination of crops (and wild plants, supporting other ES) by wild insects (mainly bees and hoverflies). Excludes pollination by managed honeybees.
	Pest control	Predation of crop or tree pests by invertebrates (e.g. beetles, spiders, wasps), birds and bats.
Cultural	**Recreation and leisure**	Provision of green and blue spaces that can be used for any leisure activity, e.g. walking, cycling, running, picnicking, camping, boating, playing or just relaxing.
	Aesthetic value	Provision of attractive views, beautiful surroundings, and pleasing, calming or inspiring sights, sounds and smells of nature.
	Education and knowledge	Opportunities for formal education (e.g. school trips), scientific research, local knowledge and informal learning (e.g. from information boards or experiences).
	Interaction with nature	Provision of opportunities for formal or informal nature-related activities, e.g. bird watching, botany, random encounters with wildlife, or feeling 'connected to nature'. There is some overlap with biodiversity, but access by people can have negative impacts on some wildlife habitats. Excludes recreational fishing; hunting / shooting (not covered); the intrinsic value of nature (covered by the biodiversity metric); existence value (from just knowing that nature exists).
	Sense of place	The aspects of a place that make it special and distinctive – this could include locally characteristic species, habitats, landscapes or features; places related to historic and cultural events, or places important to people for spiritual or emotional reasons.

Woodland habitats tend to have high scores for the regulating and cultural services, because trees are highly effective for storing carbon, intercepting rainwater and stabilising soil as well as being attractive locations for recreation. Semi-natural grasslands also score highly for cultural services but less for services such as carbon storage and flood protection. Farmland has a maximum score of 10 for food production, but tends to have low scores for most of the other services (with the exception of water provision via groundwater recharge). However certain elements of farmed landscapes (hedges, field margins, woodlands, paths) do have higher scores for regulating and/or cultural services. The matrix also includes scores for watercourses, wetlands and urban green infrastructure.

To complement the scores, we also provide estimates of carbon storage in tonnes per hectare, and carbon sequestration in tonnes per hectare per year, based on literature evidence from Natural England[2] and other sources.

MULTIPLIERS

The scores for some services are adjusted using multipliers, as follows.

1. **Agricultural Land Class:** a multiplier based on ALC is applied to the Food production score, to reflect the fact that high grade land produces higher yields and is also more versatile (i.e. it can produce a range of crops, including horticulture). The multiplier ranges from 2.4 (Grade 1) down to 0.5 (Grade 5). After applying the multiplier, scores are re-normalised to the scale of 0-10. Grade 1 agricultural land (arable and improved grassland) thus scores 10, Grade 2 scores 7.6, Grade 3 scores 4.9, Grade 4 scores 3.5 and Grade 5 scores 2.1. The multipliers are roughly based on expected differences in productivity (in tonnes per hectare) between the different land classes, and a further arbitrary uplift to reflect the versatility of Grade 1 and 2 land.
2. **Public accessibility** is used to adjust the scores for recreation. For paths, the ecosystem service of recreation is delivered not from the path itself (which could be a sealed surface which scores zero) but from the way in which the path enables the user to experience a green space setting. We therefore assume that the service of recreation in green space is delivered by the area within a 50m buffer zone on each side of the path. Habitats within this 50m buffer receive a 'public access' multiplier of 0.75, reflecting that although they are not actually accessible to the path user, they contribute to the experience of recreation in green space. The accessibility multiplier is not currently applied for the services of education, aesthetic value or interaction with nature, where the application of the multiplier is less straightforward (e.g. some areas could be available for educational trips but not publicly accessible). The accessibility multiplier is arbitrary and is:
    - 1 for open access
    - 0.9 for schools, which are accessible only to pupils and only during school hours but are nevertheless very important for recreation
    - 0.75 for the zone 50m each side of paths (see above)
    - 0.75 for semi-restricted access (areas restricted to clubs or members, e.g. allotments, bowling greens, but where access is not expensive or exclusive)
    - 0.5 for restricted access (e.g. golf courses, where membership is expensive)
    - 0.25 for private gardens (very useful to owners but not anyone else).

[2] Gregg, R., Elias, J.L., Alonso, I., Crosher, I.E., Muto, P. and Morecroft, M. D. (2021) Carbon storage and sequestration by habitat: a review of the evidence (second edition) Natural England Research Report NERR094. Natural England, York.

3. **Nature and cultural designations**.
    - There is an arbitrary multiplier of 1.1 for the service of aesthetic value for areas within AONBs.
    - There is an arbitrary multiplier based on the number of nature and/or cultural designations for each site for the services of education (nature and certain cultural designations), interaction with nature (nature designations only) and sense of place (nature or cultural designations). The multiplier is 1.1 for one designation, 1.15 for two and 1.2 for three or more.

DISPLAYING THE ECOSYSTEM SERVICE MAPS

With scores for 18 different ecosystem services, it can be difficult to get an overview of where the land delivers benefits to people. Adding scores for different services together is best avoided, because this is not comparing like with like. The scores are simply rankings of the capacity of different habitats to deliver each service on a scale of 0 to 10. A score of 10 for recreation means that we think that land parcel delivers the maximum possible level of service for recreation (in terms of habitat type and accessibility), but that does not make it equivalent to a score of 10 for carbon storage or food production because the scores are not in common physical or monetary units. However, to help identify the important natural assets in the area, we show the maximum score out of all the regulating and cultural services. Polygons with high maximum scores are known to have a high value for delivering at least one regulating or cultural service. An example of the maps for carbon storage (left) and the maximum score for ecosystem services (right) is in Figure 8.

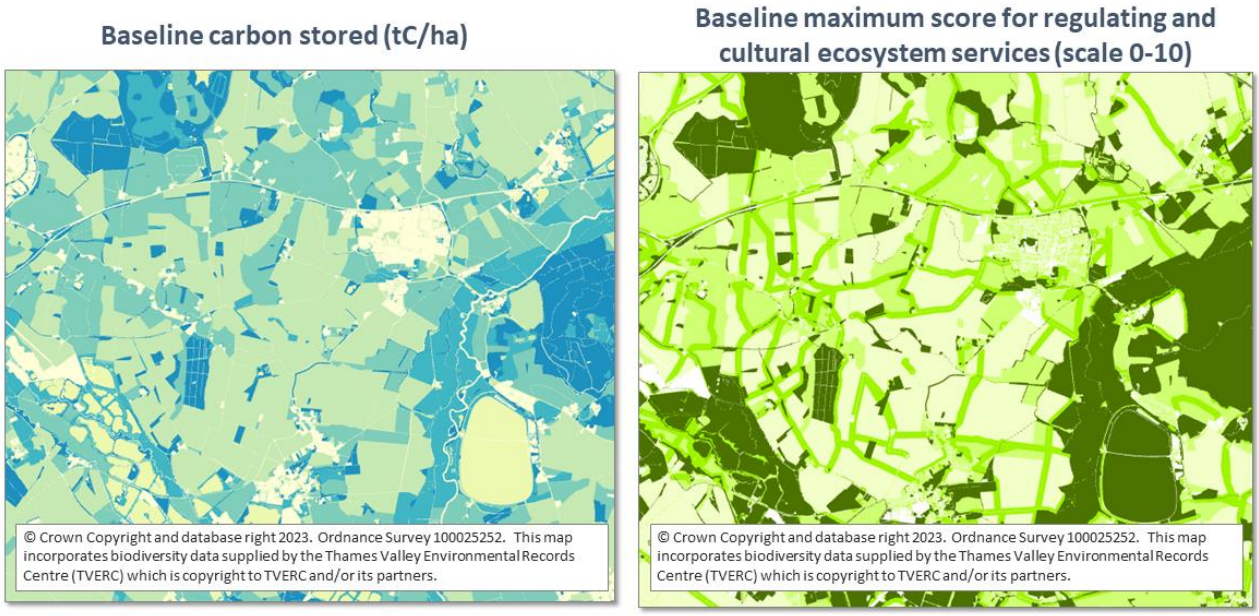

Figure 8. Agile maps of carbon storage (left) and the maximum score for regulating and cultural ecosystem services (right)

The maximum score for regulating and cultural services is intended to be displayed together with a separate overlying layer showing high-scoring areas for food production (i.e. Grade 1 and 2 arable and improved grassland). Areas with high scores for food production have low scores for most of the regulating and cultural services. Following feedback from users, we display these areas in a different colour (orange) to distinguish them from the areas with high scores for other services (green) (Figure 9).

The maximum scores are a useful way of synthesising the scores from multiple services, but they do not reflect the multi-functionality of habitats. Thus a habitat with a high score for just one service will appear in the same shade of green as a habitat that delivers high levels of multiple services. We therefore also provide the average score for all

the regulating and cultural services (again both with and without water supply) – though this should be interpreted with caution because, as explained above, scores for different services are not directly comparable. We are interested in feedback on these different methods of displaying the results.

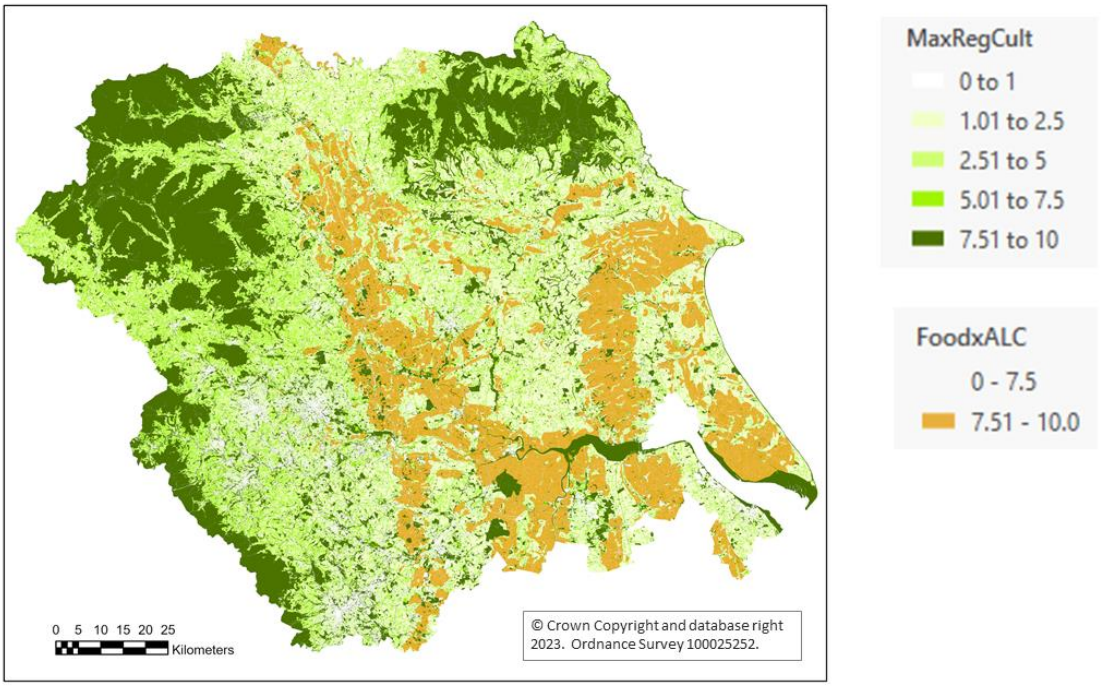

Figure 9: Maximum score for cultural and regulating services (green) or food provision (orange)

CAVEATS FOR THE ECOSYSTEM SERVICE MAPS

Please be aware of the following caveats when interpreting the ecosystem service scores.

- As the scores are based on habitat type, all habitats of the same type will have the same score, unless one of the multipliers has been applied.
- The scores reflect only potential supply of services, not demand or actual flow of services.
- Scores for most of the ecosystem services are indicative rankings of different habitats based on best available evidence. The exceptions are carbon storage and air quality regulation, where the scores are directly proportional to biophysical evidence (carbon stored in soils and vegetation[3], and estimates of the health benefits of air pollution removal by vegetation in the UK Natural Capital Accounts[4]). Scores for cultural services such as aesthetic value are subjective, as they are dependent on personal views. However, the scores are about as robust as this type of scoring system can be.
- The service of fish provision is delivered by rivers and lakes. These score 10, but the scores should be adjusted according to the ecological quality of the waterbody. This can be done using the Water Framework

[3] Cantarello, E., Newton, A. C. and Hill, R. A. (2011) Potential effects of future land-use change on regional carbon stocks in the UK. *Env. Sci and Pol.* 14:40-52.

[4] Jones, L., Vieno, M., Morton, D., Cryle, P., Holland, M., Carnell, E., Nemitz, E., Hall, J., Beck, R., Reis, S., Pritchard, N., Hayes, F., Mills, G., Koshy, A., Dickie, I. (2017). Developing Estimates for the Valuation of Air Pollution Removal in Ecosystem Accounts. Final report for Office of National Statistics, July 2017.

Directive status provided by the Environment Agency, but this is not currently automatically integrated into the maps.

- Hedgerows and individual trees are very important for delivering ecosystem services. We have been developing a hedgerow and tree map with an external partner which we hope will be released soon.

Stage 4: Identifying nature recovery and NbS opportunities

Opportunities for nature recovery and NbS have been identified using the constraints shown in Table 2. The general ecological rules used to identify opportunities were initially developed in partnership with the Oxfordshire Treescapes Project, and have been expanded to include a wider range of habitats, as described below.

1. **Target low-biodiversity habitats** (arable land, improved grassland, poor quality semi-improved grassland, felled woodland, bracken), thus avoiding conversion of semi-natural habitats to other habitats. The exception is degraded deep peat, which is prioritised for restoration regardless of habitat type (except for manmade surfaces or gardens) unless the Natural England peat status dataset records the presence of valuable semi-natural habitats or native woodland. Note that some areas mapped as 'Wood-pasture and parkland' are actually mainly improved grassland, possibly with a few trees – this is a known issue due to the Natural England dataset mapping entire parkland areas regardless of detailed habitat type within the estate boundaries. We therefore allow semi-natural grassland restoration on areas of 'Wood-pasture and parkland' which the CROME crop map identifies as improved grassland.
2. **Avoid the conversion of high-grade farmland** (ALC grade 1 or 2) to other habitats. The exceptions are for peatland and wetland, where food production produces high carbon and biodiversity impacts and so restoration takes priority, and for agroforestry or restoration of improved grassland to semi-natural grassland, where food production can still continue. This rule is intended to minimise displacement of food production and associated impacts to other regions, as high-grade land can produce twice as much food as low-grade land. However, it does have complex implications and trade-offs that we intend to discuss further with stakeholders, especially for restoration of chalk grassland which is largely confined to Grade 2 land in certain regions, and for production of horticulture on fen peat, which has implications for food security and local economies.
3. **Avoid conversion of peat to other habitats** except for degraded shallow peat or peaty pockets, which might be suitable for restoration to wetland, heathland or semi-natural grassland (or mosaics) if it cannot be restored to peat bog. Tree planting is a particular risk on peat (even on shallow peat), because it results in loss of soil carbon that can outweigh the carbon sequestered by the trees.[5]
4. **Wetland and pond creation opportunities** are currently restricted to the flood zone (1 in 100 year risk of flooding; Environment Agency flood zone 2). We are also working on a method of identifying non-flood zone sites for wetland creation using the Topographic Wetness Index.
5. **Woodland, grassland, heathland and wetland** opportunities are zoned depending on distance from core habitat patches (200m, 500m, 1km, or over 1km but within the Natural England Nature recovery network for that habitat). This is based on the approach pioneered by Gloucestershire Wildlife Trust for the Gloucestershire Local Nature Partnership nature recovery network maps. The core patches are above a certain size limit, currently 1000 m^2 for woodland, 500 m^2 for grassland and heathland, and 100 m^2 for wetland. For woodland, grassland and wetland they are restricted to areas identified as priority habitat

[5] Friggens, N. L., Hester, A. J., Mitchell, R. J., Parker, T. C., Subke, J.-A., & Wookey, P. A. (2020). Tree planting in organic soils does not result in net carbon sequestration on decadal timescales. *Global Change Biology*, *26*(9), 5178–5188.

(excluding areas identified only as 'floodplain grazing marsh' in the Priority Habitat Inventory, which can include improved grassland on the floodplain). A fifth zone identifies areas outside these networks where there are no constraints on habitat creation; these areas can be suitable for creation of stepping stone habitats in network gaps. The maps include entire fields in each zone, even if only part of the field is within the distance limit; the rationale is that most interventions will target a whole field. However, this could be changed in response to user feedback.

6. We map separate networks for **calcareous, neutral,** or **lowland acid grassland**, with calcareous grassland restricted to calcareous soils, and lowland acid grassland restricted to the Natural England lowland acid grassland recovery network (as the soil type is difficult to predict). We use the freely available British Geological Survey Soil Parent Material Model at 1km resolution to identify calcareous soils, though there is also a facility to use Soilscapes or the National Soil Map for a more accurate result if a license has been purchased from Cranfield University. We also map a '**combined grassland network'** that includes all these types as well as less specific core grassland areas such as 'good quality semi-improved grassland'.
7. **Agroforestry** is considered to be suitable even for high grade farmland, as evidence suggests it can make food production more resilient (there might be a small yield loss in the short term for silvoarable, but evidence suggests no loss or even a gain for silvopasture due to increased animal welfare). However, we avoid suggesting conversion of existing pasture to silvoarable, as that would involve loss of stored soil carbon and biodiversity. We also do not suggest conversion of high-grade arable land to silvopasture, on the grounds that it is more appropriate to continue plant-based food production on high grade land. An exception could be if the area is at high risk of erosion (though this is not yet implemented).
8. **Community orchards** follow the same rules as woodland opportunities but are also restricted to within 500m of urban areas (identified using Ordnance Survey Zoomstack urban areas).
9. **Erosion prevention opportunities** are identified on steep slopes (over 7 degrees), with a higher priority if the area also has highly erodible soils. Note that freely available soil erodibility datasets have low accuracy, so the slope is the main indicator. We currently use the British Geological Survey Soil Parent Material Model dataset at $1km^2$ resolution. The National Soil Map from Cranfield University, if available, can give a much better indication of erodibility, but this is not free.
10. **Natural flood management using woodland** is targeted using the Wider Catchment Woodland dataset from the Environment Agency. This indicates areas where soils have restricted drainage, where woodland creation can help to improve soil infiltration and thus reduce flooding.

Table 2. Constraints used to identify opportunities for nature recovery and NbS

	Arable	Improved grassland	Amenity grassland	Poor semi-improved grassland	Bracken	Felled woodland	Semi-natural habitats	Deep Peat	Shallow peat and peaty pockets	Verges	ALC 1 or 2	Flood zone
Woodland	y	y	y	y	y	y	n	n	n	n	n	y
Grassland	y	y	y	y	y	y	n	n	y	y	If impr. grass	y
Heathland	y	y	y	y	y	y	n	n	y	n	n	y
Wetland	y	y	y	y	y	y	n	n	y	n	if peat	essential
Peatland	y	y	y	y	y	y	y	y	y	n	y	y
Silvoarable	y	n	n	n	n	n	n	n	n	n	y	y
Silvopasture	unless ALC 1 or 2	y	n	n	n	n	n	n	n	n	y	y
Community orchard	y	y	y	y	y	y	n	n	n	n	n	y

An example of an opportunity map for restoration of semi-natural grassland is shown in Figure 10. We map zones according to the distance from core habitat in shades of green. The 'extension zone' in dark cream (unfortunately not clear on the extract below) is areas that are not within 1km of core habitat patches but which are located within Natural England's habitat network. This picks up areas that link together networks that are close together. The even paler cream colour (also not visible in this figure) is areas that are not in a network but for which there are no constraints. These could be opportunities to create stepping stones.

For designated areas, restoration may or may not be appropriate and additional consultation is necessary with the relevant site managers and local ecological experts. We therefore map designated areas in shades or purple rather than shades of green, to distinguish them.

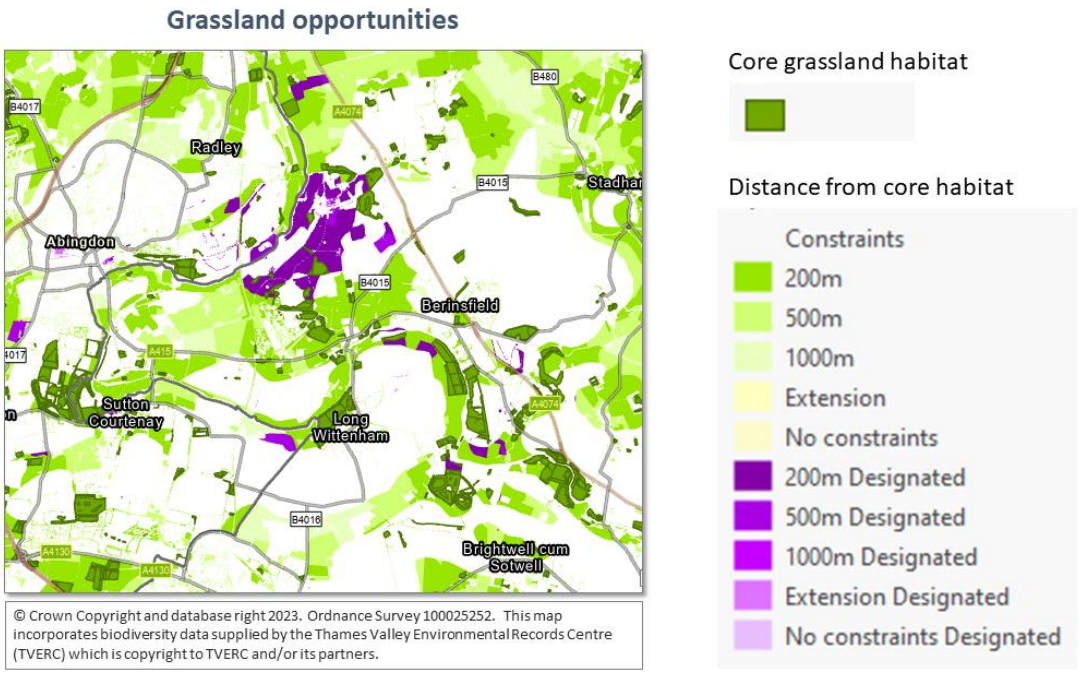

Figure 10. Combined grassland opportunity network, with designated sites distinguished by using purple shades

PRIORITISING THE OPPORTUNITIES

We are developing a system for indicating which might be the highest priority opportunities in a given location. These rules are still developing and we are seeking to refine them as feedback emerges. It is important to emphasise again that detailed ground-truthing and consultation with stakeholders and local experts is essential before any interventional are implemented on the ground: the Agile maps should only be used to indicate which options might be best suited to certain locations. See the Ground Truthing Guidance for more details.

Peat restoration is always prioritised on deep peat, due to the urgent need to cut the exceptionally high level of emissions from degraded peat. **Wetlands** are currently prioritised on floodplains, although we emphasise here that these should be part of a mosaic of f**loodplain meadows, ponds**, and small patches of **wet woodland**. More detailed 'Stage zero' modelling of floodplain restoration potential (i.e. modelling the potential to restore the floodplain to its original state prior to human intervention), using higher resolution height data (1m or 2m rather than the 5m LIDAR used here) can identify which parts of the floodplain are slightly higher or lower.[6] This can then be used to target wetland creation in the lower areas, wet woodland on the slightly drier areas, and meadows in the areas in-between (as floodplain meadows do not benefit from prolonged inundation).

For **woodland, grassland and heathland**, the habitat closest to a patch of the same habitat is prioritised. However, this approach has drawbacks as it ignores opportunities to create 'stepping stones' in areas currently deprived of existing habitat.

For many areas, two or more options are equally suitable and we record a list of all the equally suitable options. We always note opportunities for agroforesty or community orchards, though these occur further down the list than the opportunities for semi-natural habitat restoration.

Following the approach pioneered by the Gloucestershire Local Nature Partnership, for areas where more than one habitat is equally suitable, we suggest that one option is to aim to create **mosaic or intermediate habitats** that could be used by species from each habitat as a corridor between patches of their core habitat. For example, where

[6] E.g. see the Stage Zero modelling of potential floodplain reconnection in the Evenlode Catchment by Atkins Réalis.

grassland and woodland are equally suitable, options could include wood-pasture and parkland with scattered trees, scrub, silvopasture or orchards. This is reflected on the map by showing the symbol for grassland with scattered trees. For areas where heathland and woodland and/or agroforestry are equally suitable, the map shows the symbol for heathland with scattered trees. Often three, four or even five options might all be suitable. We do not attempt to show all these via the map symbology, but clicking on a polygon will reveal the full list of priority options. However, in some cases it might be more appropriate to prioritise a specific habitat that is particularly at risk, or supports rare and threatened species, rather than simply the one that is closest to existing core habitat patches. For example, in some areas, semi-natural grassland and lowland heathland are more scarce than native woodland.

English landscapes often consist of highly fragmented small patches of woodland and grassland in a matrix of farmland. In these areas, the priority opportunities symbology will often cover almost the whole area with suggested nature recovery opportunities. **This does not imply that all these areas should be targeted for intervention**, as that would leave no space for food production! It simply suggests the highest priority opportunities in any one area. The idea is that these maps can be used to support a process of participatory stakeholder engagement, to take account of local priorities and the need for nature-based solutions to tackle local problems.

We are investigating how the maps could be further developed to select the highest priority polygons to meet specific targets, e.g. to increase woodland or grassland to a certain percentage cover. There are several ways in which the maps can be refined to narrow down the selection of areas for intervention. For example, the following areas could be selected as being higher priority:

- Areas mapped as having erosion protection and/or NFM opportunities in addition to habitat restoration opportunities
- Grade 4 and 5 farmland – as well as being suitable for restoration, this also often follows river valleys and therefore can contribute to a connected network.
- Areas falling within existing nature recovery networks identified by local stakeholders (such as the Oxfordshire nature recovery network)
- Areas within nature recovery networks mapped using other software, such as Circuitscape or Omniscape, which identify the shortest links between core habitat patches.
- Areas targeted using 'nature reserve selection' software such as Zonation or Marxan. The Agile maps can feed input data into this process and can also be used to target specific interventions (taking account of constraints and opportunities) within the zones identified by the software.
- Taking a pragmatic approach, areas where local stakeholders, landowners and land managers are keen to support interventions.

Stage 5: Assessing the benefits

The final stage of applying the maps is to use the output to assess the outcomes of different interventions. This is not fully automated but can be achieved by the following process (we strongly recommend you contact us for guidance).

1. Export the habitat inventory and a summary of the baseline ecosystem service scores from the maps as a text file (we provide a Python module to do this).
2. Copy the text file into a spreadsheet.
3. Make a copy of the baseline habitat sheet to reflect the post-intervention habitats, and change the areas of different habitats to reflect your planned interventions.

4. Using the scoring matrix, calculate the new ecosystem service scores resulting from the planned changes and apply any relevant multipliers as described in this document.

It could also be possible to apply Natural England's Environmental Benefits from Nature Tool for this assessment, although only a few of the 40 condition multipliers can usually be applied when using the EBNT at county scale. Contact us if you are interested.

How can the maps be used to support local decision-making?

1. **Areas for protection**. The maps identify existing natural assets which already have the potential to deliver a range of ecosystem services, including cultural services, regulating services and food production. These areas can be flagged for protection.
2. **Natural asset register**. Data can be exported from the maps, to provide an asset register in terms of areas of different habitats, area of designated sites, publicly accessible areas, and carbon stored and sequestered.
3. **Opportunities for interventions.** The opportunity layers show options for interventions as part of a Local Nature Recovery Strategy (LNRS) or similar strategy, and the basic rules help to maximise benefits and reduce trade-offs (such as by discouraging loss of high-grade agricultural land or priority habitats). Figure 11 shows how the maps can support different stages of a LNRS. Contact us for more information.
4. The maps are intended as a **decision-support tool** as part of a process of participatory engagement with stakeholders (see our separate Recipe for Engagement), and should always be used in conjunction with **ground-truthing and consultation with local experts** (see the separate ground-truthing guidance document).

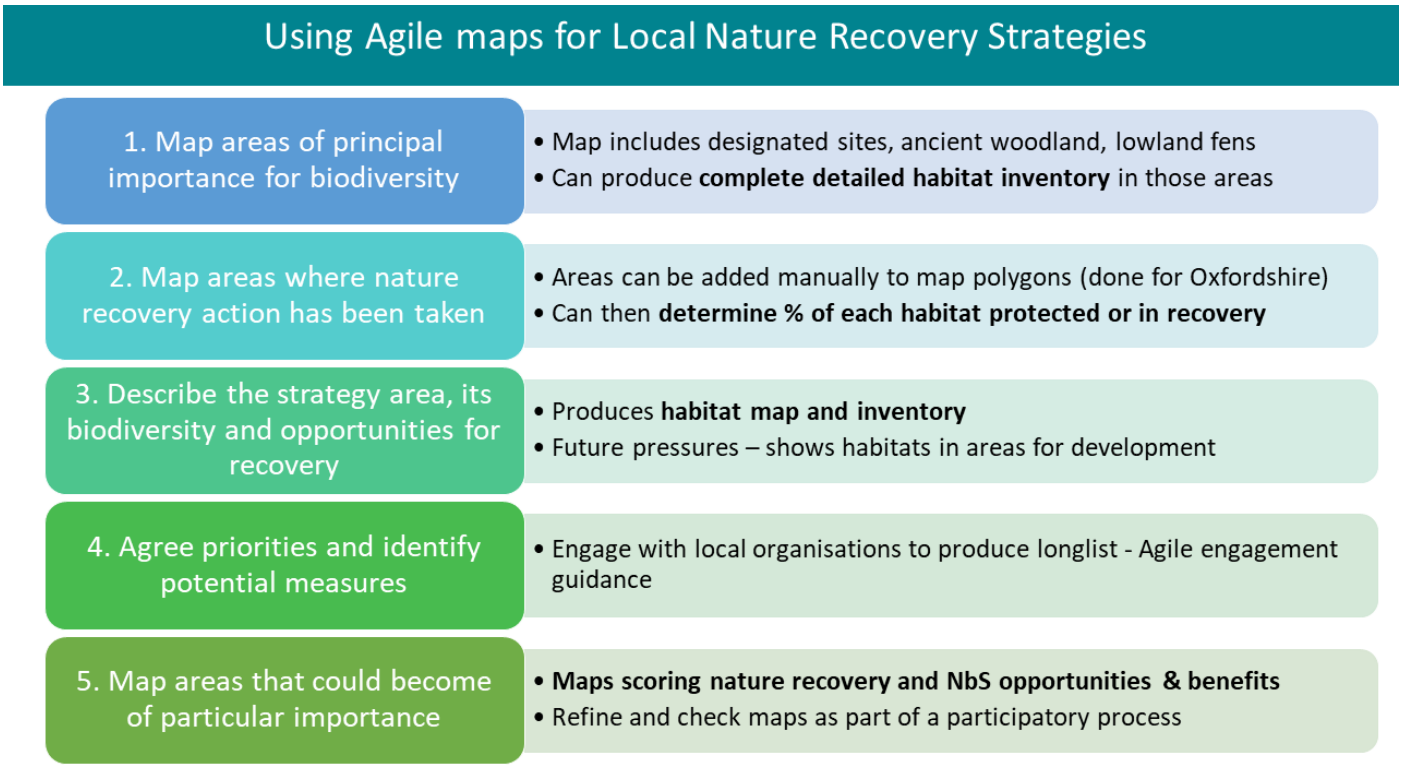

Figure 11. How the Agile maps can be used to support a Local Nature Recovery Strategy

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https://www.agile-initiative.ox.ac.uk/

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