Roles of Spatial Data by Regional Land Use Partnerships:

A Report of the SEFARI Gateway Think Tank on Spatial Data

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Acronyms

CAMERAS	Co-ordinated Agenda for Marine, Environment and Rural Affairs Science
CICES	Common International Classification of Ecosystem Services
CONFOR	Confederation of Forest Industries
CREW	Centre for Expertise for Waters
EU	European Union
FAIR	Findable, Accessible, Interoperable and Reusable
GEMET	General Multilingual Environmental Thesaurus
GHG	Greenhouse Gas Emissions
GIS	Geographic Information Systems
INCA	Natural Capital and ecosystem services Accounting
INSPIRE	Infrastructure for Spatial Information in the European Community
JRC	Joint Research Centre of the European Commission
MAES	Mapping and Assessment of Ecosystems and their Services
MAIA	Mapping and Assessment for Integrated ecosystem Accounting
NAR	Natural Asset Register: Data Portal
NBN	National Biodiversity Atlas Scotland
NCA	Natural Capital Accounting
NGO	Non-Governmental Organisation
OS	Ordnance Survey
PSGA	Public Sector Geospatial Agreement
ScotLIS	Scotland's land Information Service
SEEA-EA	System of Environmental Economic Accounting – Ecosystem Accounting
SEFARI	Scottish Environment, Food and Agriculture Research Institutes
SEPA	Scottish Environment Protection Agency
SEWEB	Scotland's Environment Web
SIMD	Scottish Index of Multiple Deprivation

Executive Summary

The Scottish Government Programme for Government (2021/22) commits to the creation of Regional Land Use Partnerships (RLUPs) and Regional Land Use Framework (RLUFs), as set out in the Land Use Strategy. In spring 2021 it announced five pilot Partnerships for testing approaches and practicalities, with particular reference to governance and local engagement.

The Partnerships are expected to help stakeholders across national and local government, communities, land owners and stakeholders to work together to optimise land use in a fair and inclusive way, and meet objectives and supporting a just transition to net zero greenhouse gas emissions. They are expected to facilitate a "natural capital led collaboration on regional land use changes to help Scotland's just transition to net-zero."

Spatial data can be used in a range of roles to support the RLUPs in achieving their expected aims, providing information about an area, its natural, cultural and human resources. Progressively, such data have become more extensive for all or parts of Scotland, and made available by various mechanisms. Access to datasets, or their metadata, is enabled through several portals supported by Scottish Government and public sector and research bodies. The topics of datasets within these portals include environmental and socio-economic characteristics of Scotland, organised using internationally recognised protocols (e.g. Common International Classification of Ecosystem Services, CICES). The providers of these spatial data are public and private sector, research, and citizen science facilitated by non-governmental organisations (NGOs).

Spatial data is used in a broad range of applications that would be expected to be within the tasks of RLUPs. These cover the presentation of information, such as proposals and plans; querying biophysical or socio-economic characteristics for user defined places or areas; viewing and comparing characteristics of areas at different times, or through time, or combining and viewing multiple types of data; online summarising and presentation of data; and downloading data for in-house uses such as mapping and deriving new products tailored to the area of interest such as elements of natural capital and different ecosystem services.

Access to data for in-house uses enables a broad range of applications enables the derivation of outputs from combining, or integrating, data representing different characteristics. However, appropriate human and technical resources are required to make effective use of spatial data by the RLUPs. Consideration is required of the purposes to which spatial data will be put, and thus access to relevant expertise on the handling of spatial data, and in the topic domains (e.g. soil). Similarly, access is required to the software and hardware required for the uses of the spatial data in the context of achieving the aims of the RLUP.

The pilot Regional Land Use Partnerships provide opportunities to identify gaps in data suitability and availability for the achievement of their purposes. The needs of the RLUPs, and other new institutions, should inform negotiations of the content of the update of the Public Sector Geospatial Agreement which is likely to be a significant means by which access to spatial data will be enabled.

The pilot RLUPs may motivate the collection of new spatial data to support their aims of locally democratic engagement, and tackling challenges within their remit. The effective use of spatial data by the RLUPs could expand the engagement of stakeholders in delivering on visions for their area and the aim as set out in the Land Use Strategy of facilitating 'regional decision-making to help achieve Scotland's climate and environment targets through land use change.'.

1. Introduction

The Programme for Government (2021/22) (Scottish Government, 2021) gives a commitment to the creation of the Regional Land Use Partnerships and Regional Land Use Framework (RLUFs), as set out in the Land Use Strategy (Scottish Government, 2021). These Partnerships are to be developed by 2023. In spring, five pilot Partnerships were announced in Aberdeenshire, South of Scotland, Highland Region, and the two National Parks, Cairngorms and Loch Lomond and The Trossachs. Of those, the Partnership aligned with the Cairngorms National Park intersects with the Perth and Kinross area, and those of Loch Lomond and The Trossachs, and Aberdeenshire, area adjacent.

The Partnerships are being set the aim of helping national and local government, communities, land owners and stakeholders work together to optimise land use in a fair and inclusive way, and meet local and national objectives and supporting a just transition to net zero greenhouse gas emissions. They are expected to facilitate a "natural capital led collaboration on regional land use changes to help Scotland's just transition to net-zero."

Spatial data can be used in a range of roles to support the RLUPs in achieving their expected aims (Scottish Land Commission, 2020). The representation of features and characteristics of areas and places by spatial data enables certain types of tasks to be undertaken, such as answering questions of 'what is where?' and 'what is the extent of?'. Spatial data underpin assessments of natural capital, and pressures on its elements, at levels from farm to continent. However, the effective use of spatial data will be dependent upon the human and technical resources available, and the specific purposes to which it is to be put.

To inform discussion of the needs of the RLUPs in achieving their aims and undertaken activities, the Scottish Land Commission and SEFARI Gateway formed a Think Tank on Spatial Data.

The aims were to:

i) identify the types of spatial data available for Scotland that may be relevant to the remit and operation of the RLUPs;
ii) the types of uses of spatial data to comment on requirements and limitations of its usability;
iii) human and technical resources required to enable the use of spatial data by the RLUPs.

The members of the Working Group were drawn from organisations in Scotland with expertise in the provision or use of spatial data. These organisations included Scottish Government, relevant public agencies (NatureScot; SEPA, including Scotland's Environment Web; and Forest Research), and research organisations. Members included representatives of teams involved in the two Land Use Pilots in Aberdeenshire and Scottish Borders to build-in their experiences and the outputs from those initiatives, and SEFARI researchers contributing expertise in data that were used in those pilots.

The following sections provide:

i) Section 2, a summary of the spatial data hubs and portals containing data which are likely to be of relevance to the RLUPs (Section 2);
ii) Section 3 and Annex 2, a set of 18 example uses of spatial data, noting their purpose, intended audiences, spatial data requirements and sources, technical and human resources required, and additional comments and references as appropriate;
iii) Section 4, a discussion of the human and technical resources which are likely to be required, and issues arising.
iv) Section 5, conclusions providing reflections on the use of spatial data by the RLUPs.

Annex 3 provide additional information and links to a selection of approaches and initiatives with remits to map natural capital or assess ecosystem services in Scotland, Europe or in other regions of the world.

2. Spatial Data Hubs and Portals

2.1 Data and metadata portals

The development, by the Scottish Government, of data infrastructures and resources through its investment in ePlanning, consistent with the recommendations of Beveridge *et al*. (2016), should be beneficial to the Regional Land Use Partnerships (e.g. digital data in planning, Miller *et al*., 2016). Scotland has extensive data relating to its natural environment, social and economic contexts, and how they change through time. Many of these datasets are available through portals such as Scotland's Environment Web (https://www.environment.gov.scot/), Scotland Natural Asset Register: Data Portal (https://nar.hutton.ac.uk/), the local authority Improvement Service (https://www.spatialhub.scot/), and from the Scottish Government metadata portal (SpatialData.gov.scot). Generally, these data are open for use, subject to certain requirements.

However, for the effective operation of the Regional Land Use Partnerships those data need to be of relevance to their functions, at the appropriate scale (i.e. suitable for strategic or local planning), contemporary (i.e. up-to-date), and usable (i.e. with the skill levels of the intended users). An overview of the types of spatial data of prospective relevance to the Partnerships follows.

Information about spatial data in Scotland has been brought together into portals, or points of access, the influences behind which vary, and thus so do their purposes, timing, structures and maintenance. The principal portals of relevance to the Partnerships follow.

2.2 Spatial Data Hub

The Metadata Portal of SpatialData.gov.scot provides a catalogue of spatial data available for Scotland. In total 881 datasets describing the environment can be viewed or accessed from the catalogue. These data can be viewed and browsed by topic (Figure 1), INSPIRE themes (Joint Research Centre, 2013) (Figure 2), organisation or geography.

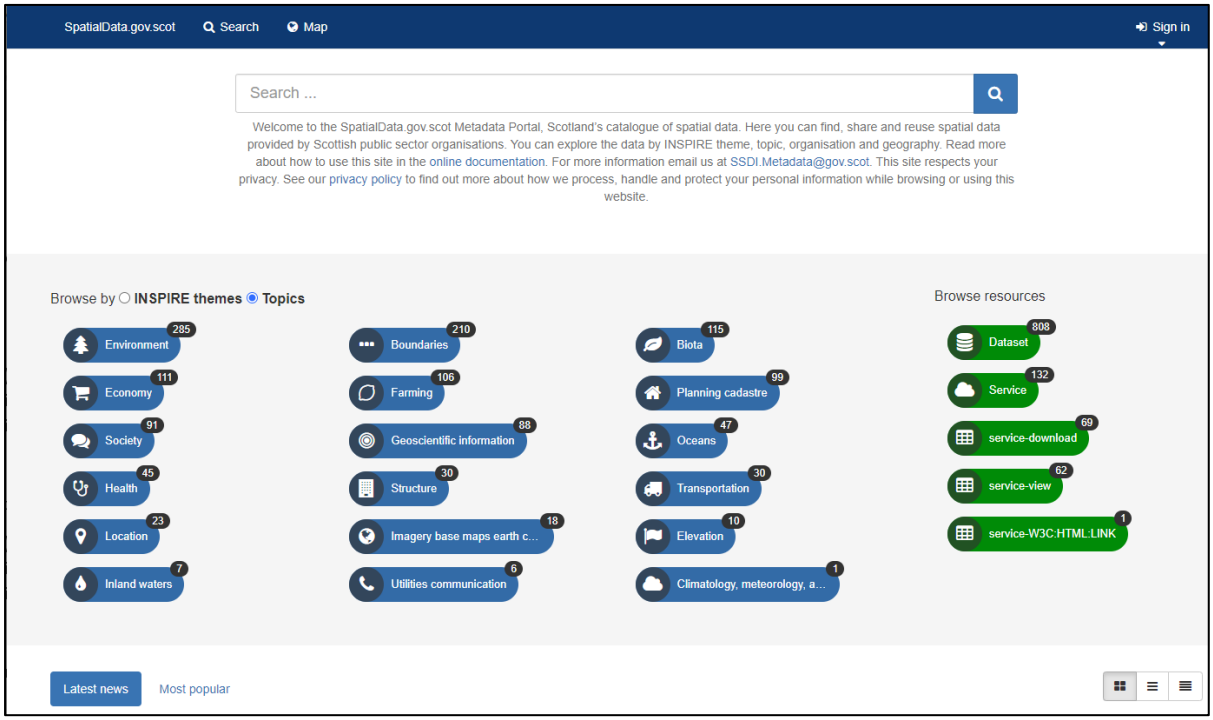

Figure 1. View of metadata entry page of SpatialData.gov.scot, organised by topics.

Figure 2. View of metadata entry page of SpatialData.gov.scot, organised by INSPIRE themes.

Individual datasets can be identified, and information provided relating to coverage (e.g. all or partial coverage of Scotland), cartographic scale, constraints on use (e.g. legal), and technical information such as source scale, data structure type (i.e. vector, raster), coordinate reference system, licence type, and information about frequency of updates. Links are provided to enable the downloading of the spatial data for the user. An example of a record is shown in Figure 3 for the 1:25,000 soils map of Scotland.

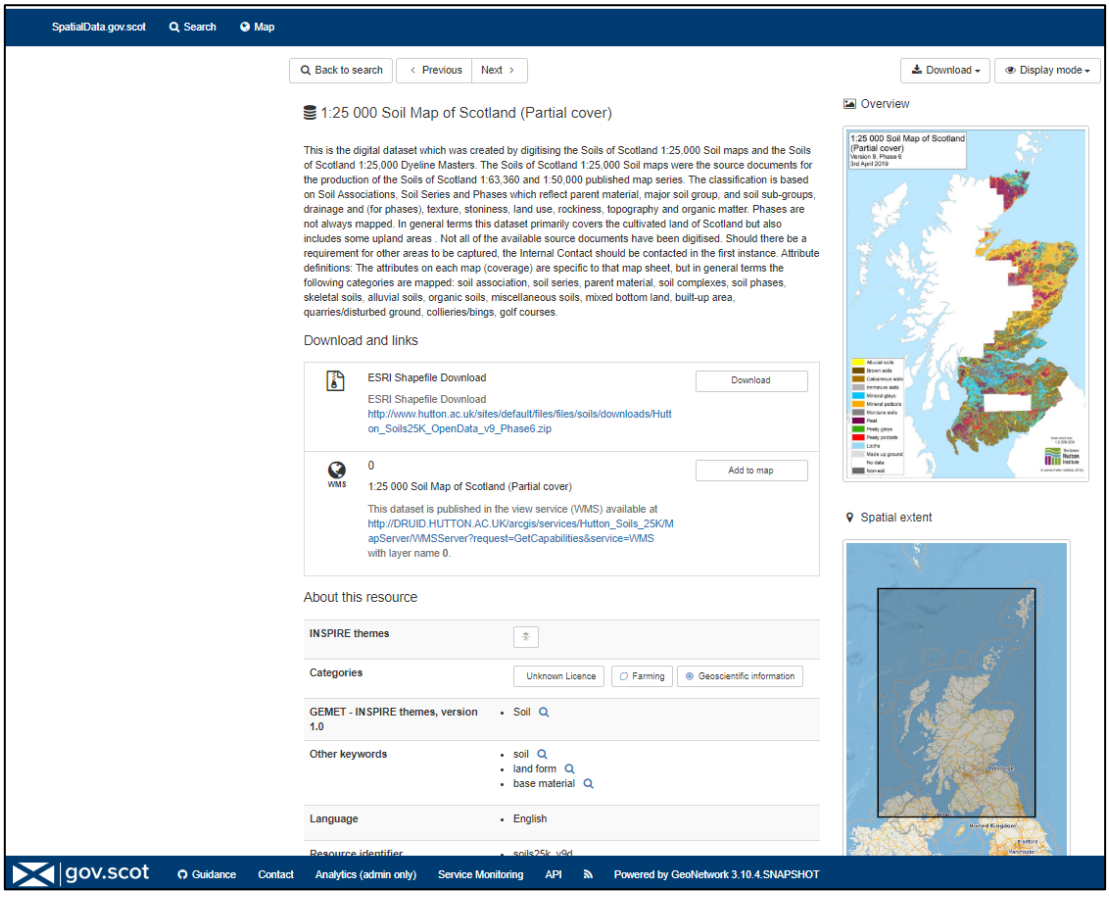

Figure 3. View of an extract of record in the catalogue of the 1:25,000 soils map of Scotland.

The functionality of the catalogue enables the development of a customised map comprising graphical overlays of different datasets (e.g. as a website or using a GIS), or the uploading of a map by a user to be added to the overlays. The map features can be queried interactively through the SSDI. The mapping system is not designed to provide any topological analysis that would lead to the production of a modified dataset that can be downloaded. In many cases, to obtain a copy of the spatial data it is necessary to access the website of the data provider.

The catalogue is hosted and managed by the Scottish Government, and harvested for storage in the UK data.gov.uk site. All datasets provided through the portal are free for use, subject to specific licencing conditions (e.g. not for commercial gain).

These example uses are typical of the types of datasets that have been used in strategies of land uses, either sectoral or multi-functional. A note on the integration of land related datasets in projects is provided in Annex 1.

2.3 Scotland's Environment Web

Scotland's Environment Web is designed to bring together "environmental information and data in one place so that is easy to search, discover, analyse and interpret." It is a shared hub for 10 partner organisations, with another 11 contributing organisations. It provides information on topics of: air, land, climate, people and environment, habitats and species, water, and state of the environment; educational resources; and mechanisms of enabling citizen science (e.g. reporting a flood).

Its functionality includes scope to develop a customised map of aspects of Scotland's environment, with graphical overlays of different elements, which can be queried to provide some information about features at a given location. Its functionality enables control over elements of the data layers (e.g. transparency, selection of basemaps). Such maps may be shared with others or stored for re-use by means of the "Share Map" function on the map viewing page. It also enables searches by postcode, grid reference, location and by user location.

Links are provided to all input data, enabling users to access and download source data for use on their own systems. The mapping system is not designed to provide any topological analysis that would lead to the production of a modified dataset that can be downloaded.

Eight websites are linked to SEWEB as part of a wider network of sources of information about Scotland's environment, details of which are provided in Table 1.

Table 1. Websites in Scotland's Environment network (Source: Scotland's Environment).

Website	Short Description	Partner Organisations
Scotland's soils	Data and information on Scotland's soils	• SEPA • The James Hutton Institute • Scottish Forestry • Scottish Government • Scottish Natural Heritage
Scotland's aquaculture	Data about the aquaculture industry in Scotland	• SEPA • Marine Scotland • Food Standards Scotland • Crown Estate Scotland
Scotland's noise	View maps of noise from road, rail, air traffic and industry	• Scottish Government
Air Quality in Scotland	Data and information about air quality across Scotland, including near-real time	• Scottish Government

	monitoring of air pollution levels.	
Marine Scotland DATA	Marine Scotland's data publishing portal	• Marine Scotland
Marine Scotland Information	Descriptions and information about the Scottish marine environment	• Marine Scotland
Marine Scotland Maps NMPi	Spatial data (using on-line GIS maps) to support national and regional marine planning	• Marine Scotland
NBN Atlas Scotland	Data on plants, animals and habitats in Scotland	• National Biodiversity Network

As above, these example uses are typical of the types of datasets that have been used in strategies of land uses, either sectoral or multi-functional.

The portal is hosted and managed by SEPA. All datasets provided through the portal are free for use, subject to specific licencing conditions (e.g. not for commercial gain). In many cases, to obtain a copy of the spatial data it is necessary to access the website of the data provider.

2.4 Scotland's Environment, Food and Agriculture Research Institutes (Natural Asset Register: Data Portal)

An obligation of many research funders is that data are made available under the principles of open access of Findable, Accessible, Interoperable and Reusable (FAIR, Wilkinson *et al.*, 2016). Spatial data that represent natural and socio-economic characteristics of Scotland have been produced as outputs from research projects across a broad range of topics of prospective relevance to discussions about land use. Some such data are available through portals hosted by organisations with a specific remit and theme or geographic area. The Natural Asset Register: Data Portal (NAR), described elsewhere, provides a formal structure for access to spatial data relating to natural and socio-economic resources.

The Natural Asset Register portal is designed to provide access to scientific data created in the Scottish Government Strategic Research Portfolio. These are geo-referenced data which describe aspects of Scotland's natural assets. There are 44 datasets comprising 120 individual resources accessible from the wwwsite of the register. Some datasets have coverage of all of Scotland and others are of specific study areas.

The datasets have associated keywords, and are grouped according to the Common International Classification of Ecosystem Services (CICES) Section (e.g. Provisioning, Regulating, Cultural Ecosystem Service) and Division (e.g. Biomass). It also contains an entry relating to the General Multilingual Environmental Thesaurus (GEMET) (e.g. forestry). Searches can be made for datasets by terms associated with these schemes, with the contact details of the person or organisation responsible for its creations and its maintenance.

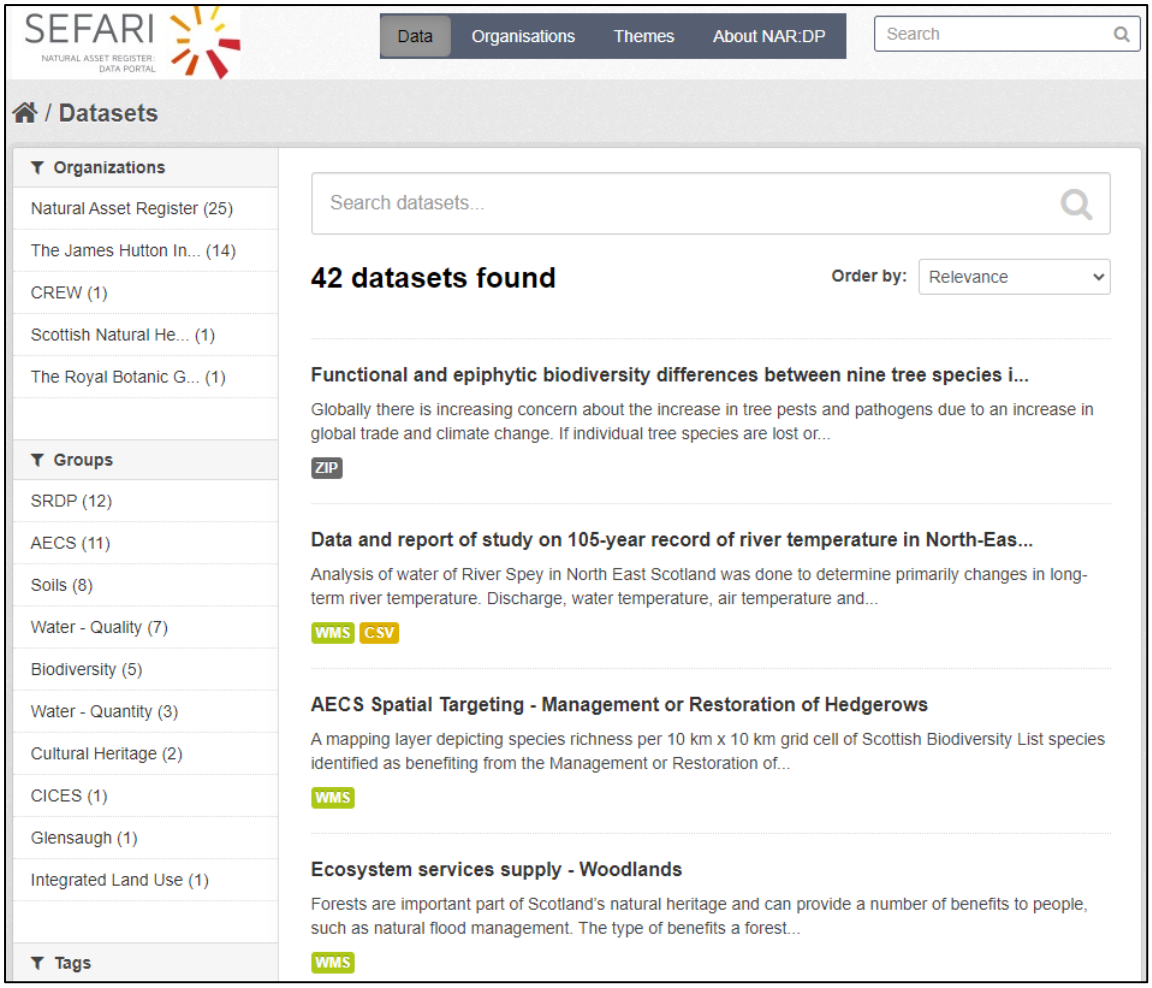

Figure 4. View of Natural Asset Register Data Portal.

Details are provided of the organisation which is principally responsible for the creation or curation of the datasets: James Hutton Institute; SRUC; Royal Botanic Garden Edinburgh; Scottish Government; Scottish Natural Heritage (Nature.scot); Scottish Environment, Food and Agriculture Research Institutes (SEFARI); and the Centre of Expertise for Waters (CREW).

Each dataset can be viewed in a map viewer, with its legend. Metadata are provided for each dataset, such as the licence arrangements for its use, format of the file which can be downloaded (e.g. Shapefile, zipped), and the dates of the creation and updating of the records.

As above, these example uses are characteristics of the types of datasets that have been used in strategies of land uses, either sectoral or multi-functional (e.g. forestry strategies, supplementary planning guidance).

The portal is hosted and managed by the James Hutton Institute. All datasets provided on the portal are free for use, subject to specific licencing conditions (e.g. not for commercial gain).

2.5 Improvement Service Spatial Hub

The 32 Scottish local authorities and two National Park authorities, are significant users and creators of spatial data relevant to consideration of issues relating to land use. The Improvement Service's Spatial Hub is a point of access provided by the Spatial Information Service, which brings together many of these datasets. The portal is accessible by organisations covered by the Public Sector Geospatial Agreement, and researchers through the University of Edinburgh Digimap service.

The input data are provided by the local authorities and National Park authorities. These cover topics of prospective relevance to Regional Land Use Partnerships such as core paths, community council boundaries, a composite of local development plans, renewable energy sites, and school catchments.

The Improvement Service adds significant value to the data submitted through its process of standardisation, quality control, and ensuring compliance with the EU INSPIRE Directive (European Commission, 2007a, 2007b). Descriptions of the datasets are available in the 'Get Data portal' (https://www.spatialhub.scot/get-data/), which contains 40 compiled national datasets as of August 2020. An example of data compiled for several local authorities is shown for core paths in Figure 5.

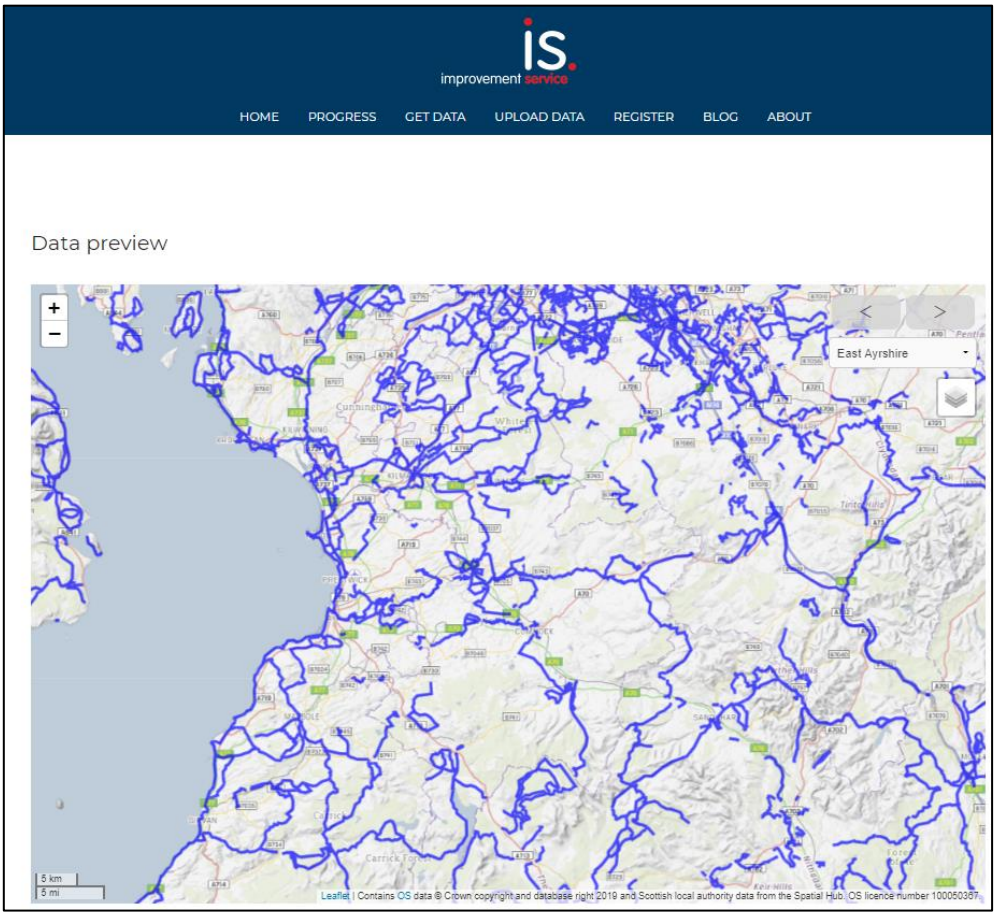

Figure 5. Screenshot of core paths data for areas of Ayrshire and Lanarkshire (Source: Improvement Service, Spatial Hub).

2.6 NatureScot Natural Spaces

The Scottish Natural Heritage Natural Space portal provides access to data and information on categories of: Protected Areas; Consultations; Habitats and Species; Landscape, Open Space and Access; Renewables; and, Administrative. Many of the datasets within these groups are likely to have a role in use cases for the Regional Land Use Partnerships.

As above, these example uses are not obligatory for a Partnership but are typical of the types of datasets that have been used in strategies of land uses, either sectoral or multi-functional, and have prospective uses in Example Use Cases (See Section 3). Almost all these data would have prospective uses in cartographic outputs.

Examples of other spatial data that are likely to be required by the RLUPs in the short or medium term are:

- Areas of protection or regulatory restrictions, several of which are of international standing (e.g. World Heritage Sites) or protected under the EU Habitats Directive (European Parliament

and the Council, 1992) and EU Birds Directive (European Union, 2009), such as Special Areas of Conservation, Special Protection Areas. This portal provides access to the public source of these data for Scotland, several of which are identified in Scottish Planning Policy (Scottish Government, 2014). Examples of topics are shown in Figure 6 for the spatial data relevant to areas where windfarms will not be acceptable.

- Habitats and species data, some of which may have roles relating to the development of strategies (e.g. Ancient Woodland Inventory; Central Scotland Green Network Integrated Habitat Networks), or engagement and consultations (e.g. Deer – vehicle collisions).
- Pressures on land uses and landscapes, such as renewable energy. This includes data which could align under natural heritage (e.g. bare peat areas from remote sensing, carbon and peatland 2016 map), but are grouped here in relation to the subject of the development pressure. It also includes spatial data on the type of development, i.e. wind farm proposals, but which are only updated annually.
- Administrative areas which reflect issues that could be significant for functions of the Partnerships, one relating to Deer Management Group boundaries (prospectively relevant to Example Use Case 1 on consultations), and Nature Conservation Orders (prospectively relevant to Example Use Case on the development of a strategy).

<table>
<tr><td colspan="3">Group 1: Areas where wind farms will not be acceptable:

National Parks and National Scenic Areas.</td></tr>
<tr><td colspan="3">Group 2: Areas of significant protection:

Recognising the need for significant protection, in these areas wind farms may be appropriate in some circumstances. Further consideration will be required to demonstrate that any significant effects on the qualities of these areas can be substantially overcome by siting, design or other mitigation.</td></tr>
<tr><td>National and international designations:

• World Heritage Sites;
• Natura 2000 and Ramsar sites;
• Sites of Special Scientific Interest;
• National Nature Reserves;
• Sites identified in the Inventory of Gardens and Designed Landscapes;
• Sites identified in the Inventory of Historic Battlefields.</td><td>Other nationally important mapped environmental interests:

• areas of wild land as shown on the 2014 SNH map of wild land areas;
• carbon rich soils, deep peat and priority peatland habitat.</td><td>Community separation for consideration of visual impact:

• an area not exceeding 2km around cities, towns and villages identified on the local development plan with an identified settlement envelope or edge. The extent of the area will be determined by the planning authority based on landform and other features which restrict views out from the settlement.</td></tr>
<tr><td colspan="3">Group 3: Areas with potential for wind farm development:

Beyond groups 1 and 2, wind farms are likely to be acceptable, subject to detailed consideration against identified policy criteria.</td></tr>
</table>

Figure 6. Examples of topics which require representation by spatial data, in Scottish Planning Policy in relation to windfarm development (Source: Scottish Government, 2014, Scottish Planning Policy, page 39).

2.7 OS Data Hub

Ordnance Survey is the national mapping agency of Great Britain, responsible for the creation, maintenance and distribution of geospatial data. It provides the fundamental topographic datasets to which most land based applications are referenced, including the products supplied under Mastermap, and series of basemaps for use as backdrops and the provision of geographic context, and products likely to be relevant to Regional Land Use Partnerships (e.g. Digital Terrain Data, Transport Network).

Almost all spatial data for Scotland are underpinned by data provided by the Ordnance Survey. These data are almost all made available to public bodies in Scotland through the Public Sector Geospatial Agreement (PSGA). Access to data is also enabled through the OS Data Hub (osdatahub.os.uk). There are extensive data resources available from this source, most of which are included in the PSGA. Data accessible from the Data Hub include those for England and Wales, which are covered by the PSGA.

If specific requirements arise that are not covered in the current agreement, then they can be obtained for the relevant fee. Terms and conditions of use of data accessed from this source are available at osdatahub.os.uk/legal/termsandconditions.

2.8 Other examples of available spatial data

To comply with requirements of the Aahrus Convention (UNECE, 1998), and public policies associated with enabling access to data, it is likely that all public bodies make data available of some relevance to the Regional Land Use Partnerships. Not all of that need be in forms which can be downloaded for free or purchase, and used directly in a Geographic Information System. For example, spatial data are used extensively to communicate elements of messages or the provision of information, in digital form, as images (e.g. in formats such as *.jpg, *.tif, etc.) or as *.pdfs. It is likely that data provided using such formats will be expected to be final copies of outputs and not for subsequent editing. However, most such data can be edited using appropriate tools.

Some geographically specific information is available for places or themes but does not represent (or seeks to represent) an accurate delimitation of boundaries. An example is Scotland's land Information Service (Annex 2, Example 15)[1]. In compliance with the Land Registration (Scotland) Act 2012, Registers of Scotland are required to make information on the land register publicly available. Progressively, the aim is to open the register to digital deeds, authenticated using a digital signature.

ScotLIS enables an online search of the Land Registry providing information on the properties Title Number. With this further information can be purchased regarding 'who owns the house or land, the address of the owner, and details of Charges and Burdens affecting the property'. Registers of Scotland includes information on certain types of use of the property (residential, commercial, land, agriculture, forestry and other), which may assist with searches of records. Data for properties are entered after transactions of ownership are completed. Only records which have been transferred are available in ScotLIS. As of early 2018, 63% of properties had been entered, equivalent to approximately 2.5 million hectares of land area, approximately a third of Scotland's land. This reflects the predominance of properties in urban areas.

The boundary in the Title Record of an individual property will have a high level of absolute accuracy. However, those represented on the online tool will be relationally and topologically accurate, but will not be accurate in absolute terms (i.e. correct in shape and size but not in geographic location. Figure 7 shows an example of the inspection of a property online (Great Glen House, Inverness).

Access and use of the dataset of ScotLIS is unlikely to be a direct requirement of the Regional Land Use Partnerships. However, inspections of areas of land or sets of properties may be relevant in

[1] Note: Scotland's Land Information Service, ScotLIS is not to be confused with the Land Information Search (LIS) in Example use 5, Annex 2.

understanding prospective future land uses (e.g. housing development), changes in land use at a local level, or in raising awareness of individual owners of opportunities relating to the management of natural capital of their land, such as peatland restoration or woodland expansion. All such enquiries could be undertaken using the online tools, subject to the limitations of the data available.

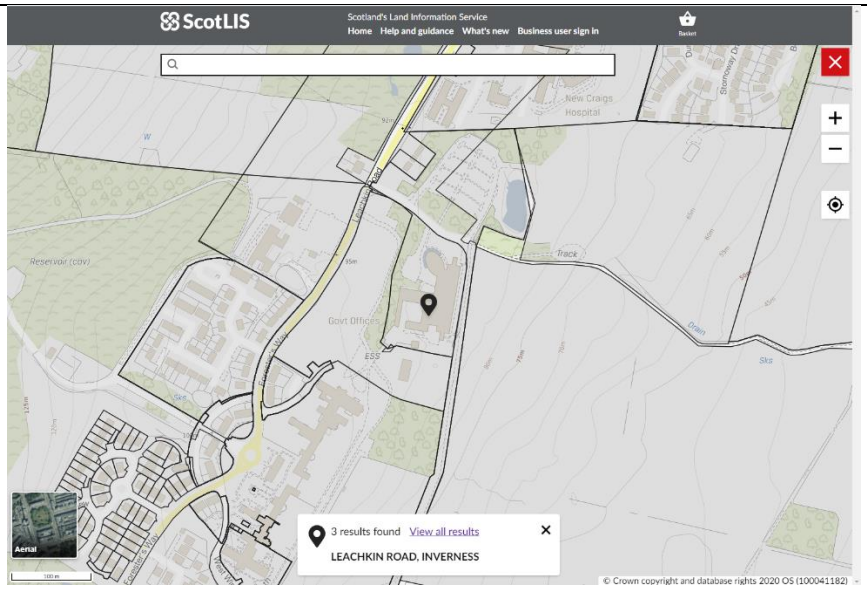

Figure 7 (a). Example of online presentation of property boundaries in ScotLIS. Area shown is south-west Inverness, with a property queried.

Property details

Title number	INV15737
Address	LEACHKIN ROAD, INVERNESS
Last purchase price	£12,825,953
Last purchase date	31st May 2006
Land register	Registered
Interest	Proprietor What's This?
Property type	Land Only What's This?

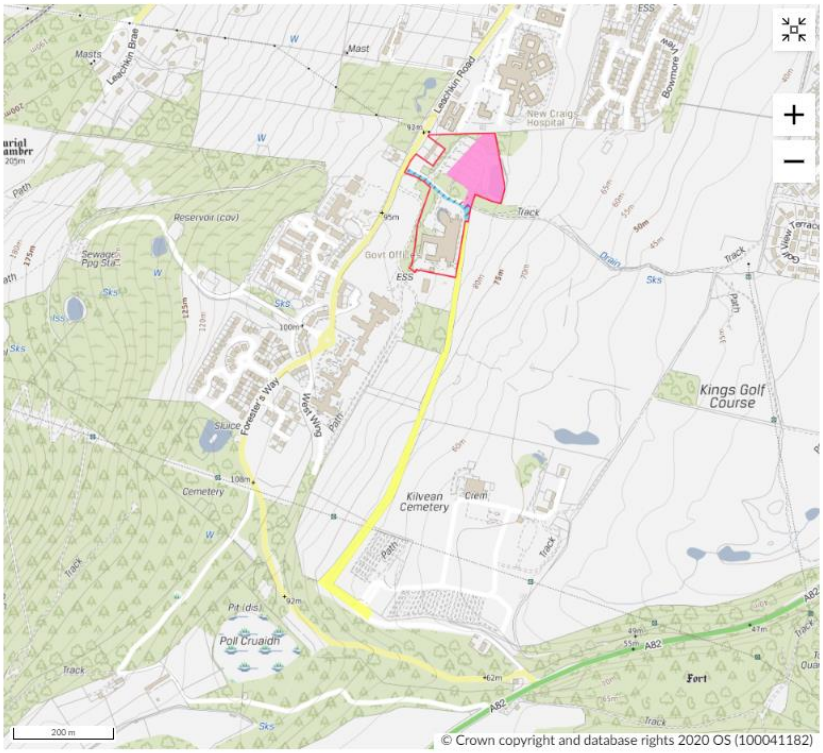

Figure 7 (b). Example of online reporting of query about an individual property.

Other sources of data comprising national records are available by pre-set geographical units. For social and economic data, the geography which is used most commonly is that of data zones (see also Example Use Case 4). The data zones are the fundamental geography used in Scotland for representing information at the level of a community or 'small area'. The types of data that are available in this geography are those relating to population (e.g. decadal census), Scottish Index of Multiple Deprivation (SIMD), and geographically presented data from national surveys (e.g. Scottish Household Survey). They are designed to comprise approximately 500 to 1,000 household residents, and align within local authority areas. There are 6,976 data zones covering the whole of Scotland.

A further example is the National Biodiversity Atlas Scotland (NBN Atlas). The NBN Atlas Scotland provides a range of functions that support engagement, education and informing people about the natural world. Those functions include presentation of the geographic distribution of records of certain species, combining details of the species, their indicative location, geographic context, and means of analysis and exporting. It also provides a mechanism for citizen science, with an interface through which users can submit observations. The members of the National Biodiversity Network in Scotland are NatureScot (Scottish Natural Heritage) and SEPA.

Figure 8 shows a view of the Atlas in which particular species are shown in the 100 m x 100 m squares within which they have been recorded. These locations are overlaid on aerial imagery which provides

geographic context, and the boundary of a designated area, which is Balmedie Country Park (Aberdeenshire).

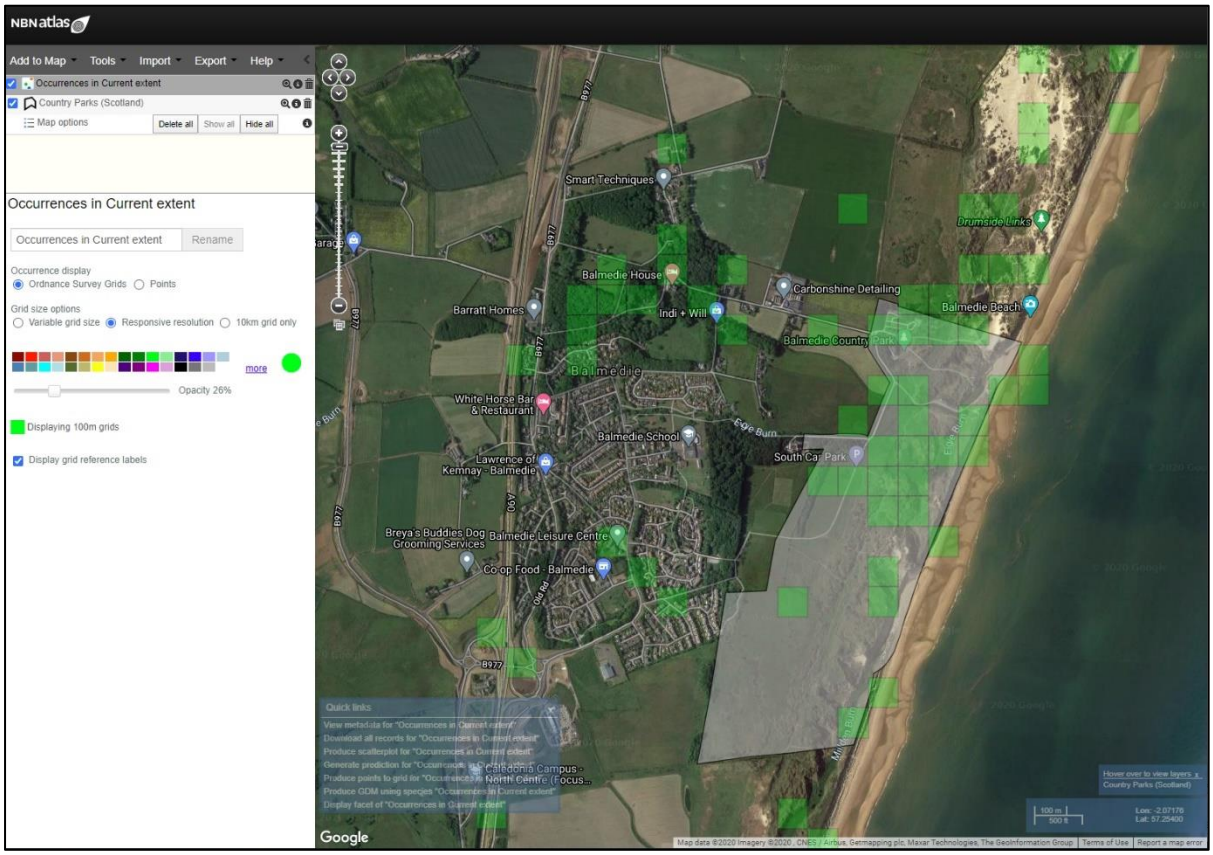

Figure 8. Image of the NBN Atlas showing the distribution of records of species, represented as 100 m x 100 m squares, with aerial imagery and the boundary of Balmedie Country Park as backdrops.

A further potentially significant source of spatial data is the National Library of Scotland (Figure 9). The map categories provide an extensive history of Scotland documented in maps and images. They provide geographic evidence of change in Scotland through time from Roy Military Survey of Scotland (1747 to 1755), the different series of Ordnance Survey from 1841 to approximately 1970 (i.e. present day less 50 year protection under copyright), thematic maps of land utilisation survey of Dudley Stamp (1931 to 1935), estate maps from 1730s to 1950s, and aerial photographs of Scotland (e.g. aerial photographic mosaic 1944 to 1950).

Most of the collection of maps and imagery is georeferenced enabling their viewing together with contemporary imagery to aid interpretation. Due to their nature as archive document, most of the digital data are scanned (i.e. raster data structures). Licencing enables the use of some of the materials for the derivation of new products, an example being the OpenStreemap project.

The data in the collections provide means of desk-based research on the land and geography of Scotland. They can be used to understand changes in land use and insights to where they may be historic connections between areas or sources of contention.

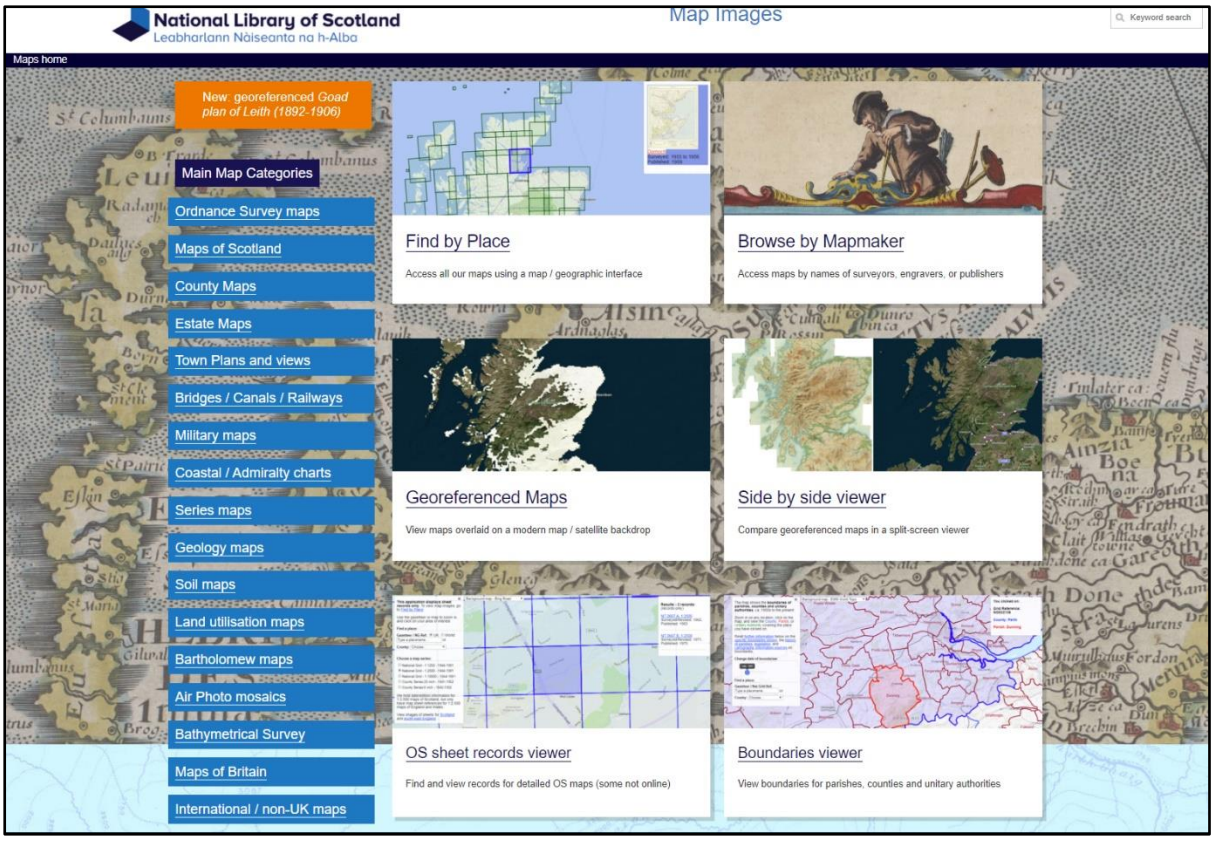

Figure 9. View of options for accessing georeferenced information hosted by National Library of Scotland

Access to georeferenced maps of areas of Scotland from the Ordnance Survey large scale town plans (1847 to 1895) and series dating from 1843 to approximately 1970 provide insights to the presence of features in Scotland (indications of vegetation, land use, building use, sites of historic importance). More Ordnance Survey maps will be made available as they emerge from protection under copyright.

The side-by-side viewer enables those maps, and other imagery, to be viewed two at a time to enable interpretation of context (e.g. built areas in relation to topography or soils), and change (e.g. forest cover at multiple dates). An example of that facility is provided in Appendix 3, Example 15.

Other sources of spatial data which are likely to be of relevance to the Regional Land Use Partnerships are listed in Table 2.

Table 2. Other portals for spatial data of relevance to remit of Regional Land Use Partnerships

Topic(s)	Host Organisation	WWW link
Datasets relating to the environment (downloadable)	SEPA	https://www.sepa.org.uk/environment/environmental-data/
Roads for which Scottish Ministers are the Roads Authority, viewed through a webmapping service	Transport Scotland	https://data.gov.uk/dataset/92b780e3-0622-4ece-ad02-bc9f9fd2d8c8/_trunk-road-network-wms-service
Datasets covering statistical and geographic data about Scotland	Scotland National Statistics Portal	https://statistics.gov.scot/home

It is a reasonable expectation that spatial data covering more types of topics will become available for Scotland. The sources of such data will include more from international sources with coverage that includes the UK and Scotland, such as the EU Copernicus earth observation programme 'drawing on satellite Earth Observation and in-situ (non-space) data.' Other sources of spatial, or georeferenced, data are likely to be from private sector suppliers, and portals enabling access to citizen collected data (i.e. citizen science), of which the National Biodiversity Atlas described above is one.

3. Uses of Spatial Data

The nature of spatial data being made available is expanding rapidly. This is reflected in the setting-up, in 2018, of the UK Cabinet Office Geospatial Commission, with the purpose of developing a strategy that 'unlocks the power of geospatial data'. The remit includes considering how to 'level-up' communities, broadening the domains of users of spatial data, and encouraging innovation in the development of digital approaches (e.g. data capture, analysis, presentation and use).

A set of examples has been identified to provide contexts for the requirements of spatial data by the Regional Land Use Partnerships, and access to and availability of different types of such data. The examples do not provide any analysis of characteristics of specific Regional Land Use Partnerships, or any newly derived data. Rather, the selection was based upon tasks that could be expected to be associated with the remits of the Partnerships as introduced in the Scottish Land Use Strategy (Scottish Government, 2016), learning from the Rural Land Use Pilots, and expanded by applications by Think Tank partners. The examples are listed in Table 3 and presented in Annex 2.

Advanced uses of spatial data were explored in the Rural Land Use Pilots of Scottish Borders (Example 6 and Aberdeenshire (Example 2). These produced and tested different means of combining spatial data to provide derived assessments of characteristics and opportunity mapping of certain topics (e.g. Biodiversity opportunity, Scottish Borders, Example 6).

Examples of approaches to combining or integrating spatial data for Scotland-wide assessments of characteristics of natural resources or opportunities for land use change, as may be anticipated of use in spatial planning, is that of the possible emissions for area-based afforestation (Matthews *et al*., 2020) is an example of combining spatial data that represent different types of input data, underpinned by process based understanding (also see Example 9, and Annex 1). The model can provide estimates on a regional basis. In principle such regional estimates and outputs could be aligned to the areas of individual RLUPs. The derivation and representation of characteristics and ecosystem services at national and continental levels raise challenges for appropriateness of the use of the data, such as aggregation and generalisation of spatial data.

The examples have been updated to include data that have become newly available over 2021 (e.g. data reporting on funding for tackling COVID-19, presented in dashboards using map and other graphical interfaces; Example 14 of the Community Funding Mapping for COVID-19). The use of such tools in the communication of information with a geographic component has become widespread reflecting ease of access to spatial data by products aimed at consumers (e.g. mobile devices) as well as business and public sector organisations. Similar such applications enable access to information about the uses of land, such as woodlands (Example 5), soils and derived characteristics (Example 16), and historic land uses (e.g. Example 8). A wide range of tools are available that can be implemented for bespoke applications, designed for specific uses (e.g. by or for an RLUP) (Example 13).

Combining information about places can help inform interpretation of their characteristics, or changes in characteristics through time, without analytical tools being developed or implemented. The National Library of Scotland 'side-by-side' viewer provides such capability for a broad range of dates of maps across Scotland, and some environmental data, such as soils and terrain (Example 15).

The examples cover applications at levels from Scotland-wide (e.g. assessment of carbon sequestration potential through woodland expansion, Example 9), local authority (e.g. delivery Communication of a Local Development Plan, Example 1; overview of CO_2 emissions by sector,

Example 17), local (e.g. assessment of socio-economic performance by datazone, Example 4) or information at property level (e.g. ownership of selected properties, Example 18).

Several of the examples provided can be expected to be continue to be developed under as the source organisation progresses through its work programme (e.g. Registers of Scotland. ScotLIS, Example 18), producing regular updates (e.g. monthly; National Atmospheric Emissions Inventory, Example 17).

Other datasets and their provision are analysis which are not within any update programme (e.g. Social-economic performance at datazone level, Example 4; or snapshots in time which are updated by other mechanisms (e.g. mapping of urban greenspace, Example 10), or are illustrative of how access to contemporary spatial data in near real time can be used to inform tackling disaster or major incidents (e.g. wildfires using earth observation data, Example 11).

Spatial data are valuable elements of tools that inform processes of deliberation about land use futures, such as documents for public consultations (e.g. by local authorities, Example 3), new and emerging approaches to participatory approaches to developing visions of futures of rural areas (e.g. Example 7), and communicating information about local strategies and plans (e.g. Example 1).

Geographic representation of indicators relating to Scotland's National Performance Framework enables their tracking through time and interpretation with respect to trends (Scottish Quality Evidence Finder, Example 12). This is an example of the increased public provision of information about areas, in this case at datazone level, updated by an existing process. Certain information can be extracted for defined areas (e.g. the datazones within or intersecting areas of RLUPs), and which are updated without any local resources being required.

Table 3. Table of example of uses of spatial data of prospective relevance to RLUPs

Example Use Number	Example Use
1	Information that supports communication of a Local Development Plan, example of South Ayrshire Local Development Plan
2	Spatial data for use in exploring potential impacts of rural land use change, example of Aberdeenshire Land Use Strategy Pilot
3	Spatial data used in consultation documents, e.g. local authority Local Development Plan proposals
4	Spatial data for assessing Socio-Economic Performance, at Data Zone level
5	Spatial data in the Land Information Search Agri-Environment and Forestry
6	Spatial data for use in developing a land use framework, example of Scottish Borders Land Use Strategy Pilot
7	Spatial data in support of participatory approaches to visions of future land uses, e.g. Tarland area, Aberdeenshire
8	Spatial data in use or investigation of Historic Land Uses
9	Spatial data in analysis of potential of new woodlands to store carbon
10	Spatial data in analysis of Urban Greenspace
11	Earth observation data for mapping wildfires
12	Scottish Equality Evidence Finder
13	Filtering, finding, selecting and sharing OS map features API
14	Dashboard presentation of Community Funding Mapping for COVID-19
15	Comparing data between dates, and types (National Library of Scotland)
16	Soils of Scotland
17	CO_2 Interactive Map (National Atmospheric Emissions Inventory)
18	Scotland's Land Information Service (ScotLIS)

The Land Use Strategy (Scottish Government, 2020) notes that its three overarching objectives "recognise that Scotland's natural capital is one of our greatest assets and needs to be managed in an inclusive and sustainable way to maximise the provision of a wide range of economic, environmental and social benefits for current and future generations." The concept of natural capital, a means of framing the stocks and flows of services that nature provides to society (Barbier, 2020), is embedded in plans for the Regional Land Use Partnerships (RLUPs), and expected to be in the Regional Land Use Framework (RLUFs), as set out in the Land Use Strategy.

The Report of the Advisory Group on Economic Recovery (Scottish Government, 2020b) recommended investment in Scotland's natural capital, providing means of supporting the design and implementation of carbon positive businesses and multi-functional land use. They propose that natural capital approaches could provide valuable opportunities for land-based industries of the future through rural and nature-based economies. It notes that they can form part of 'brand Scotland'. It also identifies the need for financial solutions to fund nature-based solutions, forestry and agriculture.

The development of spatially explicit evidence of natural and cultural resources at regional to national and international levels is a focus of work in public agencies, NGOs and research projects. Further information is provided in Annex 3 of sources of information, frameworks and approaches and outputs derived from or presented using spatial data. These provides a link to data available in Scotland for some aspects of mapping or deriving estimate of natural capital in the Natural Asset Inventory and Natural Capital Accounts (App. 3i), details of which are also provided in Section 2.4.

A review of the uses of natural capital based approaches at estate and farm levels in Scotland. (Blackstock *et al*., 2020). They concluded that these can be used to build consideration of the natural environment into discussions about business decisions. Tests of the application of the Natural Capital Protocol are extending across different types of environments and land management systems. Ovando (2021) applied the natural capital protocol at its Glensaugh Climate Positive Initiative, Aberdeenshire. Findings suggested it provides a tool for businesses to understand their impacts and dependence on natural capital, and "to identify risks and opportunities that could be integrated into business models to respond to global environmental challenges." Other such implementations of the natural capital protocol on Glensaugh Farm, Aberdeenshire, Glenlivet Estate, Moray, and the Dryfesdalegate dairy farm, Dumfriesshire. Further, the NatureScot Natural Capital Pilot Programme (NCAPP) is exploring how to work with natural capital at different levels. It appears to use some spatial data in the pilot project 'Facilitating Local Natural Capital Investment' (Hume *et al.*, 2021).

A set of indicators of ecosystems has been derived for Scotland using the Common International Classification of Ecosystem Services (CICES) (see also Section 2.4; Annex 3iii). The framework is a refinement of the one proposed in the Millennium Ecosystem Assessment (MEA), and is used by the European Union in its assessment work. It has been applied in the mapping of 10 ecosystem services under cultural, regulating and provisioning services. The outputs are interactive maps of the services, at different spatial resolutions or geographies (e.g. water catchments). An example is shown in Annex 3iii.

The United Nations Systems of Environmental Economic Accounting (SEEA) provides an international framework for integrating economic and environmental data (Annex 3vi.a). It sets out standards to enable comparisons to be made internationally, and has a working group dedicated to issues of the use of spatial units (Bogaart *et al*., 2019). An example of the implementation of that standard is the mapping of aspects of natural capital for Amazonia (Annex 3vi.b; Conservation International, 2015). This produced an online storymap showing the spatial distribution of selected elements of natural capital (e.g. Figure App3.2).

At the level of the European Union, significant investments are made in the collation, analysis and reporting of ecosystem services across Europe, informing dialogue and monitoring of policies such as the Biodiversity 2030. Comprehensive assessments of ecosystems at EU level are presented in spatially

explicit outputs from the 2020 Mapping and assessment of ecosystems and their services (MAES) Report (Maes *et al*., 2020). In turn that is one of the underpinning evidences bases of the Biodiversity Information System for Europe (Annex 3vii.b), and the derivation of a natural capital accounting for the European Union (European Commission, 2019).

Integrating the natural capital and ecosystem accounting approach of MAES and the SEAA has been implemented in the Mapping and Assessment for Integrated ecosystem Accounting (MAIA) programme (Annex 3vii.b). Outputs of the approach are spatially explicit assessments for 10 counties in Europe (Lof *et al*., 2022).

At a regional level, an example of the MAES mapping approach is to the Limburg Province (The Netherlands) from which an 'Ecosystem Unit (EU_NL) Map' was produced (Annex 3vii.c). This mapping implements the United Nations Systems of Environmental Economic Accounting framework, with an output resolution of the spatial resolution of individual fields and land cover units.

The representation of characteristics of areas at different spatial resolutions, and in different geographies, would create challenges for combining the output data. Such analysis requires appropriate human and technical capabilities (Section 4).

4. Human and Technical Resources

The pilot Regional Land Use Partnerships, announced by Scottish Government in February 2021, are set up in different institutional contexts and arrangements. Their compositions are likely to reflect local circumstances, and potentially their access to human and technical resources relating to spatial data and its use. The following comments reflect on the resources required for handling spatial data in five example arrangements of future Partnerships.

i) Stand-alone organisations – The Partnerships are resourced to have their own technical capabilities and capacity to undertake all the tasks required under their remit.
   a. Skills –
      - Spatial data handling and analysis, with expertise in relevant software, and understanding of issues of data quality, accuracy (and its limitations), scale, and fitness for purpose of spatial data;
      - Design and production of cartographic outputs (analogue or 'static');
      - Design of cartographic outputs and delivery online (e.g. web-based mapping at different scales);
      - Spatial planning, with knowledge of planning requirements and principles;
      - Data management, back-up archiving, and licencing.

   As with all organisations, access to skills or knowledge is required to ensure good governance and business processes. It is unlikely that any direct capture of spatial data will be required as a major, or ongoing task, for a Partnership, and thus there are no direct requirements for specific data capture skills. However, indirectly it can be expected that data gathering could be initiated or sought through citizen observations. One element of relevance will then be that of information governance and compliance with relevant data protection legislation, including the General Data Protection Regulations.

   b. Spatial Data –
      - Access to data provided through national agreements (e.g. Public Sector Geospatial Agreement with Ordnance Survey; Aerial Photography Great Britain Contract [note, there is no certainty that under some forms of arrangement Partnerships would be eligible for membership of these types of agreements];
      - Access to data available through data portals (e.g. Scottish Government Spatial Hub; Scotland's Environment Web; Natural Asset Register; Improvement Service Spatial Hub; OS OpenData);

- Access to spatial data directly from the supplier or publisher, including that from Scottish Government (e.g. Scottish Index of Multiple Deprivation);
- Management, storage and archiving of data collected for, or derived by, the Partnership (e.g. social attitudes of residents, businesses, visitors).

c. Software –
- Geographic Information Systems (free to use o, or requiring purchase) for the handling, management and presentation of spatial data for purposes of the Partnerships (e.g. production of Regional Land Use Strategies, cartographic outputs);
- Web Mapping Services for publishing materials online;
- Possible requirements for specialist software for data visualisation (e.g. for community engagement, communications materials).

d. Hardware –
- Computing facilities suitable for the effective processing of spatial data, taking account of data volumes, computational demands, graphics capabilities; or using online infrastructure such as ArcGIS Online.
- Storage and archiving of spatial data, taking account of data volumes and security. Some data may enable the identification of individuals (e.g. address or postcode relating to surveys of residents, businesses, visitors), so requiring data storage processes to be compliant with GDPR).

ii) Partner bodies – The Partnerships could draw on the resources of partner bodies, with specific partners allocated lead responsibility for particular tasks. However, it is likely that such partners would require resources which may be above those already available.

a. Public sector organisation - Where such a partner is a public sector organisation, (e.g. local authority, CAMERAS partner, National Park Authority) then high levels of knowledge about spatial data and skills in its use can be expected to be available. Although the specific capabilities within such organisations will vary, all have the infrastructure required for almost all of the tasks identified, with the likely exception of aspects of modelling (e.g. environmental change).

b. Effective formal networks in which Regional Land Use Partnerships could be eligible to participate include the public sector organisations through membership organisations (e.g. AGI Scotland), or user groups relating to data agreements. Such networks facilitate sharing of information about the content or licence arrangements for datasets. Examples are:

i. Spatial Hub Scotland which is "dedicated to discussions around spatial datasets owned by Scottish local government and published on the Improvement Service Spatial Hub".
ii. One Scotland Mapping Agreement Annual Conferences.

c. Informal networks largely based on personal contacts developed between representatives on formal bodies and related interests or remits.

d. Research organisations – Partners organisations which have access to relevant spatial data, skills and hardware (e.g. James Hutton Institute, SRUC). Examples of such partnerships are the Aberdeenshire Rural Land Use Pilot **and the** Scottish Borders (Pilot) Regional Land Use Framework (see also Appendix 2, Examples 2 and 7).

e. Civic society organisations - Currently, it is unlikely that most civic society organisations in Scotland would have the same level of skills available for most of the use cases required with spatial data. It is also unlikely that there is the capacity for handling most tasks identified in Section 4 whether for one Partnership or more.

iii) Private sector contracted – Scotland has businesses with experience in the handling and analysis of spatial data, some of which originated were created from public sector bodies (e.g. Forth Valley GIS, which became ThinkWhere).

Public procurement infrastructure (e.g. Public Contracts Scotland, Quickquote) are likely to be appropriate mechanisms for obtaining specialist resources of skills, software or hardware for specific tasks. Examples of topics contracted out which could have come into the remit of a Partnership and make use of access to spatial data are regional wind energy strategies, landscape capacity studies, visualisations, public attitude surveys. Such work would require the contractor to have access to spatial data, often provided through the mechanisms of the client (e.g. their licence agreements with data suppliers).

Resources for subsequent uses of spatial data also require consideration. The use of cartographic or geovisualisation outputs, in analogue or digital form may require access to other forms of human capital such as mediation or presentation skills, or knowledge of relevant regulations or technical issues, or local contexts. Prospectively, specialist hardware or software may also be appropriate any of which would most likely be sourced externally, or from partners, and not be a core resource of a Partnership.

5. Conclusions

The natural resources, cultural heritage and characteristics of land in Scotland are represented by an extensive range of spatial datasets, much of which has coverage that is Scotland-wide. The increased availability of spatial data is consistent with the obligations under the Aarhus Convention (UNECE, 1998) on rights of access to Information, public participation in decision-making, and access to justice in environmental matters, and the adoption of policies of Open Data and Open Science. That availability enables access to such data by a wider range of prospective users (e.g. not only public agencies, or academia under negotiated arrangements).

Some spatial data of prospective interest to the RLUPs are subject to specific agreements and costs (e.g. Met. Office), or from commercial providers not part of central agreements such as the Public Sector Geospatial Agreement (e.g. of aerial or satellite imagery). The operation of the pilot RLUPS are an opportunity to identify gaps in data provision, and inputs to negotiations of the content of the update of the Public Sector Geospatial Agreement.

The key questions to be considered by the use of spatial data in the RLUPs are:

- 'What is needed for undertaking the task'? – The purpose of the task should determine what data are required, which can then be matched to availability and means of access.
  However, when considered Scotland-wide, some data on a given topic may be of different scales, resolutions or time periods. For example, the scale of data on soils is 1:250,000 across Scotland, and 1:25,000 or 1:63,360 for lowland Scotland (Example 16). Therefore, an application within a single RLUP, and the same application applied for different RLUPs, may require a choice to be made of the most suitable dataset to be used for the purpose intended. Therefore, joining up outputs of the same requirement from different RLUPs would often be inappropriate.

  Interfaces by which information is made available increasingly includes that which is linked to a specific location or area (e.g. property, or administrative or biophysical unit). However, the means by which spatial data are made available determines, or influences, the different types of uses to which they can be put. These means do not all support the same functionalities. For example, some spatial data are available for online query for extracting information for a place or area, but may not be available for download and use by the RLUP or its partners (background maps for geographic context).

Understanding is required on the use of the spatial data taking account of their accuracy and eligibility for combinations. The widening the accessibility of uses of spatial data requires the development of skills particular to the tasks intended, noting the different types of expertise identified with each of the examples of use, such as cartography, spatial analysis, and expertise in the topics (e.g. soils, habitats) rather than software and interfaces.

- 'How wrong can the product afford to be?' – The nature of the use of the outputs should always be considered in terms of the consequences of errors in the data, and inappropriate uses.

  Many of the datasets have no explicit statements on their accuracy (e.g. positional, relative, attributional, taxonomic). Many have which are accessible have metadata which describe items such as origins of the data, means of data collection, or accuracy. However, that is not true for all datasets, or not with a clear link from the interface for accessing the data. This represents a risk to the use of spatial data (e.g. relating data at one scale with that of a different scale; combining data on an apparently similar topic from different datasets, such as land cover or habitats).

Public, private and third sector organisations and citizens are increasing equipped with the skills and technical capabilities for accessing and using spatial data relating to areas of their interest (e.g. Scotland, local authority, local area, sites within specific ownership or management). The development of those skills is a combination of formal learning, and self-taught capabilities facilitated by increased availability of data as online web resources or mobile Apps. Increasingly, these skills will support a range of applications, such as eliciting visions of local people for the land use in their area, analysis of data for a specific area, presentation of final outputs (e.g. a spatial plan).

There are likely to be gaps in the availability and suitability of existing spatial data on some topics which would have been of value to the work of RLUPs, either in general or in particular areas. However, the creation of the pilot RLUPs may provide new motivation and opportunities to collect new spatial data that can support their aims of locally democratic engagement, and tackling challenges within their remit. Such data could expand the contributions of citizen science in the provision of visions for future land uses, evidence of characteristics, and monitoring of change or insights to pressures for change. As such an outcome of the RLUPs could be an expansion of the engagement of stakeholders in delivering on visions for their area and the aim as set out in the Land Use Strategy of facilitating 'regional decision-making to help achieve Scotland's climate and environment targets through land use change.'

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Annex 1. Integration of land data for policy support in Scotland

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Background

Since 2008, the Land Systems team and others within the Information and Computational Sciences Department of James Hutton Institute have been active in undertaking land-related data integration and spatial modelling in support of Scottish Government policy teams. The projects have included specific *ex ante* policy options appraisals (e.g. for CAP reforms) and other studies that characterise current states, alternative options for use of, or potential impacts of change on land.

Typically, the data integration has taken two forms: i) linking administrative datasets concerned with land; ii) combining administrative and research-based datasets. The nature of integration can be relational (between entities – field-holding-business), or spatial - using geographical information system operations to generate characteristics of land parcels from other maps (e.g. climate, soils etc). There has also been significant effort devoted to generating maps with Scotland-wide coverage and field/business granularity.

Portfolio of examples

The land related datasets, how they are combined, and the projects undertaken using them are illustrated in App. 2, Figure 1, with a list of the projects in Table App. 2, Table 2.

The datasets are grouped by theme (closely linked to source). Administrative datasets are classified (grey scales or colour) by granularity (field- holding- or business-based) and for research data by topic (colour). The dataset groupings list topics, identify specific datasets and indicate key features such as frequency of updates and dates from- (or on-) which they are available. Some datasets where it is relevant indicate a scale or grid size.

Most policy questions require bespoke elements, but there are some combinations of datasets that are frequently reused. These datasets are identified as intermediate data (grey circles).

1. Business, Holding and Field	This dataset links the three levels with unique identifiers, this makes it possible to map data such as land use, payments, tenure etc and via GIS analysis to link in the research-based map datasets. Used for nearly all projects.
2. Stocking Rate maps	Maps of livestock units per hectare generated per holding from Agricultural Census livestock numbers and grazing land covers. Informed CAP options, and inputs to Woodland Expansion Advisory Group (WEAG) deliberations.
3. Unique Combinations	The unique combination of climate, soils and land use across Scotland – used as inputs to crop and woodlands modelling, designation of options for the agricultural Areas of Natural Constraints boundary and a Land Capability for Agriculture update
4. Composite Land Cover/Use map	A map based on (in priority order) OS data (inland water, urban, infrastructure), National Forest Inventory, IACS per field land use and Land Cover Map 2007.
5. FBS & Biophysical data	This dataset generated biophysical descriptions of the Farm Business Survey sample, linked via (1) and used this to estimate the physical limits on performance for businesses in the LFA. This linkage is in 2020 part of ongoing research.

In App. 2. Figure 1 the key datasets used for each project (black circles) are shown with the data flow or linkage as arrows.

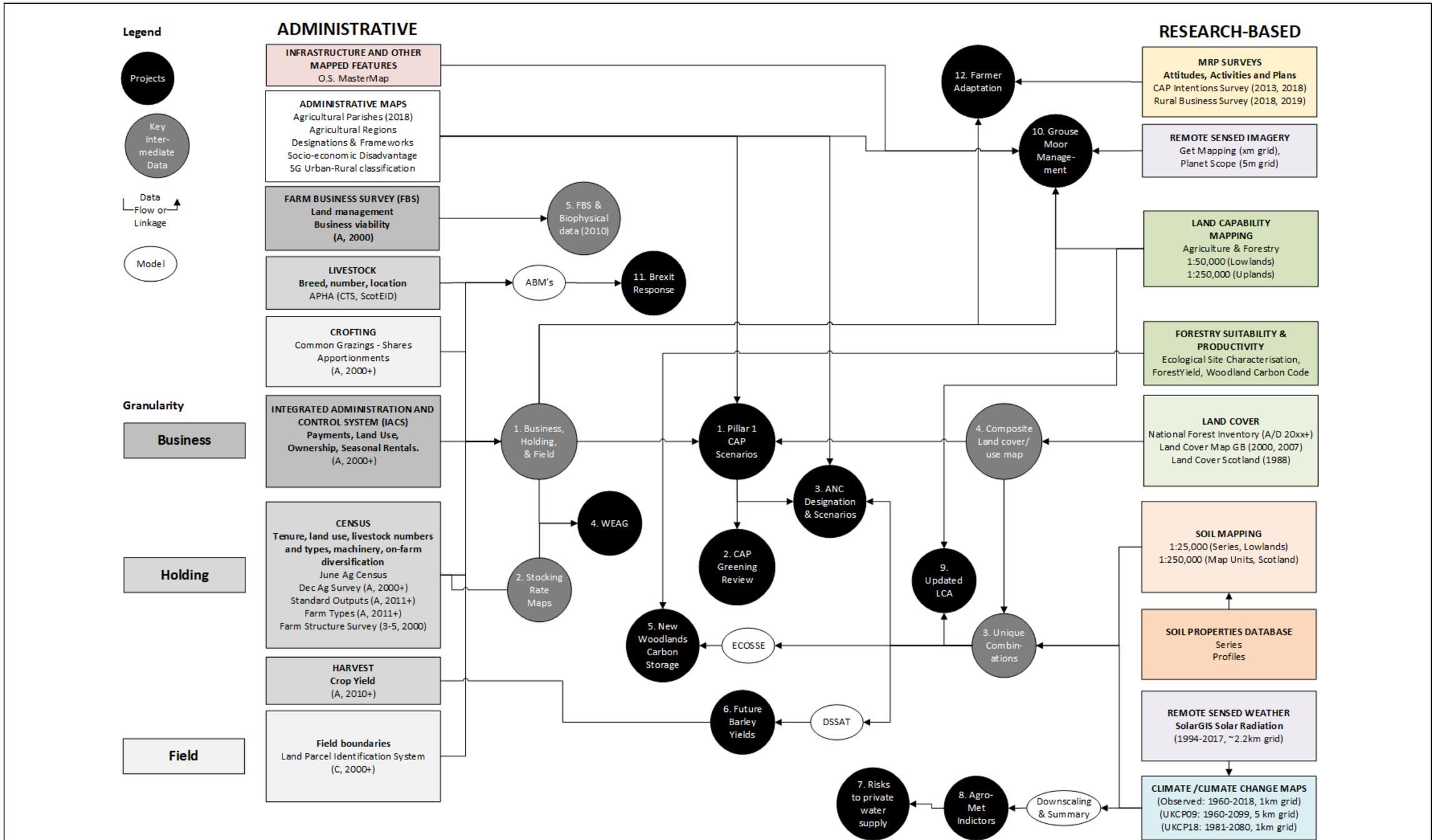


Figure 1

App2. Figure 1. Combing land related datasets at different spatial levels, and reference to projects in which the data integration was undertaken.

Table App. 2. Table 2. Project descriptions**,** with contact names of lead investigator.

1	**Pillar 1 CAP scenarios** Keith Matthews	Undertook a series of options analyses for transition from historic to area-based payments [1]. Emphasis was on how to regionalise payments (land use, capability etc.) and the degree of redistribution between regions and sectors. Used in the Pack Inquiry and for CAP Stakeholders Group briefings.
2	**CAP Greening** Keith Matthews	This study assessed trends in environmental indicators, the uptake of CAP Greening measures in 2014, with maps and provided an expert review of their likely effectiveness.
3	**ANC Designation** David Donnelly **ANC Scenarios** Keith Matthews	Areas of Natural Constraint was the planned replacement for the Less Favoured Area designation. The project undertook the testing of options for designations (biophysical) and how payments would be distributed. This formed the basis for a 2016 ANC workshop, and further analysis in 2019/20.
4	**WEAG** Keith Matthews	The Woodlands Expansion Advisory Group informed SG land use strategy. Analysis was undertaken to identify and assess the quality (LCA classes) of unstocked and lightly stocked land across Scotland.
5	**New Woodlands Carbon Storage** Keith Matthews	This project mapped the net carbon storage for 11 forestry management alternatives for new woodlands on all non-forested land in Scotland [2]. This used the unique combinations dataset with the ECOSSE soil carbon model and datasets from Forest Research.
6	**Future Barley Yields** Mike Rivington	This used the unique combinations datasets with the DSSAT crop model to model current and future barley yields under climate change. The analysis was validated against holding level harvest yield data and informed deliberation with Scotch Whisky Research Institute.
7	**Risks to private water supply** Mike Rivington	This used the spatial climate data to highlight where changes in rainfall under climate change may cause supply interruptions. Change in evapotranspiration and land use may also have an impact.
8	**Agro-Met Indicators** Mike Rivington	This project downscales the regional climate model data [3] and generates summaries of risks from climate change using agro-meteorological indicators developed in the Communicating Climate Change Consequences for Land Use (C4LU) project [4].
9	**Updated LCA** Mike Rivington	This project uses the improved resolution climate data and enhanced soil properties datasets to update the Land Capability for Agriculture mapping with emphasis on looking forward to changes by 2050 [5].
10	**Grouse Moor Management** Keith Matthews	As part of a wider analysis of grouse moor management this project identified and characterised holdings with grouse moors. The analysis assessed the potential for alternative uses, updated the mapping of strip-burning using remote sensed data and refined the estimates of grouse butt density as an indicator of intensity of management.
11	**Brexit Response** Gary Polhill	Used agent-based modelling to assess how cattle-based systems in Scotland might respond to Brexit. The models were parametrised with data from APHA and SG Agricultural Census/IACS.
12	**Farmer Adaptation** Lee-Ann Sutherland	Based on large-scale land manger surveys a series of analyses of new entrants, diversification, non-commercial farming and female-led farms have been undertaken. The surveys were structured by the Census and IACS data.

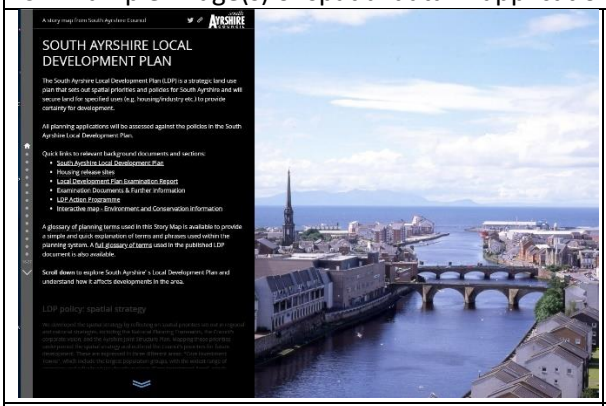
References

1. Matthews, K.B., *et al*., (2013). Reforming the CAP With area-based payments, who wins and who loses? *Land Use Policy*, 31: p. 209-222.
2. Matthews, K.B., *et al*. (2020). Not seeing the carbon for the trees? Why area-based targets for establishing new woodlands can limit or underplay their climate change mitigation benefits. *Land Use Policy*, 97.
3. Rivington, M., *et al*. (2008). Downscaling regional climate model estimates of daily precipitation, temperature and solar radiation data for specific locations. *Climate Research*, 35: p. 181-202.
4. McCrum, G., *et al*. (2009). Adapting to climate change in land management: the role of deliberative workshops in enhancing social learning. *Environmental Policy and Governance*, 19: p. 413-426.
5. Brown, I., *et al*. (2011). Climate change, drought risk and land capability for agriculture: implications for land use in Scotland. *Regional Environmental Change*, 11(3): p. 503-518.

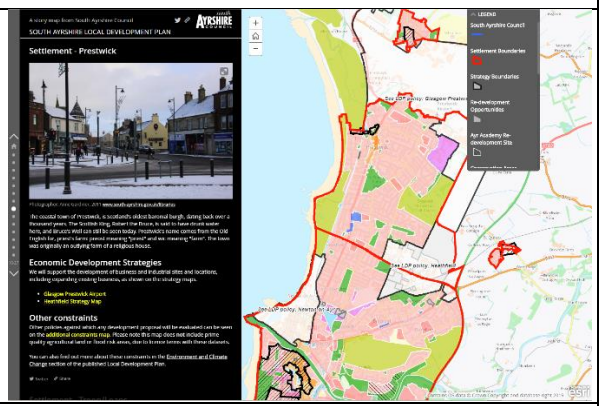
Annex 2. Examples of uses of spatial data of prospective relevance to RLUPs

Example 1. Spatial data linked to information that support communication of a Local Development Plan, example of South Ayrshire Local Development Plan

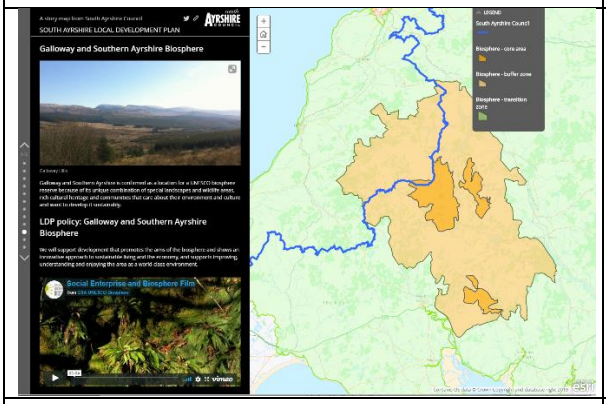
1. Purpose – The provision of information about the Partnership area
2. Audiences – Public for access to information by topic or locality
3. Spatial data requirements – Data layers relevant to Local Development Plan, made available through ArcGIS and ESRI Storymaps
4. Sources of relevant spatial data – Local authority (i.e. creator and publisher of spatial data)
5. Technical and human resources – Relevant software licences for use of ArcGIS online and associated Storymaps; skills in design of Storymap
6. Example image(s) of spatial data in application



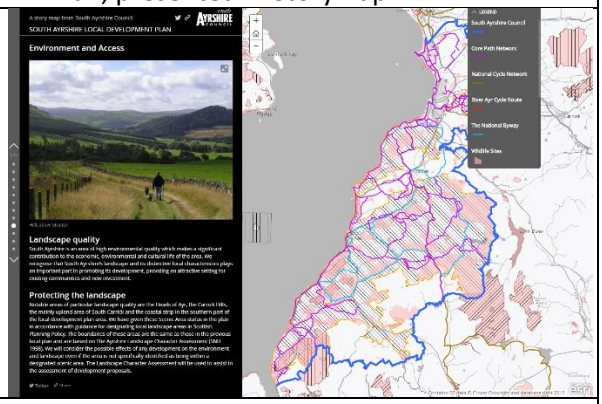
(a) Opening screen of South Ayrshire Local Development Plan Storymap



(b) Spatial data linked to description of issues relating to Prestwick in Local Development Plan, presented in Storymap



(c) Spatial data linked to Galloway and Southern Ayrshire Biosphere, and link to Social Enterprise video, in Local Development Plan, presented in Storymap

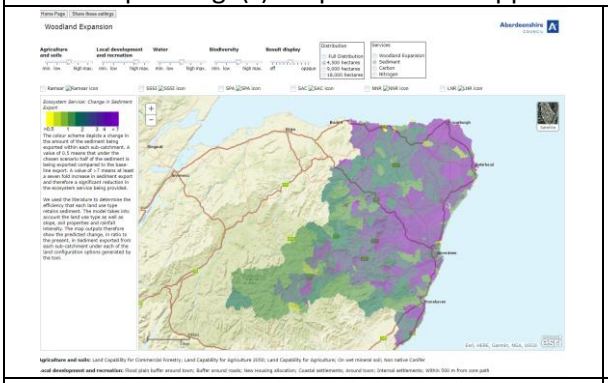


(d) Spatial data linked to environment and access, landscape quality and Protecting the landscape, in Local Development, presented in Storymap

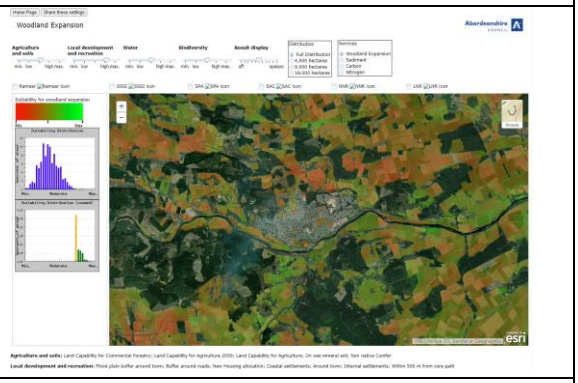
7. Comments - Each Partnership would be expected to take a different approach to the provision of information about their areas, not restricted to any one system. Currently, ESRI Storymaps are a widely used approach to providing information that can be supported by geospatial data.

Example 2. Spatial data for use in exploring potential impacts of rural land use change, example of Aberdeenshire Land Use Strategy Pilot

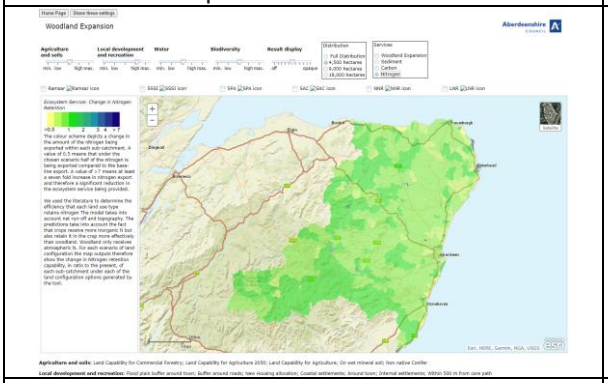
1. Purpose – Online tool to illustrate potential consequences of land use change so as to aid decision making. Prospective uses of the spatial assessment tools were considered to be in catchment management, woodland strategies and the targeting of grant funding
2. Audiences – The tool's primary intended audience was those engaged in land use change, particularly land managers, local communities, public agencies and local government.
3. Spatial data requirements – Input data layers relevant to the development of the models (e.g. woodland expansion, carbon stocks); outputs presented in the online spatial tool; backdrop data for providing context in the online spatial tool (e.g. Ordnance Survey maps, aerial imagery layer)
4. Sources of relevant spatial data – Research partners, James Hutton Institute (e.g. for derived datasets of thematic topics, e.g. biodiversity, local development and recreation, agriculture and soils, water), and factors (e.g. woodland expansion, carbon, sediment, nutrient); CAMERAS partners (e.g. Scottish Natural Heritage for data on SPAs, SACs, SSSIs, NNRs and Ramsar sites through Natural Spaces webpage); local authority access to spatial data for backdrops through the Public Sector Geospatial Agreement
5. Technical and human resources – Access to knowledge about the content and interpretation of relevant spatial data (e.g. soils, water, vegetation) and characteristics (e.g. carbon); modelling tools using with spatial data; licences for relevant software (e.g. ArcGIS); skills in design and implementation of online tools.
6. Example image(s) of spatial data in application



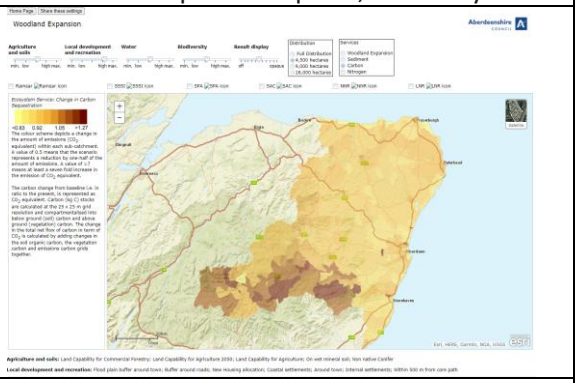
(a) Rural Land Use Pilot Online Tool: Change in sediment export



(b) Rural Land Use Pilot Online Tool: View of woodland expansion option, Banchory area



(c) Rural Land Use Pilot Online Tool: View of woodland expansion option and associated change in nitrogen retention



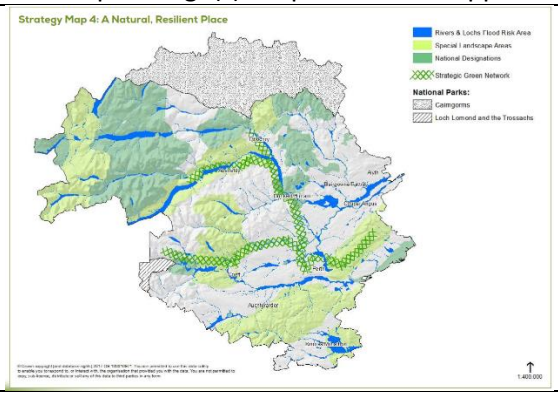
(d) Rural Land Use Pilot Online Tool: View of woodland expansion option and associated change in carbon sequestration

7. Comments – The pilot is reported as taking a 'strong partnership approach', led by Aberdeenshire Council, with a wide range of stakeholders represented on the project board, and the James Hutton Institute as key delivery partner (e.g. spatial data and online tool). Use of

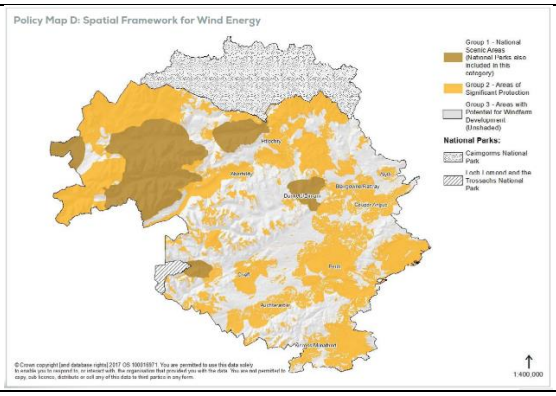
map data and aerial imagery in the online tool supported context suitable to interpretation of the geography of the outputs.

Example 3. Spatial data used in consultation documents, e.g. local authority Local Development Plan proposals

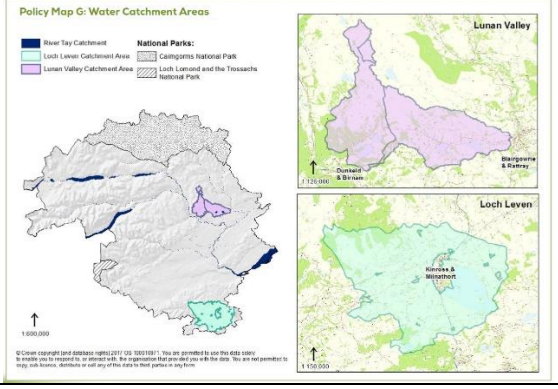
1. Purpose – A statutory requirement of local authorities which "allocates sites, either for new development, such as housing, or sites to be protected. It also includes policies that guide decisions on all planning application".
2. Audiences – All stakeholders (e.g. public, NGOs, business, public agencies)
3. Spatial data requirements – Data layers relevant to content of Local Development Plan proposals for creation of strategic maps (e.g. backdrop maps from Ordnance Survey, Digital Terrain); thematic data (e.g. from public agencies, Scottish Natural Heritage, SEPA, etc.)
4. Sources of relevant spatial data – CAMERAS partners (e.g. NatureScot Natural Places for data on SPAs, SACs, SSSIs, NNRs Ramsar sites through the Natural Spaces webpage; SEPA for catchment boundaries); local authority access to spatial data for backdrops (e.g. from Ordnance Survey)
5. Technical and human resources – Relevant software licences for use of a suitable digital mapping system
6. Example image(s) of spatial data in application



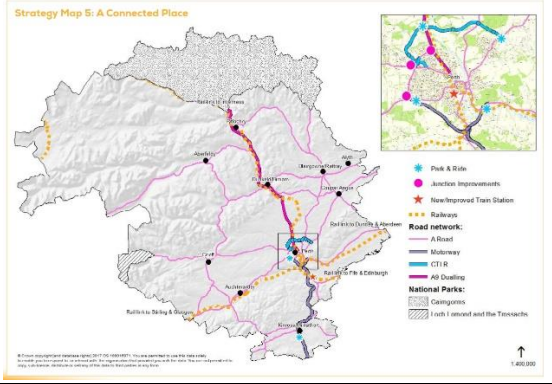
(a) Spatial Strategy for A Natural, Resilient Place, Perth and Kinross Council Local Development Plan 2, Proposed Plan (2017)



(b) Spatial Framework for Wind Energy, Perth and Kinross Council Local Development Plan 2, Proposed Plan (2017)



(c) Policy Map G. Water Catchment Areas, Perth and Kinross Council Local Development Plan 2, Proposed Plan (2017)

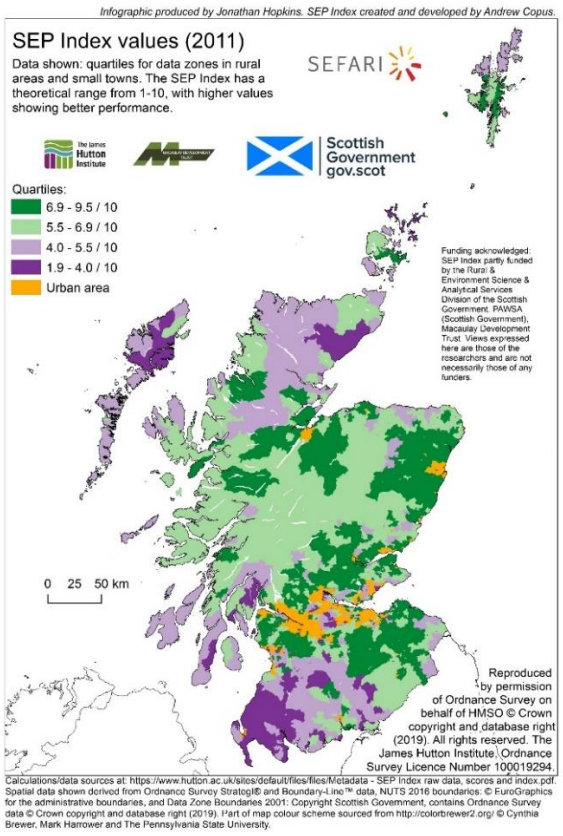


(d) Strategy Map 5. A Connected Place, Perth and Kinross Council Local Development Plan 2, Proposed Plan (2017)

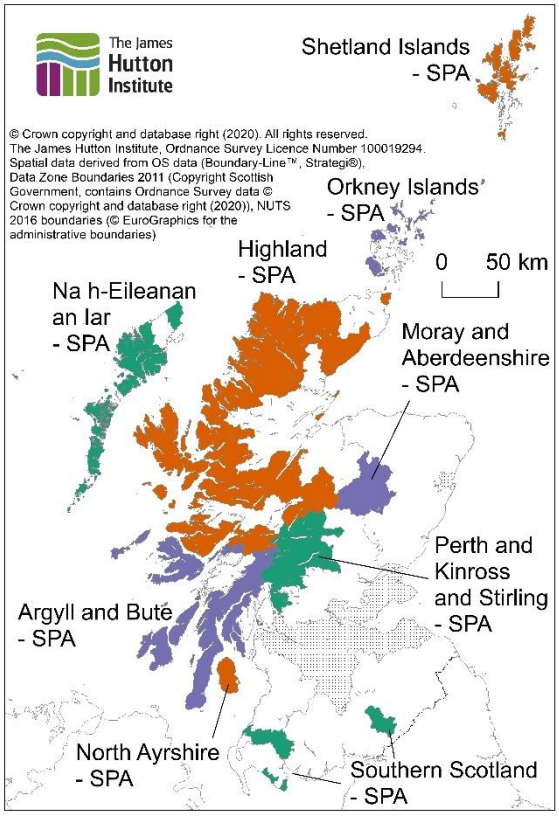
7. Comments – High quality cartographic and graphic design is required for most appropriate use of the relevant spatial data

Example 4. Spatial data for assessing Socio-Economic Performance, at Data Zone level

1. Purpose – Maps to illustrate relative socio-economic performance at a micro-geographical level (Data Zones), for rural and small town Scotland, centred on the year 2011
2. Audiences – Elected representatives, public agencies (e.g. local authorities, Scottish Government)
3. Spatial data requirements – To use the data requires access to software for reading Shapefiles (e.g. ArcGIS), or logically linking data in a tabular format (e.g. *.csv) with the relevant datazone attributes for use in a Geographic Information System
4. Sources of relevant spatial data – Research organisation (i.e. James Hutton Institute) by Open Access
5. Technical and human resources – Understanding of the data (e.g. limitations of spatial resolution of Data Zones); skills in cartographic design
6. Example image(s) of spatial data in application



(a) Map of Socio-Economic Performance representing four of the Scottish Government's Strategic Objectives (Wealthier and Fairer, Healthier, Safer and Stronger, Smarter)

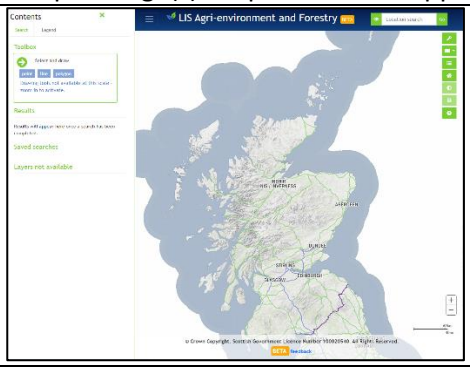


(b) Map of Sparsely Populated Areas in Scotland (bright colours): Data Zones where it is estimated that less than 10,000 people lived within 30 minutes travel (using roads and ferries) in 2011.

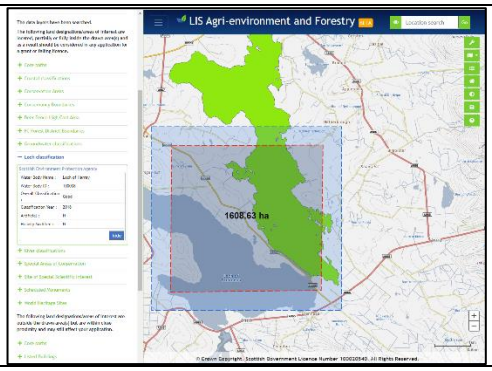
7. Comments – The Socio-Economic Performance Index can be used at the Data Zone level, and to evaluate larger areas. For example, the Index was used in the allocation of LEADER funding: the Executive Director of Economy, Neighbourhood and Environment for South Ayrshire Council stated that the "The Hutton Report was one aspect of Ayrshire receiving one of the largest LEADER allocations in Scotland; £5.78M for the 2014-20 Programme". The Index has also been cited by the Community Planning Partnership of Aberdeenshire Council and at The Highland Council. More recent spatial socio-economic analysis focused on population change in sparsely populated areas (6b), small area-level indicators relevant to dimensions of wellbeing, and related online mapping. Ongoing work with Highlands and Islands Enterprise is investigating the characteristics of inclusive growth across the Highlands and Islands.

Example 5. Spatial data in the Land Information Search Agri-Environment and Forestry

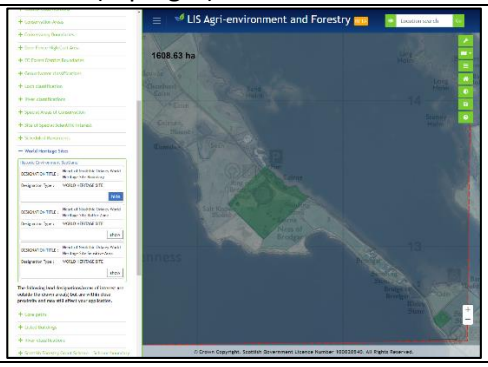
1. Purpose – A resource with Scotland-wide coverage, for the search and identification of features and environmentally sensitive areas that are within, or intersect, an area of interest.
2. Audiences – All stakeholders (e.g. public, NGOs, business, public agencies), with particular relevance to prospective applicants for Scotland Rural Development Programme grants or felling licences, woodland creation, forest grant scheme, and other related forestry activities, who are reminded they must take this information into account in their applications.
3. Spatial data requirements – Information on the location of relevance or area to be searched.
4. Sources of relevant spatial data –Scottish Natural Heritage under OS Open Data Licence, Scottish Forestry, Historic Environment Scotland, Scottish Environment Protection Agency and Improvement Service.
5. Technical and human resources for use – For users of the tool, the requirements are knowledge of the data of most relevance to the intended purpose (e.g. application to SRDP).
6. Example image(s) of spatial data in application



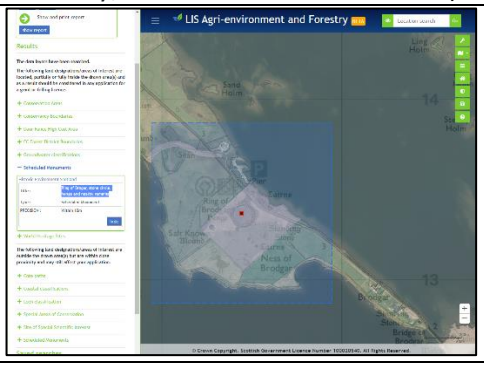
(a) Map interface to Land Information System showing basemap, search tools (top left) and toolbox (top right)



(b) Output of search of area in Orkney, showing example feature of loch classification (Loch of Harray; Overall classification: Good)



(c) Output of search of area showing World Heritage Site (Heart of Neolithic Orkney World Heritage Site Boundary)

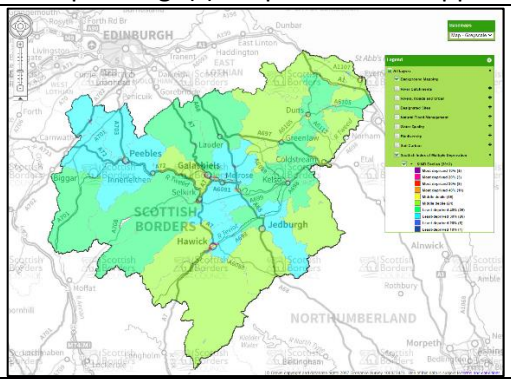


(d) Output of search of area showing Scheduled Monuments (Ring of Brogar, stone circle, henge and nearby remains)

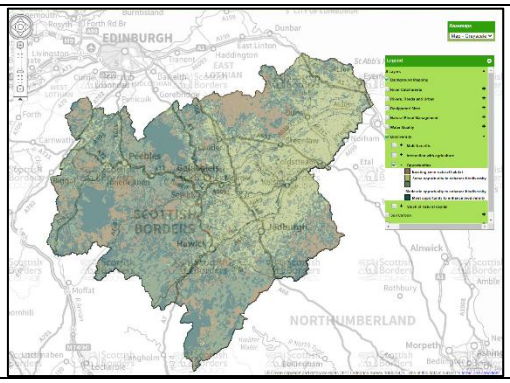
7. Comments – The Land Information Search tool is available from Scotland's Environment Web (SEWEB). It is envisaged that Regional Land Use Partnerships would be users of the search tool, not create an equivalent. A sibling search tool is available on SEWEB for Control of major accidents and hazards.

Example 6. Spatial data for use in developing a land use framework, example of Scottish Borders Land Use Strategy Pilot

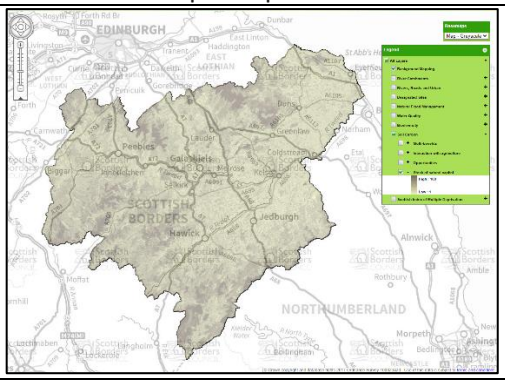
1. Purpose – The regional land use framework produced a tool to 'provide new information in mapped form on the multiple goods and services provided by land use'. It is used to promote multi-functional land uses and priorities of service functions using spatially explicit assessments of ecosystem services, maps of opportunities and stocks.
2. Audiences – The tool's primary audiences are in planning or implementing land use change, particularly land managers, local communities, public agencies and local government.
3. Spatial data requirements – 104 datasets were compiled (74 to create data layers; 17 maps for use with stakeholders). Input data layers were used for deriving maps of ecosystem services (i.e. natural flood management, enhancing soil carbon, enhancing biodiversity, improving water quality, and socio-economic information). Outputs are presented in an online mapping tool, with backdrop data providing a geographic context (e.g. Ordnance Survey maps, aerial imagery).
4. Sources of relevant spatial data – CAMERAS partners (e.g. Scottish Natural Heritage for data on SPAs, SACs, SSSIs, NNRs and Ramsar sites through Natural Spaces webpage); local authority access to spatial data for backdrops through the Public Sector Geospatial Agreement; Scottish Government (Scottish Index of Multiple Deprivation).
5. Technical and human resources – Access to knowledge to enable the derivation of output maps of ecosystem services, content and interpretation of relevant spatial data (e.g. soils, water, vegetation) and characteristics (e.g. carbon stocks); modelling tools using with spatial data; licences for relevant software (e.g. ArcGIS); skills in design and implementation of webmapping; workshop facilitation skills for use of maps in stakeholder engagement.
6. Example image(s) of spatial data in application



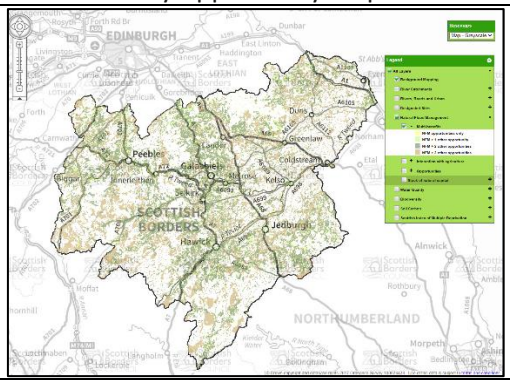
(a) Rural Land Use Pilot Mapping Tool: Scottish Index of Multiple Deprivation



(b) Rural Land Use Pilot Mapping Tool: Biodiversity opportunity map



(c) Rural Land Use Pilot Mapping Tool: Soil carbon stock of natural capital map



(d) Rural Land Use Pilot Mapping Tool: Natural flood management (NFM) multiple benefit map

7. Comments – The pilot was led by Scottish Borders Council and the Tweed Forum, generating a high level of participation through an extensive programme of stakeholder engagement. More information at Scottish Borders Council (2014).

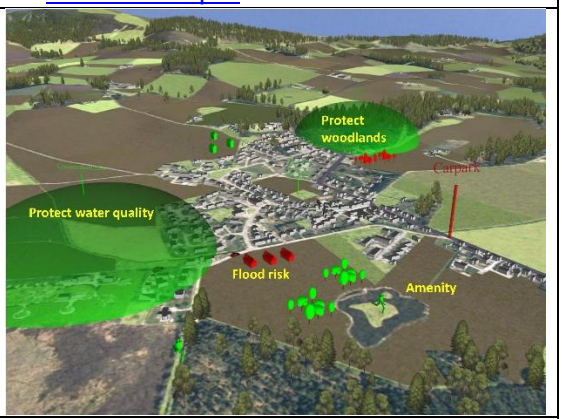
Example 7. Spatial data in support of participatory approaches to visions of future land uses, e.g. Tarland area, Aberdeenshire

1. Purpose – Public engagement for developing community visions of prospective future land uses, aspirations, and concerns over potential impacts, using virtual reality tools
2. Audiences – Public, elected representatives, public agencies, NGOs, businesses, young people
3. Spatial data requirements – Data layers for the development of 3D models for use in supporting interactive engagement with participants (e.g. Digital Terrain Models, land use); modelled spatial data to represent different scenarios of land uses under different scenarios of climate change; data on land use features (e.g. renewable energy, housing, woodlands, etc.).
4. Sources of relevant spatial data – Research organisation access to spatial data for backdrops through the Public Sector Geospatial Agreement with Ordnance Survey, including the Aerial Photography Great Britain agreement with Bluesky; CAMERAS partners (e.g. Scottish Natural Heritage for data on SPAs, SACs, SSSIs and NNRs sites through Natural Spaces webpage)
5. Technical and human resources – Software licences for the creation and use of 3D models; facilitation and presentation skills for the public development of scenarios of land use change with public audiences and stakeholders
6. Example image(s) of spatial data in application. Eliciting public opinions on alternative future land uses in the Virtual Landscape Theatre with different audiences.

(a) Local audiences, in Aboyne identifying local features

(b) Close-by audiences in Ballater, describing local landscapes

(c) Remote audiences, in Birmingham voting on options for future land uses

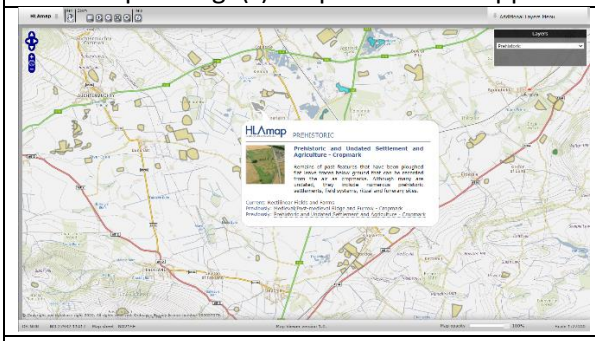


(d) Example of a compiled spatial vision for land uses in the vicinity of Tarland

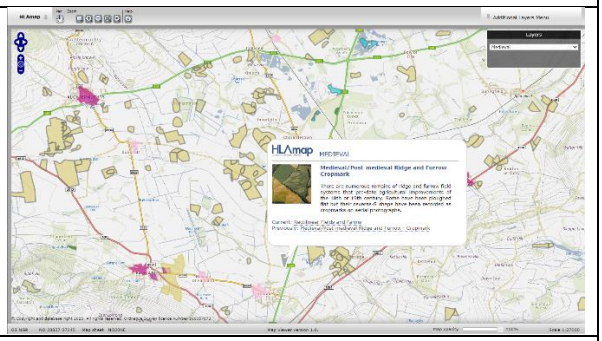
7. Comments –The visualisation tools convert storylines of land use change into spatially-explicit representations combining multiple drivers such as climate change, policy or socio-economic factors into patterns of land use change (Brown and Castellazzi, 2014; Wang *et al*., 2016).

Example 8. Spatial data in use or investigation of Historic Land Uses

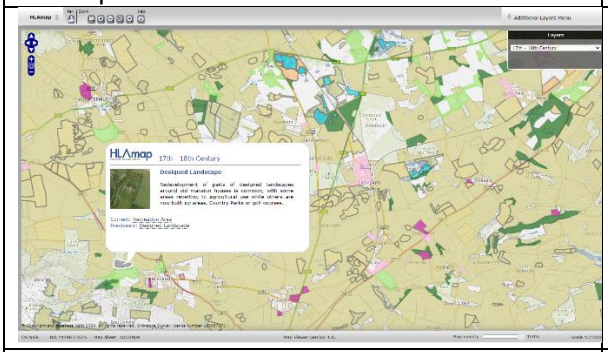
1. Purpose – A resource, with data for all Scotland, enabling the search and production of maps of land uses for set time periods of prehistoric, Roman, Medieval, 17th to 18th Century, and 19th Century to present. Areas can be identified by searches (e.g. postcode, place name or National grid coordinates). Data can be viewed in the online mapping system, and individual features queries, or data downloaded for use in a Geographic Information System.
2. Audiences – All stakeholders (e.g. public, NGOs, business, public agencies), with some pre-set queries provided for specific users in: forestry, farming and land management, development and planning, and landscaper and strategic planning.
3. Spatial data requirements – Information on the location of relevance or area to be searched.
4. Data were compiled by Historic Scotland and the Royal Commission on the Ancient and Historical Monuments of Scotland between 1997 and 2015 (now combined as Historic Environment Scotland); access to Ordnance Survey spatial data for backdrops through the Public Sector Geospatial Agreement.
5. Technical and human resources for use – For users of the tool, the requirements are knowledge of the data of most relevance to the intended purpose and the type of report to be generated.
6. Example image(s) of spatial data in application



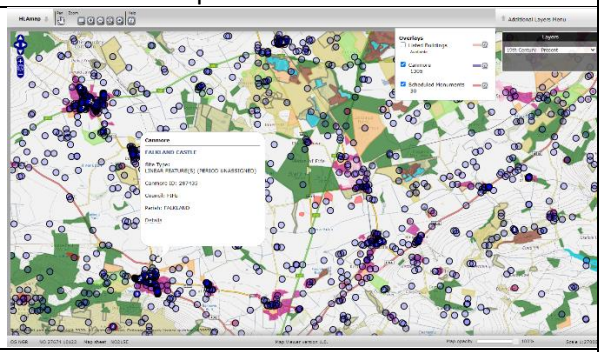
(a) Land use features of the Prehistoric period, with information shown of a settlement and cropmarks



(b) Land use features of the Medieval period, with information shown about a ridge and furrow field pattern



(c) Land use features of the 17th to 18th Century with information shown about a designed landscape queried (Falkland Castle)

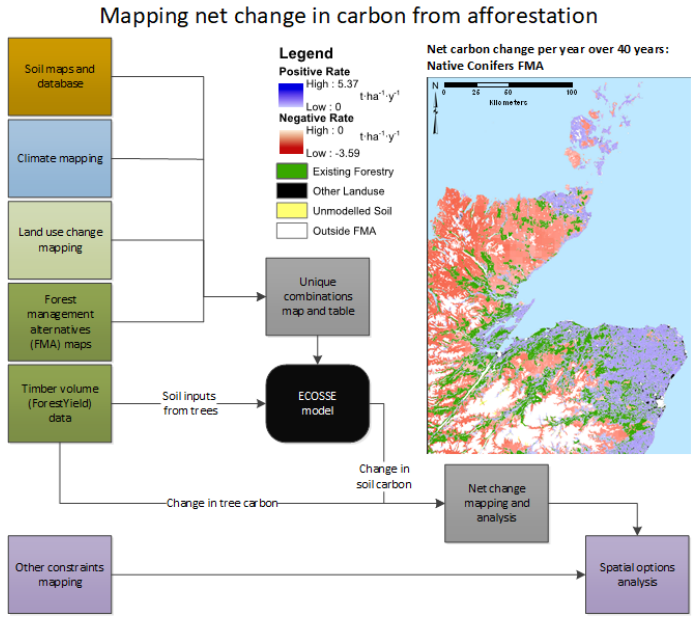


(d) Land use features of the 19th Century to present, with Scheduled monuments and Canmore sites overlaid

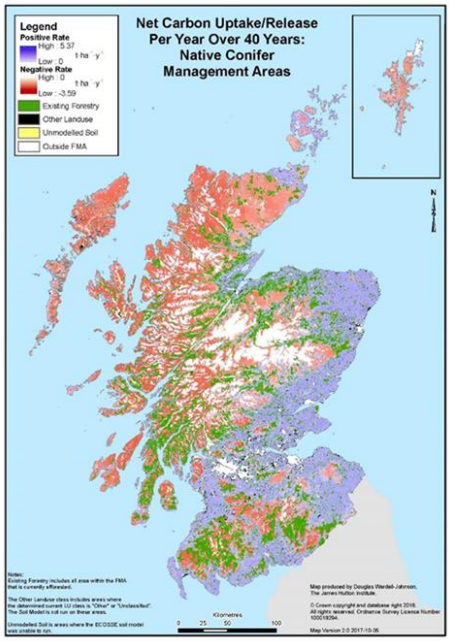
7. Comments – The HLA comprises a classification of 12 land use types, into which 80 component land uses have been compiled. The HLAMAP provides a description and photograph of an example feature of each component land use. The data can be downloaded for all Scotland, in shapefile format.

Example 9. Spatial data in analysis of potential of new woodlands to store carbon

1. Purpose – new woodlands are a key part of Scotland's Climate Change Plan providing a way to achieve "net zero" GHG emissions by offsetting sectors where it may not be technically feasible or economically viable to eliminate all emissions. The analysis provides a means to quantify net carbon storage achieved over time for forestry management alternatives on specific locations. The analysis assesses both above and below ground change and provides a means to test assumptions within policies or plans for the area needed to deliver tonnage targets and the potential impacts of any activities displaced by afforestation.
2. Audiences – the analysis was intended to inform decisions by SG Ministers, policy makers and agency staff and to provide evidence that could be drawn on by industry bodies such as CONFOR and eNGOs. The analysis was published as an open access paper with supporting online mapping website – https://woodlandexpansion.hutton.ac.uk/
3. Spatial data requirements – the analysis requires only the definition of area of interest and optionally other spatial data if analysis of opportunity costs were needed.
4. Sources of relevant spatial data – sources of spatial data include unique combinations of climate (from MetOffice), soil maps and soils properties (from Hutton), and land use data (from SG Integrated Accounting and Control System (IACS) held by Hutton). The analysis also draws on the Ecological Site Classification, ForestYield and Woodland Carbon code data all from Forest Research. The estimates of carbon storage use the ECOSSE model. The output maps are curated and can be made available by Hutton under the terms of the Strategic Research Programme.
5. Technical and human resources for use – use of the data only implies the need to understand the limitations of the analysis (assumptions, granularity etc) as set out in the paper and the technical capacity to import and use raster GIS data layers in the time series.
6. Example image(s) of spatial data in application



Graphical abstract for the analysis showing how the datasets and models combine to create the maps.

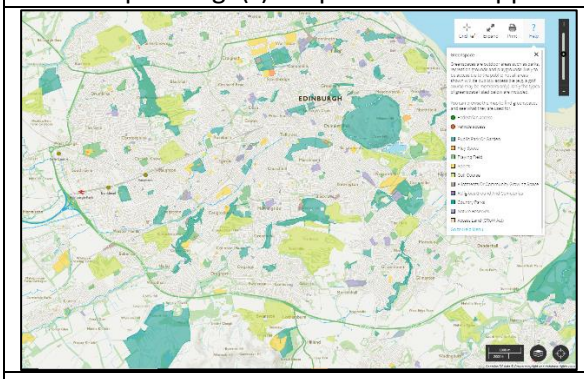


Example of net change in carbon stocks at year 40 for native conifers

7. Comments – the detail of the data is presented in Matthews *et al*. (2020)
Not seeing the carbon for the trees? Why area-based targets for establishing new woodlands can limit or underplay their climate change mitigation benefits. Land Use Policy, 97
https://doi.org/10.1016/j.landusepol.2020.104690

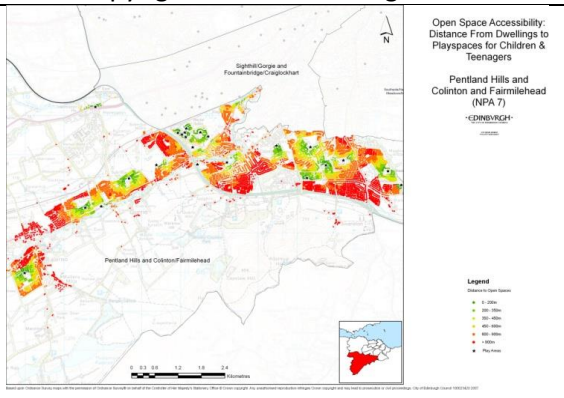
Example 10. Spatial data in analysis of Urban Greenspace

1. Purpose – Use or analysis of spatial data relating to greenspaces. Scotland's Greenspace Map is a Scotland-wide coverage of greenspaces in urban areas with a population of greater than 500. Local authority open space audits provide details of quality and quantity of green spaces at local level. Greenspaces are mapped according to the typology set out in Planning Advice Notice 65. Examples of the analysis of greenspaces are the provision of greenspaces with respect to population, distance from greenspaces and by the Scottish Index of Multiple Deprivation.
2. Audiences – Online data about greenspace for use by all stakeholders (e.g. public, NGOs, business, public agencies and research); analysis of spatial data (e.g. greenspace provision, accessibility), predominantly for public agencies, NGOs and research.
3. Spatial data requirements – If using data from Scotland's Greenspace Map or local authority audits then spatial data associated with the area of interest may be required (e.g. data zones).
4. Sources of relevant spatial data - Scotland's Greenspace Map was compiled by Greenspace Scotland, based on Ordnance Survey Mastermap and field studies in each local authority; spatial data for backdrops accessible through Public Sector Geospatial Agreement, or OpenStreetMap.
5. Technical and human resources for use – For users of Scotland's Greenspace Map or Greenspace layer, requirements are knowledge of the data, principally the typology of greenspaces. Analysis of greenspaces (e.g. accessibility) requires relevant expertise and tools (e.g. ArcGIS, QGIS).
6. Example image(s) of spatial data in application

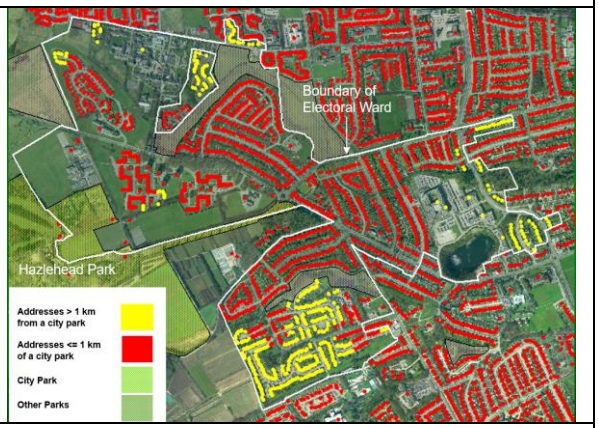


(a) Greenspace types overlaid on Ordnance Survey backdrop, accessed from https://osmaps.ordnancesurvey.co.uk (c) Crown copyright and database rights 2020.

(b) Scotland's Greenspace map, greenspace classes in vicinity of James Hutton Institute, Craigiebuckler, Aberdeen

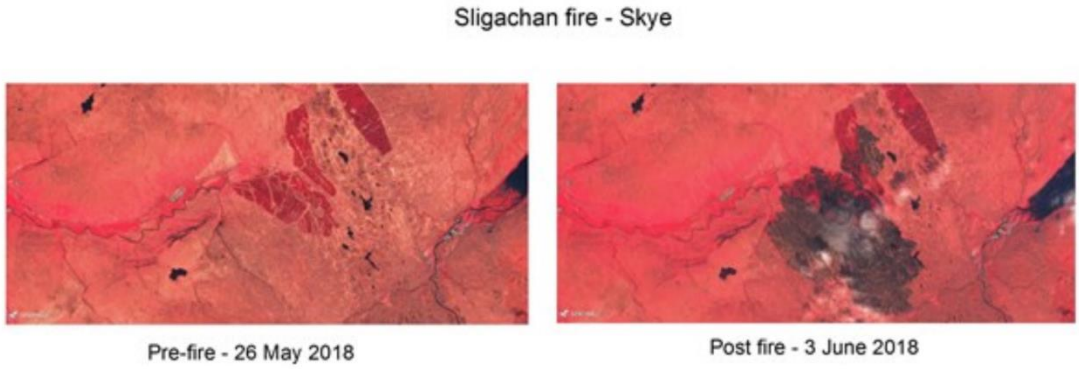
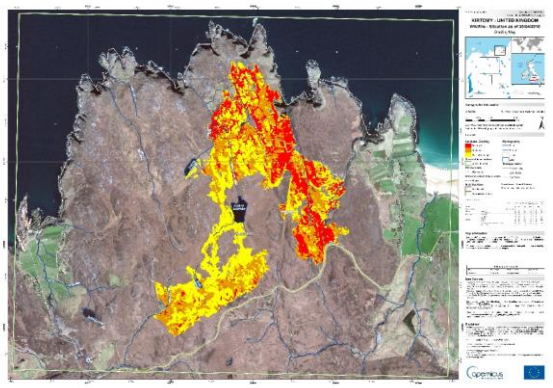
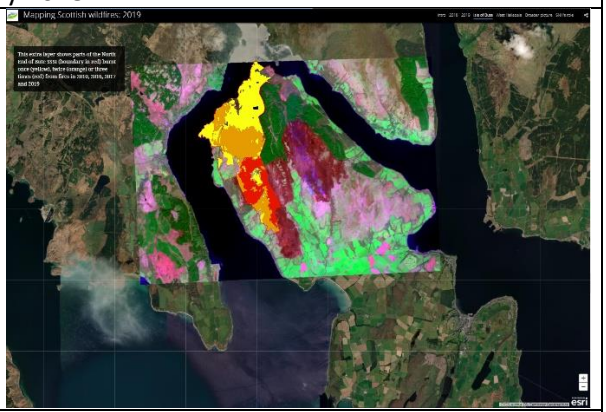


(c) Example of analysis: Access to greenspaces with play spaces for children and young people, from properties (Edinburgh Open space audit, GreenHealth project, James Hutton Institute).

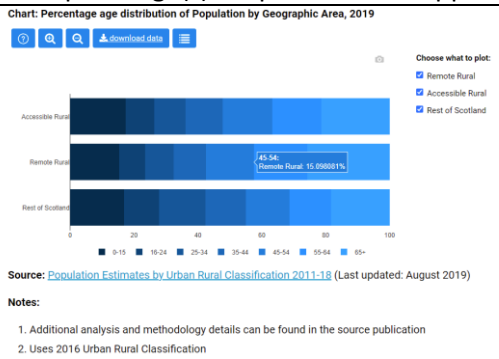
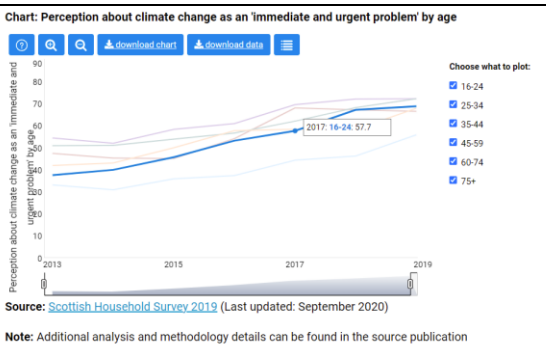


(d) Example of analysis: Distance of properties from greenspaces in west Aberdeen (EU Greenspace project, James Hutton Institute)

7. Comments – Scotland's Greenspace Map is now provided by Ordnance Survey. Spatial analysis can be undertaken at multiple levels, e.g. community, data zone, local authority.

Example 11. Earth observation data for mapping wildfires
1. Purpose – Mapping the extent of wildfires, and potential impacts on the natural environment (e.g. flora and fauna in designated areas).
2. Audiences – Earth observation data for use predominantly by experts in image analysis, interpretation of features and provisional outputs. Outputs for use by land managers, public agencies and dissemination to the public.
3. Spatial data requirements – In this example, Sentinel 2 multi-spectra; data were used. For in-house analysis, data are most likely to be multi-spectral in nature, from spaceborne, airborne or drone platforms.
4. Sources of relevant spatial data – Typically, access is from a data hub, such as Earth Explorer or the Copernicus Open Access Hub of the European Space Agency. Access to Ordnance Survey spatial data for backdrops through the Public Sector Geospatial Agreement.
5. Technical and human resources for use – For users of pre-processed data, expertise in image analysis (e.g. multi-spectral imagery) and analysis tools (e.g. ERDAS IMAGINE). For users of outputs of classified processed imagery relevant skills are in using data within a GIS (e.g. ArcGIS, QGIS), or thematic knowledge for interpretation of the findings.
6. Example image(s) of spatial data in application

(a) Imagery of the Sligachan area of Skye, from Sentinel earth observation satellites, before and after a moorland fire which ignited on 28th May 2018

(b) Fire severity map, Sutherland (2018), produced by Copernicus Emergency Management Service (© 2018 European Union)

(c) Number of times areas burnt in wildfires in North End of Bute SSSI (boundary in red) © Scottish Natural Heritage
7. Comments – Searching for earth observation data to download can be by location, date range, sensor type and other specific attributes. The Copernicus Sentinel-2 mission of 2 satellites,

results in the overpass of Scotland approximately every 5 days. Historically, cloud cover over Scotland has limited the range of types of imagery, and scope for targeting a specific area and date, and obtaining repeat coverage for measurements of change.

Example 12. Scottish Equality Evidence Finder	
1. Purpose – Providing data in graphical form relating to component of the National Performance Framework	
2. Audiences – Designed for use by the public, researchers, and organisations with purposes requiring access to data for monitoring social, economic and environmental change in Scotland.	
3. Spatial data requirements – No spatial data required in the example provided. However, the reporting has been generated by reference to spatial data (i.e. rural urban classification).	
4. Sources of relevant spatial data – Underlying data at spatial resolution of datazones.	
5. Technical and human resources for use – No technical skills or resources required apart from access to internet and suitable computer and browser.	
6. Example image(s) of spatial data in application	
	
(a) Percentage age distribution of Population by Geographic Area, 2019, with a value queried for Remote rural, age 45 – 54.	(b) Perception about climate change as an 'immediate and urgent problem' by age, with graph line highlighted for age 14-24.
7. Comments – Emphasis on making data available for different types of socio-economic and geographic area, for ease of interpretation and comparisons between categories reported. Data are also available for download and us offline in MS Excel or statistical tools.	

Example 13. Filtering, finding, selecting and sharing OS map features API

1. Purpose – Access, copy and modify and present the detailed geometry and attributes of individual features as recorded in selected Ordnance Survey map products. Features may be selected by location (e.g. a point with coordinates) or by type and location (e.g. find the nearest area of greenspace to a specified location)
2. Audiences – Developers of tools, for use in developing applications that target features, expected to be in a specified geographic area. Example outputs for use by land managers, public agencies and capturing ideas and suggestions from public audiences.
3. Spatial data requirements – Data and API provided by Ordnance Survey for use in developing a tool, or editing features as mapped in Ordnance Survey products. Features API can be integrated in a range of software platforms including: ArcGIS Online, QGIS, ArcGIS Pro, ArcMap and could also be implemented in mobile device applications. Features provided by the OS API may be integrated with other datasets e.g. land cover, protected sites etc.
4. Sources of relevant spatial data – Ordnance Survey Features API in the Ordnance Survey Data Hub. Almost unlimited access is available through the Public Sector Geospatial Agreement. Other plans are of Free OS Open Data and a Premium Plan for commercial use.
5. Technical and human resources for use – The user of the OS Features API will be expert in developing web-based interfaces for targeted applications, and the relevant software platform in which the application is being developed. The applications will be designed for use by target audiences (e.g. public, land managers).
6. Example image(s) of spatial data in application

(d) Image of Ordnance Survey data for area around Glensaugh Farm, Aberdeenshire, with a polygon selected (in blue).

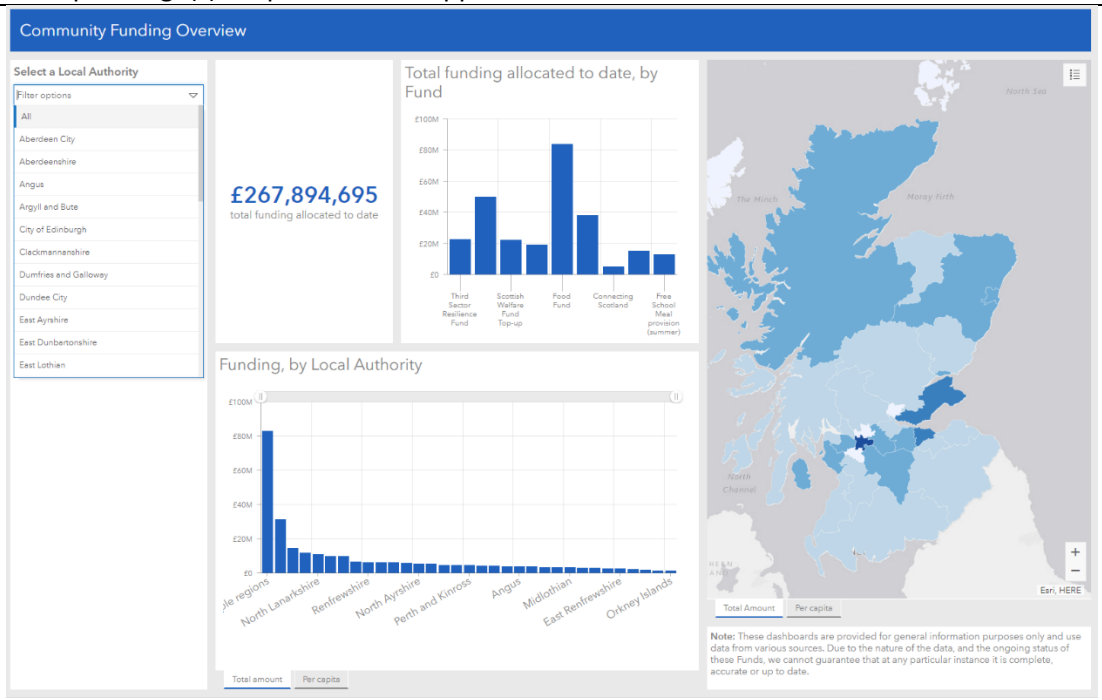
(e) Boundary of agro-forestry plot highlighted and nodes of boundary feature visible (© Crown copyright)

(f) Editing a copy of the field feature, modifying the boundary location to create a new object (© Crown copyright)

7. Comments – The API enables access to features and attributes in 10 datasets, enabling querying, modification of local copies of the geometry, customised styles and representation. There is a limit on the number of features that can be selected per transaction (currently 100), and a maximum of 600 transactions-per-minute which is calculated by OS to be equivalent to 100 concurrent users.

Example 14. Dashboard presentation of Community Funding Mapping for COVID-19

1. Purpose – To present a summary of the investment being made by the Scottish Government to help communities across Scotland affected by COVID-19
2. Audiences – General public, researchers and officers in NGOs or public agencies with responsibilities relating to the topic of COVID-19 and community support
3. Spatial data requirements – No spatial data required by users of the dashboard. For the creation of such a dashboard requires access to underlying boundary data (e.g. local authority, datazone, biophysical unit), georeferenced information to link to the geographic unit, and access to relevant software (e.g. ArcGIS online)
4. Sources of relevant spatial data –Typically, access to data for the creation of such a dashboard is from a relevant data hub or in-house sources
5. Technical and human resources for use – No technical skill or resources required by users of the dashboard illustrated. For the creation of such a dashboard, skills are required in relevant software (e.g. ArcGIS)
6. Example image(s) of spatial data in application

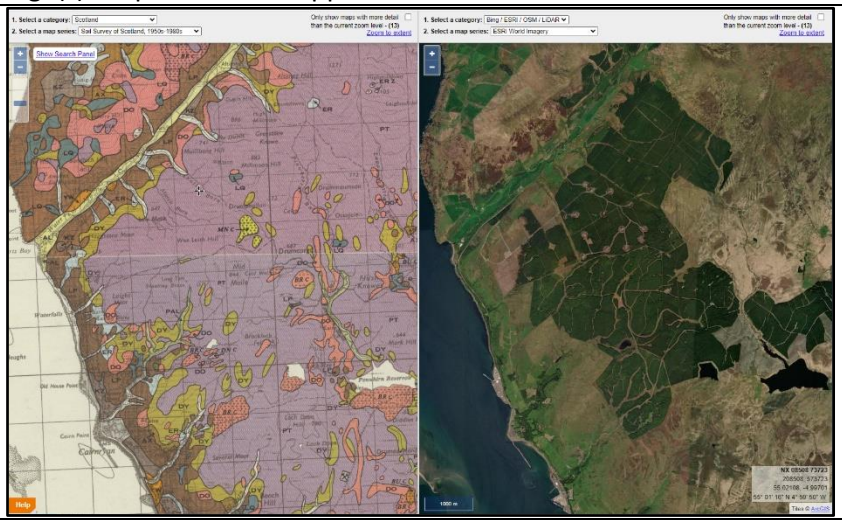


Components of dashboard illustrating funding allocated to communities, presented by local authority, as support during COVID-19.

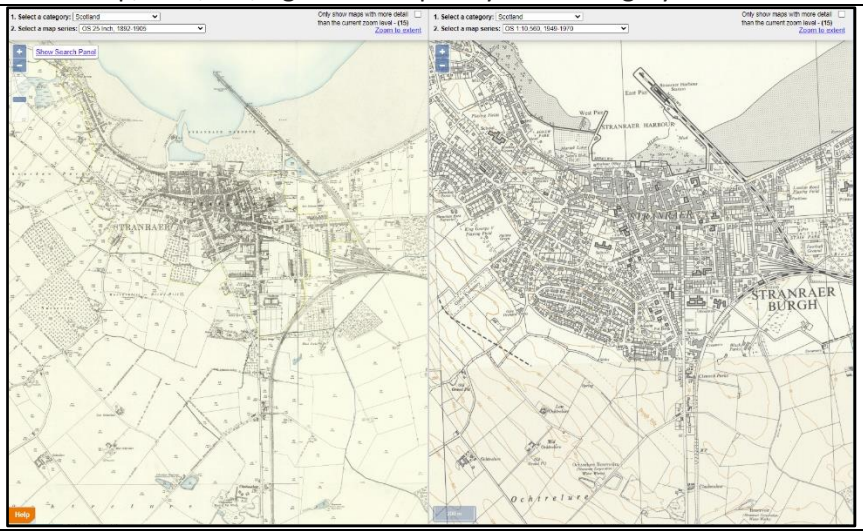
7. Comments – The use of dashboards to present data in different ways (e.g. interactive maps, graphs, values) is increasingly popular and used. Benefits include ease of access to information about defined geographic areas, on a given topic, with readily available enhancements such as user selected backdrops to maps (e.g. aerial imagery, topographic layers), as included within the software infrastructure (e.g. ArcGIS Online).

Example 15. Comparing data between dates, and types (National Library of Scotland)

1. Purpose – To identify changes in the presence or distribution of features (e.g. land use, built structures) through time, or interpret features in given locations with respect to certain characteristics (e.g. terrain, soils, land cover).
2. Audiences – General public, researchers and officers in NGOs or public agencies with interests in measuring or reporting change in a given area.
3. Spatial data requirements – No spatial data required by users of the resource.
4. Sources of relevant spatial data – Data represented sourced from different suppliers. The user cannot enter any additional data to the facility.
5. Technical and human resources for use – No technical skill or resources required by users of the facility illustrated.
6. Example image(s) of spatial data in application



(a) Comparing information in same location (Loch Ryan, Dumfries and Galloway), from two types of data, left Soil map, 1:63,360, right contemporary aerial imagery



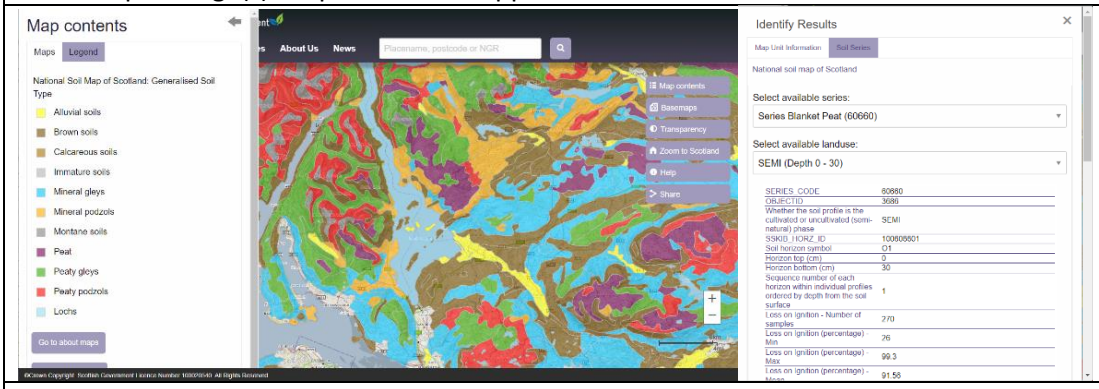
(b) Comparing information in same location (Stranraer, Dumfries and Galloway), from two dates of data, left Ordnance Survey 1:2,500, 1892-1905; right Ordnance Survey 1:10,560 1949-1970

7. Comments – Use of the comparison facility is an effective way of communicating changes in land or its uses. There is no constraint on comparing information of different accuracy, scales or levels of detail which lead to misinterpretations or conclusions. No representation of the accuracy of the data is explicit in the viewer, only by interpreting accompanying descriptions.

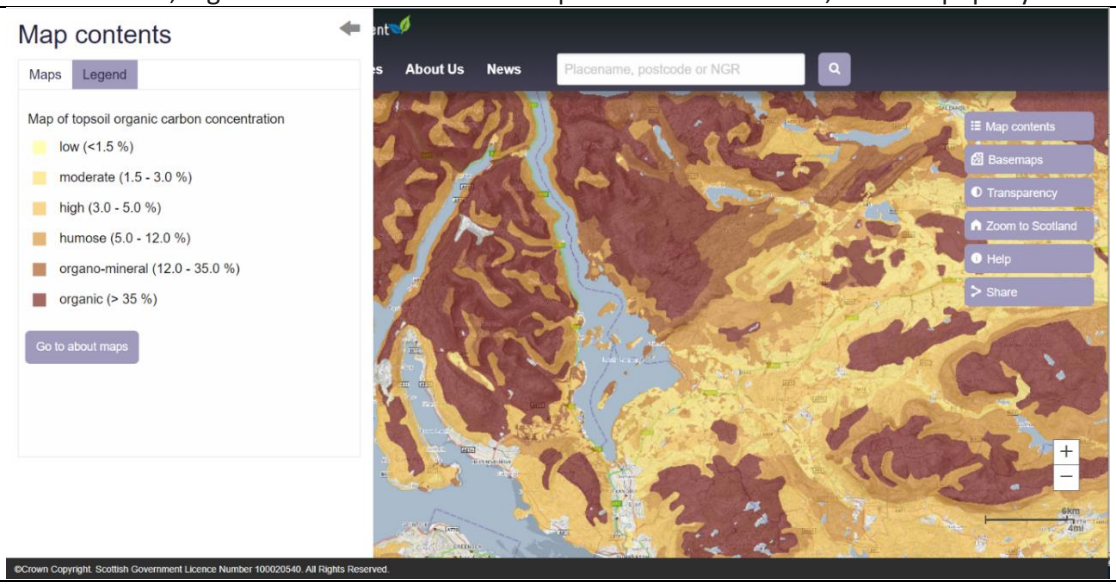
Source: https://maps.nls.uk/geo/explore/side-by-side/#zoom=5&lat=56.00000&lon=-4.00000&layers=1&right=ESRIWorld

Example 16. Soils of Scotland

1. Purpose – To access information about the types, characteristics and distribution of soils of Scotland, and details for specific geographic areas. To download spatial data on soils of Scotland for offline data analysis.
2. Audiences – General public for information at different levels (national to place); public agencies with remits that relate to planning, uses of natural resources, natural capital; NGOs with remits that involve uses of natural resources; communities with an interest in a specific area (e.g. in relation to proposed development); researchers and students.
3. Spatial data requirements – No spatial data required by users of the online resource.
4. Sources of relevant spatial data – Data provided by James Hutton Institute, in collaboration with public agencies. The user cannot add data to the online resource. Downloaded versions of the data can be used in combination with spatial data representing other factors or features at different geographic scales.
5. Technical and human resources for use – No technical skill or resources required by users of the online facility illustrated. Use of spatial data downloaded requires expertise in the use of Geographic Information Systems; licences for relevant software (e.g. ArcGIS); understanding of the characteristics of soils; and mapping (i.e. minimum mapping units, positional accuracy, and cartographic representation of environmental features).
6. Example image(s) of spatial data in application



Left: View of national soil map of Scotland, showing the generalised soils types for an area centred on Loch Lomond; Right: Characteristics of soil map unit for Blanket Peat, from map query.



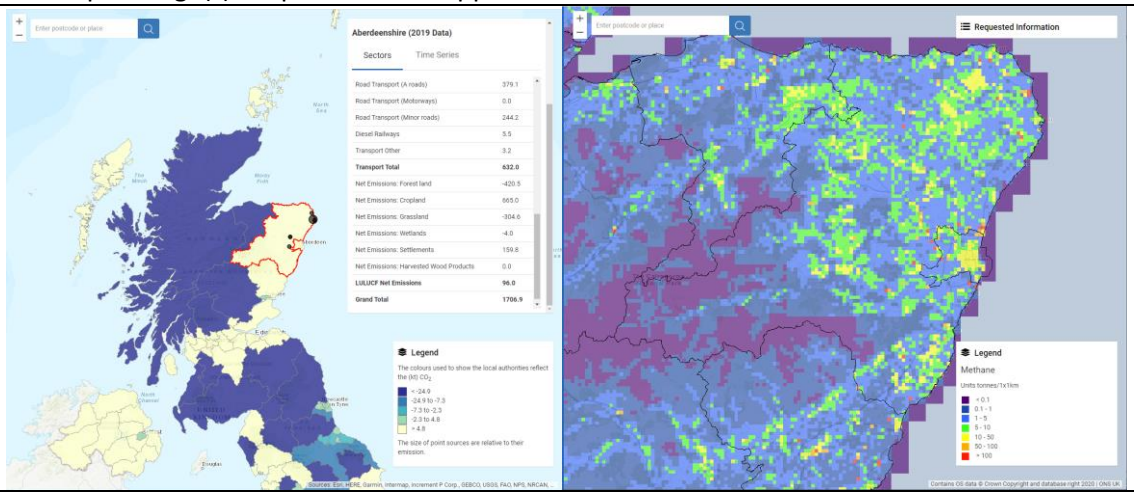
Map view of the topsoil organic carbon concentration for an area centred on Loch Lomond.

7. Comments – Spatial datasets can be downloaded for the National Soil Map of Scotland (based on 1:250,000 mapping), and larger cartographic scales (1:50,000 and 1:25,000).

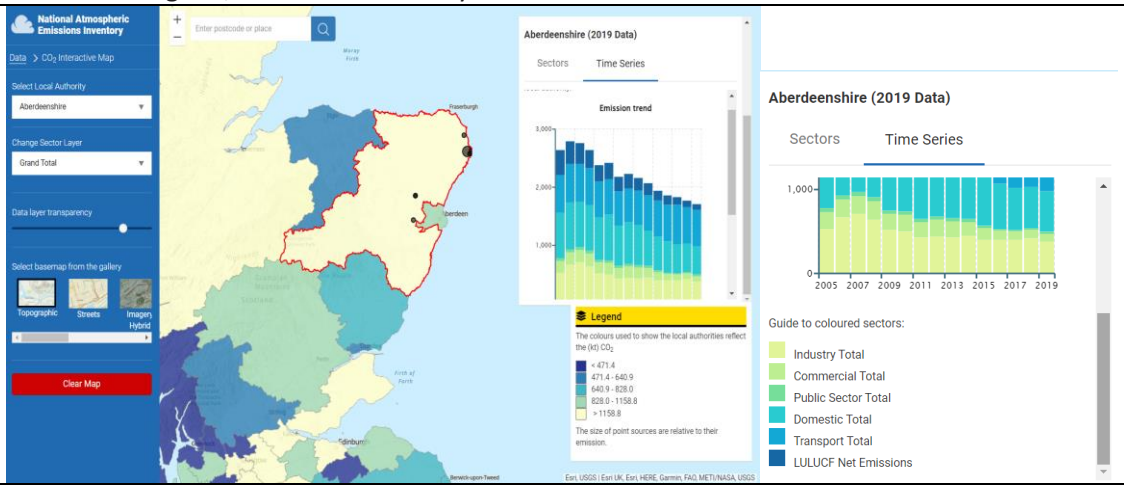
Source: https://soils.environment.gov.scot/

Example 17. CO_2 Interactive Map (National Atmospheric Emissions Inventory)

1. Purpose – To view geographic distribution of sources of atmospheric emissions, and summarise emissions by type and governance level (e.g. Scotland, local authority) and sector where appropriate).
2. Audiences – General public, researchers and officers in NGOs or public agencies with interests in trends or values on atmospheric emissions from different sources, by geographic area.
3. Spatial data requirements – No spatial data required by users of the resource.
4. Sources of relevant spatial data – Data represented sourced from UK Government, agencies or research organisations. The user cannot enter any additional data to the facility. Data can be downloaded in spreadsheet form for use offline.
5. Technical and human resources for use – No technical skill or resources required by users of the facility illustrated.
6. Example image(s) of spatial data in application



Left: Map of emission levels at local authority level for Scotland and northern England, with legend and selected data for Aberdeenshire; Right: Map of spatial distribution of sources of emissions of methane and legend, with local authority boundaries overlaid.



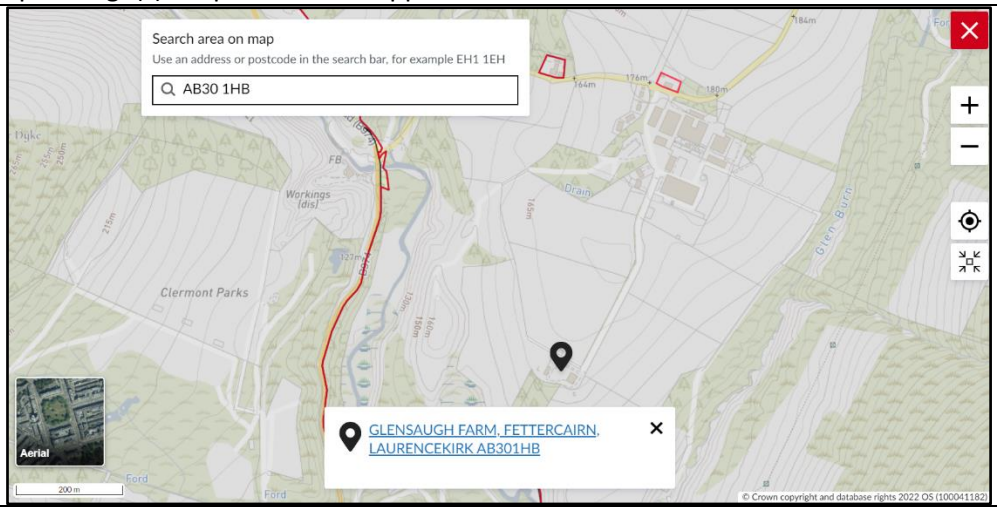
Left: Map of emission levels at local authority level, and time series of emissions of CO_2 from 2005 to 2019, by sector; Right: Bottom of graph of time series, showing dates and legend.

7. Comments – Data presented in time series are updated annually. For CO_2 emissions, the time series is from 2005 currently through to 2019 (as of February 2022).

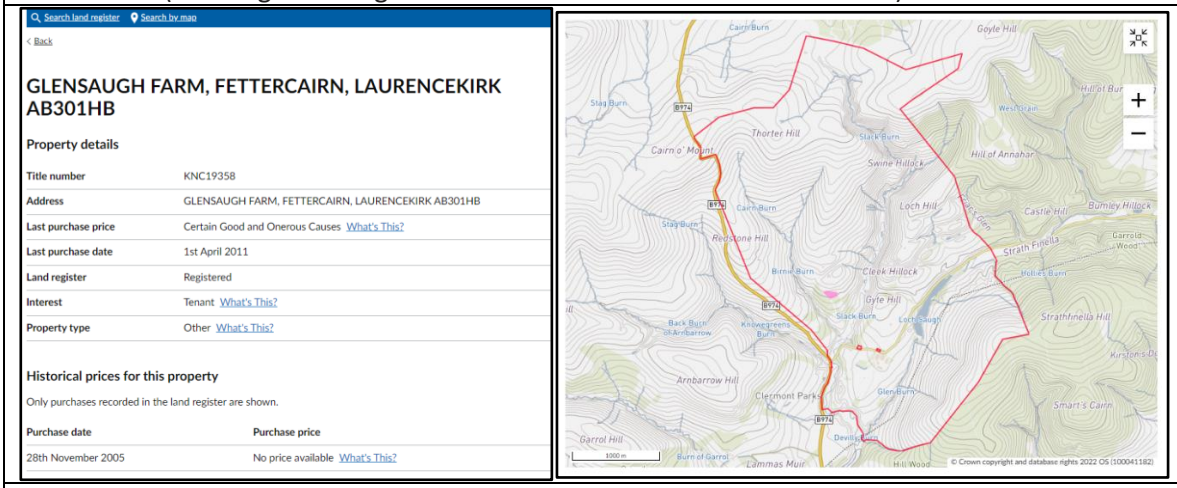
Source: https://naei.beis.gov.uk/laco2app/

Example 18. Scotland's Land Information Service (ScotLIS)

1. Purpose – To provide information about the ownership of land and properties in Scotland, including by map-based search and identification.
2. Audiences – General public interested in ownership of on specific sites.
3. Spatial data requirements – No spatial data required by users of the resource.
4. Sources of relevant spatial data – Background imagery and spatial context from Ordnance Survey. Data on ownership provided by Registers of Scotland.
5. Technical and human resources for use – No technical skill or resources required by users of the facility illustrated.
6. Example image(s) of spatial data in application



Search for property based on postcode, leading to map view of area and map-based query of site (showing Glensaugh Research Farm of James Hutton Institute)



Left: Information on property queried (e.g. Glensaugh Farm); Right: Boundary of property queried.

7. Comments – Not all properties in Scotland have information available through the ScotLIS. Complete coverage is planned.

Source: https://scotlis.ros.gov.uk/map-search

Annex 3. Note on Sources of Information Relating to Mapping Natural Capital and Natural Capital Accounting

This Appendix is an extract of a note sent to South of Scotland Enterprise, regarding the mapping of natural capital (March 2021). It signposts research or activities in Scotland and internationally in relation to assessing or mapping natural capital which could inform the work of South of Scotland Enterprise and its partners. It identifies relevant work in the Scottish Government Strategic Research Programme (2016-21), mapping or assessing natural capital at farm and estate levels, local and regional scales, and selected materials from European union projects and internationally.

i) Natural Asset Inventory and Natural Capital Accounts

Spatial data relevant to the work on ecosystem services and natural capital accounts are compiled into the Natural Asset Register (NAR), the link to which is: http://nar.hutton.ac.uk/. This is funded through the Scottish Government Strategic Research Programme (2016-22). It provides a dedicated spatially-referenced register of Scotland's natural assets, and contributes to a set of natural capital accounts for Scotland.

Data can be selected based upon category (e.g. carbon, peat, landscape), the filtering of which produces a listing of datasets that fit the criteria. Information is available for each dataset including their relevant Common International Classification of Ecosystem Services (CICES) Section and Theme, and the GEneral Multilingual Environmental Thesaurus (GEMET) theme of the European Environment Agency. The datasets accessible in the Natural Asset Register are available for viewing online, and downloading in certain formats, for use in a Geographic Information System.

A summary of the work done is provided on the wwwpage:
https://sefari.scot/research/objectives/natural-asset-inventory-and-natural-capital-accounts.

Examples of derived spatial data that represent characteristics of natural resources, are those on …

- The biophysical data sources available to produce spatially disaggregated natural capital accounts for forests and woodlands in Scotland (McVittie, A. and Glenk, K., 2019. Natural Capital Accounts for Scotland: Forest Sector Accounts. pp53.
- Mapping Aesthetics in Scotland with prototype maps for spiritual experience of landscape as cultural ecosystem services (Castellazzi, M., Aalders I. and Irvine K.N., 2021. Mapping aesthetics in Scotland,, RESAS 1.4.1bvi Cultural Ecosystem Services Indicators and Mapping - Deliverable D8, Working Paper. SEFARI Website on Mapping Aesthetics in Scotland Based on 10 metrics.

Contact: David Donnelly, James Hutton Institute, email: David.Donnelly@Hutton.ac.uk.

ii) Natural capital protocols and accounting at estate and farm levels

Blackstock *et al*. (2020) analysed five pilot studies on uses of natural capital based approaches to support sustainable land management in Scotland. They observe that the process of implementing a natural capital approach encouraged collaboration and knowledge sharing between stakeholders. However, there is limited evidence to date that it has directly affected land management.

Overall conclusions were that: i) natural capital approaches allow the natural environment to be included in discussions about business decisions, but there is limited evidence that it has directly affected land management to date; ii) there are challenges in accurately quantifying and valuing natural capital, but the process nevertheless provides valuable understanding; iii) there is scope to streamline natural capital approaches and simplify data collection; iv) the pilot studies originated from altruistic motivations and stronger economic benefits will need to be demonstrated to encourage wider adoption. A summary of the findings are accessible from the SEFARI gateway wwwsite at:

https://sefari.scot/research/using-natural-capital-approaches-to-support-sustainable-land-management-in-scotland.

a) Application of the Natural Capital Protocol on Glensaugh farm.

A summary is provided of the common rationale for natural capital approaches adoption, the types of information provided, and how these are used. Links to supporting reports are included. Those relating to the assessment of natural capital at Glensaugh Farm are expanded upon below. The full report of the application of the protocol is accessible here, and the conceptual basis reported in "Natural capital accounting approaches for land-based activities." The explanation of the approach is also accompanied by a presentation with voice over, available as a video.

Further details on dependencies and impacts, potential impacts on natural capital due to woodland expansion are provided on the SEFARI WWWsite on Assessing natural capital impacts and dependencies within upland farming systems (https://sefari.scot/research/assessing-natural-capital-impacts-and-dependencies-within-upland-farming-systems).

b) The "Trial of the Natural Capital Protocol for land-based businesses. Glenlivet Estate," carried out by Cumulus Consultants Ltd. Chipping Campden, Gloucestershire. More information is accessible on the wwwsite of the Crown Estate Scotland (http://naturalcapitalscotland.com/what-we-do/crown-estate-scotland/#.YFt63a-gJ9M).

c) A further trial application of the Natural Capital Protocols was been carried out by the Crown Estate Scotland of a dairy farm, within the area of the SOSE. That test application is of Dryfesdalegate Farm, Lockerbie. The report is accessible here.

iii) **Indicators of Ecosystem Services in Scotland**

A storymap on 'Indicators of Ecosystem Services in Scotland' (https://arcg.is/0v04WH) presents a map-based representation of topics such as soil organic content, water supply, crop production, pollination, plant species distinctiveness, and livestock densities (cattle, sheep), water purification nutrients, soil organic stocks, recreation and amenity, floral distinctiveness.

An example of the spatial representation of a derived characteristic of ecosystem service in Scotland is shown in Figure App3.1 of soil retention. This shows the format of the storymap of the context and explanations of the basis of the mapping (left) and an interactive map of Scotland-wide coverage of the derived dataset (right).

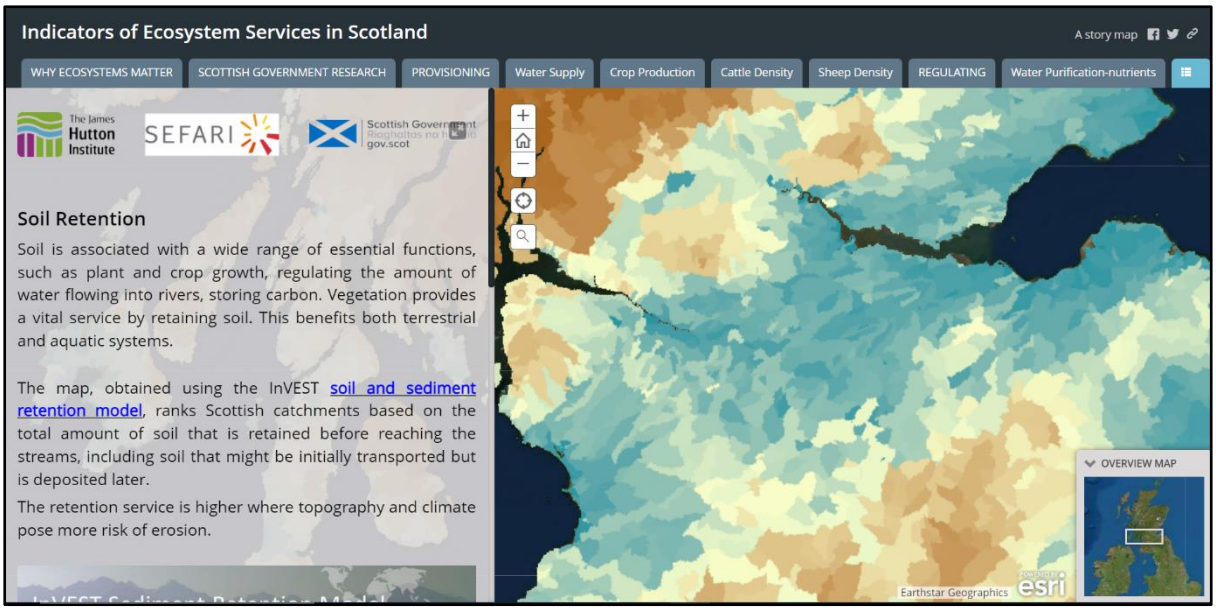


Figure App3.1. Soil and sediment retention model for water catchments, derived using InVEST model.

The spatial resolutions of inputs data vary depending upon the topic, and limitations of input datasets are recognised and reported in the relevant papers. Links are provided to the relevant models used for producing the map outputs. The outputs are from mapping and modelling of indicators of ecosystem services undertaken in the Scottish Government Strategic Research Programme (2016-22). The Natural Assets Theme of the research programme is concerned with the identification, quantification and valuation of Scotland's environmental assets, biodiversity and ecosystem services.

Contact: Dr Alessandro Gimona, James Hutton Institute, email: Alessandro.Gimona@Hutton.ac.uk.

iv) **Mapping net change in carbon from afforestation in Scotland**

A Scotland-wide assessment of the range of possible emissions outcomes for area-based afforestation targets is reported by Matthews *et al.* (2020). It comprised a spatial analysis of eleven alternatives for forest management across Scotland, the outputs of which illustrate a range of possible outcomes for any target area of planting. Spatial data on antecedent land use were analysed with respect to mapped outputs from forest models defining the suitability and productivity of eleven forestry management alternatives. Data on above ground carbon were integrated with outputs from the ECOSSE (Estimation of Carbon in Organic Soils – Sequestration and Emissions) model which simulates the soil carbon dynamics.

The spatial data outputs combine the above and below ground carbon to highlight where net carbon surpluses and deficits are likely to occur, how long they persist after afforestation, and their relationships with antecedent land use, soils, weather conditions and afforestation management strategies. Maps for all the sub-Forest Management Areas, across all time periods can be viewed and inspected at: https://woodlandexpansion.hutton.ac.uk/

Reference:

Matthews, K.B., Wardell-Johnson, D., Miller, D., Fitton, N., Jones, E., Bathgate, S., Randle, T., Matthews, R., Smith, P. and Perks, M. (2020). Not seeing the carbon for the trees? Why area-based targets for establishing new woodlands can limit or underplay their climate change mitigation benefits. *Land Use Policy*, 97, https://doi.org/10.1016/j.landusepol.2020.104690.

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v) SEFARI Fellowship on Helping Businesses Develop New Opportunities from Natural Capital

SEFARI is running a Fellowship on 'Helping Businesses Develop New Opportunities from Natural Capital'. The aims is to work 'with businesses to understand how taking account of these connections with nature can provide benefits and will likely focus on the SMEs and micro-businesses in the food and drink sector.' The stakeholder involved in this Fellowship is the Scottish Forum on Natural Capital.

The Fellowship is held by Dr Alistair McVittie, SRUC, email: Alistair.McVittie@sruc.ac.uk

vi) International systems and approaches

a) United Nations Systems of Environmental Economic Accounting

The United Nations 'System of Environmental-Economic Accounting (SEEA) is a framework that integrates economic and environmental data to provide a comprehensive and multipurpose view of the interrelationships between the economy and the environment and the stocks and changes in stocks of environmental assets, as they bring benefits to humanity. It contains the internationally agreed standard concepts, definitions, classifications, accounting rules and tables for producing internationally comparable statistics and accounts.'

The SEEA Working Group dedicated to spatial units aims 'to establish statistically and accounting relevant classifications for land use, land cover and ecosystem types and application, where possible, of existing classifications of this type.' A technical paper addresses issues of spatial units of relevance, classification schemes and mapping (Bogaart *et al.*, 2019).

The United Nations System of Environmental-Economic Accounting is accessible at:

SEEA Experimental Ecosystem Accounting Revision | System of Environmental Economic Accounting

Reference:

Bogaart P., Chan J.Y., Horlings H., Keith D., Larson T., Sayre R., Schenau S. and Soulard F. (2019). Discussion paper 1.1: An ecosystem type classification for the SEEA EEA. Paper submitted to the SEEA EEA Technical Committee as input to the revision of the technical recommendations in support of the System on Environmental Economic Accounting. Version of 29 April 2019.

b) Application of mapping natural capital - Amazonia

Tools for mapping and representing natural capital have been applied to Amazonia (Conservation International, 2015). The aim was to present evidence of the distribution of natural capital across Amazonia in ways that can be used by 'governments, development banks, conservation organizations, and other actors seeking to meet conservation and sustainable development goals'.

The storymap is accessible at Mapping Natural Capital in Amazonia (StoryMap) (arcgis.com), with a series of interactive maps and accompanying text and imagery reporting a three class zonation of Amazonia, topics such as biodiversity priority areas, forest biomass and carbon stocks, endemic species, and climate mitigation vulnerability to future deforestation (Figure App3.2).

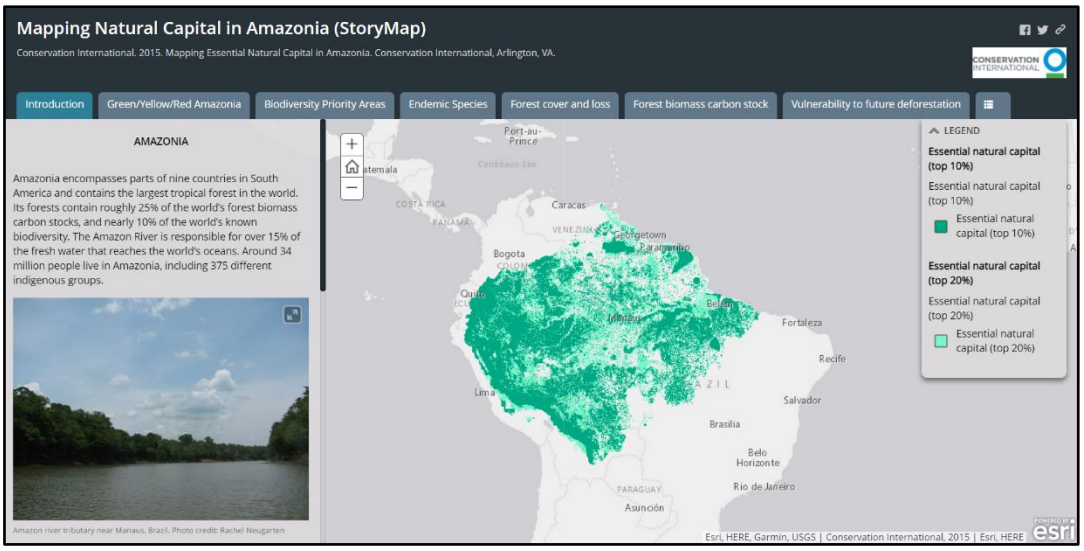

Figure App 3.2. Storymap of mapping natural capital of Amazonia, showing forest biomass carbon stocks. (source: Conservation International).

The methods and modelling used are described in the technical reporting (Conservation International, 2015), and the input data, and attribution of scores or values to classes in biophysical (e.g. species richness, vulnerability) and socio-economic datasets are described in the Appendices.

Reference:

Conservation International, 2015. Mapping Essential Natural Capital in Amazonia. Conservation International, Arlington, VA. Technical report, pp73 (APPENDICES_Mapping Essential Natural Capital in Amazonia_30Dec2015.pdf - Google Drive), and Appendices. pp33 (REPORT_Mapping Essential Natural Capital in Amazonia_23Feb2016.pdf - Google Drive).

c) Canada – Environmental Valuation Reference Inventory

Environment and Climate Change Canada has developed the Environmental Valuation Reference Inventory from the early 1990s. The inventory contains summaries of over 4,000 valuation studies from around the world. The Inventory is a "searchable compendium of summaries of environmental and health valuation studies. These summaries provide detailed information about the study location, the specific environmental assets being valued, the methodological approaches and the estimated monetary values along with proper contextualization."

Use of the Inventory wwwsite requires registration, which is free. The wwwsite is accessible at: EVRI, www.evri.ca/en

d) New Zealand

The New Zealand Treasury provide a detailed assessment of the assessment of natural capital for the country, in a discussion paper on 'The Start of a Conversation on the Value of New Zealand's Natural Capital' (Joey and Sonette, 2018). The paper describes the derivation of the national assessments of natural capital. Multiple sources of data are used for national mapping (e.g. land cover, biodiversity estimates, water status, etc.). Valuations of biodiversity and resources are informed by the studies in the Canadian Environmental Valuation Reference Inventory. No geographic mapping of natural capital is presented.

The authors note that, "Although some conclusions can be drawn from the analysis completed to date, the exercise has highlighted the gaps and limitations of both approaches and further strengthens the view that significant work will be required to define the appropriate measures for each type of natural resource and ensure that the required data for each measure are accurate and readily available."

Examples of the derivation of Total Economic Value, such as to forests, and approaches to valuation techniques, are provided in the Appendices.

Reference:
Joey, A. and Sonette, van Z. (2018). The Start of a Conversation on the Value of New Zealand's Natural Capital (treasury.govt.nz), 978-1-98-853490-9 (Online).

vii) European Union: policies and projects

a) EU Policies -
The definition of natural capital used by the EU is set out in its 7th Environment Action Programme (EAP) as "biodiversity, including ecosystems that provide essential goods and services, from fertile soil and multi-functional forests, to productive land and seas, from good quality fresh water and clean air to pollination and climate regulation and protection against natural disasters."

Several European Union policies include natural capital as one of their considerations, notably the Biodiversity Strategy 2030, and the Farm to Fork Strategy. (e.g. as assets, or in relation to monitoring. Their opening page on natural capital is at: https://ec.europa.eu/environment/nature/capital_accounting/index_en.htm).

An overview of work on mapping and assessing natural capital, as of 2019, is described in a European Commission report on 'Natural Capital Accounting: Overview and Progress in the European Union'. It includes a summary of the approach of the Integrated system of Natural Capital and ecosystem services Accounting in the EU (INCA) project., and the links to the MAES reporting of ecosystem services, about which more information is provided below.

Reference:
European Commission (2019). Natural Capital Accounting: Overview and Progress in the European Union, 6th Report, Final. European Commission, pp80.

b) Example EU Research projects -
The European Union fund numerous projects carrying out mapping and assessments of natural capital, or ecosystem services. The following examples address different aspects of using spatial data for developing evidence bases for regional or national assessments.

- Integrated system of Natural Capital and ecosystem services Accounting in the EU – INCA.

  The INCA project is designing and implementing an integrated accounting system for ecosystems and their services to inform decision making in the EU. It is a joint project of Eurostat, DG Environment, DG Research and Innovation and the Joint Research Centre of the European Commission and the European Environment Agency.

  The key objectives are to: i) develop a system of natural capital accounting, focusing on ecosystems; ii) address EU policy needs; iii) integrate existing georeferenced data from EU data bases and reporting by Member States; iv) identify data gaps and how they can be addressed; and, v) developing a geo-spatial data platform for a regular production of accounts.

  The aims and overall approach are described in the presentation by Vyšná (2019) at PowerPoint Presentation (maiaportal.eu)

  Details of the data being used and captured are available through Eurostat, at Methodology - Environment - Eurostat (europa.eu).

- The Mapping and Assessment for Integrated ecosystem Accounting - MAIA

The MAIA project, is coordinated by Wageningen University (The Netherlands), involving 11 countries, one of which is in the UK (World Conservation and Monitoring Organisation, Cambridge)

The aim of MAIA is to 'mainstream natural capital and ecosystem accounting (NCA) in EU Member States.' It applies the United Nations System of Environmental Economic Accounting – Ecosystem Accounting (SEEA-EA) as the basis of its methodology for natural capital accounting (NCA). (the SEEA Experimental Ecosystem Accounting Revision, System of Environmental Economic Accounting).This is a spatial approach which uses data and models as inputs to the preparation of accounts. Guidance on biophysical modelling and analysis of ecosystem services in an Ecosystem Accounting Context is reported by Lof *et al*. (2022).

The approach has been applied to 10 European countries: Belgium, Bulgaria, Czech Republic, Finland, France, Germany, Greece, Netherlands, Norway and Spain, for each of which information is provided in factsheets. The MAIA viewer is accessed through free registration. A series of webinar presentations on its use is available at: Presentation (maiaportal.eu).

- The Biodiversity Information System for Europe

  The Biodiversity information system is a partnership between the European Commission and the European Environment Agency. It provides an overview of the importance of biodiversity, and a context for the 2020 Mapping and assessment of ecosystems and their services (MAES) Report (Maes *et al*., 2020) for the European Union. The report provides an in-depth assessment of ecosystems at the EU level. The report provides details of the technical aspects of the approach including the spatial input data, its assessment, and reporting. A copy of the report is also attached for reference.

  Additional reference data are provided for ecosystem mapping on topics such as land cover, soils, transport infrastructure, with links to relevant input datasets (https://biodiversity.europa.eu/ecosystems/mapping-and-assessment-of-ecosystems-and-their-services-maes-1/reference-data-for-ecosystem-mapping).

  The Mapping and Assessment of Ecosystems and their Services provides an assessments of the key ecosystems in the EU, evaluates the EU 2020 biodiversity targets and provides a baseline for the 2030 biodiversity policy and EU nature restoration plan. (details are available at https://biodiversity.europa.eu/ecosystems).

  Information about the mapping of datasets onto ecosystem services is accessible at (https://biodiversity.europa.eu/ecosystems/mapping-and-assessment-of-ecosystems-and-their-services-maes-1/reference-data-for-ecosystem-mapping). The input data for the MAES ecosystem assessment mapping is documented in Annex 1 (page 392), and the ecosystem condition by type in Table 6.4 (page 405).

  References:

Lof, M., Grondard, N., Hein, L., Barton, D.N. and Martin, F.S. (2022). Guidance on Biophysical Modelling and Analysis of Ecosystem Services in an Ecosystem Accounting Context. Mapping and Assessment for Integrated ecosystem Accounting (MAIA). pp47.

Maes, J., Teller, A., Erhard, M., Conde, S., Vallecillo Rodriguez, S., Barredo Cano, J.I., Paracchini, M., Abdul Malak, D., Trombetti, M., Vigiak, O., Zulian, G., Addamo, A., Grizzetti, B., Somma, F., Hagyo, A., Vogt, P., Polce, C., Jones, A., Marin, A., Ivits, E., Mauri, A., Rega, C., Czucz, B., Ceccherini, G., Pisoni, E., Ceglar, A., De Palma, P., Cerrani, I., Meroni, M., Caudullo, G., Lugato, E., Vogt, J., Spinoni, J., Cammalleri, C., Bastrup-

Birk, A., San-Miguel-Ayanz, J., San Román, S., Kristensen, P., Christiansen, T., Zal, N., De Roo, A., De Jesus Cardoso, A., Pistocchi, A., Del Barrio Alvarellos, I., Tsiamis, K., Gervasini, E., Deriu, I., La Notte, A., Abad Viñas, R., Vizzarri, M., Camia, A., Robert, N., Kakoulaki, G., Garcia Bendito, E., Panagos, P., Ballabio, C., Scarpa, S., Montanarella, L., Orgiazzi, A., Fernandez Ugalde, O. and Santos-Martín, F., Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment, EUR 30161 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17833-0 (online),978-92-76-22954-4 (supplement), doi:10.2760/757183 (online),10.2760/519233 (supplement), JRC120383. pp. 452.

c) Example of mapping natural capital at regional level, Limberg Province, The Netherlands

A pilot mapping of ecosystems at a regional level was undertaken for Limberg Province, The Netherlands (de Jong *et al*., 2016), funded by the Netherlands Ministries of Economic Affairs and of Infrastructure and the Environment. Amongst the aims of the mapping was to compile land accounts (i.e. use and activity) for the Netherlands, for which it notes the spatial delineation of ecosystem types underpins all subsequent ecosystem accounts.

The pilot applies the SEEA–EEA approach to the Limberg Province, an output of which was the 'Ecosystem Unit (EU_NL) Map', consistent with the mapping approaches of the MAES. Building on the EU_NL map they developed spatial representations of physical state, environment state, and ecosystem state indicators, with which condition accounts are derived. The physical supply and use was mapped for crop production, fodder production, drinking water extraction, hunting, carbon sequestration, PM10 capture, nature tourism and recreational cycling. In conclusion it notes that 'the main strength of the accounting approach lies in the consistent, regular monitoring of ecosystem condition and services supply and use', with timeseries of data derived and compared to policy measures as well as economic and social developments.

Further details are reported by UNEP on: Towards natural capital accounting in the Netherlands (unep.org).

Reference:

de Jong, R., Edens, B, van Leeuwen, N., Schenau, S. Remme, R. and Hein, L. (2016). Ecosystem Accounting Limburg Province, The Netherlands, Wageningen University and Statistics Netherlands (CBS)., pp26.

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