RESAS Strategic Research Programme: D5-2 Climate Change Impacts on Natural Capital

D1.1 Risk and Opportunities Assessment Framework: Scope, Concepts and Structure.

Overview

The purpose of this document is to present an outline of a spatial Risk and Opportunities Assessment Framework (ROAF) that explores the impacts of climate change on Natural Capital in Scotland. This outline of the scope, concepts and methods and proposed structure are presented here to facilitate the process of co-construction of a ROAF with a broad range of stakeholders. The ROAF is to be used in the RESAS Strategic Research Programme D5-2 'Climate Change Impacts on Natural Capital' project. The project will need the advice and expertise from a wide range of stakeholders hence we hope that through this document we can initiate a meaningful discussion leading to the co-construction of the specifications and framework design that will lead to a high quality and utility research tool.

The research team developing the ROAF are seeking your engagement to co-construct the design and specification of the ROAF.

The aim of this document is to start the conversation with stakeholders on developing a ROAF that can answer two key questions: 'How can we best assess the impacts of climate change on Natural Capital' with the resources available, and subsequently 'How do the impacts affect the ability of Natural Capital to provide ecosystem services and serve as the basis for Nature Based Solutions, specifically climate change mitigation?'.

The objective of this engagement is to initiate and facilitate the co-construction of an ROAF with stakeholders. The overall objective is to develop a framework that is flexible enough to assess climate change impacts on a broad range of Scottish Natural Capital assets, yet sufficiently detailed to enable meaningful high quality scientific assessments for specific assets.

Recognising limitations and possibilities: The Project will not be able to assess all types of Natural Capital asset or the full range of ecosystem services they contribute towards. We will however aim to develop the risk and opportunities assessment framework in such a way that enables greater asset coverage and level of detail assessed to be develop over time, as and when resources, data and knowledge become available. We are keen to avoid bottlenecks now at the design phase that may inhibit future development and coverage.

Contents

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Project Aims and Objectives

The Project aim is to assess the risks to Natural Capital assets under future climate projections and what the consequences may be on ecosystem function and supply of ecosystem services, particularly climate regulation. The approach will enable us to identify the level of risk to an asset at a range of geographical scales, and which ones are at most risk or have the greatest potential beneficial opportunities. The objective is to develop and apply a spatial Risk and Opportunities Assessment Framework (which is flexible enough to enable both broad summary level and detailed asset specific assessments) so that we can:

- Identify risks to Natural Capital assets.
- Identify opportunities for mitigating risks.
- Assess how impacts on Natural Capital affect their ability to support Nature Based Solutions.
- Identify gaps in knowledge and how these may be filled.

The purpose is to provide Government, CAMERAS, agencies, planning authorities, Regional Land Use Partnerships, business stakeholders (including e.g. investors and insurance companies) and the public with high quality information to aid decision making on risk avoidance and to make the most of opportunities.
The project will operate within the context of multiple drivers of change (beyond climate impacts) affecting assets, such as land use change, policies and market forces, including the growing private interest in investing in Scotland's natural capital (e.g. for carbon, traditional forestry). Hence a further goal for the project is to inform other areas of research on the impacts of climate change on Natural Capital and how this relates to other key drivers.

Please note: a linked part of the overall Project focusses on people's risk perceptions and use of risk information (we will use fire risk as the issue to focus on with relevant stakeholders). The risk perception (Work Package 3) will utilize output from the framework to communicate risks and opportunities.

Defining a Framework

In the context of the aims and objectives for the D5-2 Climate Change Impacts on Natural Capital project, we will use the following approach to define the Risk and Opportunities Assessment Framework. The ROAF will be:

- **A research platform** (data and database structures, computing resources, analytical methods, result visualization and communication, e.g., maps) that enables the integration of new findings with existing scientific knowledge.
    - This includes existing resources and new ones to fill gaps in capabilities.
- **A suite of modelling tools** and assessment methods that run on or use data from the research platform.
    - Tools are used independently of each other but can be run using common data sources.
    - Where practical and meaningful, tools may be coupled to improve representation of assets.

- **A conceptual approach** that seeks to unify diverse methods that assess the impacts of climate change on Natural Capital assets.
    - We will use the concept that Risk is function of an asset's Vulnerability, Exposure to Threats (R=VET) – see below for details.
    - A set of asset-specific criteria to assess its risk and opportunities.
- **A point of integration**: the ROAF will seek to utilise data, methods and findings already generated and yet to be produced by relevant research undertaken in other parts of the SRP and projects funded by the UKRI, EU and others.
- **A spatial analytical tool:** where feasible, spatial assessments will be undertaken, with results presented as maps and accompanying graphical and tabular data visualisations.
    - Present outputs at a range of spatial scales, including asset specific at a macro or national level.
- **A process** that facilitates cascading climate change impacts to be assessed on assets for which data or modelling capabilities do not yet exist.
- **A medium** to support the Science-Policy Interface: the process of ROAF development and utilisation of outputs can help serve as a medium for discussion between science and policy, as well as a broad range of stakeholders.

Further objectives for the Framework, to help set the design specifications, are:

- It must be easy to use by researchers and transparent to end users.
- Have outputs that are open data and relevant to a broad range of stakeholders.
- Should align with IPCC and World Bank types of approaches and enable reporting upwards in spatial scale.
- Be consistent with existing methods, data and approaches, where possible (e.g., Natural Capital Asset Index, National Performance Indicator 'Increase or Natural Capital').
- Conform to international standards.
- Be open ended, to enable refinement, increasing asset coverage and further future development (i.e., avoid developmental bottlenecks).
- Be aligned with the development of policy and tools for data and verification as part of the Scottish Government's Responsible Private Investment in Natural Capital Programme.

Framework name: the suggestion so far is - Ecosystem Risks under Climate Change – ERICC. Further suggestions are very welcome.

Guiding principles and primary issues of concern

In developing the Project and ROAF, there are several key principles and issues to take into consideration:

- The framework structure and methods should be justifiable to RESAS, NatureScot and other relevant government agencies.
- Evidence of climate change impacts on Natural Capital must have sound scientific backing, with a strong justification to support mitigation and adaptation responses.

- There is a wide range of types and sources of uncertainty in making projections of future climate conditions, impacts and asset responses: where feasible, probabilistic approaches should be used to assess the range of possible impacts and responses.
- The condition of an asset is not a constant but is instead a dynamic variable, therefore impacts assessment must take account of the assets' condition at the initiation of assessment and how it changes over time with climate impacts.
    - An objective of the project is to indicate whether an assets' condition will improve or decline with climate change.
- With respect to the granularity (spatial scale) used, there is need to balance the level of detail assessed with that of the capability enabled by the available data and extent of knowledge. Care will be needed to make sure the research does not become more complex than is useful, whilst also avoiding being constrained in the future due to technological bottlenecks.
- Assessment must include impacts on the ability of the asset to supply ecosystem services.
    - An objective of the project is to improve understanding of whether an assets' ability to supply ecosystem services, particularly climate regulation, will increase or decrease with climate change.
- It will not be possible to assess all assets and their contributions to ecosystem services, but the framework can be constructed in such a way as to be open ended and to enable coverage expansion and improvements in the level of detail.
- The framework must be technically achievable: the extent of development must be bounded by the resources available (time, computing capacity and expert knowledge).

The approach taken has partially been developed following lessons learned during a recent Centre of Expertise on Water (CREW) project assessing the role of Scotland's wetlands in buffering the impacts of extreme weather[1].

Intended benefits to stakeholders

Why engage with this process? The approach we are taking is designed to enable a range of stakeholders to engage with the process of co-construction of the framework to increase utility and relevance to your needs. This is so that you can help shape the design of the framework and its outputs to help meet your objectives and help fill knowledge gaps. We hope to ensure the research and outputs have positive impacts for your responsibilities and intended outcomes.

A key goal for us is to provide insights into future risks and opportunities that enable foresight in planning policies and management for Natural Capital assets. This is particularly important in respect of the ability of Natural Capital to help achieve net zero targets and the scale and intensity of activities needed to minimise risk and gain benefit from climate change impacts. For example, climate impacts may impede an asset's ability to sequester carbon, or increase emissions (e.g. peatlands). If there is a net increase in emissions from Natural Capital due to climate impacts, emission reduction targets from other sectors may need to increase.

Similarly, understanding the impacts on Natural Capital assets will also inform planning for adaptation needs, hence informing the needs within the future Scottish Climate Change Adaptation Programmes.

[1] CREW: Main Report ; Combined Technical Appendices ; Policy Note

In terms of benefits to the public, outputs from the framework will help raise awareness of risks and opportunities and improve our understanding of the consequences of climate change impacts on Natural Capital. The planned mapped outputs can help serve as a powerful medium for communication of complex issues and the consequences of trade-offs in land use objectives.

Defining Natural Capital Assets

The UK Government Natural Capital Committee defines Natural Capital Assets as:

"*a distinctive component or grouping of natural capital components, including soils, freshwater and species. Natural capital assets are not mutually exclusive - there is overlap between categories (for example, soils include species, minerals and water), illustrating the complexity of natural capital. Natural capital assets typically come in systems, rather than discrete atomised components, limiting the scope for conventional economic analysis. Natural capital assets provide ecosystem services (flows) such as pollination and water purification, which support the production of goods and services, and generate benefits*" [2]

In recognition of the complexity of overlap, dependencies and interactions among and between assets, in order to assess the climate change impacts on these and their ability to provide ecosystem services, it is first necessary to group the assets into broad categories.

For the purposes of *starting* the process of the Framework development, we will use the following broad classifications of assets:

Asset type	Consisting of…	Process for assessment
Habitat: natural, semi-natural, managed (NCAI based)	Soils, water, biota communities and species (+ management practices)	Climate Threats applied to asset Vulnerability and Exposure criteria / indicators.
Cultivated product: Crops	Soils, water, biota communities and species (+ management practices)	Simulation modelling and climate Threats applied to asset Vulnerability and Exposure criteria / indicators.
Forestry	Soils, water, biota (+ management practices)	Climate Threats applied to asset Vulnerability and Exposure criteria / indicators.
Soils	Physical, chemical, hydrological and biotic components	Simulation modelling and climate Threats applied to asset Vulnerability and Exposure criteria / indicators.
Water	Water bodies, rivers / streams, wetland, soil and ground water, vapour (evapotranspiration)	Simulation modelling and climate Threats applied to asset Vulnerability and Exposure criteria / indicators.

From this broad range of asset types, we aim to be able to sub-divide these into categories that enable an appropriate level of detail and precision. Initially the level will need to be at a general resolution, e.g., using the Natural Capital Asset Index categorisation of habitats and ecosystem

[2] Natural Capital Terminology: Natural Capital Terminology (publishing.service.gov.uk)

services[3]. An objective for the project is make the framework flexible enough to enable specific asset types to be added in the future.

The Risk and Opportunities concept to be used

Climate change impacts on and opportunities for Natural Capital assets will be assessed using the concept that Risk is a function of an asset's Vulnerability and how Exposed it is to a range of Threats (R=VET). This will be applied to a set of asset-specific assessment criteria. The project will use the following to initiate discussion on and development of the ROAF:

- **Vulnerability:** is defined as "The degree to which a system [asset] is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation [Threat] to which a system is exposed, its sensitivity, and its adaptive capacity." (IPCC 2001). Vulnerability is an indication of asset resilience and includes its adaptive capacity (with or without human intervention), reflecting its ability to cope with or withstand different types of Threat (e.g., extreme events) or exceedance of variation (climate trends). Vulnerability can be sub-divided into biophysical and social dimensions requiring different approaches. Assets may have vulnerability tolerance thresholds (tipping points) beyond which it cannot or is unlikely to recover. Cascading vulnerability refers to inter-connection with other assets: one asset may have low direct vulnerability to CC but relies on another that has high vulnerability.
- **Exposure:** "The nature and degree to which a system is exposed to significant climatic variations" (IPCC 2001). Exposure is concerned with the spatial extent and quantity of an asset (abundant versus rare) and sensitivity to different threats and their probabilities (e.g. frequency and spatial distribution of droughts).
- **Threat:** encompasses different types of threat (climate, social, biological) an asset is exposed to and whether it is direct (climate extreme event, flood, drought, storm) or indirect (fire susceptibility due to drought, altered energy and nutrient transformation in food webs). This includes the nature and severity of the climate threat, its spatial extent, frequency and intensity and or duration.

Natural Capital assets to be assessed

The ROAF will be developed to be flexible enough to enable assessments to a wide range of Natural Capital assets. However, the initial focus will be on soils and water (as they underpin many other types of assets), woodlands, peatland and arable cropping areas. This choice reflects the assets providing key ecosystem services and for which there are already a range of assessment tools and data. We will explore options to develop assessment criteria for a small number of key species or species groups (e.g., Sphagnum, Red Deer) to test the scope of the ROAF.

The term 'asset' refers to a range of things, from a single species through to communities / habitats, ecosystems and physical properties, as well as groupings of assets. For example, 'soil' is an asset that consists of physical properties (texture, organic matter, bulk density, water holding capacity, carbon and nitrogen content etc) and biodiversity (micro-organisms,

[3] NCAI: https://www.nature.scot/sites/default/files/2021-05/Natural%20Capital%20Asset%20Index%202021%20%28data%20to%202019%29.xlsx

fungi). A key challenge will be to develop asset assessment criteria that enable the consequences of cascading and connecting impacts of climate change between assets to be explored.

How the process will work in practice

The proposed Risk and Opportunities Assessment Framework is detailed in Figure 1. The framework will be a spatial assessment tool.

Development

We propose that over the 5-year period of the project there are ten main stages:

1. Develop an overview of the ROAF within the Project team and prepare materials to present to stakeholders to enable further co-construction (*this document*).
2. Engage with stakeholders (July 2022) to ensure the proposed framework is feasible, viable and that outputs meet stakeholder requirements and help achieve desired outcomes.
    a. Identify key assets to focus on.
    b. Select primary climate change threats to utilise in assessments.
    c. Identify primary ecosystem services to assess.
    d. Assess methodological approaches.
3. Design data pipeline and Initiate construction of computing platform, databases and data integration / harmonisation, processes of assessment (including use of existing modelling and analytical capabilities, see below) and output generation (e.g., maps).
    a. Include assessment of options for asset condition state (monitoring schemes, remote sensed data etc.), e.g., linking to Soil Monitoring Framework (C5 – WP2), soil health indicators (D3 RQ10), and agency-based monitoring NatureScot, SEPA etc).
4. Develop a process to enable output validation and checking for consistency between impacts on different assets, and a confidence rating approach to enable improving uncertainty assessment.
5. Engage with asset experts and utilise published data / findings to develop the details for the Vulnerability and Exposure parts of the Assessment Criteria and how climate change impacts will affect an assets' ability to provide a range of ecosystem services.
6. Analyse climate projections and use 2b. outcomes to develop climate Threats criteria.
7. Develop coding of Assessment Criteria and data flows to enable the climate change impacts on an asset to be assessed based on its Vulnerability and Exposure to a range of Threats.
8. Engage with stakeholders to appraise progress and evaluate initial results and consequences on supply of ecosystem services.
9. Refine based on feedback and generate initial outputs.
10. Generate climate change impacts maps and summary reports on those Natural Capital assets selected as being of primary interest to stakeholder.

Please Note: The existing modelling and analytical tools (beige box in Figures 1 and 2) can operate as standalone research efforts (with associated outputs) that will individually and collectively generate important meaningful insights into the impacts of climate change on assets (some examples are provided in Appendix A). The aim is that these findings will be incorporated into the framework process. This enables a twin track approach to be taken.

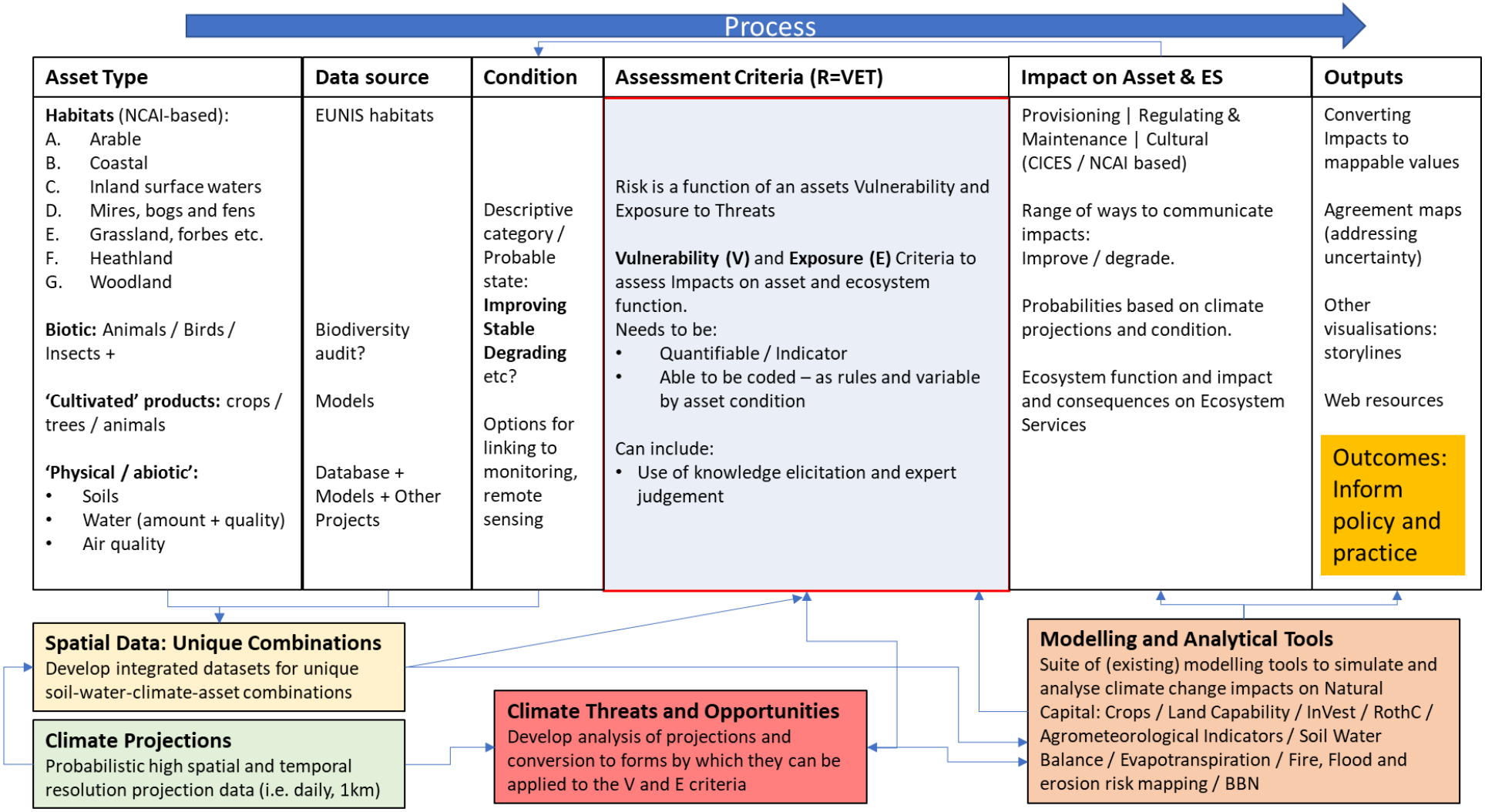

Figure 1: Proposed Risk and Opportunities Assessment Framework

Operation

The ROAF will be a research tool utilising large data sets and inputs from a range of modelling tools, hence will not be a PC based tool.

A worked example of the proposed framework is illustrated in Figure 2 for the NCAI G1 – Broadleaved deciduous woodland habitat type. Two examples of the assessment criteria are presented, based on two types of Threat – however, the main intention for development of this part of the framework is that it is open-ended, hence additional Threats can be added, and further Vulnerability and Exposure assessment criteria can be included. Only one example is given for the impact on ecosystem services (NCAI Provisioning 1.9 – Water for non-drinking purpose. Again, the framework will be developed to enable multiple ecosystem services to be included.

A benefit of this approach is that the assessment criteria can serve as the basis to accumulate knowledge and hence improve understanding of the inter-relational or cascading impacts and consequences (e.g., on an asset's condition and ecological function) ad ability to provide ecosystem services.

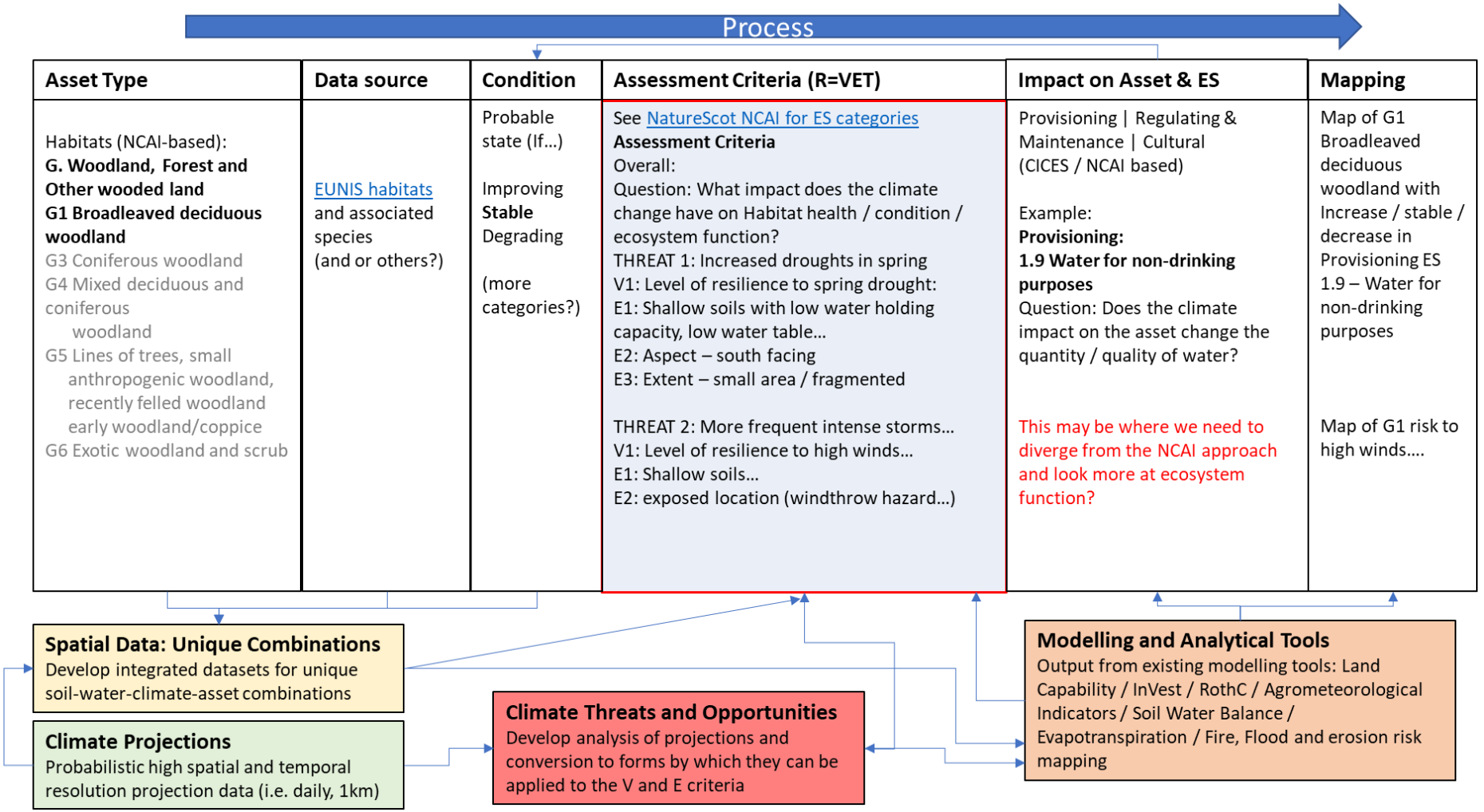

Figure 2: A worked example of the proposed Risk and Opportunities Assessment Framework, using the Natural Capital Index habitat type G1 Broadleaved deciduous woodland with two type of climate Threat (increased droughts in spring and more frequent intense storms) and impact on one ecosystem service: NCAI 1.9 water for non-drinking purposes.

Developing definitions and criteria for assessing assets

A key task is to develop the asset specific criteria to assess the Vulnerability and Exposure for each individual asset (and combinations of assets) and its (their) response to different climatic Threats. This includes the identification of data, tools and computing requirements to apply data to the criteria. Criteria may include:

- The current physical and biological tolerances of an asset, e.g. growing temperature range, water availability requirement, susceptibility to heat stress.
    - How these may vary depending on the asset's condition.
- The spatial extent and abundance.
- What the underpinning soil-water and details are: these will be informed by the unique combinations database.

Development of the assessment criteria will require inputs from experts beyond those in the project team. We will explore options to enable knowledge elicitation to inform assessment criteria development, e.g. online questionnaires.

Overview of modelling-based assessment

Various spatial modelling and assessment tools and data already exist that can be used to conduct some impacts assessments. During the stakeholder engagement we aim to identify how these can be best utilised and how outputs can be used with the assessment criteria.

- Land Capability under climate projections[4]: this is a new research platform to assess climate change impacts on Land Capability for Agriculture.
- Spatial crop modelling: high spatial and temporal resolution application of a process-based crop model simulating crop growth (e.g. barley) under current and future climates.
- Spatial Agrometeorological Indicators: 1km resolution future projections for the whole UK of things like length of growing season, plant heat stress, occurrences of frosts, heatwaves and precipitation intensity, plus monthly climate summaries (e.g. precipitation amount, maximum and minimum temperatures).
- InVest model (Integrated Valuation of Ecosystem Services and Tradeoffs)[5]: a suite of models used to map and value ecosystem services. It helps explore how changes in ecosystems can lead to changes in the flows of many different benefits to people.
- RothC: a model for the turnover of organic carbon in non-waterlogged topsoil that allows for the effects of soil type, temperature, soil moisture and plant cover on the turnover process.
- Soil Water Balance: a model to estimate daily soil water balance run using the National Soils Database and 1km resolution climate data to give 477,209 unique soil-climate combinations covering the whole of Scotland.
- Linkages to D3 – Water catchment scale hydrological modelling.

A design specification for the framework is that it is capable of utilising a range of existing and any new modelling and spatial analytical capabilities.
Several examples of the models above are provided in Appendix A.

[4] https://www.climatexchange.org.uk/research/projects/the-land-capability-for-agriculture-building-a-tool-to-enable-climate-change-assessments/
[5] InVEST | Natural Capital Project (stanford.edu)

Planned Outputs

The framework will be developed to produce a range of outputs designed in collaboration with stakeholders to meet their needs and reflect the specific issues for individual assets. Examples include:

- Maps indicating an assets' level of risk to specific climate threats.
- Maps indicating where there is agreement between different climate projections of risks to and opportunities for an asset (see Figure 8 for an example).
- Structured tables of impacts on an asset and the consequences on its ability to provide ecosystem services.
- Outputs from individual modelling and analytical tools. These will both inform the application of the asset assessment criteria process and standalone investigations.

Timeline

The initial aim for the first five months of Year 1 of the project is to:

- Discuss and develop specifications of the ROAF by co-construction with the research team
- Identify data, tools and methods that can be utilized or adapted.
- Scope opportunities for integration of existing data and tools.
- Write Deliverable D1.1 - Framework Outline (this document) setting out the overview of the specifications and design of the framework, data and tools available already, new data needs and computing requirements (Due end of May).
- Undertake a literature review of key climate change impacts on Natural Capital and mitigation opportunities (due June 2022).
- Hold stakeholder meetings to present the framework outline and refine with their input (July 2022). Identify key stakeholders and invite to the July workshop.
- Undertake further research team framework specification meetings (July-August 2022) - Deliverable D1.3 (due October 2022) will formalize the framework design.
- Produce climate trends summaries (D2.1a, due September 2022) and climate extremes (D2.1b, due November 2002). As these develop, they will help inform the scope for asset response estimation.

Appendix A Examples of existing spatial modelling tools

Land Capability for Agriculture: a new computing platform enables the estimation of land capability under future climate projections (1km climate resolution with multiple soil series within the 1km grid)

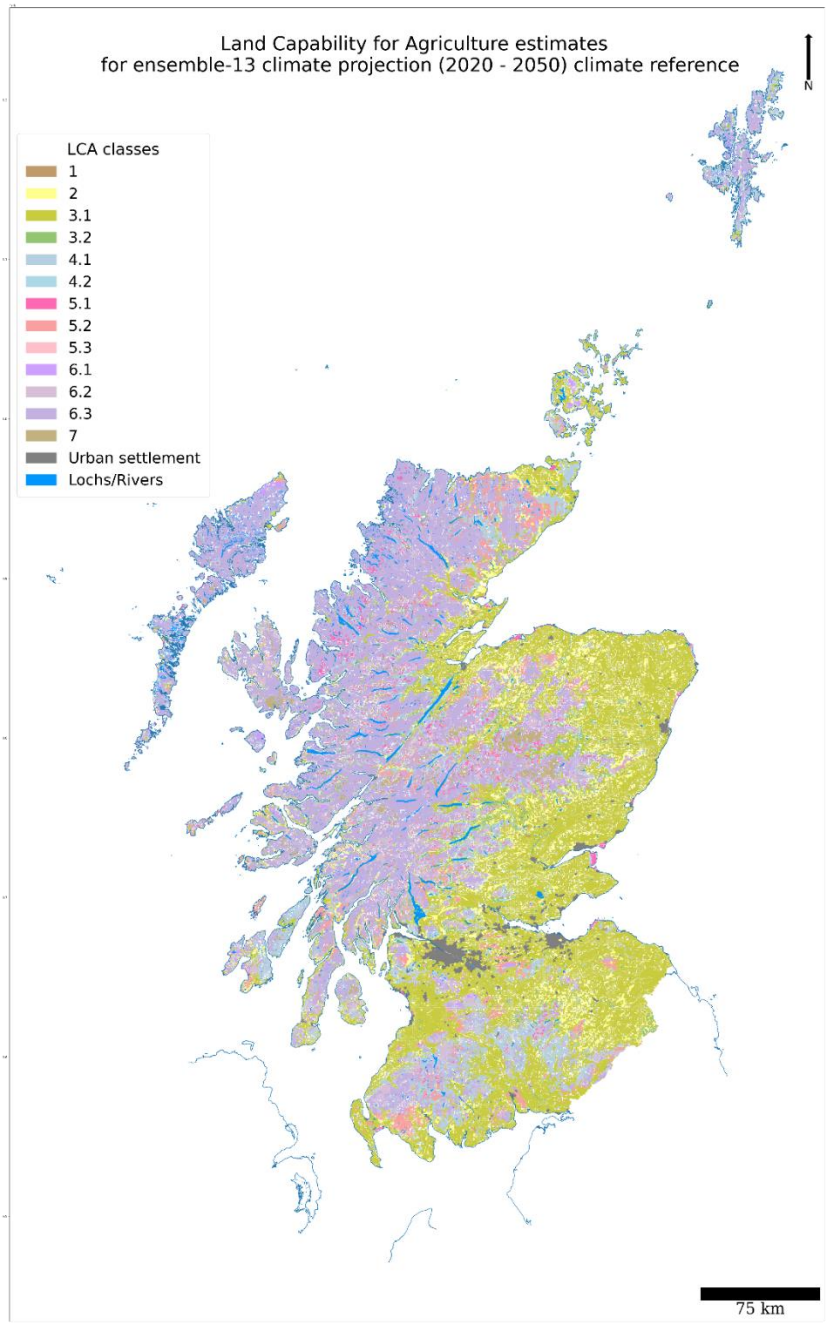

Figure 3. Land Capability for Agriculture estimated using future climate projections (UKCP18 ensemble member 13, RCP8.5) for the period 2020 – 2050.

Soil Water Balance: A simple model has been developed and applied to 477,209 unique climate-soil combinations in Scotland using bias corrected UKCP18 climate projections.

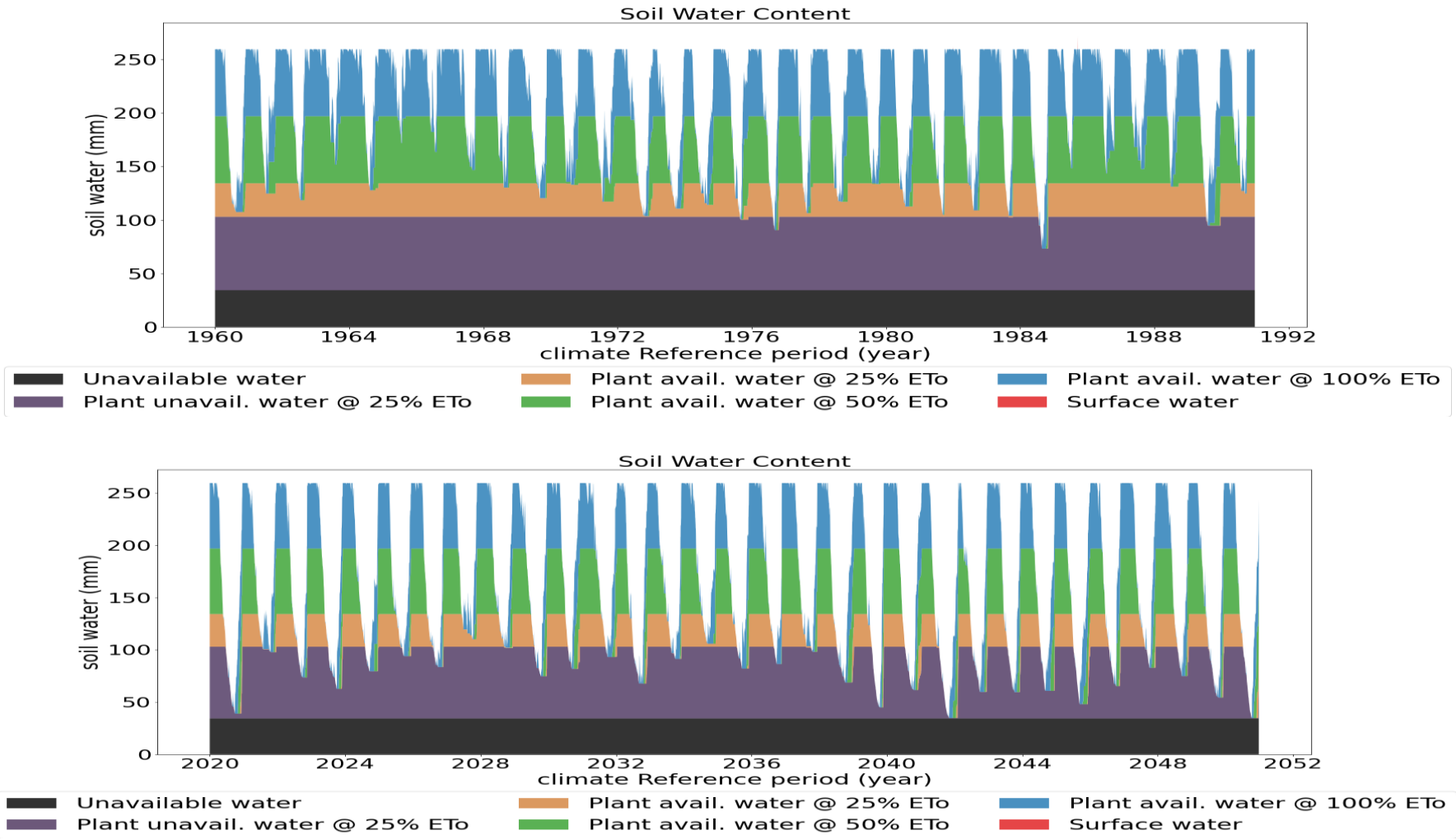

Figure 4: Time series of soil water balance for a Brown Earth Soil (unique ID 355179). Top: 1960 - 1990, Bottom: 2020-2050 for UKCP18 ensemble member 12. Y axis is soil water (mm), X axis is Year.

Spatial Agrometeorological Indicators: These include indicators like the length of growing season, occurrences of frosts in spring and autumn, the date when soil water falls below field capacity (Figure 5) etc. These have been estimated at a 1km resolution for the whole UK, enabling comparison of impacts in Scotland in a wider context. A further example, Plant Heat Stress, is illustrated in Figure 6 (projections for three ensemble members).

Field Capacity Days: The number of days per year when soil water is at or above field capacity (amount of water a soil can hold against gravity).

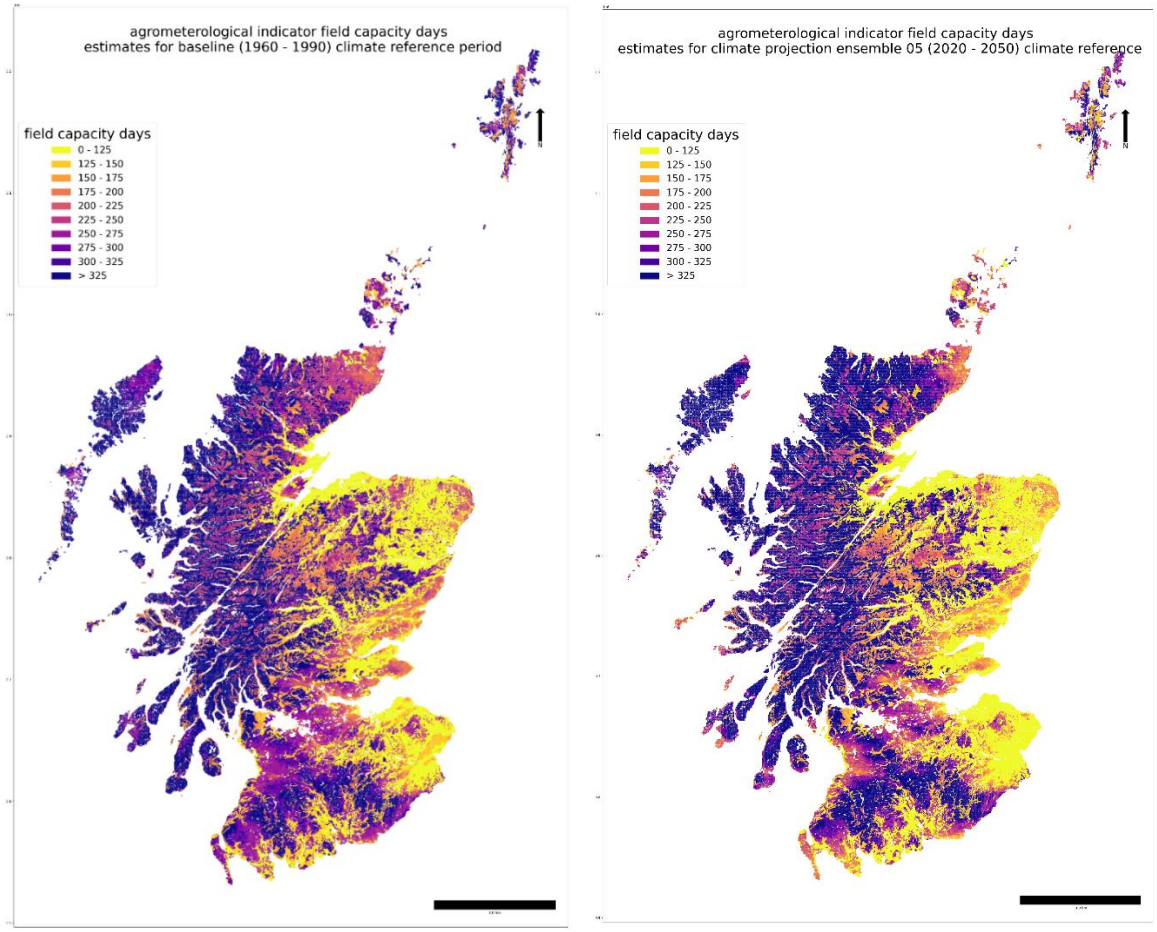

Figure 5. Estimated number of days in the past (1960 – 1990) and a plausible future (UKCP18 ensemble member 05, RCP8.5) when soils are at or above Field Capacity.

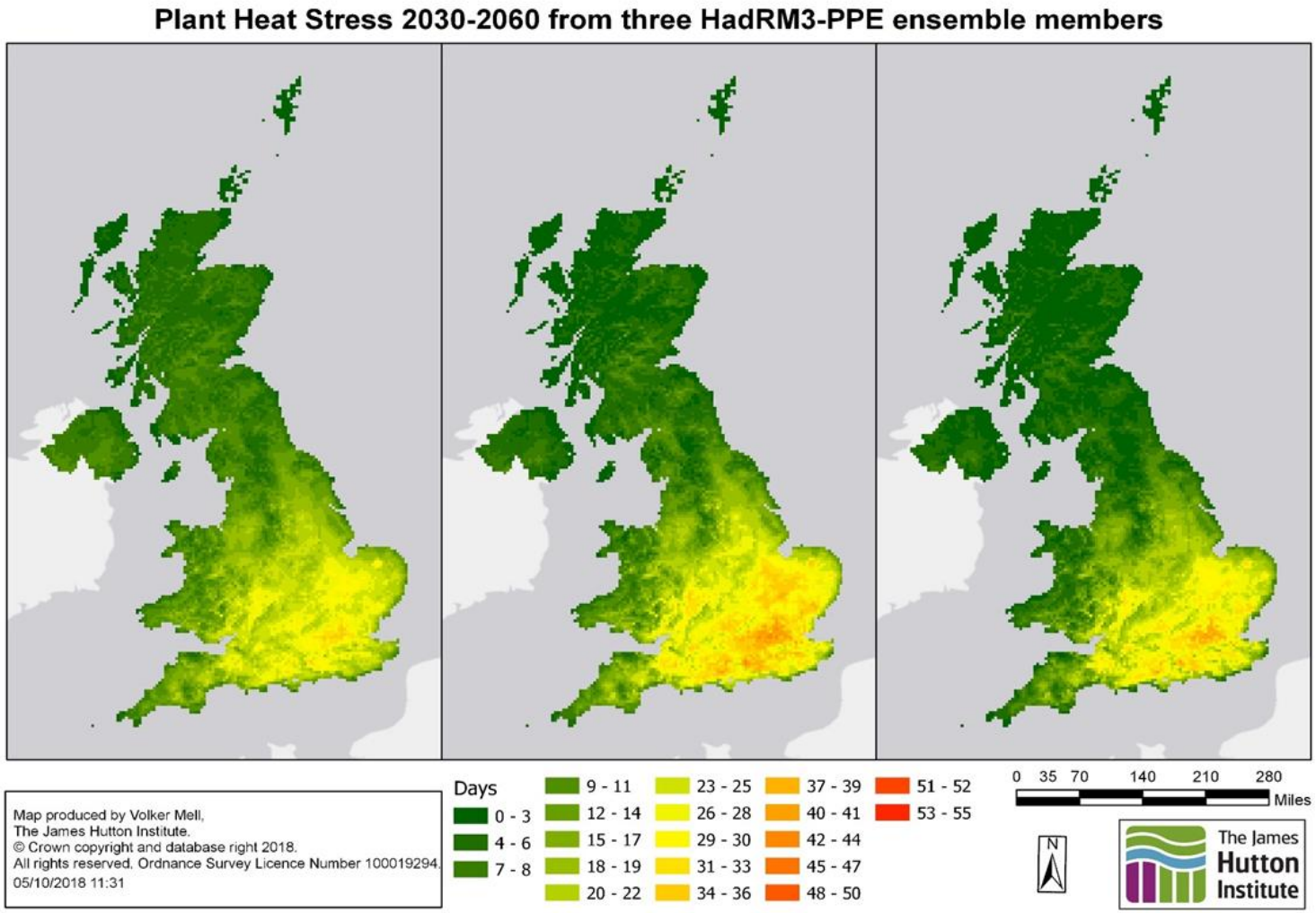

Figure 6. Projected changes in the mean Plant Heat Stress Indicator (number of days in a year when the maximum temperature is greater than 25°C) for the 2030 - 2060 period for three UKCP18 ensemble members (RCP8.5).

Crop Modelling: a detailed process-based crop simulation model has been applied to 56,256 unique climate-soil combinations covering the arable areas of Scotland, using observed and bias corrected UKCP18 climate projections.

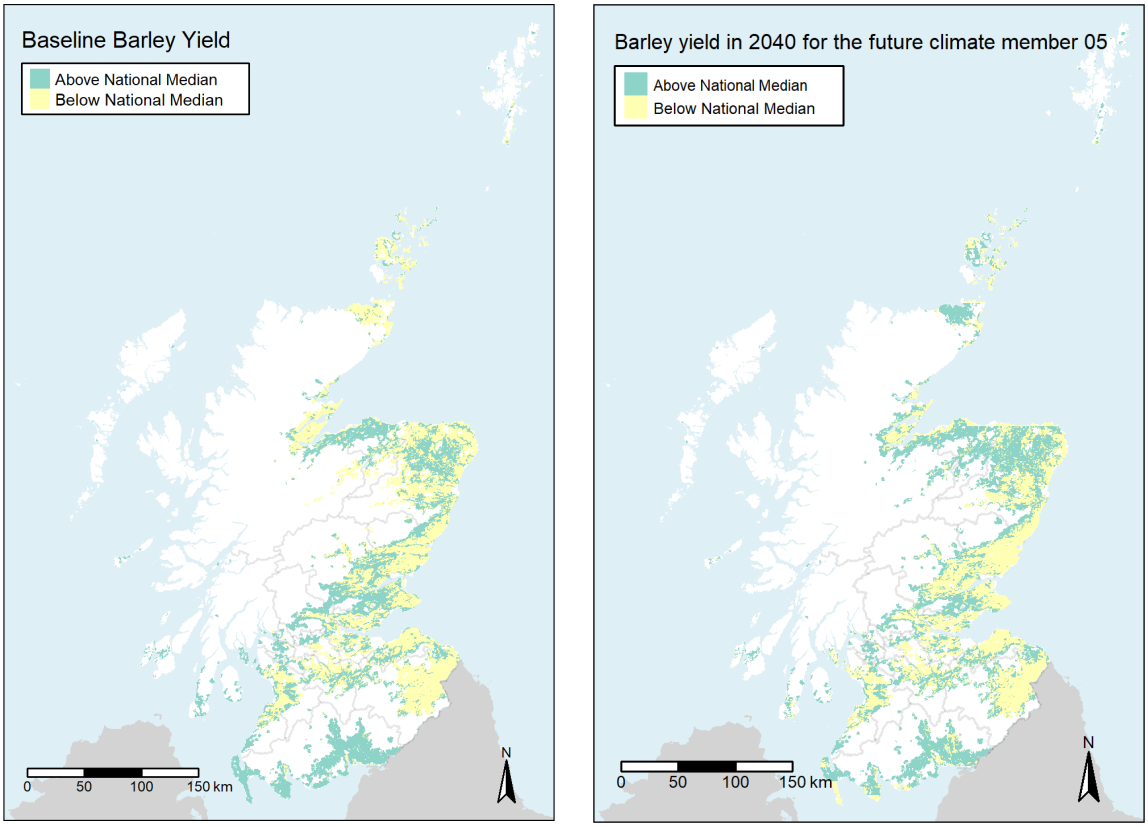

Figure 7. Spatial distribution of barley median national yield for the observed (1994 – 2015) and future (2040s) when sowing date is 01-Apr for the future UKCP18 projections climate member 05.

Addressing uncertainty: using multiple climate projections enables probabilistic estimates of climate change impacts, for example on the barley yields (Figure 8). Where there is agreement on the mapped estimate in more climate model projections (in this case the sign of yield change), the more confident we may be that the change may occur at that location.

We will assess options to utilise this approach in mapping outputs from the framework.

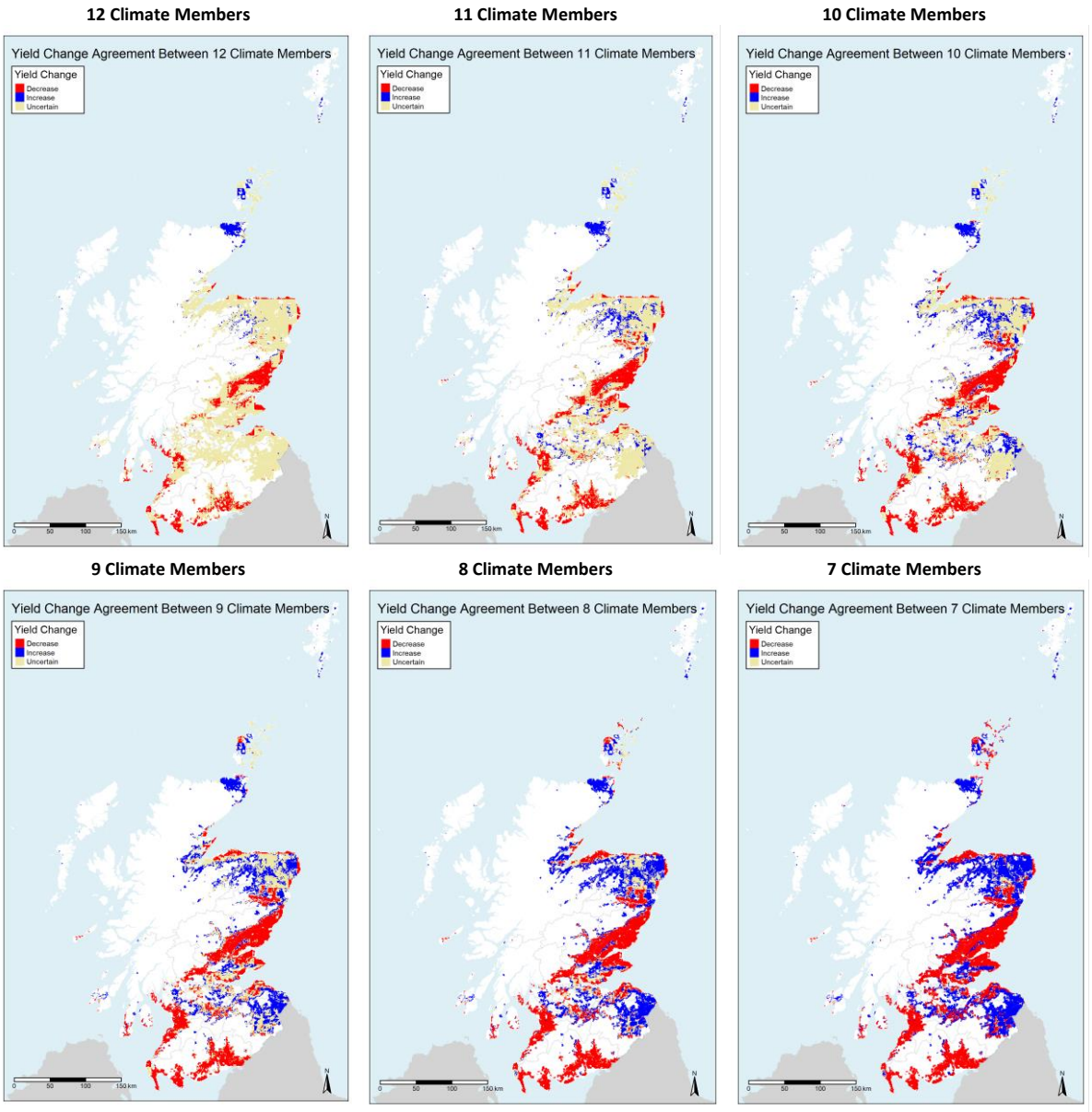

Figure 8. Simulated barley yield agreement maps for 7 to 12 climate model ensemble members.