Prioritising Catchments for Nature Restoration in Scotland to Support Climate Change Adaptation.

A report for NatureScot

28th March 2025

The James Hutton Institute

verture

Summary

Climate change is already impacting on Scotland's communities, businesses, infrastructure, natural capital and nature's ability to provide ecosystem services. Restoration or enhancement of ecosystems at a catchment scale offers a significant opportunity for climate adaptation that achieves a range of multiple benefits for people and nature. Given the pace of climate chance, we need to act now to restore nature to help us adapt to climate change.

This report provides the results of a combined analysis using integrated spatial data sets, desk research, expert opinion and stakeholder survey and interviews to identify proposed priority catchments in Scotland where nature restoration can deliver multiple benefits, including climate adaptation outcomes.

The objective of the study is to provide information and evidence to NatureScot and those agencies, organisations and stakeholders involved in discussions and decision making on which catchments to prioritise for restoration.

This project brings together technical mapping analysis, desk research and the views of key stakeholders to produce a single list of catchments. This prioritised list is the combination of the spatial analysis and responses to the stakeholder survey and key informant interviews. It was built based on the locations of risks identified from the survey *and* that have a higher normalised score from the spatial analysis.

Key Messages:

We have identified 18 proposed catchments and 4 sub-catchments as priorities for nature restoration to achieve multiple benefits. Using a combination of spatial analyses, desk research, researcher perspectives and survey and key informant interviews, these catchments and sub-catchments are identified in Figure 1 and detailed in Table 1 below (no specific order of priority).

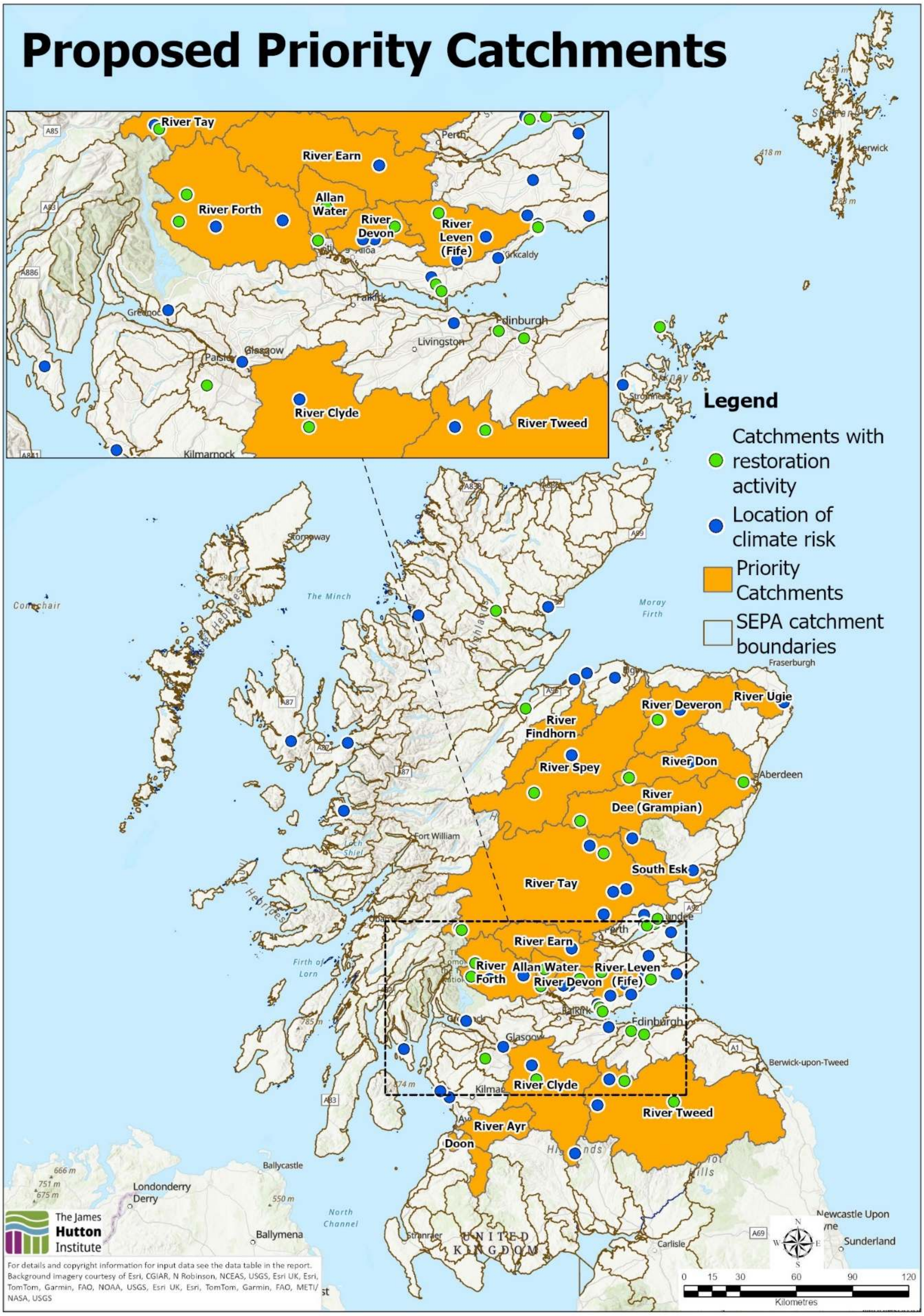

Figure 1. Proposed priority catchments for nature restoration (no order of priority). Green dots indicate locations identified in the survey where respondents provide information on existing projects. Blue dots indicate where they perceive risks.

Table 1: Proposed Priority Catchments using combined analysis

<table>
<tr><th rowspan="2">Catchment</th><th rowspan="2">Priority from one or both methods</th><th rowspan="2">Spatial assessment justification for benefits and identification of risks (limitations in italics)
Additional information from report reviews in [ ]</th><th colspan="2">Identified as priority in</th></tr>
<tr><th>Survey</th><th>Interviews*</th></tr>
<tr><td>Tay
4991 km^2</td><td>Both</td><td>• Large areas of degraded peat†.
• Largest catchment, flood risk reduction (e.g. to Perth).
  ◦ 2,100 properties at risk, £7.4m annual average damage**. See Local Plan District LPD_08_Sources
• Securing water abstraction.
• At risk of future reduced water availability therefore need for water retention to reduce low river flow.
• Impacts on nitrates in south-east of catchment.
• Opportunities to reduce soil runoff.
• Large areas of designated sites (CNPA).
• Within the Climate Ready Tayside regional adaptation partnership area
• [Tay Special Area for Conservation]</td><td>Yes: Six risks identified by participants, plus one existing nature restoration projects. (Bioregion Tayside, Tay Rivers Trust)</td><td>No</td></tr>
<tr><td>Forth
1028 km^2
and
Allan Water
216 km^2</td><td>Both</td><td>• Benefits for securing water abstraction (Forth).
• Large areas of peat†
• Flood risk reduction.
  ◦ 430 properties at risk, £1.4m annual average damage**. See Local Plan District LPD_09_Sources .
• Reduced erosion risk (upper catchments)
• Reduced flooding.
• At risk of future reduced water availability in upper catchment therefore need for water retention to reduce low river flow.
• Favourable conditions for vegetation recovery (long growing season).
• Large proportion of owned land (Allan).
• Some reduced soil runoff risk (more in Allan).
• [FORTH2O Policy Innovation Partnership]</td><td>Yes: Four risks identified in the survey and two nature restoration projects (Forth Rivers Trust) Multiple nature restoration projects under way / delivered</td><td>Yes: Network Rail</td></tr>
</table>

Tweed 3349 km^2	Both	• Some benefits for securing water abstraction. • Flood risk reduction (e.g. Peebles). ◦ 4,600 properties at risk, £10.5m annual average damage**. See Local Plan District LPD_13_Sources • Large areas of peat† • Reduced erosion risk (upper sub-catchments) • Reduced risk of flooding (upper west and southwest sub-catchments). • At risk of future reduced water availability especially in elevated upper catchment therefore need for water retention to reduce low river flow. • Favourable conditions for vegetation recovery (long growing season). • Large proportion of owned land. • Potential to reduce nitrates impact (NVZ in east of catchment). • Peatland areas in upper sub-catchments. • Reduced erosion risk (upper catchments). • Urban Waste Water Treatment Directive (UWWTD) sensitive area. • [Tweed Special Area of Conservation]	Yes: Two risks identified and two existing nature restoration projects	
Clyde 1939 km^2	Both	• Benefits for securing water abstraction. • High number of buildings in catchment. • Flood risk reduction (e.g. Glasgow). ◦ 9,600 properties at risk, £22m annual average damage**. See Local Plan District LPD_11_Sources • Large areas of peat, some bare / eroded†. • Reduced soil erosion risk (upper catchment). • Reduced soil runoff risk (upper catchment). • Favourable conditions for vegetation recovery (long growing season). • UWWTD sensitive area. • Within the Climate Ready Clyde regional adaptation partnership area and Metropolitan Glasgow Sustainable Drainage Partnership area • Within the Clyde Mission action area	Yes: Two risks identified and one existing nature restoration project. (Glasgow Clyde Valley green network)	Yes: NHS Scotland Assure
Dee (Grampian) 2084 km^2	Both	• Benefits for securing water abstraction. • Large areas of peat, some bare and degraded†. • Flood risk reduction (e.g. Ballater, Aboyne, Aberdeen).	Yes: One risk and one existing nature	Yes: Scottish Water

		• 10,000 properties at risk, £13.5m annual average damage**. See Local Plan District LPD_06_Sources • Reduced soil erosion risk (upper catchment). • At risk of future reduced water availability especially in elevated upper catchment therefore need for water retention to reduce low river flow. • Reduced soil runoff risk (upper catchment). • Large area of designated sites (CNPA). • UWWTD sensitive area. • Within the Cairngorms Regional Land Use Partnership area • [River Dee SAC and Fresh Water Pearl Mussels]	restoration project identified in the Dee	
South Esk (Angus) 563 km^2 Including: • Glen Prosen • Glen Isla • Glen Clova	Both	• Large areas of peat, some bare and degraded†. • Reduced flood risk (e.g. Brechin). • 230 properties at risk, £0.81m annual average damage** See Local Plan District LPD_07_Sources • Reduced soil erosion risk (upper catchment). • At risk of future reduced water availability especially in elevated upper catchment therefore need for water retention to reduce low river flow. • Potential to reduce nitrates impact (NVZ at lower half of catchment). • Reduced soil runoff risk. • Ease of access. • Some designated site areas (CNPA in upper catchment). • UWWTD sensitive area. • Within the Climate Ready Tayside regional adaptation partnership area • [Esk Special Area for Conservation]	Yes: Two risks identified in South Esk. (survey)	
Don (Aberdeen shire) 1317km^2	Both	• Reduced flood risk (e.g. Inverurie, Aberdeen). • 3,100 properties at risk, £5.9m annual average damage** See Local Plan District LPD_06_Sources • Large areas of peat, some bare and degraded peat in upper catchment†. • Reduced soil erosion risk (upper catchment). • At risk of future reduced water availability especially in elevated upper catchment therefore need for water retention to reduce low river flow. • Potential to reduce nitrates impact (NVZ in lower half of catchment).	Yes: One risk identified and one nature based project	

		• Some benefits for securing water abstraction. • UWWTD sensitive area. • Ease of access. • Some designated site areas (CNPA in upper catchment).		
Deveron (Moray) 1232km^2	Both	• Reduced flood risk (e.g. Banff and coastal areas). • 360 properties at risk, £1.3m annual average damage** See Local Plan District LPD_06_Sources • Some benefits for securing water abstraction. • Reduced soil erosion risk (upper catchment). • Areas of peat, some bare and degraded in upper catchment†. • At risk of future reduced water availability especially in elevated upper catchment therefore need for water retention to reduce low river flow. • Potential to reduce nitrates impact (NVZ in lower half of catchment). • Reduced soil runoff risk in some areas. • UWWTD sensitive area. • *Mostly rented land*	Yes: Two risks identified	
Devon (Clackman nanshire 198km^2	Both	• Benefits for securing water abstraction. • Reduced flood risk benefits (e.g. Hillfoots Villages: Tillicoultry, Menstrie, Dollar). Considered catchment prone to flash floods. • 890 properties at risk, £1.6m annual average damage (59% river, 41% surface) See PVA 09/04 • Areas of bare and degraded peat in elevated parts of catchment • Reduced soil erosion risk (elevated parts of catchment) • At risk of future reduced water availability therefore need for water retention to reduce low river flow. • Reduced soil runoff risk in some areas. • Favourable conditions for vegetation recovery (long growing season). • *Mostly rented land*	Yes: Two risks identified and one existing nature restoration project	

Doon (Ayrshire) 322 km^2	One (spatial)	• Securing water abstraction. • Flood risk reduction. ◦ 730 properties at risk, £1.6m annual average damage**. See Local Plan District LPD_12_Sources • Reduced soil erosion risk. • At risk of future reduced water availability in upper catchment therefore need for water retention to reduce low river flow. • *Mostly rented land*	No	No
Ayr 584 km^2	One (spatial)	• Eroded peatland in upper catchment† • Flood risk reduction. ◦ 5,900 properties at risk, £10m annual average damage (includes Irvine catchment)**. See Local Plan District LPD_12_Sources • Reduced erosion risk (upper catchments) • Reduced soil erosion risk • Designated sites (upper catchment) • Favourable conditions for vegetation recovery (long growing season). • Urban Waste Water Treatment Directive (UWWTD) sensitive area. • *Mostly rented land*	No	No
Spey 2947 km^2 including the Kingussie sub-catchment	One (spatial)	• Benefits for securing water abstraction (distilleries) [see MOVING Project]. • Downstream reduced flood risk benefits. • Reduced erosion risk • Flood risk reduction (e.g. Spey Bay). ◦ 700 properties at risk, £1.8m annual average damage**. See Local Plan District LPD_05_Sources • Large areas of degraded peat†. • At risk of future reduced water availability especially in elevated upper catchment therefore need for water retention to reduce low river flow (biodiversity and distilleries). • Potential to reduce nitrates impact (NVZ at lowest level of catchment). • Large area of designated sites (CNPA). • Partly within the Highland Adapts regional adaptation partnership area • Within the Highlands and Cairngorms Regional Land Use Partnership areas	No	No

Ugie 333 km^2	One (spatial)	• Potential to reduce nitrates impact (NVZ). • Small amount of peatlands. • Ease of access. • UWWTD sensitive area. • Within the Climate Ready Aberdeenshire regional adaptation partnership area	No	No
Findhorn 786 km^2	One (spatial)	• Reduced flood risk. • 560 properties at risk, £2.4m annual average damage**. See Local Plan District LPD_05_Sources • Large areas of peat, some bare and degraded†. • Reduced soil erosion risk. • Reduced soil runoff risk • At risk of future reduced water availability especially in elevated upper catchment therefore need for water retention to reduce low river flow. • Ease of access. • Few Designated sites	No	No
North Esk (Angus) (765 km^2)	One (spatial assessment)	• Large areas of bare and degraded peat. • Reduced flood risk. • 170 properties at risk, £0.56m annual average damage**. See Local Plan District LPD_07_Sources • Reduced soil erosion risk. • At risk of future reduced water availability especially in elevated upper catchment therefore need for water retention to reduce low river flow. • Potential to reduce nitrates impact (NVZ at lower half of catchment). • Reduced soil runoff risk • Some designated site areas (Cairngorms National Park in upper catchment). • UWWTD sensitive area. • Within the Climate Ready Tayside and Climate Ready Aberdeenshire regional adaptation partnership areas.	No	No

Earn 867 km^2	One (spatial assessment)	• Benefits for securing water abstraction. • Areas of peat in upper catchment, some bare and degraded†. • Reduced flood risk (e.g. Bridge of Earn). ◦ 730 properties at risk, £2.8m annual average damage** See Local Plan District LPD_08_Sources • Reduced soil erosion risk (upper catchment). • At risk of future reduced water availability especially in elevated upper catchment therefore need for water retention to reduce low river flow. • Potential to reduce nitrates impact (NVZ in north-east of catchment). • Reduced soil runoff risk. • Some designated site areas (Loch Lomond & Trossachs NP in upper catchment). • Within the Climate Ready Tayside regional adaptation partnership area	No	No
Leven (Fife) 422 km^2	One (survey)	• Reduced flood risk benefits (e.g. Methil and Leven). ◦ 180 properties at risk, £0.82m annual average damage (75% from river flooding) (see PVA 10/03). • At risk of future reduced water availability therefore need for water retention to reduce low river flow. • Small areas of peat† • Reduced soil runoff risk. • Favourable conditions for vegetation recovery (long growing season). • Potential to reduce nitrates impact (NVZ in part of catchment). • Reduced soil runoff risk in some areas. • UWWTD sensitive areas in part of catchment. • *Mostly rented land*	Yes: Five risks identified	

Notes:

* The maps shown in this report and the Supplementary Material include point locations for existing climate risk and areas of proposed or active nature based solution projects identified through the survey. Catchments identified in key informant interviews related to climate risk or areas of proposed or active nature based solution projects were not represented as data points in the spatial maps as they were collated and shared with project partners after

the spatial maps were created by JHI. They include climate risks identified in the Clyde (NHS Scotland Assure), the Dee (Scottish Water) and the Forth (Network Rail). This emphasises that the published report serves as a foundation for further conversation with infrastructure providers as a next step.

** Flood Risk Management Strategy Local Plan District. Note: example figure provided are for river flooding and do not include surface water flooding. Some properties at risk examples from SEPA Potential Vulnerable Areas.

† See Table 2 in Supplementary Material for peatland areas per condition class in each proposed priority catchment.

There are other catchments and sub-catchments, along with locations that are identified as Potential Vulnerable Areas that would benefit from restoration that are not listed above. We later provide a few examples where restoration would have single benefits or locations at risk. The survey analysis also identified the Dighty Burn in the Dundee Coastal catchment, but this is not proposed as a priority. A list of catchments identified through stakeholder survey and interviews is provided in Table 3. Further analysis is required to determine if it could be a whole catchment priority.

Scope

While this list is based on the best available data and evidence, it should be noted that not all priority criteria were able to be integrated into the analysis due to availability, scalability or coverage of datasets, and responses to the survey, while wide-ranging, are not statistically representative of the entirety of Scotland. For example, all of the proposed priority areas in Table 1 are on the Scottish mainland. However, there are significant climate hazards facing island communities across Scotland, with many areas extremely vulnerable to climate change impacts. Risks were identified in Orkney and the Outer Hebrides through the stakeholder survey, but were not identified through the spatial analysis. Nature restoration that can deliver adaptation outcomes should also be explored further for island communities.

This report should be used to inform further prioritisation by NatureScot, agencies, and stakeholders in each catchment. It is also important to highlight that all catchments in Scotland will be impacted by climate change and require adaptation action in the coming years. This report highlights catchments where early action on nature restoration would deliver the greatest multiple benefits. NatureScot and other organisations will also need to identify how action will be supported in all other areas in the years to come, too.

Next steps

- NatureScot will discuss the proposed priority catchments with other Government agencies and Scottish Government to confirm which ones are priorities during summer 2025.
- NatureScot will engage with a wide range of stakeholders later in 2025 to ensure that the right priorities have been identified, and fill any gaps in 2026
- NatureScot will complete a gap analysis by the end of Q2 2025/ 26 and identify where new landscape scale restoration projects are needed, with a view to working with other agencies and partners to develop these during 2026.

Contents

Citation: This report should be cited as:

Rivington M, Aitkenhead M, Wadsworth E, Stewart L, Casey J, McFarlane F, Gagkas Z, Naha S, Jabloun M, Robb C, Coull M, McKean M (2025) Prioritising Catchments for Nature Restoration in Scotland to Support Climate Change Adaptation. A report for NatureScot. The James Hutton Institute, Aberdeen, UK. DOI: **10.5281/zenodo.15854103**

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Acknowledgements

This report has been produced by The James Hutton Institute and Verture through funding provided by NatureScot. The spatial analyses capabilities have been enabled through the Scottish Government Strategic Research Programme JHI-C3-1 Supporting Land Use Transformations and JHI-D5-2 Climate Change Impacts on Natural Capital. We are very grateful to the following colleagues who have contributed input data, comment and suggestions: Rachel Helliwell (CREW), Mark Wilkinson (JHI), Mads Troldborg (JHI) Miriam Glendell (JHI), Alessandro Gimona (JHI), Marie Castellazzi (JHI). We also thank and acknowledge the UK Meteorological Office for use of the 1km gridded observed climate data and UKCP18 climate projections, SEPA and other data providers. Thanks also to all the organisations who contributed to the survey and participated in stakeholder interviews, including members of the Climate Ready Infrastructure Forum and the Public Sector Climate Adaptation Network. These are detailed in the Supplementary Material document.

Verture, Scottish Charity No SC022375, Company No SC149513. Registered Office: Caledonian Exchange, 19a Canning Street, Edinburgh, EH3 8HE Introduction.

Introduction

The **purpose** of this report is to present the findings of an integrated spatial analyses and stakeholder engagement process developed to identify proposed priority catchments in Scotland where nature restoration can deliver multiple benefits. Primarily these restoration benefits are:

Climate change adaptation:

- Reduced flood risk
- Reduced water scarcity risk
- Improved water quality
- Reduced risks to infrastructure
- Restoring resilient ecosystems

Additional benefits:

- Benefits for biodiversity
- Climate change mitigation
- Improvement in wellbeing and opportunities for recreation
- Nature Networks

These benefits have been used as a guide to inform the selection and use of spatial data to enable the analysis to identify priority catchments for restoration. However, there are many benefits arising from the restoration of nature, not all of which have been included as criteria in this assessment (e.g. 'Improvement in wellbeing' which is hard to quantify, or due to lack of data). Instead, we refer to these additional benefits where possible and provide supporting information. Supplementary Material Table 1 in the contains the list of criteria used.

The primary **objectives** of the study are to provide information and evidence to NatureScot and those agencies, organisations, and stakeholders involved in discussions and decision making on which catchments to prioritise for restoration. This consideration is being conducted as part of NatureScot's work to prioritise landscape-scale restoration[1], requiring information to identify where investment is most likely to meet multiple objectives for land and water as set out in the third Scottish National Adaptation Plan (SNAP3): "Landscape scale solutions are implemented for sustainable and collaborative land use, including protecting and enhancing Scotland's soils."[2] [3]

The **aim** of the research was to develop an integrated approach to combine multiple spatial data sets and priority assessment criteria, coupled with stakeholder survey and interview approaches to identify priority catchments and sub-catchments in Scotland. The information presented is based on current best evidence discernible from the available data.

The **context** for the study is that climate change is already impacting Natural Capital and Nature's ability to provide ecosystem services. The combination of climate trends (Rivington and Jabloun 2022) and more variable climate extremes (Rivington et al 2022) and loss of ecosystem services, particularly the buffering of climate extremes by Nature, is leading to increased threats to people, infrastructure, businesses and ecosystems (CREW 2022, CREW 2024). Restoration or enhancement of ecosystems through Nature-Based Solutions offers the opportunity for reducing risk that achieves a range of multiple benefits.

Spatially targeting Nature-based solutions helps increase the probability of successful outcomes (Finch et al 2023) and delivers better value for public investment. The strategic landscape zonation

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[1] NatureScot is leading on action 2.1 in the Scottish Biodiversity Strategy Delivery Plan, to review and prioritise landscape scale restoration across Scotland

[2] https://www.gov.scot/publications/scottish-national-adaptation-plan-2024-2029-2/pages/6/#:~:text=Objective%3A%20Landscape%20scale,enhancing%20Scotland%E2%80%99s%20soils.

[3] This work will also support SNAP 3 PS3 - Partnerships for water resource planning and rainwater drainage networks are active in **prioritised catchments** to support drought resilience, flood resilience and climate resilient places.

for restoration supports the Scottish Biodiversity Strategy and informs discussion on the nexus between biodiversity, water, agriculture and climate change (Gimona and Castellazzi 2025).

Inclusion of foresight: the analysis includes the use of indicators derived from climate projections to enable consideration of future conditions, particularly potential meteorological water availability. Whilst there remains uncertainty in terms of what the specifics of the future climate will be like in Scotland, there is growing certainty of the overall change in trends and increases in variability leading to greater extremes than we have previously experienced.[4]

Exclusions: Spatial analyses were conducted for the whole of Scotland, therefore all catchments, but recognising that landscape scale restoration is unlikely on certain landscapes (urban, high value arable crop land), these have been clipped out after completion of the WISE2 method analysis.

This study has not quantified the scale of effort required for restoration or likelihood of successful outcomes. This is best done at the scale of individual catchments. It does not include cost-benefits analysis of restoration or the costs of inaction (i.e. the risks embedded in current patterns of land use and its management (for productivity and yield) which assumes a largely stable and predictable climate versus the warming and more chaotic climate (within and across years) we are in and moving further into). We have included consideration of the practicalities of restoration (i.e. distance from roads), and areas of priority from key informant interviews also consider the most relevant areas for action.

Note: A Supplementary Material document is also provided, with additional maps of normalised scores for specific spatial data layers, maps of other spatial data that helps inform discussions on identifying priority catchments, analysis of climate related risk disclosures from infrastructure operators, and details of the survey and key informant interviews, including specific locations identified by stakeholders of climate risks to infrastructure assets, and existing priority locations for nature restoration.

Methods

This study has taken an integrated approach combining different methodologies, including:

- Consultation to develop key objectives of what restoration needs to achieve and how to identify priority catchments.
- Co-construction of prioritisation criteria and inclusion of expert knowledge perspectives.
- Identifying, sourcing and integrating spatial data.
- Developing a spatial analysis method.
- Designing and deploying a stakeholder survey and undertaking key informant interviews.
- Review of sustainability disclosure reporting (including climate risk reporting) from all relevant infrastructure organisations in Scotland.
- Combination of geospatial and stakeholder consultation results to produce a list of priority catchments.

[4] https://adaptation.scot/scotland-and-climate-change/climate-change-trends-and-projections/

Establishing objectives and prioritisation criteria

The context and objectives for the study and the criteria for catchment prioritisation and subsequent methodological approaches for the research were defined through a series of meetings and correspondence between NatureScot and the research teams at James Hutton Institute and Verture.

Priority criteria were co-constructed and then selected based on their level of importance and utility (red, amber, green rating for low, medium and high importance, see Table 1 in Supplementary Material). This resulted in a list of criteria used to inform the identification of the geospatial analysis approach and required spatial data. However, not all 'green' level criteria could be included in the geospatial analyses due to either data availability, utility or practicalities of integration (data format, scale etc.). Hence the geospatial analyses represent some prioritisation criteria, but not all. Where data layers have not been included the project team have used their knowledge of these datasets to 'sense check' the results of the analysis.

Respondents to the stakeholder survey of more than 50 respondents were asked to identify specific locations for nature restoration for climate adaptation based on identified climate risks or planned/existing nature restoration efforts. A similar request was made of research colleagues at the James Hutton Institute , including those not on the project team. This was used as a 'safety net' to ensure that the spatial analysis methodological approach used did not omit any key catchments, and to provide additional information to inform discussions.

Geospatial analyses

A spatial normalisation method was developed to enable multiple data sets to be integrated at the same spatial resolution (50m) and apply an objective approach to enable equal levels of priority per input data set. The study has utilised the WISE2 approach to multiple data set integration and analysis (WISE booklet v2 Nov 2013 reduced size.pdf). The key features here are:

- Different spatial data sets are integrated and standardised to the same spatial granularity to enable analysis and mapping.
- A normalised scoring method is applied to all data sets to ensure an equal weighting to avoid some data layers dominating the process.
- Additional data sets not compatible with the WISE2 approach are used as a secondary level of analysis.

This approach enables a combination of both a systematic method and individual data layers assessment. Further details are provided in the Supplementary Material.

Note: A Supplementary Material document is also provided, with additional maps of normalised scores for specific spatial data layers, maps of other spatial data that helps inform discussions on identifying priority catchments, and details of the survey and key informant interviews.

The list of prioritisation criteria and spatial data sets used is provided in SM Table 1 in the Supplementary Material.

Stakeholder Survey

To supplement JHI's geospatial analysis, Verture conducted a qualitative survey of infrastructure providers and local authorities to ask them where they think nature restoration can best reduce risks to their assets and to communities. The survey also worked to understand locations of identified climate risks, and what strategies are currently being used to reduce these risks. A list of respondents is provided in the supplementary material.

Verture conducted an online survey and key informant interviews to understand more about how climate risks have been assessed and asked for locations of these assessments. Climate risks were mapped as was the use of nature-based solutions across non-governmental agencies, local authorities, public bodies/agencies, landowners, and infrastructure asset owners including the NHS, SSEN, Network Rail, Transport Scotland and Scottish Water.

The survey was distributed widely using existing networks and contacts, such as the Adaptation Scotland Public Sector Climate Adaptation Network and Climate Ready Infrastructure Forum Scotland, and through promotion via Verture and Adaptation Scotland social media channels, website and e-newsletters. There were 50 responses submitted via an online survey. A list of all respondents to the survey can be found in the Supplementary Material.

The survey data was analysed for frequency of response for certain questions (common forms of climate risk) and general themes. An iterative approach was used, in collaboration with the James Hutton Institute, which informed the selection of priority locations for data analysis.

Insights were recoded for each organisation type. Specific responses to the survey questions *“Has your organisation identified any priority locations for nature-based climate adaptation, and if so where”* and *"Are you already progressing any nature-based climate adaptation projects? If so, where?”* were mapped across Scotland using GoogleMyMaps (see SM Figures 36 and 37).

Additional information sources and analysis

Verture also conducted interviews with six ‘key informants’; infrastructure providers including NHS Scotland Assure, Transport Scotland, Network Rail, SSEN Distribution, Scottish Water and Scottish Government (NHS assets) to gather information of their understanding of climate risk, their assets and their use of nature-based solutions to reduce the impact of these risks on their assets. These interviews were conducted online, and the line of questioning followed the format of the survey. Scottish Gas Networks, Scottish Power Energy Networks and Scottish Canals were all sent a request for interview, but discussions were unable to be scheduled within the time available to complete this report.

To supplement understanding, a register of sustainability disclosure reports was also developed to identify existing or proposed nature restoration work being used to restore and enhance ecosystems and their value in mitigating risk and achieving multiple benefits.

Combined, the methods provide a rich perspective on the understanding of climate risk and identify specific areas of activity where nature-based solutions are being actioned across Scotland. The research starts to establish a shared understanding of co-benefit. The research also highlights the challenges in using both Nature-based Solutions to reduce risks and Nature Restoration to restore and enhance ecosystems for adaptation.

Results

Proposed Priority Catchments identified by spatial analysis

The catchments identified as proposed priority for restoration are shown in Figure 1 with justifications along with information from the survey and interviews are provided in Table 1 (no order of priority). This is derived from the WISE2 method and use of the primary spatial data sets available (see SM Table 1 in Supplementary Material).

Figure 2 shows the normalised scores from the WISE2 method. To interpret the map, a score of 1 (yellow on the legend gradient) indicates that there is agreement on the level of priority for the range of data sets used as input. This integrated weighting map can be used to identify areas where prioritisation will always be considered important for achieving the multiple objectives of restoration, based on randomised stakeholder preferences for what might be considered important.

The map is therefore a representation of an objective approach based on the data rather than preference for any particular prioritisation criteria.

The aim of this approach is to provide stakeholders involved in identifying priority catchments for restoration with an unbiased objective map on which to base discussion and inclusion of additional knowledge and preferences for particular priorities.

Figure 2 includes locations of Nature-Based Solutions projects (green dots) and locations at risk from a range of threats (blue dots) identified in the survey and key informant interviews (see Supplementary Material for details).

To interpret Figure 2, those areas with the brightest yellow have a score of 1, meaning that they are score highest across the range of criteria and have a high priority for restoration, whilst darker yellow / brown consistently have low scores hence lower priority for restoration.

The spatial granularity is at 50m (standard rasterization across input data sets) hence areas of larger, homogeneous spatial extent will be more visible in the output. In terms of influence however, this is something that is regulated by the multiple random weightings, as there will be runs in which these features will be weighed both high and low. No one dataset or feature will dominate and areas will only score highly where the datasets align regardless of the weightings used, i.e., consensus is reached by the random virtual stakeholders and a consistently high score is achieved. This method seeks to avoid issues of understating the risks associated with maintaining existing land use systems, e.g. in areas such as high quality arable and horticultural lands, by excluded them on the basis that restoration is unlikely to be feasible. The assumption is made that restoration will not be made across the entire catchment, but that high-scoring sites within each catchment are where this restoration will take place. The detailed granularity can help to inform discussion on specific sub-catchments or areas within them.

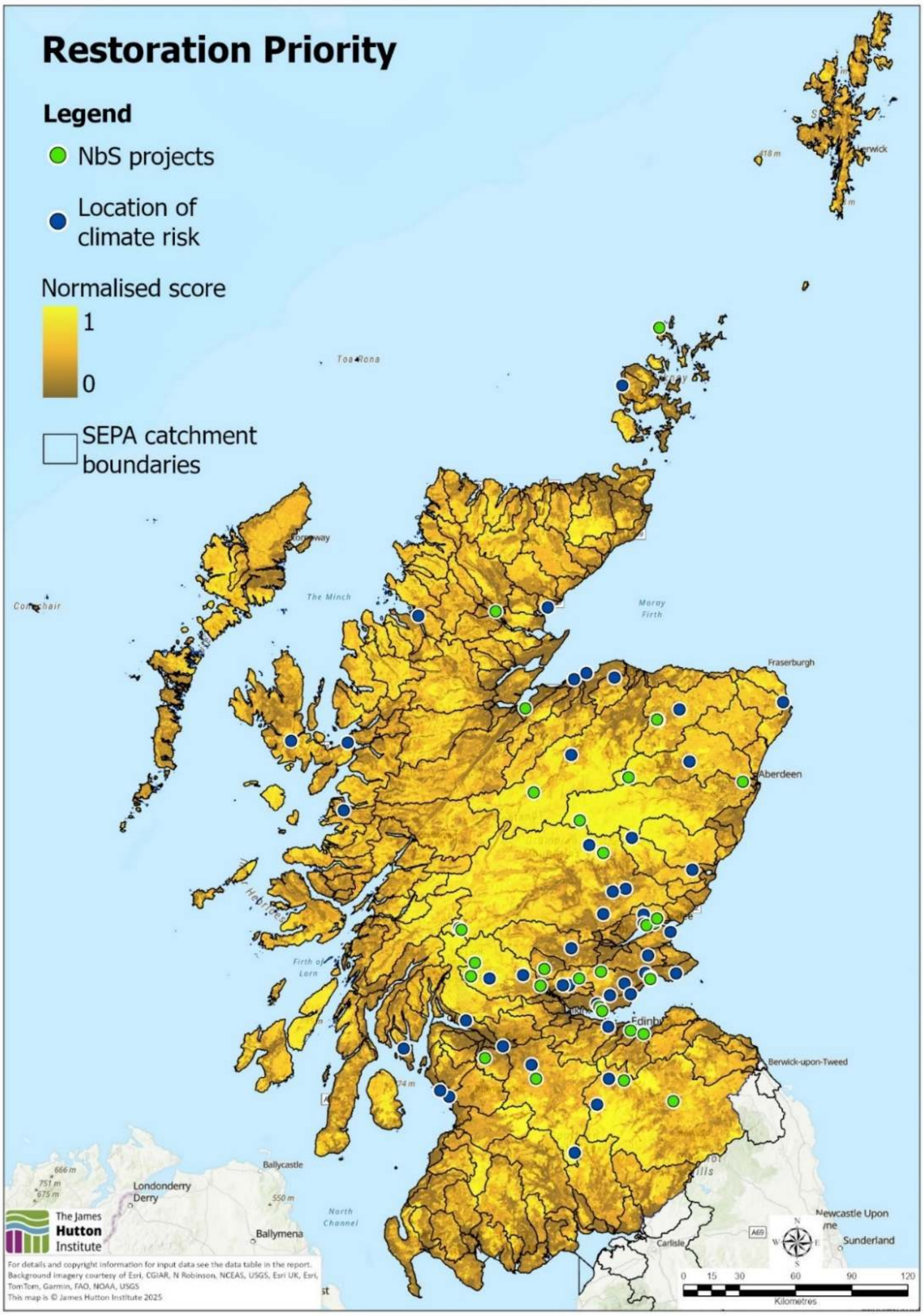

Figure 2. Normalised restoration priority score. Green dots indicate locations of existing nature restoration projects identified in the survey, blue dots are locations identified as at risk from climate change. Spatial granularity is 50m.

Figure 2 covers the whole of Scotland and includes areas where restoration is not currently likely as they are either under arable or improved grass land use and may have high commercial and supply chain value, or are urban areas or where access is prohibitive. Figure 3 is a copy of Figure 2 but has had these areas removed (white on the map). Areas of peatland have also been removed as these have been considered in research projects elsewhere[5] focusing on peatland (and see Peatland restoration prioritisation framework (WISE2).

[5] Home | Land Use Transformations

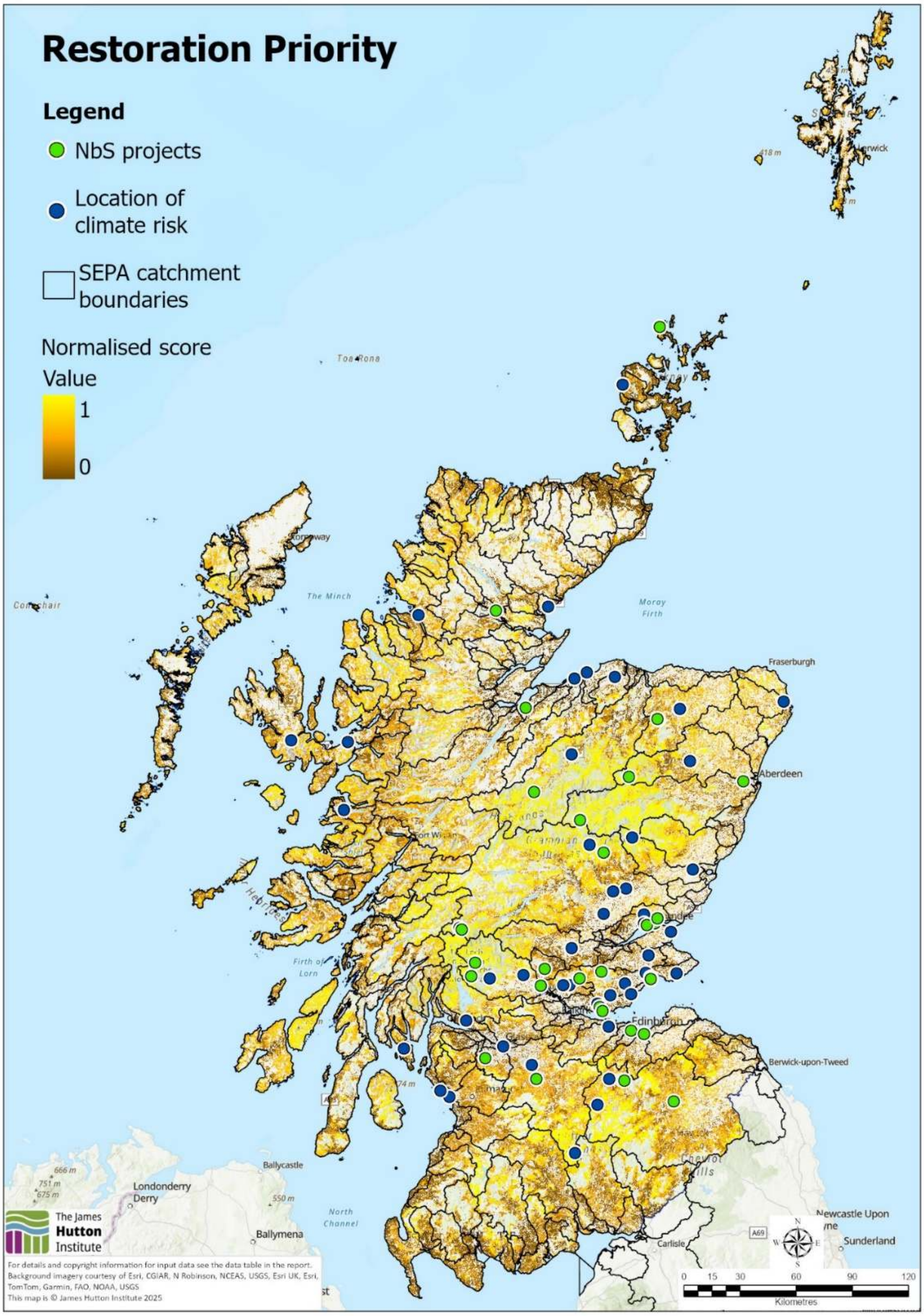

Figure 3. Normalised restoration priority score with areas where restoration is not currently feasible removed (i.e. arable, urban). Green dots indicate locations of existing nature restoration projects identified in the survey, Blue dots are locations identified as at risk from climate change. Spatial granularity is 50m.

Proposed Priority Catchments identified by researchers in JHI

The following have been identified as proposed priority catchments and sub-catchments for restoration based on *a prior*i expert opinion and personal ranking (1 = low, 10 = high, James Hutton Institute research staff) before the spatial analysis. This list was used as a cross-reference check with the spatial analysis and to add details of specific sub-catchments in the event these were not identified.

Note: This is a separate exercise to the stakeholder survey, the priority catchments identified in that process can be found in the section below:

Table 2: Proposed priority catchments identified through consultation with James Hutton Institute researchers.

Catchment (ranking 1 = low, 10 = high)	**Sub-catchments**	**Justification** (summarised from Hutton staff information)
South Esk (9)	Glen Prosen, Isla and Clova	EELG* catchment; flood risk (Brechin); stakeholder interest in restoration; large % of land use change potential. CREW has been in consultation with ENRA CSA Mat Williams and other colleagues in Scottish Government on the need to focus on the issue of soil erosion/bare ground in the South Esk.
Findhorn (8)		Extensive areas of degraded peatland.
Forth (8)	Allan Water Almond	Lot of existing activity including ForthERA/Forth2O/MOT4R/Hydro Nation Scholar research activity.
Spey (8)	Kingussie	Multiple industries: significant degradation, heavy reliance on biodiversity and water quality. Kingussie SEPA PVA with lots of flooding/sedimentation issues. Spey Partnership looking to restore this sub-catchment. more manageable scale than the whole Spey.
Nith (7)		Flooding, significant soil erosion risk.
Tyne (7)		WFD 2022 status; notable flooding areas; stakeholder (farmer) interest in restoration.
Almond (5)		Scottish Water priority catchment; high resolution monitoring by ForthERA & University of Stirling.
Eden (4)	Motray	Ongoing research and development of Decision Support Tool (monitoring opportunity). Solid track record of ongoing research, strong community involvement in restoration initiatives through the River Eden Sustainability Partnership, seedcorn pilot project funded by Nature Scot.
Cessnock, Mein, Abbey Mill, Greens Burn, Burnside Burn, Vinny Water (4)		SEPA intensive monitoring catchments

* EELG: Environment and Economy Leaders Group

Additional issues raised relevant to all proposed priority catchments include:

- Hydromorphological alterations are one of the key reasons why Scottish catchments are failing to attain good status (Water Framework Directive) in addition to diffuse pollution, sewage management and control of invasive species. These alterations have the potential to exacerbate vulnerability to climate threats if they are not specifically designed as part of mitigation and adaptation efforts.

- Other restoration efforts (not detailed in the survey results) include:
    - Beltie Burn, Mar Lodge and Logie Burn re-meandering projects.
- Surface flooding in urban areas is highlighted as an increasing issue.

Proposed Priority Catchments identified by stakeholder survey

Many parts of Scotland are at risk to climate change, particularly the impacts of flooding, which was the most cited climate risk, followed by combined climatic effects, warming water temperatures, coastal erosion and prolonged periods of heat or cold. Key findings from the survey were:

- 88% of survey respondents have identified locations that are vulnerable to the impacts of climate change.
- With 92% of those already exploring the potential for nature restoration to reduce the identified climate risks.
- 85% of survey respondents said they were already progressing with nature-based climate adaptation projects.
- 65% of those who weren't already progressing with projects said they were interested in collaborating to deliver nature-based climate adaptation, with 34 email addresses being supplied in response.
- 56% of survey respondents thought that their organisation would be able to contribute towards the cost of nature restoration in their priority locations.

The types of locations identified at risk from climate change include rivers, a variety of urban locations, coastal regions and upland areas. Because locations identified in the survey considered risk at varied scales; from specific sites and specific assets through to neighbourhoods, urban areas more generally through to specific waterways and wider catchment level, its challenging to use this information pinpoint specific locations. Instead, they provide a view of prioritised areas of risk and start to build a shared geospatial understanding of areas of activity in using nature-based solutions to reduce the impact of these risks. This has been combined with the spatial analysis from JHI.

Table 3. Catchments identified as being at risk from climate change in the stakeholder survey

Catchment	Number of risks identified and mapped
Tay	6
Leven (Fife)	5
Allan Water	2
Devon	3
Forth River	4
Clyde	2
Tweed	2
South Esk	2
Deveron	2
Eden	2

Generally, locations towards the east of the country are where most climate risk has been recorded and attempts to reduce this risk through nature restoration highlighted by survey respondents. This aligns to some prioritisation from the key informant interviews particularly of water source challenges in Eastern regions exacerbated by shifts in population from West to East as well as lower rainfall. The maps (SM Figures 36 and 37) show respondent's indications of activities and risks create the impression that there isn't much effort in the West and regions like Glasgow[6], but this is more likely due to the limited response rate from those regions. Further work is required to assess these risks.

From the survey, the majority of locations that have progressed nature-based projects are in the central belt and the East of the country. In the River Tweed catchment, there are multiple nature-based solutions being developed. Common types of nature restoration that were identified include natural flood management, woodland creation, sustainable urban drainage systems (SuDS) and peatland restoration.

The data collected from local authorities, public bodies/agencies and NGOs prioritised areas for nature restoration in city regions, neighbourhoods and "communities". They focus on areas of high population density but acknowledge the role of the wider catchment in relation to climate risks. This list doesn't highlight all the nature-based solutions done or in progress in urban areas.

Table 4. Catchments identified with nature restoration projects being progressed in the stakeholder survey.

Catchment	Sub-catchments	Number of nature restoration projects
Tweed		**Two**
Forth River Basin	Allan Water, Devon catchment, River Almond and Water of Leith	**Four**
Clyde		**One**
Tay River Basin	Tay catchment and Dundee coast	**Three**
Don		**Two**
Dee		**One**
Spey		**One**

Integrated list using both spatial and stakeholder engagement

The spatial analysis and responses to the stakeholder survey provided two sets of outputs each suggesting a list of proposed priority catchments. The strength of this project lies in its commitment to the bring together both technical mapping analysis and the views of stakeholders to produce a single prioritised list. This integration was done by identifying those catchments that have both locations of risks identified from the survey (blue dots on the maps provided) *and* those that have a higher normalised score from the spatial analysis (areas that are more yellow on the map).

[6] The Green Infrastructure Strategic Intervention is undertaking work around Glasgow.

https://www.nature.scot/funding-and-projects/green-infrastructure-strategic-intervention

The overall list of proposed priority catchments considering both approaches is provided in Table 1.

Some catchments have only one identified risk each in the survey responses. These risks are all linked to coastal erosion and river flooding or impacts on water temperature and quality. Whilst there is a certain amount of overlap in the two lists, there are catchments identified by only one methodology that could still be considered a priority for other reasons. This detail is captured in the table below.

It is worth noting that the overall evaluation of risk will depend on whether specific risks are considered as individual, combination (multiple) or as cascading impacts. Some organisations have considered each risk in isolation; others have done so by considering multiple and cascading risks. This prevents an over-arching risk statement, as this would require more detailed data collection and analyses. Further research is required to enable a better understanding of how organisations perceive and assess risks to avoid issues of exposure and vulnerability to climate change.

Other catchments benefiting from restoration

The objectives of the research and spatial analytical methods aimed to capture where restoration will achieve multiple benefits. There are, however, other notable catchments and locations where restoration will lead to benefits for either single benefits such a flood risk reduction, or have previously experienced damage due to extreme weather events. The following are some examples only and have been provided to further stimulate discussion on identifying where restoration is required;

- The Nith catchment (1115km^2) could be considered, particularly for reducing flood risk to Dumfries.
    - There are sections of the upper catchment with multiple benefits but overall it has lower normalised scores at lower elevations.
    - Climate projections for the catchment indicate that there is likely to be an increase in the number of days with very heavy rain, particularly in the winter period[7], though this also applies to many catchments on the west of Scotland.
- Areas with bare and eroding peat are present in the Brorar and Shin catchments, as well as the Lewis and Harris Coastal island catchment, if practical aspects (i.e. access) enables the potential for peatland restoration.
    - Specific locations for a particular benefit include Jura (climate regulation) which has peat that is drained but currently in good condition, hence a targeted ditch blocking campaign over the island would help with maintaining its condition.

It is also important to note that there is a spatially stochastic aspect to the probability of an extreme event, particularly heavy rainfall, occurring in any one location or catchment. This means that whilst restoration may be targeted to as set of prioritised catchments, there is a probability that extremes will still occur elsewhere.

Barriers to using nature restoration in Scotland

While the key informant interviews were limited in their contributions to priority catchments as many infrastructure organisations work nationally and are working internally to calculate their own climate risks and areas for investment, they unearthed many factors that limit the use of nature-

[7] Scotland's observed climate trends and future projections

based solutions to address climate risk. The barriers identified build on those highlighted by NatureScot in their case studies for large scale nature restoration and include:

- A lack of demonstrative examples that restoring nature at scale is a suitable and effective alternative to a solution that has already been defined.
- Difficulties in making the business case and accounting for investments in nature. There is lack of examples of investments in nature restoration being good value for money and a challenge around quantification of benefits.
- Regulators largely focus on economics and are limited in considering the social and environmental perspectives. Current cost benefit analysis does not sufficiently capture social benefits.
- Organisations that should be collaborating in this space have incompatible financial cycles and policy target years which makes the prospects of joint funding challenging.
- Government policies lack coherence and decisions makers operate in silos
- There are broader nature market challenges like the availability of suitable options and a clear understanding of added benefit while the ‘do nothing option’ or status quo has the tactical advantage of being the default option, despite the risks embedded in it (e.g. designed on the assumption of a stable and predictable climate).
- A lack of technical knowledge and data that demonstrates the success of restoration interventions to provide reassurance to key audiences like engineers, regulators and policy makers.
- There is a lack of skills necessary to integrate spatial mapping to climate risk.
- There is need for behaviour/culture change within organisations where they primarily focussed on ‘fixing the problem’ within their corridor or related to a specific asset to working in true collaboration and partnership.
- Costs can appear be prohibitive (especially given the wide acceptance of externalised costs and risk), so working with lineside neighbours and stakeholders has to be an imperative.

Of those organisations interviewed, there was consensus that current efforts do not go far or fast enough because efforts for restoration are not happening at the right scale – they are too fragmented and piecemeal.

There is a need for national policy alignment and spatial coordination to focus direction, new governance structures and greater collaboration from SEPA, Scottish Government, NatureScot and local authorities.

This could be achieved through existing mechanisms such as Environment and Economy Leaders Group, regional adaptation partnerships, which the Scottish Government has committed to expanding to the whole of Scotland by 2029 in SNAP3. Where priority catchments in Table 1 lie within the area of existing regional adaptation partnerships, these have been identified. Partnerships such as Climate Ready Tayside are focusing on landscape-scale nature restoration as a key priority for building resilience to climate change across the region, and can act as catalysts for equitable and effective action if supported by NatureScot.

Ensuring strong policy alignment and coordinated support is vital to deliver the greatest level of co-benefits and support the most climate vulnerable places and communities. There is a need to associate upstream investments in catchments with impacts downstream on neighbourhoods, villages and city centres that were often prioritised in the survey responses.

To address this, a series of questions, such as the following may help tease out benefits, risks and burdens:

- 'How bad could this be?'
- 'How much does that matter?'
- 'What can we do about it?'
- 'Who pays when it all goes wrong?'
- 'Is that fair/ just?'
- 'How can this help us improve our place?'
- 'What other priorities can this address?'
- 'Who do we need to collaborate with?'

Recommended next steps

Given the potential for nature restoration to deliver multiple benefits and considering the need for careful integration of restoration objectives to avoid unwanted outcomes, we recommend the use of more detailed studies assessing opportunities and trade-offs in undertaking nature restoration within each catchment and during the design of delivery projects.

- NatureScot should use the prioritised catchments together in dialogue with other organisations to convene and interpret assets in selected catchments to identify risks, including the costs of inaction, and share approaches to integrating nature-based solutions. The aim should be to build where there is work already happening and provide evidence of success, for example in areas with existing partnerships (Forth2O) and initiatives (regional adaptation partnerships, land use partnership and landscape scale project partnerships).
- NatureScot and stakeholders should consider prioritising specific benefits as an approach to reduce the proposed 14 catchments, considering technical feasibility, local stakeholder priorities and capacities, and the potential for co-financing from a range of sources, including infrastructure providers.
- Academic research should focus on removing the barriers to delivery, in particular the need to quantify benefits from nature restoration, this should be a core consideration in the Scottish Governments Strategic Research Programme 2027-32.
- There is a need to better estimate the costs of inaction (maintaining the *status quo*) and use as a guide to inform investment in Nature.
    - This includes understanding the evaluation of Nature-based Solutions and Nature Restoration in a spatial context.
- Prioritisation can use other data integration and criteria application methods alongside the WISE2 approach as well as more comprehensive spatial data coverage, including:
    - Landscape zonation for restoration (e.g. Gimona and Castellazzi 2025).
    - Wider range of climate change indicators (e.g. The James Hutton Institute Climate Data Visualisation).
    - Understanding of how climate change may impact Land Capability for Agriculture
    - Integrating restoration with overall Land Use Transformations objectives.
    - Utilising improving ecosystem condition monitoring and mapping capabilities (e.g. Updating Peatland Condition Mapping)
- Organisations responsible for key infrastructure that underpins society including our transport networks, energy systems and networks of health and social care all have an

established understanding of climate risk (especially extreme events). Many are now in the process of attaching that risk to specific areas, places and people. A number of major infrastructure providers including Network Rail and Scottish Water will be sharing more relevant geospatial datasets of climate risk in the near future. These can be used to inform ongoing discussions on priority landscapes.

- There needs to be a central record of places that have been flooded.
- There is potential in collaboration with the Climate Ready Infrastructure Forum for a next stage to support the development of an integrated infrastructure map, aligned with locations of shared climate hazards and opportunities for collaborative nature restoration initiatives to deliver adaptation outcomes.
- Crowd sourced and citizen perspectives should be included in further mapping of climate risks. An example of this is the Climate Ready Southeast Scotland Storymap:
- Outputs from the Scottish Government Strategic Research Programme (2022-2027) will be of value to inform further analysis and decision making. There is an opportunity to directly link SRP place-based research within the priority catchments to ensure the multiple benefits can be better quantified. This will be critical to demonstrating the benefits accrued.
    - The Gimona and Castellazzi 2025 report (see References) is a good example, as it contains a more detailed integration of data and analysis to identify zonation for restoration.
- There is need for improved linkages between developing methods for restoration prioritisation, including costs, with finance mechanisms. There is need to better estimate the costs / benefits relationship of restoration, including the avoided spend arising from it and the risks embedded in the status quo/ do nothing option.
- Long term maintenance and finance of nature restoration schemes to ensure effectiveness is currently overlooked and is key to their success, hence access to finance is an important factor.
- A Fellowship, funded by the Centres of Expertise, possibly through SEFARI Gateway in 2025-26 is one option to take this work forward.

How the spatial analysis could be further developed.

From a spatial analysis perspective:

- There is scope for a wider range of spatial analysis using more data sets, however for this to work equitably (i.e. using the WISE2 approach) they would need to be at a national level.
- There is scope to better use details available from SEPA on Potential Vulnerable Areas and the Flood Risk Management Strategy to identify specific sub-catchments where nature restoration may reduce river flood risks.
    - Surface water flooding risk may be reduced through integrated nature restoration in urban environments.
- There is potential to use stakeholder engagement to weight specific criteria based on importance of benefits (currently WISE2 uses equal weighting).
- The spatial granularity of the standardised data sets enables more detailed assessments which could be used to help identify more sub-catchments.
- The research identified infrastructure maps; however, these are in different forms and with some omissions on publicly available data (i.e. for security reasons) which presents

challenges for integration during the timescales of this project. For this reason, only the number of buildings has been used in the analysis. Relating buildings to risks, i.e. flooding is a key next step.

Conclusions

The ability of nature restoration to contribute to climate change mitigation through climate regulation, whilst reducing the risks of impacts is dependent on the ecosystem condition and types of nature restoration project developed. Whilst the analysis presented is a robust, data-led approach to identify priority locations, engagement with stakeholders in each area is essential to design a programme of works that will deliver on the aims of this research.

From the analyses we conclude that the proposed catchments are priorities for nature restoration to achieve adaptation outcomes and multiple other objectives. This initial analysis only takes us to a certain point and should be followed with further engagement that might change the prioritisation of the catchments – such as technical feasibility, financing opportunities, and the priorities of local communities.

Further analysis to explore the specific climate risks and adaptation opportunities in each location will be essential to inform the design of solutions in each catchment. This could be aligned to existing work being undertaken by regional adaptation partnerships and regional land use partnerships in Scotland (see maps in SM Figs 37 and 38). It may also be beneficial to align priorities with areas identified as part of the Nature Networks being implemented by local authorities, and where co-investment from infrastructure providers may be possible.

There are many other nature restoration projects being considered, under development or are in early stages of implementation which are not captured in the survey but are being mapped and prioritised by NatureScot separately.

Urgency and timescales

There is considerable urgency in the need to increase momentum in undertaking nature restoration, as there is increasing evidence that the climate is destabilising faster than previously thought, evidenced by record ocean temperatures, increasing cryosphere loss particularly in Antarctica, and increases in extreme events. Mitigation of climate change through reduction in fossil fuel use is not yet occurring, with current National Declared Contributions (as required in the Paris Agreement) globally only reducing emissions to 2.6% from the 2019 levels, whereas this needs to be 43% by 2030 to keep below 1.5°C. By 2035, global emissions need to be cut by 60% compared to 2019 levels. Globally, natural sequestration of CO_2 is declining, which will accelerate climate change (Curran and Curran 2025). This implies the urgency and imperative to work with nature to ensure the delivery of ecosystem services, particularly climate regulation.

Taking an ecosystem-based mitigation and adaptation approach using the restoration of natural ecosystems that have been degraded is increasingly seen as necessary to achieve multiple socio-ecological system benefits including climate mitigation (Munang et al 2013). Healthy ecosystems impart resilience through their better buffering capacity against extremes. However, ecosystem restoration may take time to develop, finance and implement. Some restoration efforts, such as peatland re-wetting using leaky dams may produce positive early benefits, whereas others such as riparian or other forms of woodland creation may take many years before benefits are realised.

Hence the sooner restoration commences, the better the chance of success and conversely, the longer the delay the greater the chance of failure both for net zero and exposure to climate risks.

Considering the urgency of the climate and biodiversity crises the project team recognised that, whilst not a comprehensive approach to restoration priority assessment, we needed to start somewhere and soon to identify proposed prioritised to inform wider discussions. There is urgency to our actions and necessity for stakeholders to be working collaboratively at pace and at scale (Zamurieva et al, 2023).

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The James Hutton Institute

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Supplementary Material:

Prioritising Catchments for Nature Restoration for Climate Change Adaptation.

21st March 2025

Summary

This Supplementary Material presents additional information to support the Prioritising Catchments for Restoration Report.

Contents

Citation:

This report should be cited as: Rivington M, Aitkenhead M, Wadsworth E, Stewart L, Casey J, McFarlane F, Gagkas Z, Naha S, Jabloun M, Robb C, Coull M, McKean M (2025) Supplementary Material to the Prioritising Catchments for Nature Restoration for Climate Change Adaptation: A Report to NatureScot. The James Hutton Institute, Aberdeen. Scotland. DOI: **10.5281/zenodo.15854494**

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Acknowledgements

This report has been produced by The James Hutton Institute and Verture through funding provided by NatureScot. The spatial analyses capabilities have been enabled through the Scottish Government Strategic Research Programme JHI-C3-1 Supporting Land Use Transformations and JHI-D5-2 Climate Change Impacts on Natural Capital. We are very grateful to the following colleagues who have contributed input data, comment and suggestions: Rachel Helliwell (CREW), Mark Wilkinson (JHI), Mads Trolberg (JHI) Miriam Glendell (JHI), Alessandro Gimona (JHI), Marie Castellazzi (JHI). We also thank and acknowledge the UK Meteorological Office for use of the 1km gridded observed climate data and UKCP18 climate projections and all other data providers. Thanks also to all the organisations who contributed to the survey and participated in stakeholder interviews.

Introduction

The purpose of this Supplementary Material is to provide additional information to inform discussions on the prioritisation of catchments for nature restoration to deliver climate adaptation outcomes. The purpose of the parent report is to present the findings of an integrated spatial analyses and stakeholder engagement process developed to identify candidate priority catchments in Scotland where Nature restoration can support the delivery of climate adaptation outcomes and deliver a range of multiple benefits.

Note: The following list of prioritisation criteria was developed through consultation with NatureScot, Verture and James Hutton Institute research staff. This is not an extensive list and has been developed to enable addition of further criteria and sub-criteria if of value for future further development. The list is not in any order of priority.

Table 1 (following pages). Primary criteria, sub-criteria list, importance indication and whether used in analysis.

Primary criteria	**Sub-criteria**	**Sub-criteria**	**Importance** Red= low, amber= medium, green= high	**Used in analysis** Red= No Green= Yes Amber = 2nd level	**Notes**
1. Reduce flood risk	1.1	Number of properties at risk			Total area of properties at risk have been included
	1.2	Where has already experienced severe flooding			Some flooding details but it is inconsistent and not national coverage
	1.3	Flood risk areas			Included (SM Figure 8 - SEPA PVA flood risk maps not directly used in WISE2 but used as a secondary level (properties at risk).
	1.4	Field Capacity Days / Maximum potential soil moisture deficit			Constraint maps from Land Capability for Agriculture are as yet unpublished Where the LCA changes under future climate scenarios (for secondary analysis)
	1.5	Peatland degradation - reduced water holding capacity in upper catchment			Included
	1.6	Wetland types with high potential for moderating flood risk			Separate material: Moderating extremes in water availability: a review of the role of functioning wetlands (https://www.crew.ac.uk/publication/moderating-extremes-water-availability-review-role-functioning-wetlands) Not included in prioritisation map but included in peatland map
	1.7	Catchment area above flood risk receptor (main point of flooding)			Smaller sub-catchment areas could be better to target to have impact on flooding https://wires.onlinelibrary.wiley.com/doi/abs/10.1002/wat2.1211.
	1.8	Has it been identified by SEPA for NFM actions or works?			Not included - required data from SEPA (sought but not acquired). SEPA have reviewed which PVA catchments could be key priorities for NFM studies or actions.
2. Reduce water scarcity risk	2.1	Catchments at risk of low flow			Hydrological (low flow) modelling using 2 model (GR6J, HYPE) at the outlets of 82 catchments (many nested, outlets at SEPA flow gauge locations) used by SEPA to conduct drought risk assessments. Drought modelling here refers to the process of calibrating river flows at the outlets, with a focus on low flows. This is done by using objective functions that give more weight to low flow conditions.
	2.2	Future Climatic Water Balance (P-ETo)			Included
	2.3	Use of hydrological drought metrics—drought frequency, duration			Data under future climate scenarios is included

	2.4	Wetland types with high potential for moderating drought risk			Findings from CREW report: Moderating extremes in water availability: a review of the role of functioning wetlands: https://www.crew.ac.uk/publication/moderating-extremes-water-availability-review-role-functioning-wetlands
					Duplication of wetland types (in peatland prioritisation maps)
	2.5	SEPA abstraction datasets.			Total abstraction rates rather than points in an area. From HNC crucible and CREW project: Raw abstraction datasets at the water body level for different abstraction sectors provided by SEPA. Sectors include Agri Irri, Agri Non Irri, Distillery, Golf, Fish, Hydropower, Other Industrial/commercial
	2.6	Private Water Supply dataset.			Not included currently but could be integrated as additional analysis – Map of PWS sampled for water quality provided below. See also CREW Reports: https://www.crew.ac.uk/sites/www.crew.ac.uk/files/publication/CRW2022_05_Main_Report_and_Appendices.pdf and https://www.crew.ac.uk/publication/water-scarcity-impacts-distilleries-agricultural
3. Improve water quality	3.1	Areas of poor water quality			Not included as data not accessed. River segments of WFD poor water quality can be identified by SEPA datasets. Can be incorporated separately
	3.2	Soil leaching potential			Only available for, mainly cultivated, areas covered by the 1:25,000 Soil Map (partial-cover) (Soil Survey of Scotland Staff, 1970-1987). Gagkas and Lilly (2024)
	3.3	Nitrate runoff			Included
	3.4	Total Phosphorous loss			Dataset available for catchments that include Lochs, based on a CREW report. Not used as it requires expert input.
	3.5	Peat erosion & dissolved organic carbon			Included. Soil erosion risk class map is available for, mainly cultivated, areas covered by the 1:25k Soil map (partial-cover) (Soil Survey of Scotland Staff (1970-1987). Gap areas were filled using a disaggregated soil series map at 50m grid cell resolution (Gagkas and Lilly, 2024) translated to soil erosion risk classes.
	3.6	Pathways of diffuse pollution to waters			No data available (secondary - requires expert input). Findings from CREW report: A state of knowledge overview of identified pathways of diffuse pollutants to the water environment (https://www.crew.ac.uk/publication/state-knowledge-overview-identified-pathways-diffuse-pollutants-water-environment)
4. Reduced risks to infrastructure	4.1	Infrastructure mapping			WISE-2: Distance to nearest road, windfarms, buildings mapping. See Sub-criteria 1.1. None of the other infrastructure datasets have been integrated - issues around appropriate scaling

5. Restoring resilient ecosystems	5.1				Partially included (see also Gimona and Castellazzi 2025)
6. Likelihood of getting investment in restoration	6.1				
7. Where restoration projects are already happening	7.1				Identified through stakeholder survey, key informant interviews, and climate risk disclosure reporting.
8. Improve benefits for biodiversity	8.1				Included via Gimona and Castellazzi 2025
Important salmon rivers	8.2				Agreed not to include
Special areas for conservation	8.3				Included as "designated sites"
Existing Riverwoods projects	8.4				Included in wider NS database of existing restoration projects
Target areas for riparian woodland	8.5				Potential to use RIVERTOOL and dataset from Scottish Forestry https://www.forestry.gov.scot/news-releases/boosting-tree-planting-around-rivers-and-streams
9. Climate change mitigation	9.1				Peatland restoration included; most (but not all) woodland included
10. Improvement in wellbeing and opportunities for recreation	10.1				Not included, as agreed
11. Improve soil health	11.1	Soil health Indicators			Work not at a stage to include. Research under way to develop a National Soil Monitoring Framework.
12. Peatland condition	12.1	Peatland Condition maps			Included
	12.2	Existing peatland restoration sites			Included
	12.3	Combination with Climatic Water Balance (Criteria 18)			Included
13. Groundwater recharge / geology	13.1	Low groundwater recharge rates			Not included, but see BGS maps to add narrative info: https://www.crew.ac.uk/sites/www.crew.ac.uk/files/publication/CRW2023_05_Intensive_Lifestock_Infographic_FINAL.pdf
14. Stakeholder survey	14.1				Included
15. Water Quality: NVZ designation	15.1	Current NVZ catchments			Updates available of the national scale nitrate modelling (NIRAMS), so we have updated maps of nitrate leaching to groundwater for Scotland.

					NVZs are designated based on SEPA's nitrate monitoring network (i.e. areas where nitrate concentrations exceed a maximum (50 mg/l) or mean (37.5 mg/l) threshold, or there is a risk they will do so). NIRAMS modelling is used as an additional strand of evidence to evaluate the degree of confidence in NVZ designation. Note that the spatial extent of NVZs are based on groundwater bodies (GWBs) defined by BGS and SEPA; these GWBs are assumed to be self-contained from the point of view of diffuse nitrate pollution. The NVZ map therefore just shows the (aggregated) GWBs that have been designated as NVZ/vulnerable to diffuse nitrate pollution.
					Included
16. Downstream flow length	16.1				Included. River lengths for 81 DRAT stations up to the downstream NRFA station
17. Topography (elevation/slope/aspect etc.)	17.1				Slope topography & growing season length
18. Future climate: Climatic Water Balance	18.1	Locations with higher water deficit			Included
	18.2	Locations with higher water surplus			Included
	18.3	Soils with low water holding capacity			Not included (although data available) - some methodological and interpretational challenges about actual impact on ecosystems
19. Future climate: extremes	19.1	Higher probability of consecutive dry days			Not included but available at: https://climatedata.hutton.ac.uk/index.html There are large spatial and temporal variations and between climate projections.
	19.2	Higher probability of heavy rain days			Not included but available at: https://climatedata.hutton.ac.uk/index.html There are large spatial and temporal variations and between climate projections.
20. Historical land use	20.1				Used in WISE2 for impact on the response of the soil to restoration practices
21. Practicalities of restoration: distance to roads / rurban areas	21.1	Distance from where restoration required to access point			Included (part of WISE2 for peatland restoration assessment)
22. Land ownership	22.1	Single / multiple owners?			Distinction between owned and rented land included (owned land higher priority)
23. Erosion Risk: Water	23.1	Erosion risk map			Included. Available at 50m grid resolution for the area primarily covered by cultivated land in Scotland and adjacent uplands, shows the risk of a bare soil being eroded by water under intense or prolonged rainfall (Lilly and Baggaley, 2014). See also sub-criteria 3.5
24. Erosion Risk: Wind	24.1	Forested areas at risk			Not included (ongoing work on this at JHI)
	24.2	LCA class - erosion constraint			Arable areas at risk of wind erosion (ongoing work on this at JHI)

					Not yet included in new LCA
25. Insurance costs	25.1	Blue line areas (uninsurable)			Not included - hard to access data
26. Identified need in existing climate adaptation plan	26.1				Included where available within Verture analysis
27. River basin management plans	27.1				Included where available within Verture analysis

References:

Gagkas, Z.; Lilly, A. (2024) Spatial disaggregation of a legacy soil map to support digital soil and land evaluation assessments in Scotland, Geoderma Regional, 38, Art. E00833. https://doi.org/10.1016/j.geodrs.2024.e0083

Lilly, A & Baggaley, N.J., 2014. Developing simple indicators to assess the role of soils in determining risks to water quality, CREW project number CD2012_42. Available online at: crew.ac.uk/publications www.crew.ac.uk/publications

Soil Survey of Scotland Staff (1970-1987). Soil maps of Scotland (partial coverage). Digital version 10 release. James Hutton Institute, Aberdeen. DOI 10.5281/zenodo. 6908156.

Restoration prioritisation data integration

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Purpose of the work

The decision to carry out restoration at a specific site depends on multiple factors, many of which are subjective and relate to the particulars of the site. In this project we have adapted earlier work to provide a framework of spatial datasets and weighting for calculating a score for prioritisation of restoration across Scotland. The aim of the work is to provide stakeholders with information for future decision-making on restoration, and also to provide information on where prioritisation scores will be consistently high regardless of which factors are considered more important than others. This work was carried out under the NatureScot Landscape Restoration project and aligns with JHI-C3-1 Supporting Scotland's Land Use Transformations, and the JHI-D3-2 CentrePeat project within the 2022-2027 Rural and Environment Science and Analytical Services Division (RESAS) Strategic Research Programme.

The original WISE framework concept

Published in 2014 (WISE booklet v2 Nov 2013 reduced size.pdf), the original WISE concept was designed to provide a decision support tool for identifying where peatland restoration would be most desirable by a range of stakeholder groups. This framework produced a set of 100 metre resolution spatial datasets and explored stakeholder 'weighting' of each of the factors represented. The work was not able to produce some of the datasets that were identified as important in relation to restoration, due to data shortages and computational processing restrictions. The goal of the current work is to expand on the original WISE concept, with updated datasets and a framework for integrating and analysing these in a manner that goes beyond reliance on small numbers of stakeholders with very different opinions from one to another.

Datasets used

We used multiple spatial datasets, compiled from a range of sources and adjusted to provide normalised inputs to the framework model. A metadata table has been developed for each dataset (described below) with justification for why it was included and information on how the data was presented within the framework. Each dataset was normalised so that it had a minimum value of 0 and a maximum of 1. This was done to avoid having datasets with larger numerical ranges 'swamp' the score/summation process. Normalised datasets were reprojected where necessary to the OSGB 1936 projection, and resampled to 50 metre grid resolution.

Downstream impact: at each point identified as having peat, the total path length downstream was calculated. Values at each point were then divided by the maximum path length found across Scotland, to give a range of values between 0 and 1. This dataset was included because peatland in good condition has an impact on areas downstream of it, with improved water buffering and filtering, and mitigation of flood risk. Restoration at a point with a larger potential downstream impact might therefore be considered more important than at a point with no downstream impact.

Slope: steeper slopes have faster hydrological flow rates and greater erosion risk. We therefore assumed that flatter areas might have greater probability of success in post-restoration recovery. Values of slope (in degrees) were calculated at each point, and divided by the maximum. These values were then subtracted from 1 to give flat locations a value of 1 and steep locations a correspondingly lower value.

Land ownership type: we included this factor on the assumption that land managers who rented their land were less likely to invest in restoration or to spend time applying for funds to achieve this; the reasoning here was that with less confidence that they would continue to live at that location, they are less likely to make long-term investments in land management. Therefore, locations where private land ownership was identified were given a value of 1, and locations where land was rented were given a value of 0. Where land ownership was unknown, we defaulted to the 'private ownership' category.

Historical land use: soil properties are affected by land use. Historical land use impacts on soil may have declined over time, but may not have disappeared entirely. Using the historic land use map at the Historic Land-use Assessment project (HLA), we produced a map of historical land use 'intensity' based on expert judgement of the impacts of specific land use/land cover types. Less intense land use history gave each location a higher value, on the assumption that post-restoration recovery would be less affected under less intense historical land use conditions.

Site designations: we have assumed that if there is a designation with any effect in terms of environmental protection in place at a location, then it will be inherently easier to get planning approved for restoration work to be carried out on that location. We have combined maps of different types of designation across Scotland, to produce a map with 'designation' given a value of 1 and 'no designation' given a value of 0.

Distance to roads: transport of equipment and materials across rough and/or boggy terrain is difficult and expensive. Restoration sites that are near roads are therefore assumed to be favoured by practitioners. We have scored sites next to roads with a value of 1, and those further from the nearest road with a correspondingly lower value as the distance increases.

Agricultural payments: the values used in this dataset are derived from the level of Direct Agricultural Support Payment per hectare for 2022. This includes Basic Payment Scheme (BPS), Greening and Less Favoured Area Support Scheme (LFASS) payments. The assumption being made here is that restoration would lead to a loss or reduction in payments and so where payments are higher, there may be more reluctance to consider restoration. It is important to note that the dataset used does not always connect a payment rate to the exact piece of land for which the claim is appropriate but rather can include larger parcels of land within which the agricultural land use is contained.

Impact of future climate: derived from JHI analysis of the number of months when drought risk will increase under future climate, this dataset is used to indicate where restoration success may be affected by changing weather patterns across Scotland. Our assumption is that in places where this success rate is compromised by future climate, practitioners may prefer not to carry out restoration work.

Growing season length: vegetation recovery will depend on growing season length, with shorter growing seasons assumed to be less preferred for growth of vegetation as well as for other species. The dataset we used for this is Growing Season Length as defined by Matthews et al (2008) http://dx.doi.org/10.3354/cr00751, calculated using HADUK GRID observed interpolated gridded daily values at 1km over the period 1991-2020.

Windfarm development: if a windfarm development exists at a site of potential restoration, it is assumed that this will complicate access and the movement of equipment and materials. We have compiled GIS layers of known windfarm developments and given these a score of 0 in this layer, with other areas having a score of 1. This layer is one of several where further evidence may provide nuance, such as whether the contractor doing the restoration work is part of the same organisation as the windfarm owner/developer, or whether the developer has a stated goal of having restoration work carried out (in which case this could make restoration easier rather than harder to coordinate).

Erosion risk: Soil erosion risk class map is available at 50m grid cell resolution for, mainly cultivated, areas covered by the 1:25k Soil map (partial-cover) (Soil Survey of Scotland Staff (1970-1987). Gap areas were filled using a disaggregated soil series map at 50m grid cell resolution (Gagkas and Lilly, 2024) translated to soil erosion risk classes. Areas of high erosion risk are marked with 1, while areas of low erosion risk are marked with 0.

Nitrate Vulnerable Zones: designation of an area as an NVZ aims to reduce or prevent the pollution of water caused by the application and storage of organic and inorganic nitrogen fertiliser on agricultural land. By controlling land use management, the legislation aims to protect drinking water supplies, aquatic ecosystems and other legitimate uses of water. This dataset, from the Scottish Government GI-SAT (Geographic Information Science and Analysis Team) has been used with a value of 1 where an NVZ exists, and a value of 0 where it does not.

Soil runoff risk: The risk of the soil becoming saturated, causing water (or any liquid applied to the soil) to flow over land (runoff) and carry potential pollutants into water courses, or to collect (pond) on the surface. This dataset, derived from the Hydrology of Soil Types (HOST) classification (Lilly and Baggaley, 2014) , has been normalised to have a value of 1 at the areas of highest runoff risk, and a value of 0 at the lowest runoff risk areas.

Randomised weightings

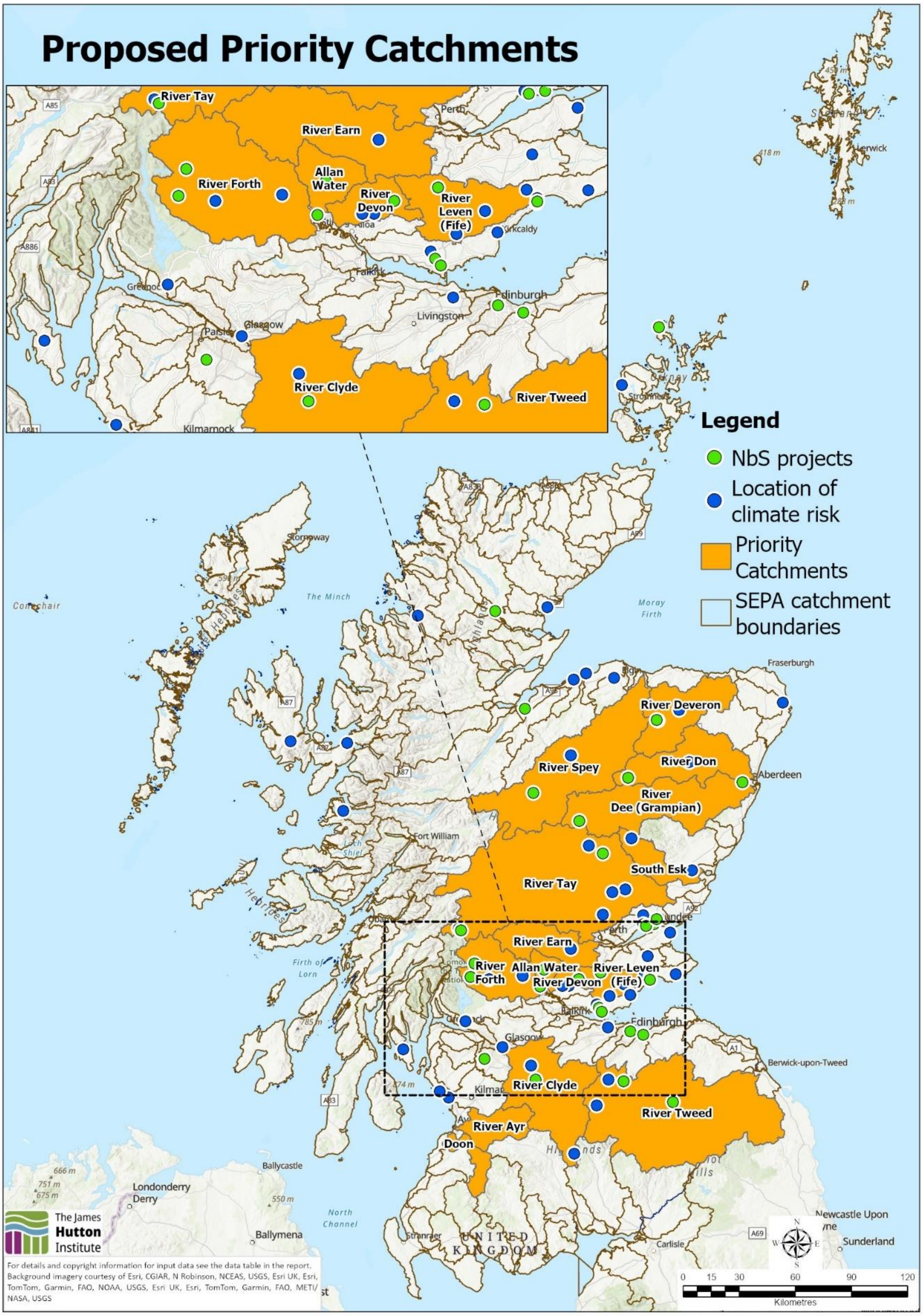
The fundamental concept behind this work is that each stakeholder involved in restoration (in any sense of involvement) will have specific priorities and will attach different importance to each factor for consideration when deciding where restoration should take place. In the original WISE work (Artz et al., 2014), multiple stakeholders were asked to provide weightings for a range of normalised factors similar to those used in the current work. The spatially explicit factors were then multiplied by each weighting, and the resultant weighted maps added together to give a final map of individualised prioritisation. Artz et al. found that there was significant variation between the maps generated for each set of stakeholder preference, making it difficult to identify areas where agreement on high priority of restoration could be reached.

Here we have generated 100 sets of random 'virtual stakeholder' weightings for each of the datasets/factors described above, and used these to create 100 maps of individual stakeholder restoration prioritisation. We have then calculated the mean prioritisation value at each location across these maps to explore whether there are areas where, regardless of stakeholder preference, the prioritisation 'score' is likely to be high. We have also calculated the variance in the prioritisation value, to show where prioritisation values tend to vary a lot or a little. This work involved a significant amount of spatial data computation, which was carried out using the JHI High Performance Computing system (Supercharging science with high performance computing - James Hutton Institute).

A final step is to clip mapped data to remove land cover types where restoration is inappropriate or unlikely to occur, for example urban areas, arable crop land and intensively grazed grassland. It is worth noting however that ecosystem restoration within these land cover types, e.g. riparian woodlands and or land use changes such as uptake of agroforestry, are compatible with the multiple benefit objectives of landscape restoration.

Additional Data Inclusion

A secondary level of spatial data consideration of criteria and prioritisation can then occur using additional data sets that are not suited to the WISE2 approach. This approach enables a combination of both a systematic method and individual data layers assessment. The ability to do this systematically and in detail per input data set has however been limited as they vary in their national coverage and due to resources constraints. Examples are provided below.



SM Figure 1 (Repeated from main report). Proposed priority catchments for nature restoration.

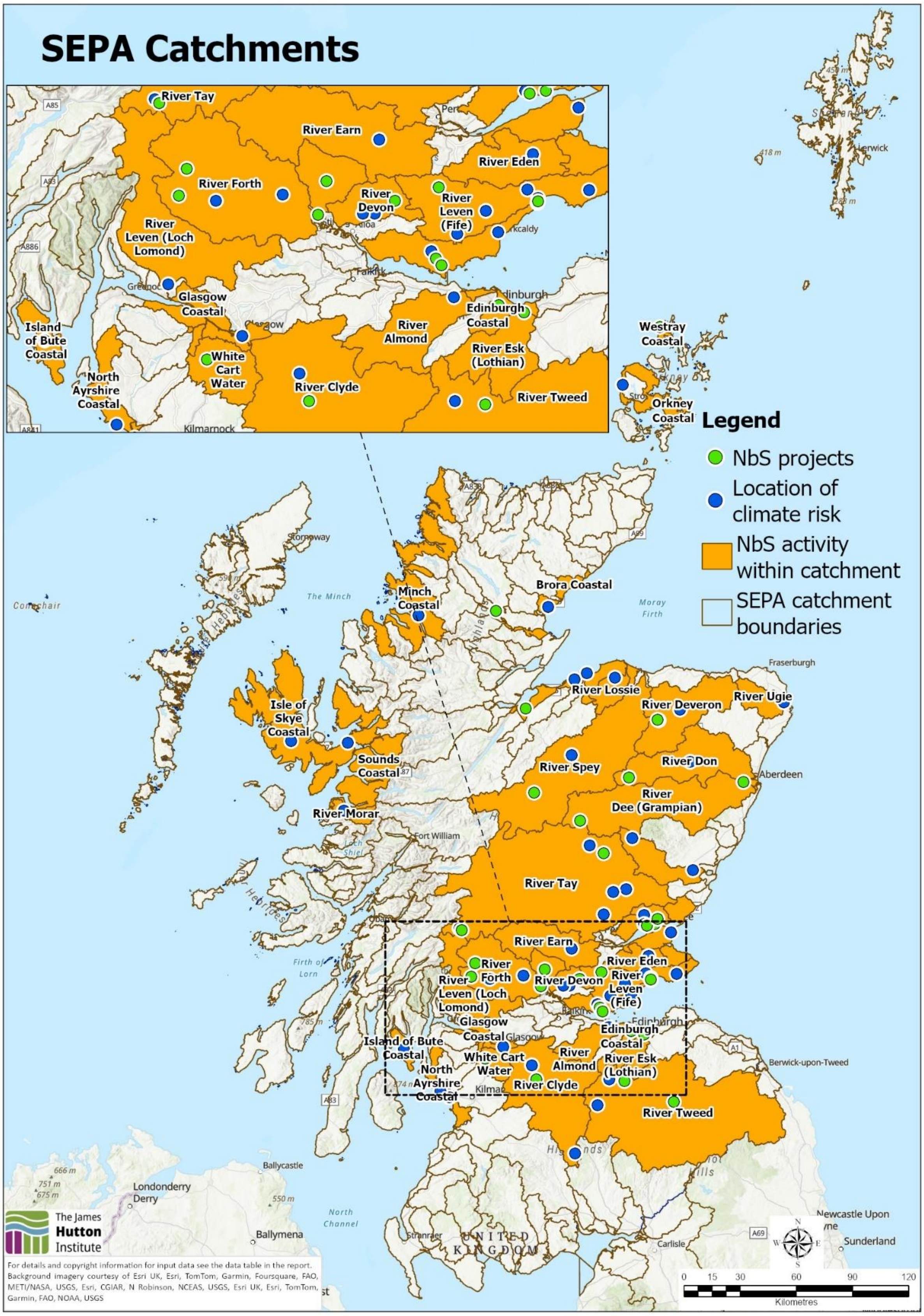
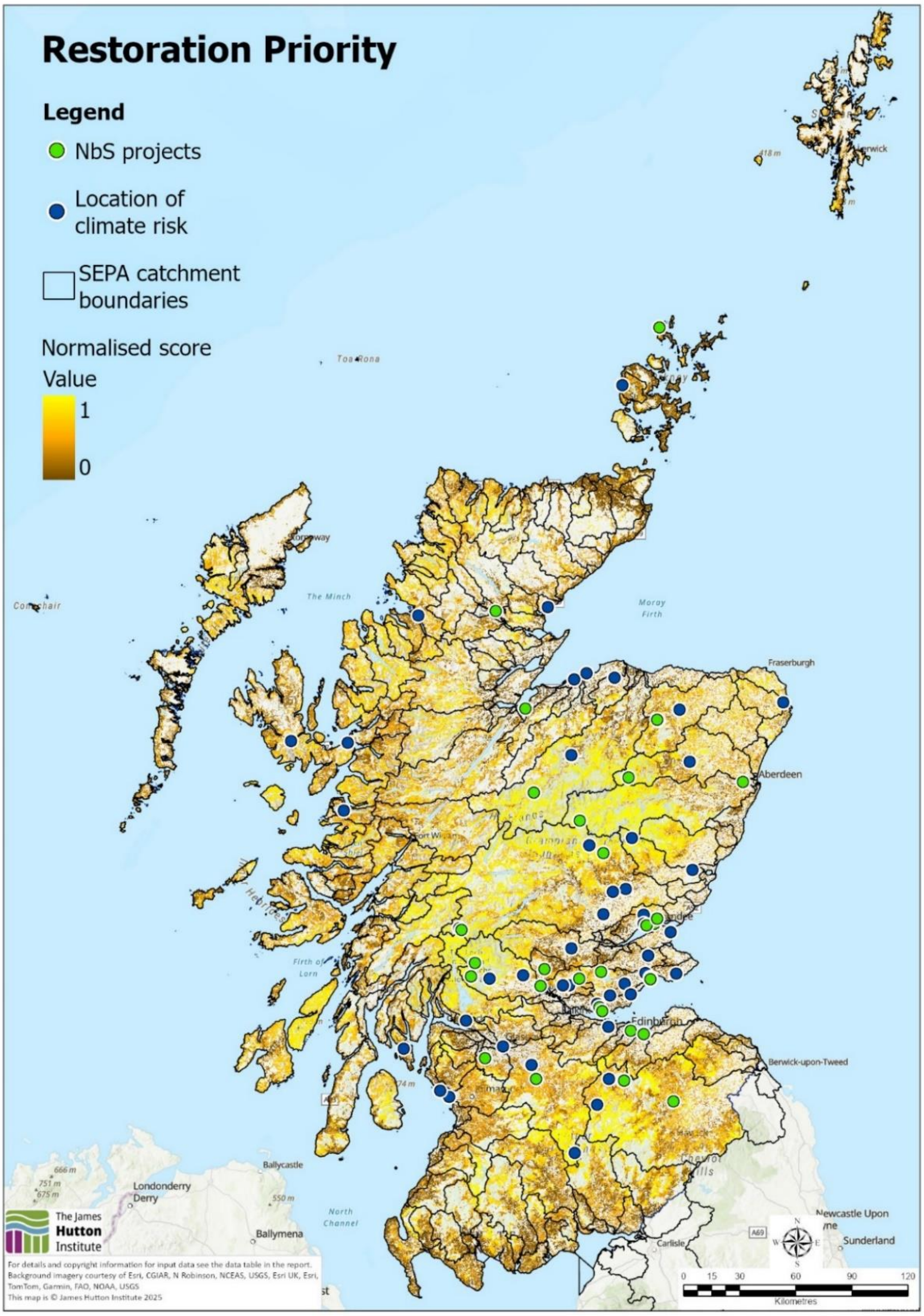


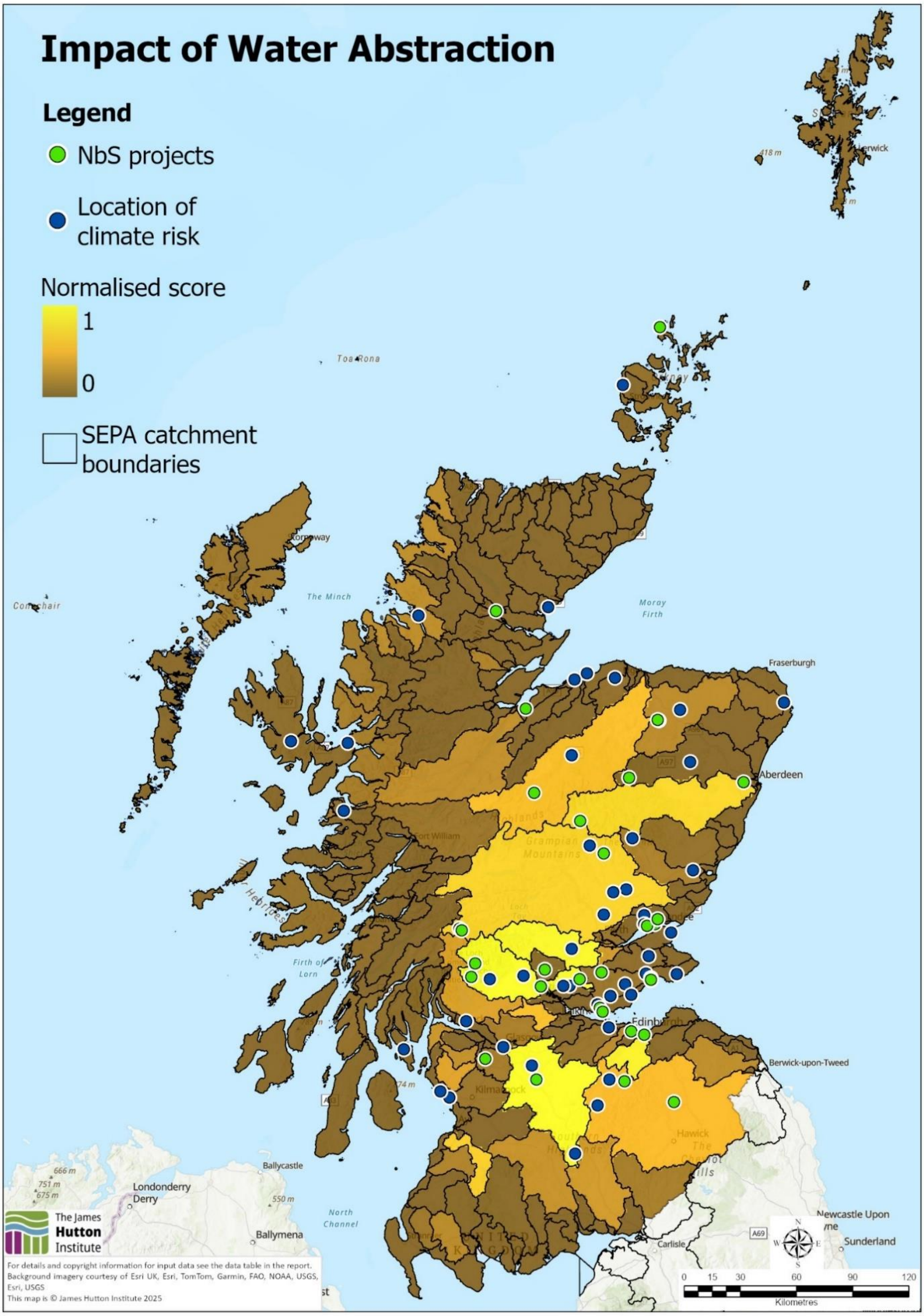
Figure SM2: SEPA Catchments boundaries, where point locations are those identified from the stakeholder survey and are not exhaustive of all climate risks (blue dots) or nature-based projects (green dots).

Interpreting the WISE 2 Normalised Score

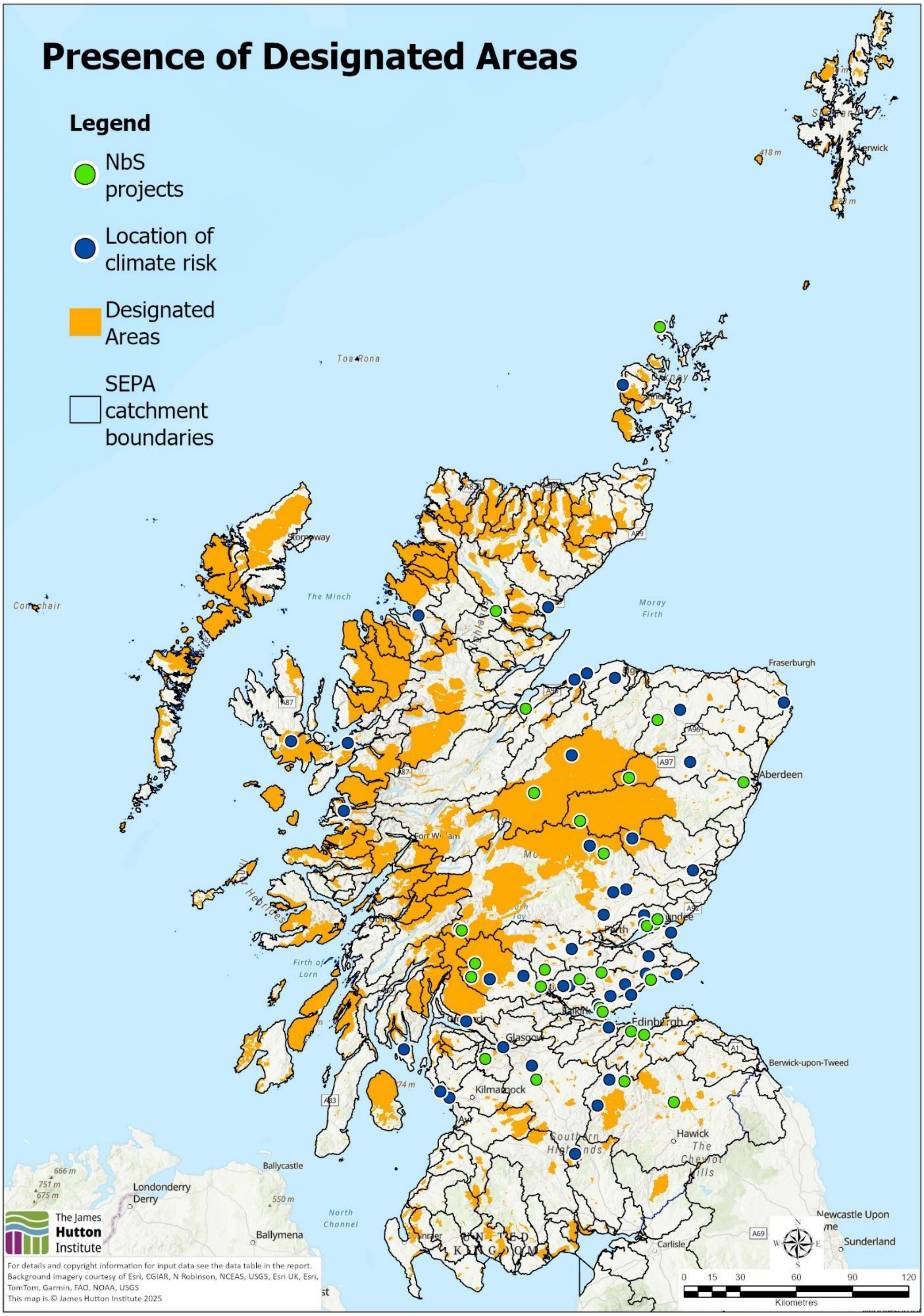
To interpret the following normalised score Figure 3, those areas with the brightest yellow have a score of 1, meaning that they score highest across the range of criteria and have a high priority for restoration, whilst darker yellow / brown consistently have low scores hence lower priority for restoration.



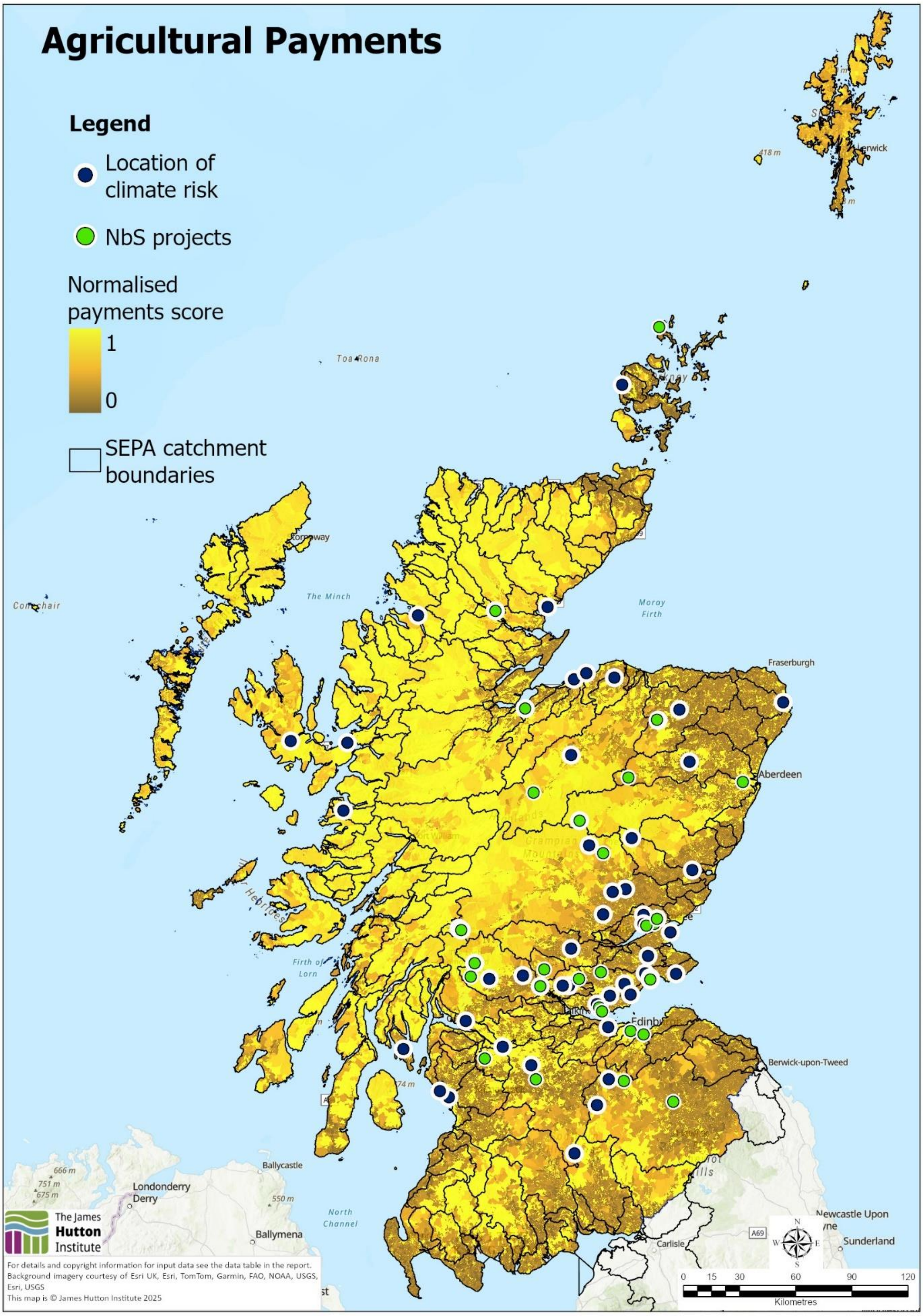
SM Figure 3 (repeated from report) Normalised restoration priority score with areas where restoration is not currently feasible removed (i.e. arable, urban). Green dots indicate locations of existing Nature-based Solutions restoration projects identified in the survey, Blue dots are locations identified as at risk from threats.



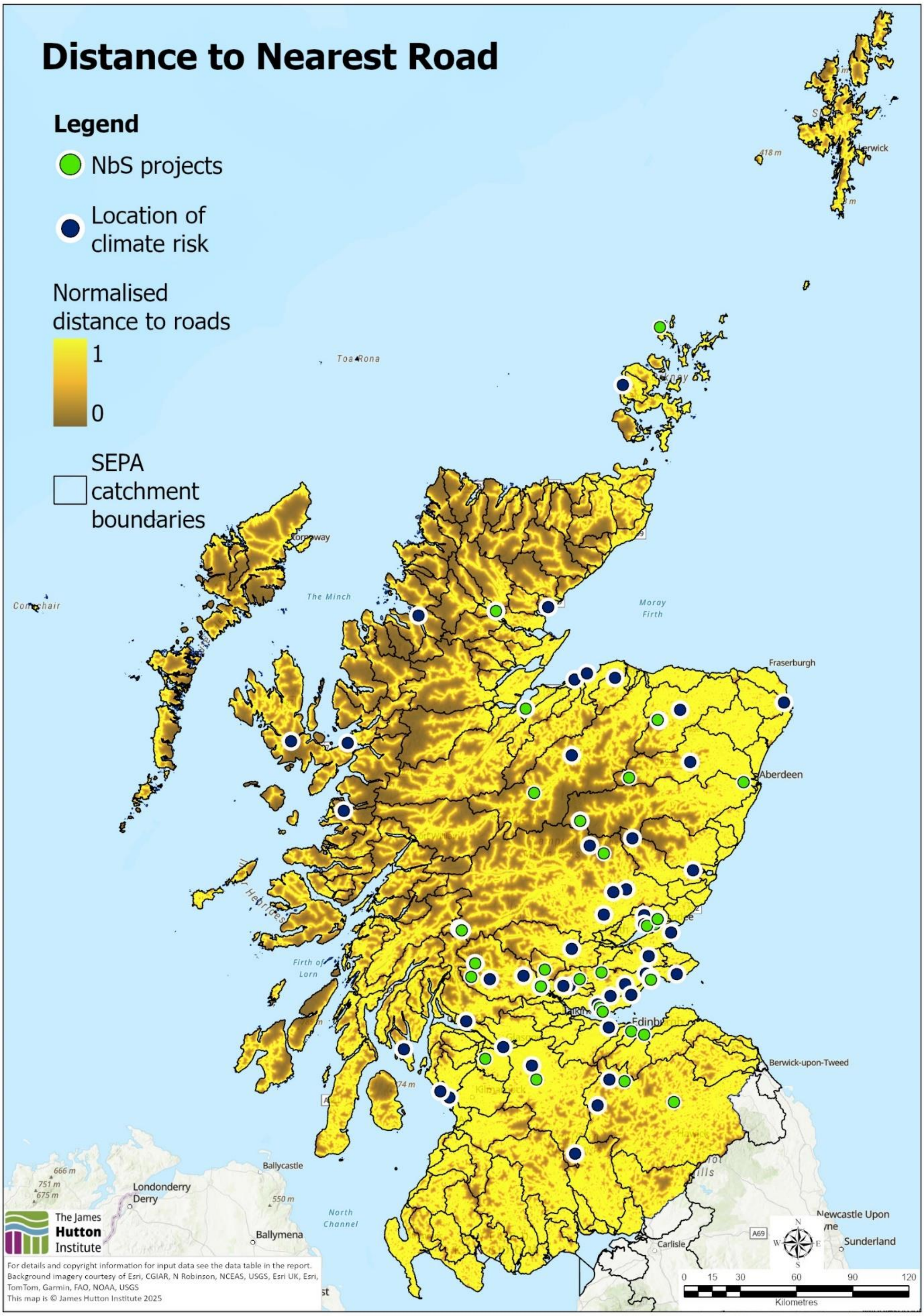
SM Figure 4. Impact of water abstraction normalised score.



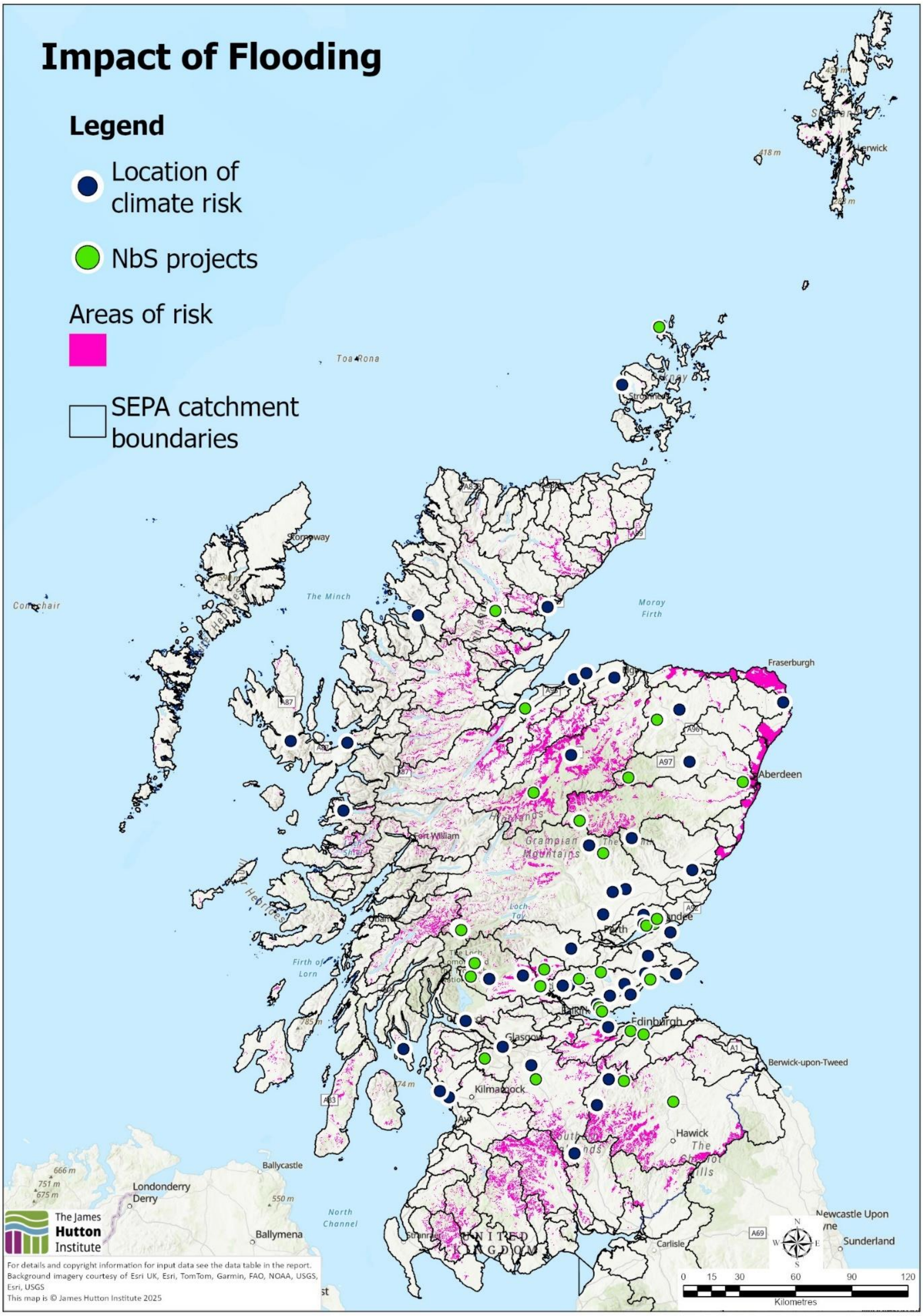
SM Figure 5. Designated sites (all types).



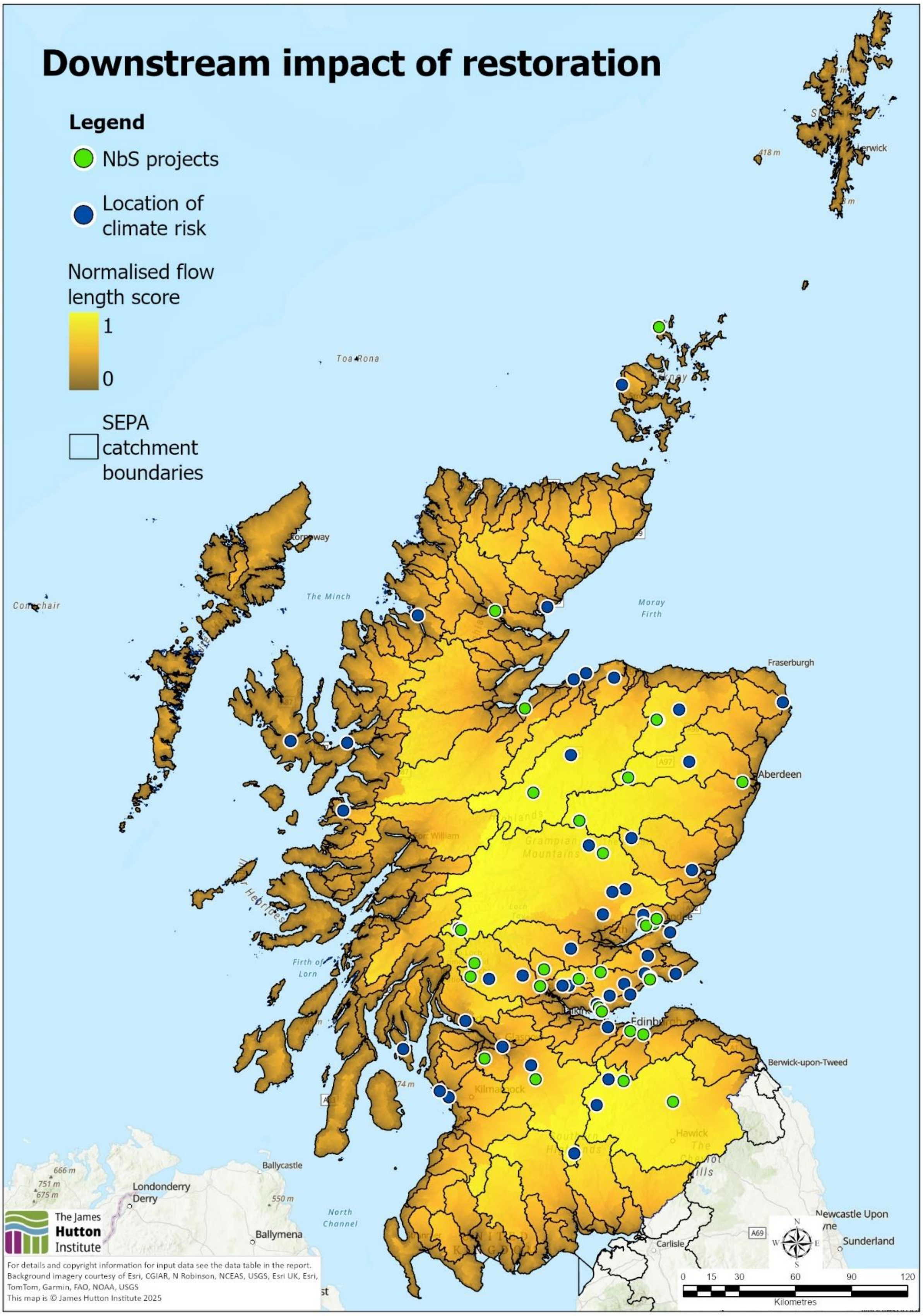
SM Figure 6. Agricultural payments normalised score. See Wise2 method description.



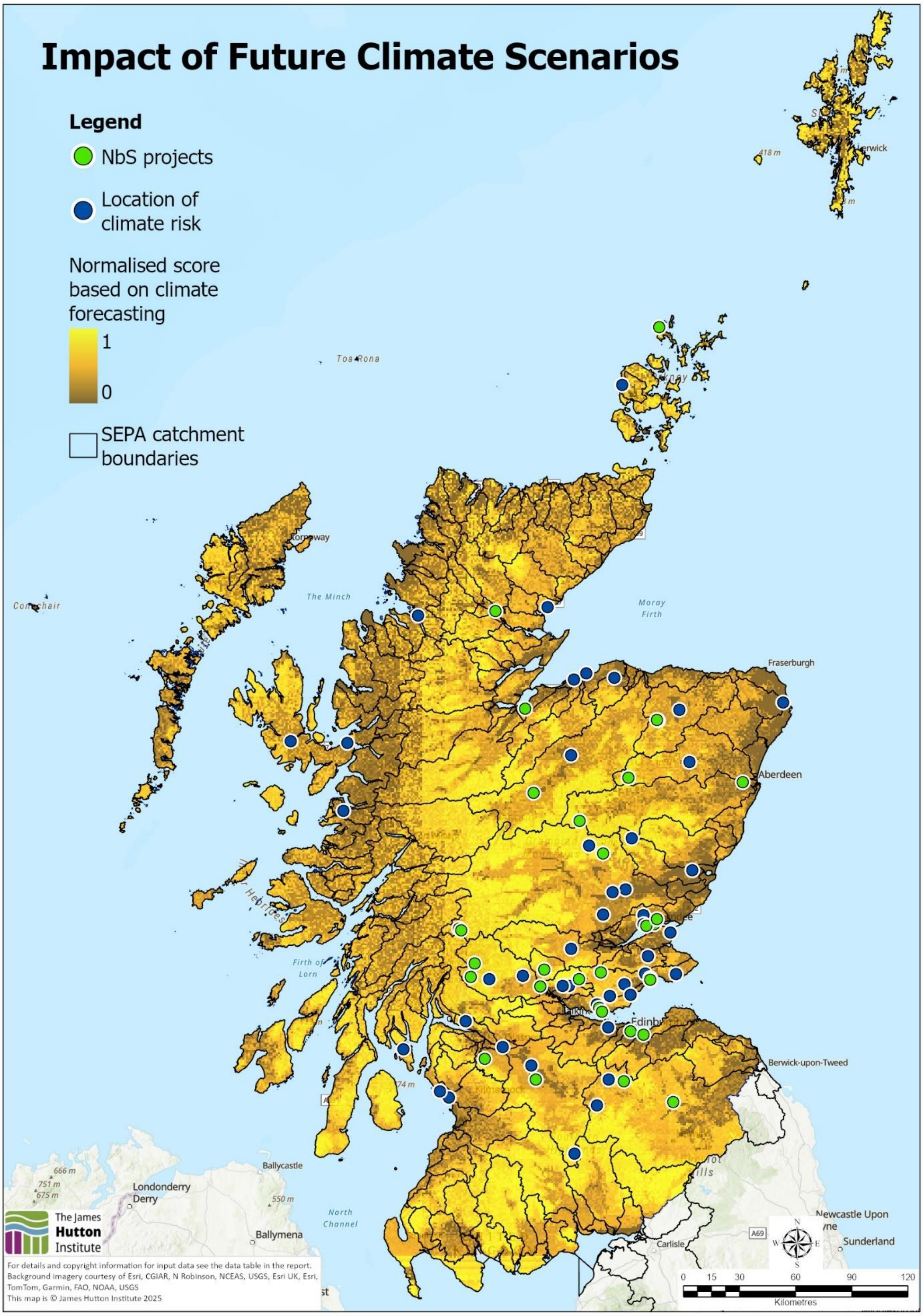
SM Figure 7. Site Access (distance from roads) normalised score.



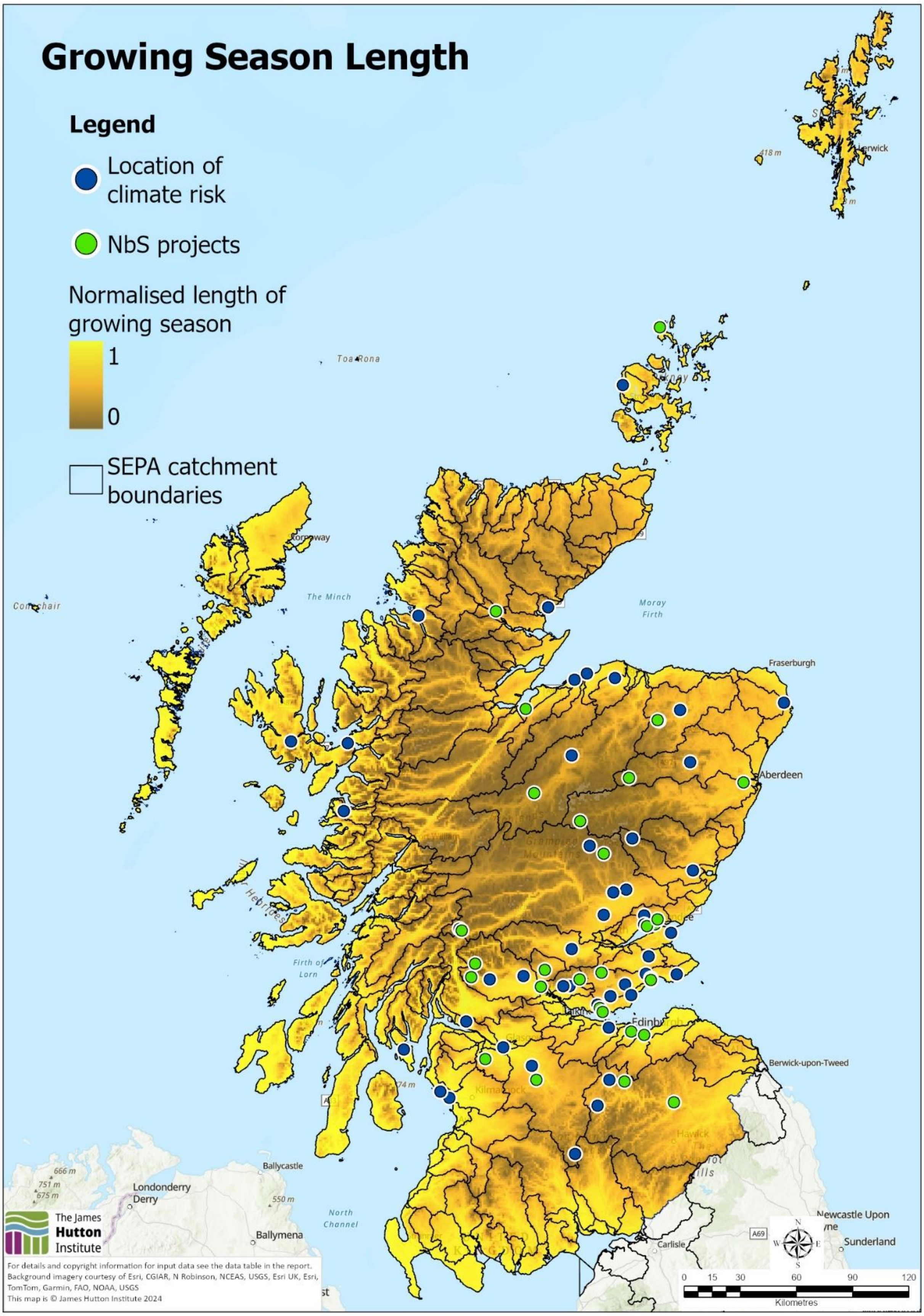
SM figure 8. Areas of flood risk



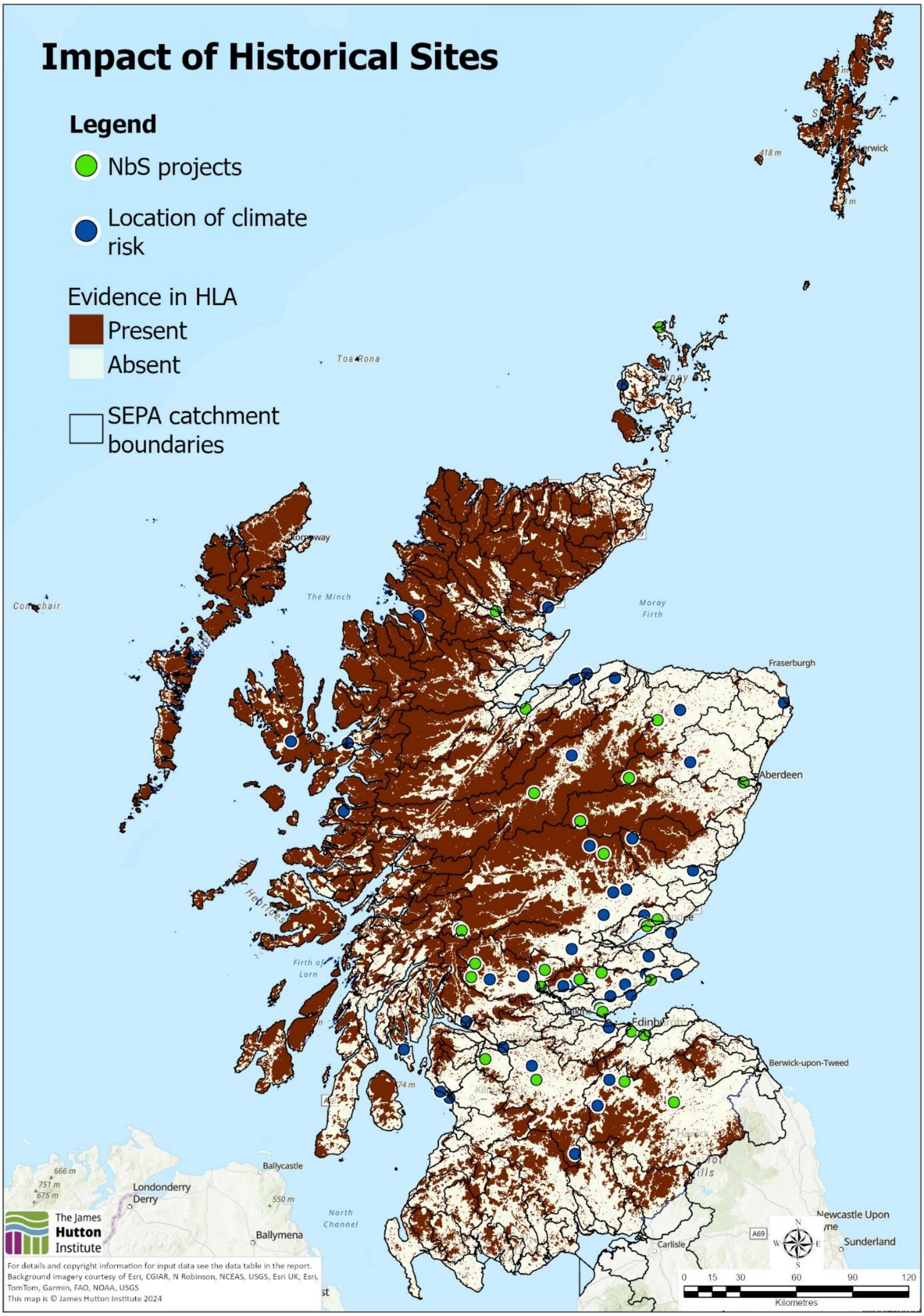
SM Figure 9. Flow length normalised score for impact on downstream



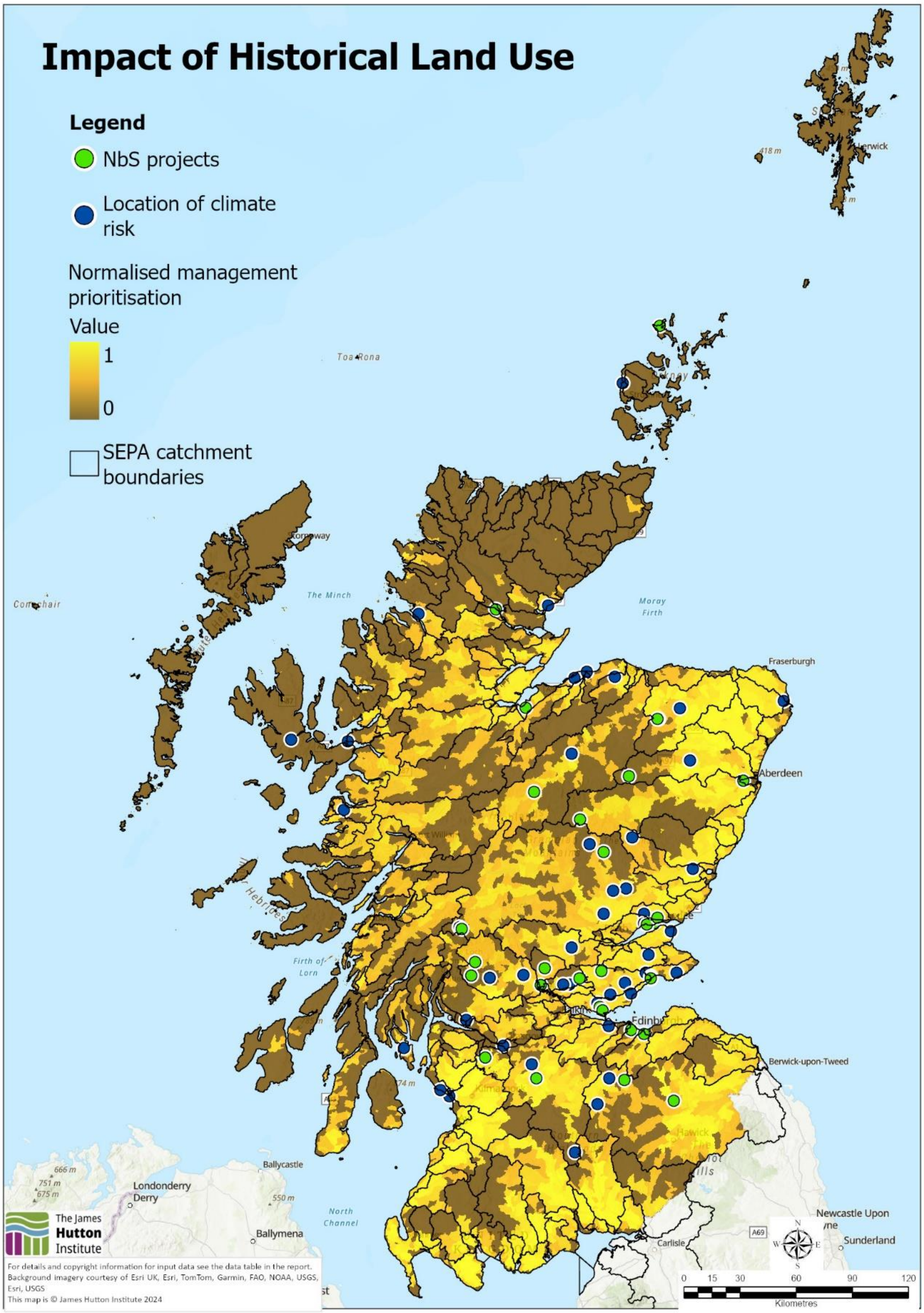
SM Figure 10. Future climate change impact normalised score. See also SM Figures 23-2 and [The James Hutton Institute Climate Data Visualisation] for other climate indicators and summaries.



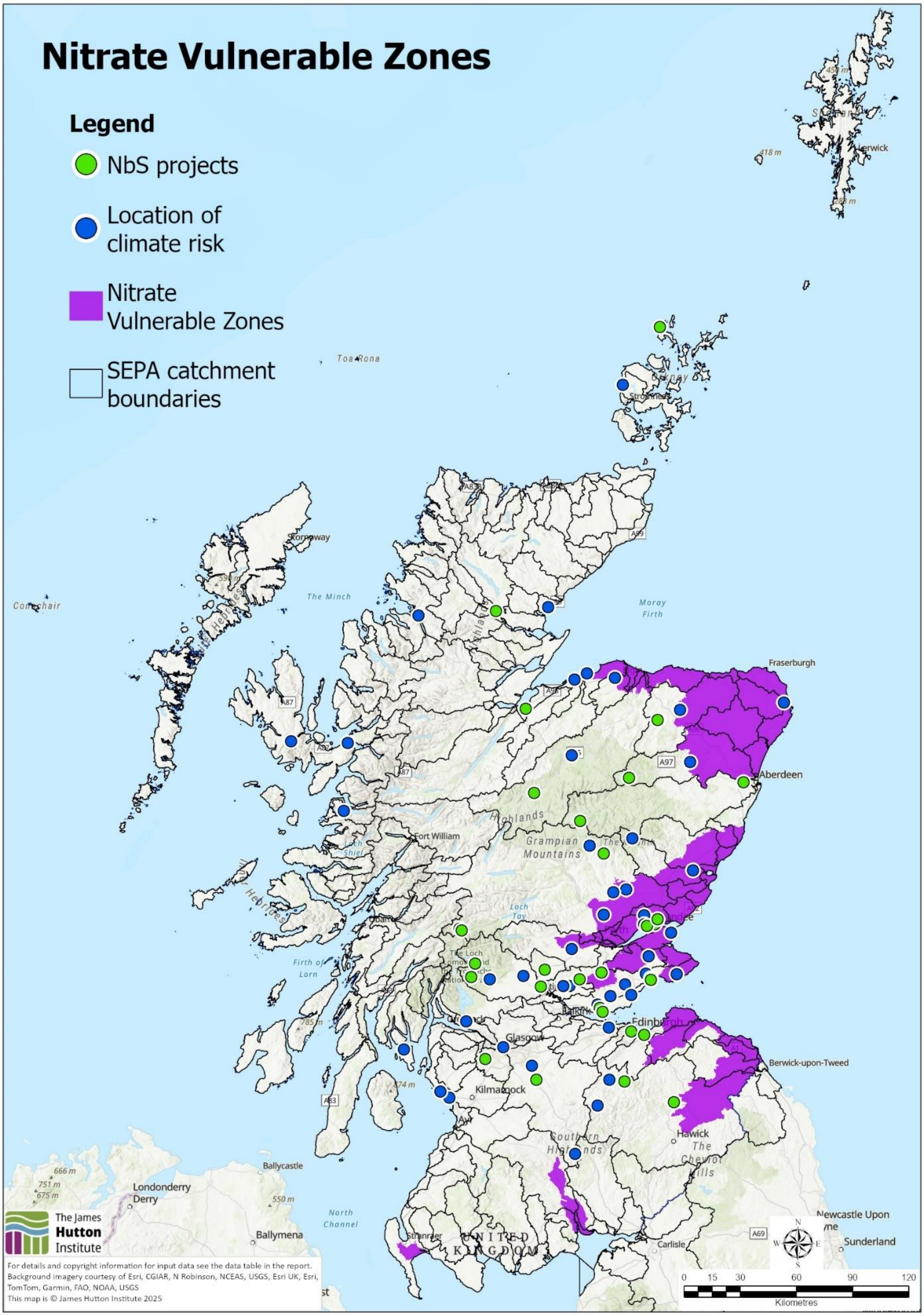
SM Figure 11. Growing season impact normalised score. Also see [The James Hutton Institute Climate Data Visualisation] for other relevant Agrometeorological Indicators.



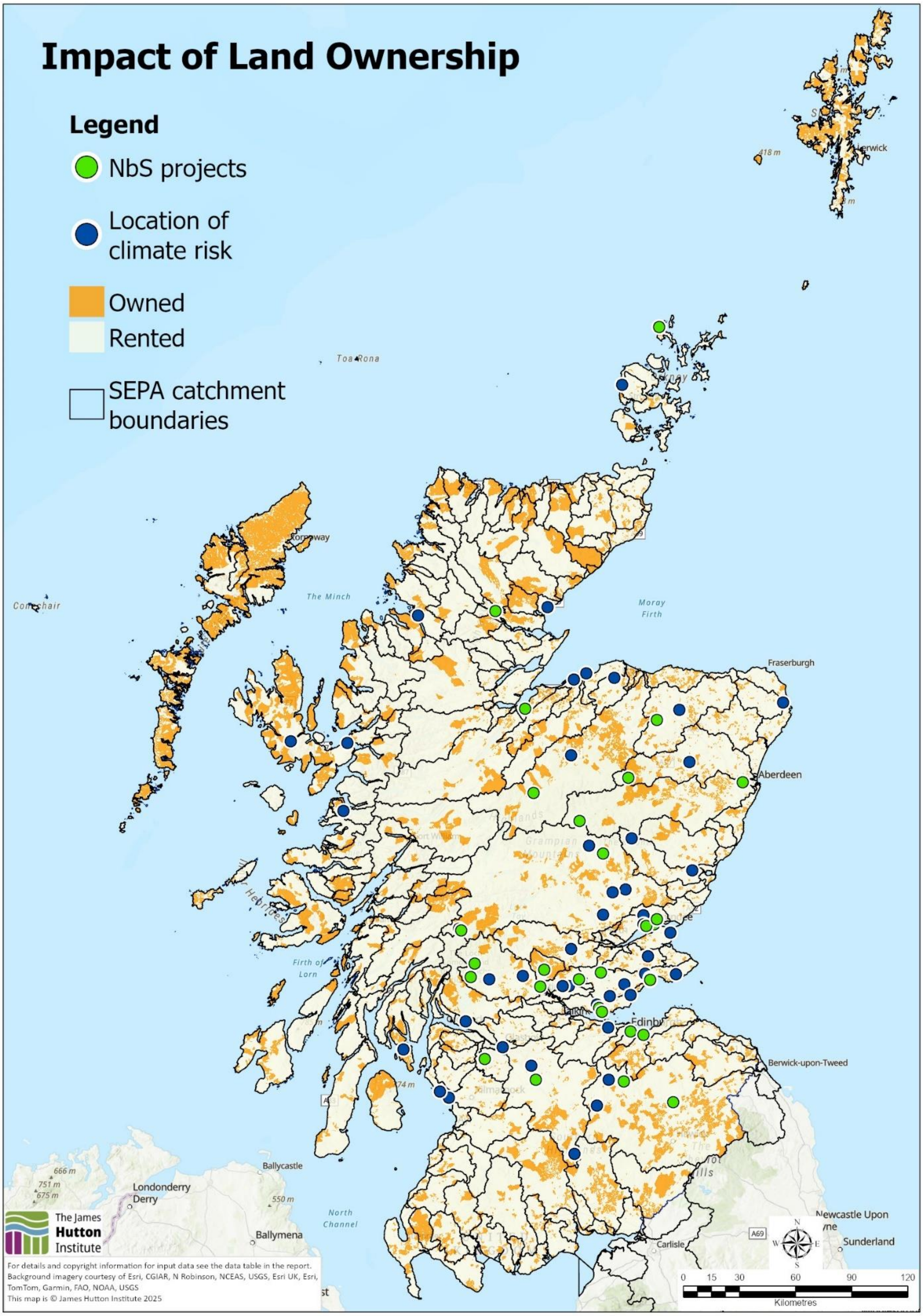
SM Figure 12. Impact of historical land use. See Wise2 method description. HLA: Historic Land-use Assessment



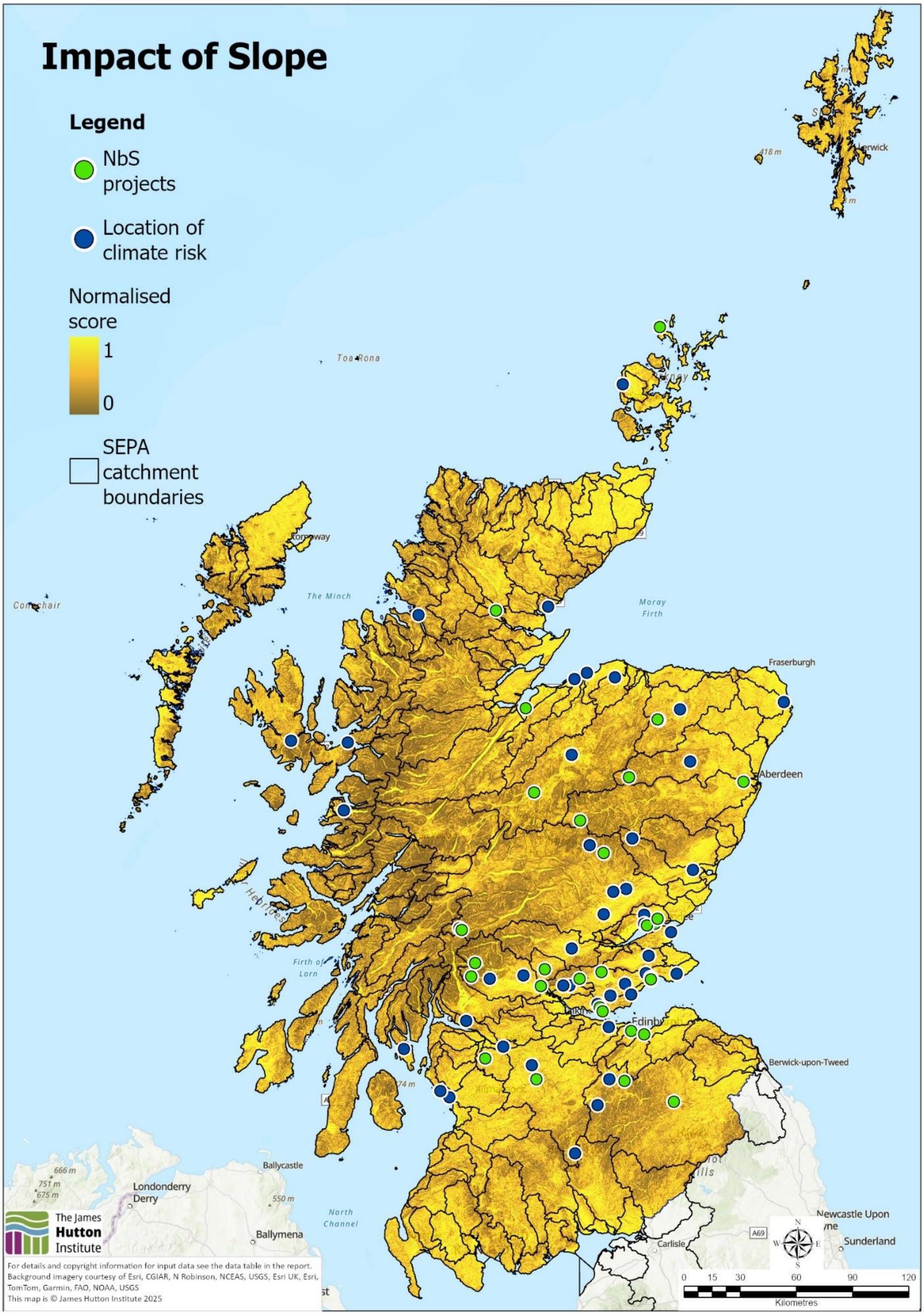
SM Figure 13. Impact of historical land use. See Wise2 method description..



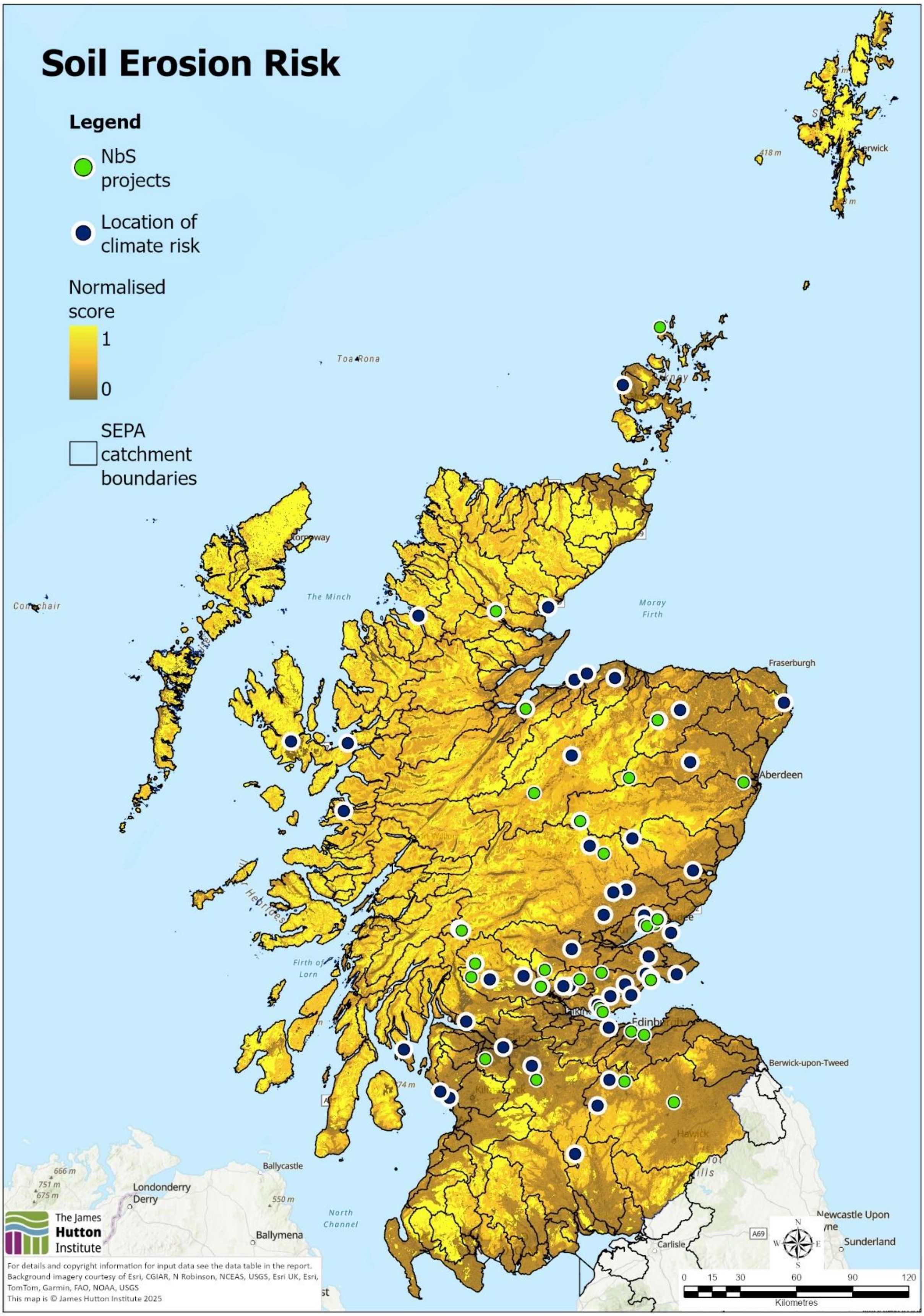
SM Figure 14. Nitrate Vulnerable Zones.



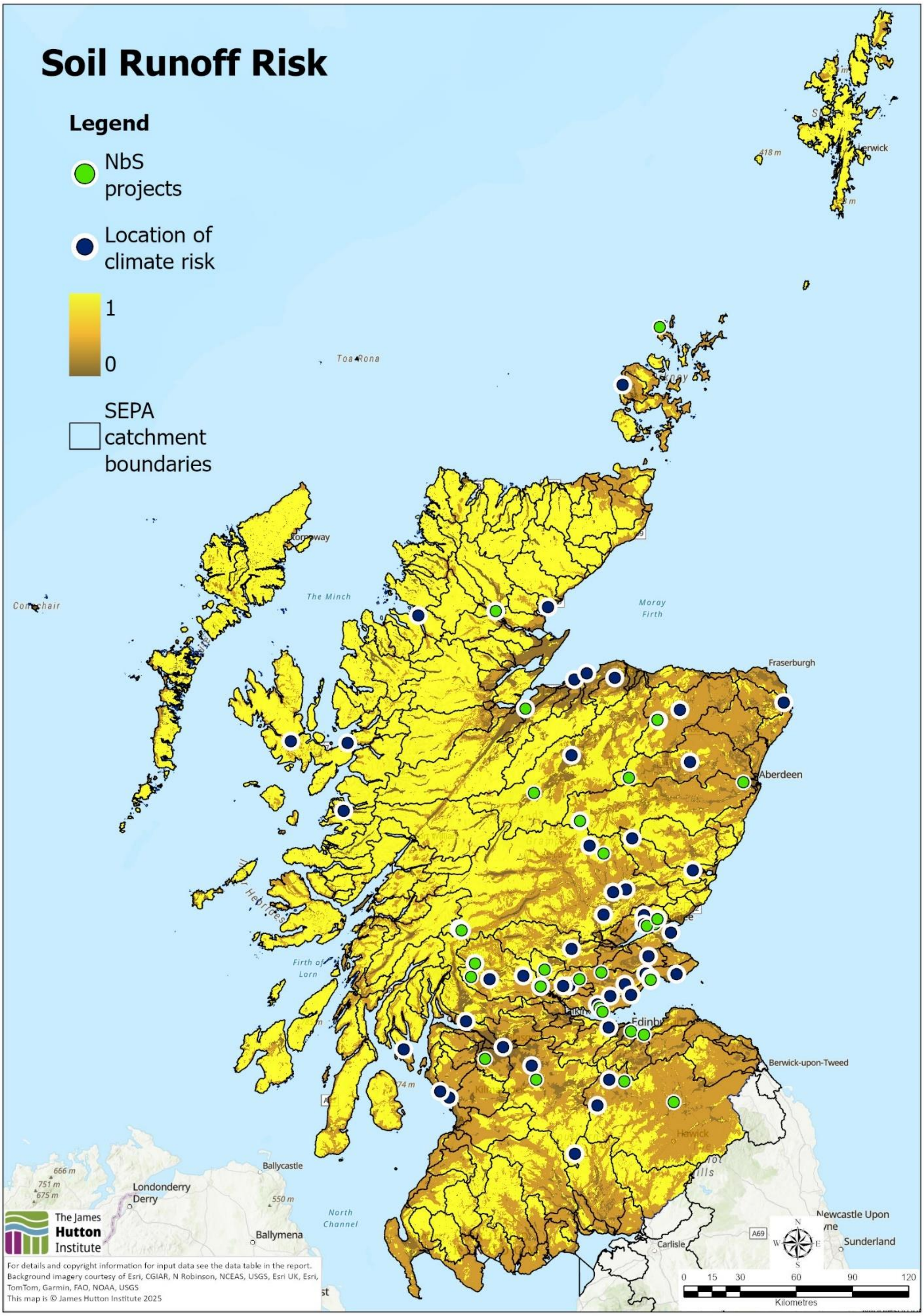
SM Figure 15. Land ownership (owned or rented). See WISE2 method description.



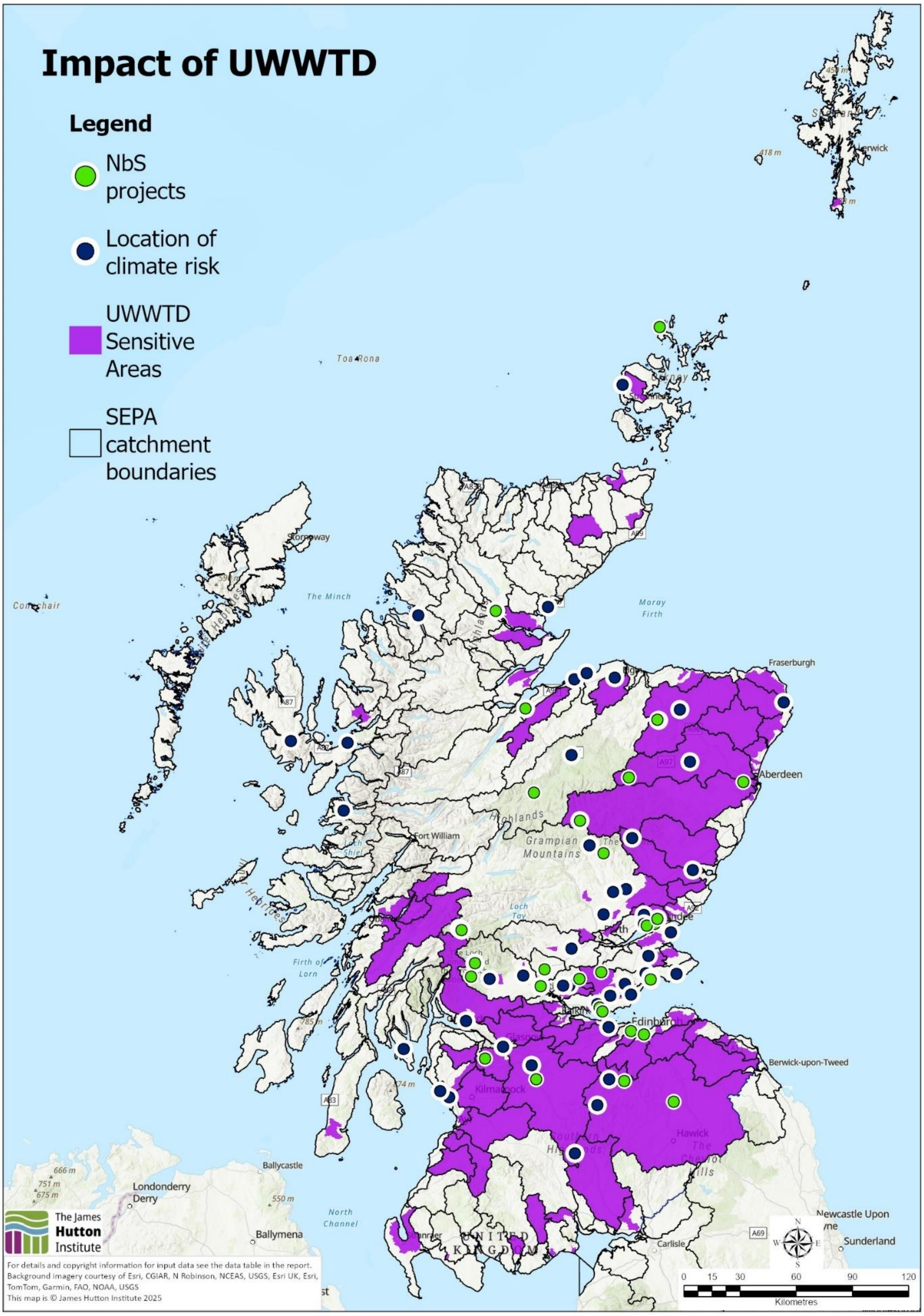
SM Figure 16. Normalised score for slope. See Wise2 method description.



SM Figure 17. Soil erosion risk



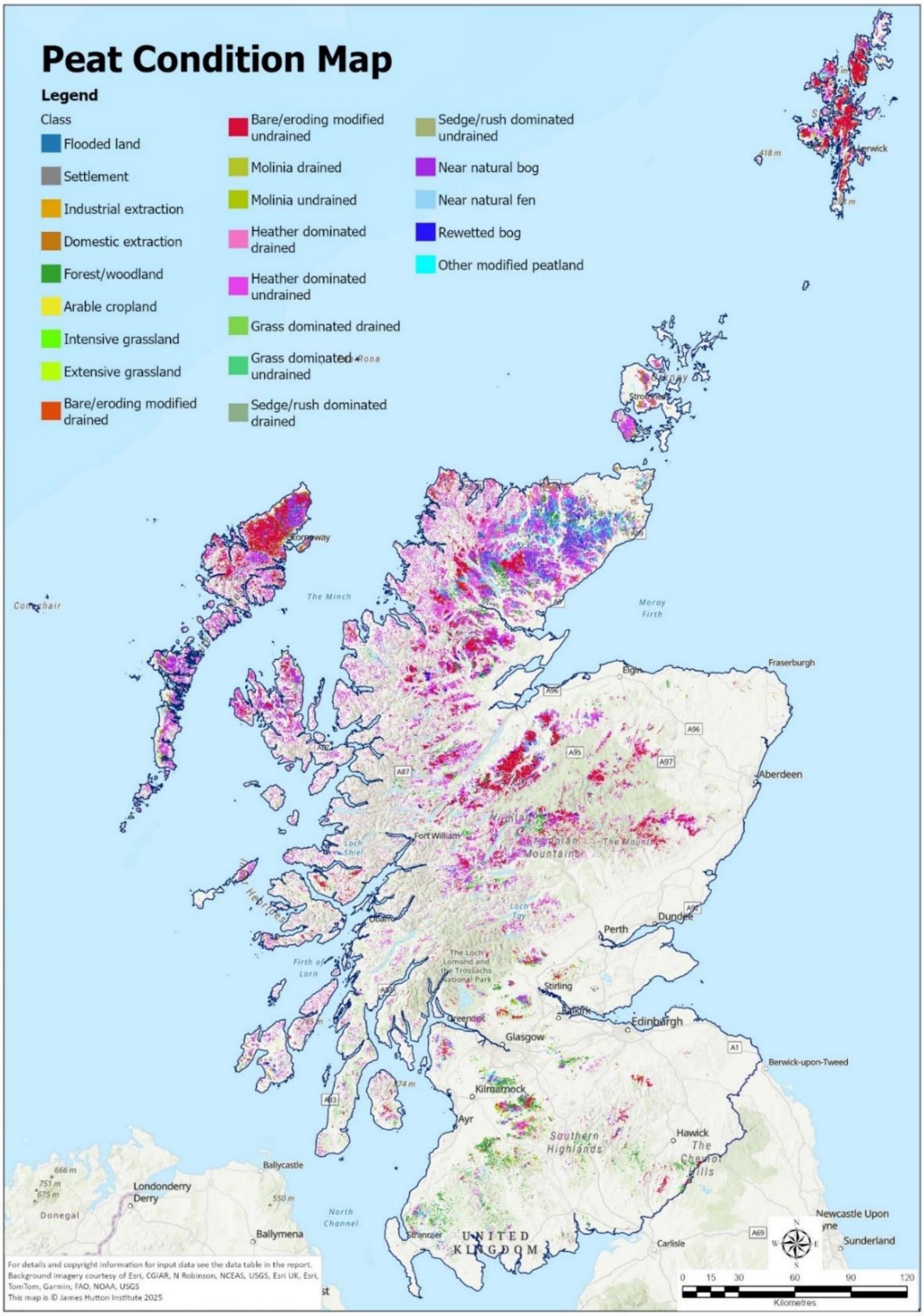
SM Figure 18. Normalised score for risk of soil runoff.



SM Figure 19. Urban Waste Water Treatment Directive (UWWTD) sensitive catchments.

Additional spatial data to inform catchment prioritisation discussions.

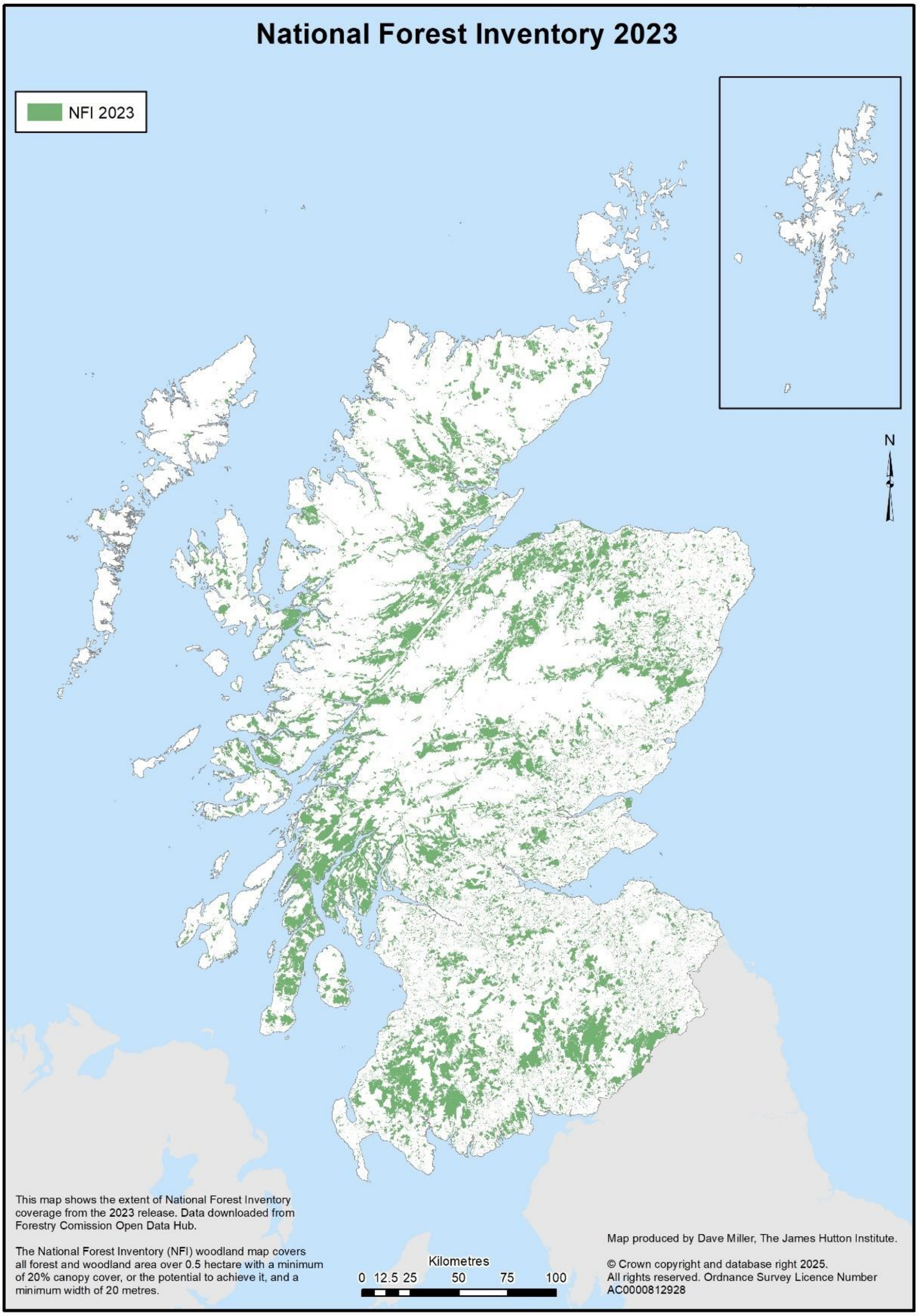
The following maps and graphics are provided to facilitate further consideration of other factors not included in the prioritisation process.



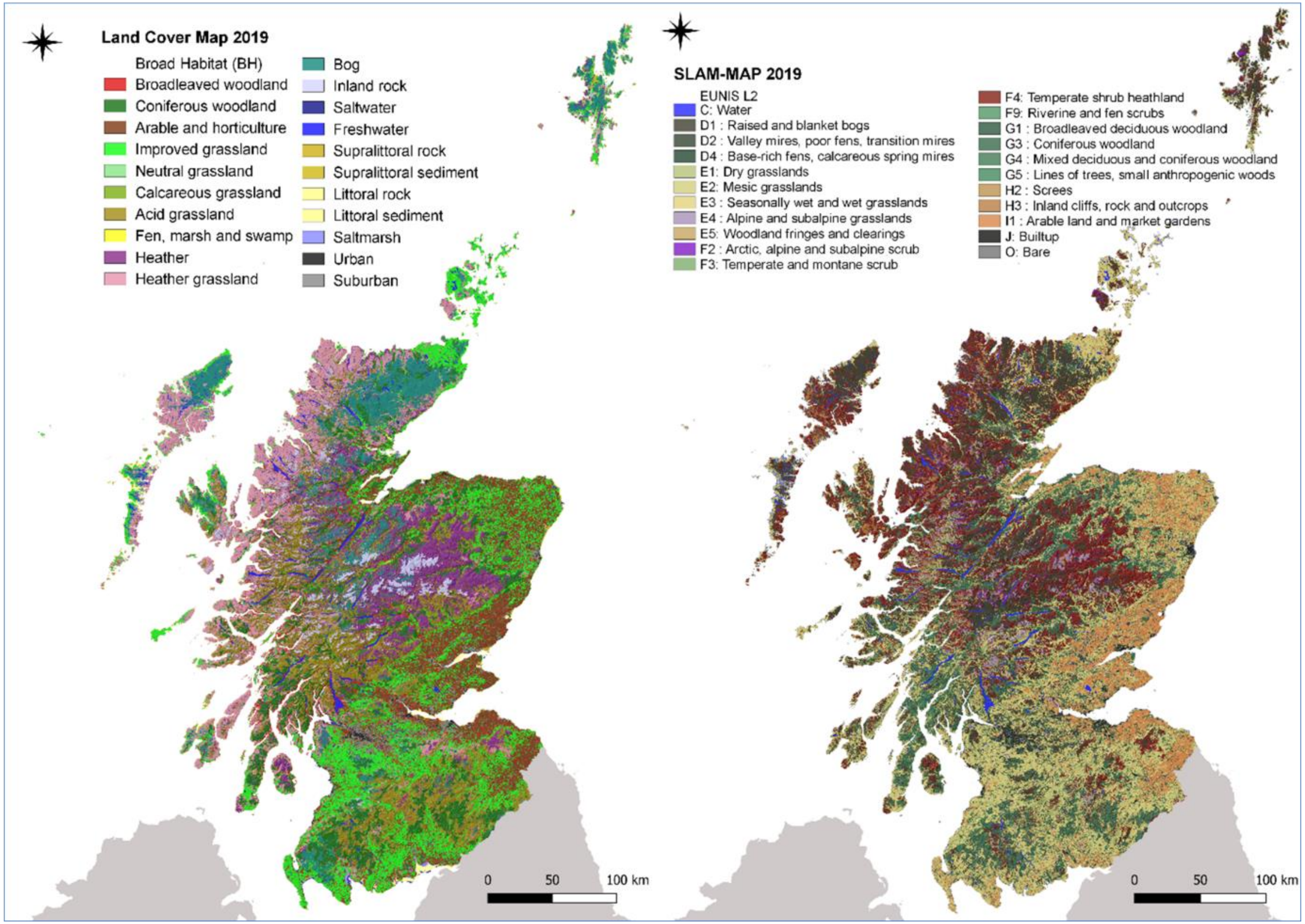
SM Figure 20a. Peatland condition map. Developed using RESAS Strategic Research Programme projects C3 (Land Use Transformations) and D3-2 (CentrePeat).

Table 2. Areas of peat (hectares) by condition class (bare / eroding are highlighted) for proposed priority catchments.

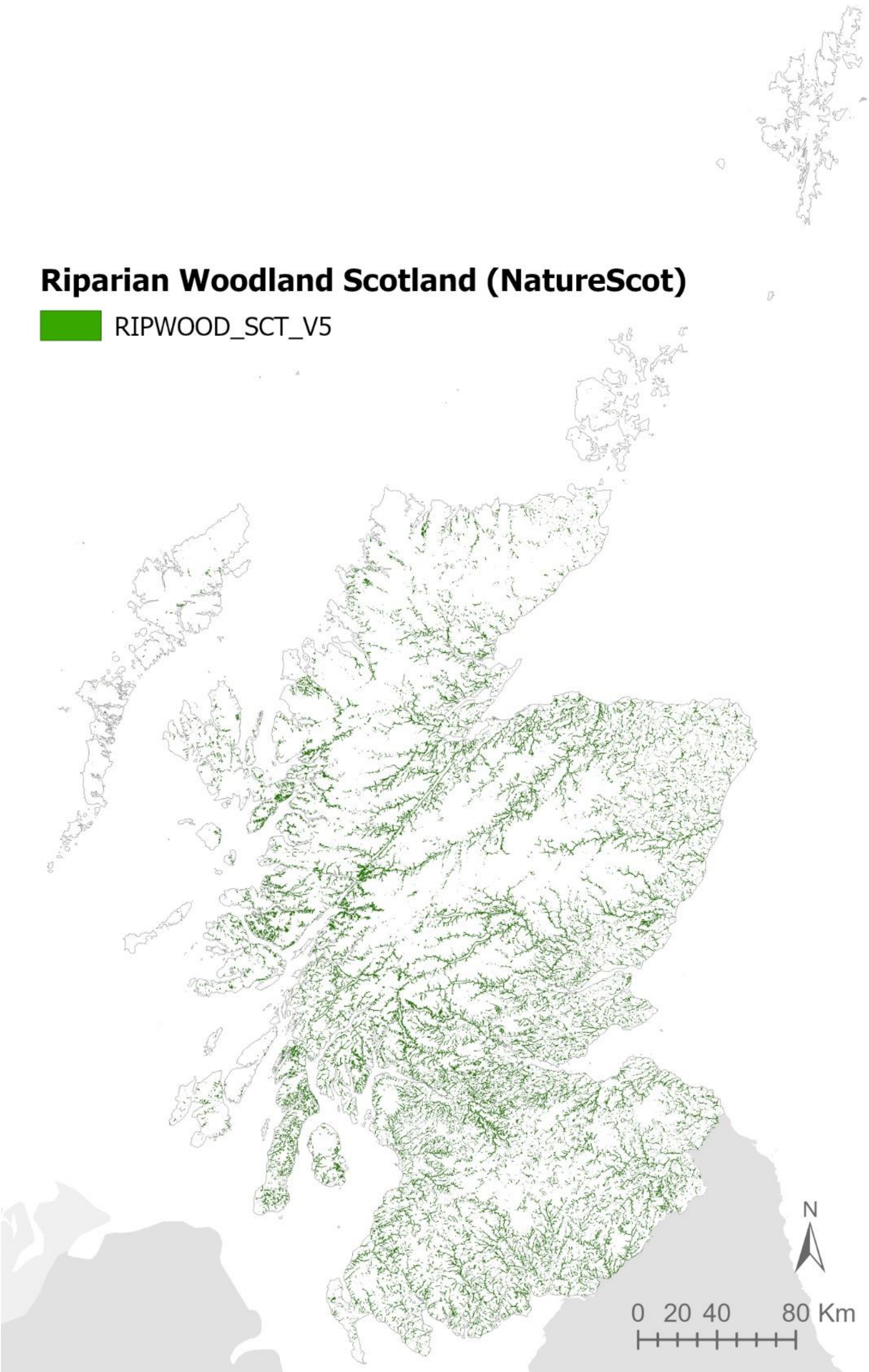
Condition class	Leven (Fife)	Devon	Allan Water	Forth	Tweed	Doon	Ayr	Clyde	Deveron	Don	Dee (Grampian)	South Esk	Tay	Earn	Spey
Flooded	13	62	3	1756	134	690	179	246	2	4	133	25	4400	253	399
Settlement	105	103	22	382	109	287	335	568	36	40	48	20	367	130	299
Industrial extraction	42	0	0	69	23	0	0	273	87	0	0	0	0	0	23
Domestic extraction	3	0	0	0	0	0	224	21	342	7	55	0	8	0	115
Forest/woodland	1403	1204	1686	13681	15385	6850	6476	16477	3538	1195	2402	806	21075	2848	13021
Arable cropland	88	31	80	386	44	2	11	8	93	66	156	2	77	53	25
Intensive grassland	120	32	147	700	394	109	1005	3751	414	104	93	68	687	136	442
Extensive grassland	0	0	0	0	0	0	53	34	0	0	0	0	2	0	1
Bare/eroding modified drained	0	1	150	222	1148	15	510	634	474	173	206	56	1516	272	550
Bare/eroding modified undrained	27	516	603	3451	6336	151	1503	2982	2220	2114	11019	2633	21023	2426	22684
Molinia dominated drained	3	47	153	370	282	467	2901	4864	1	0	19	0	2347	299	5
Molinia dominated undrained	121	2629	1210	3558	4661	2056	3680	7113	10	8	1124	0	8965	2955	1512
Heather dominated drained	7	5	417	473	1697	322	1385	2857	2202	781	2015	500	10831	1112	4292
Heather dominated undrained	131	112	1637	7995	8087	3224	2266	6566	5432	7739	32458	4691	82342	9174	57423
Grass dominated drained	0	1	5	30	0	4	140	45	0	0	20	1	173	6	72
Grass dominated undrained	16	3	14	820	14	61	230	196	8	1	958	54	2359	43	2593
Sedge/rush dominated drained	2	4	7	23	10	5	74	66	5	3	1	4	118	23	7
Sedge/rush dominated undrained	66	28	56	556	171	99	155	218	216	32	127	39	1289	88	322
Near natural bog	39	461	776	2421	1117	1421	1718	3342	171	20	1424	216	12415	1074	6223
Near natural fen	0	0	0	21	0	0	15	14	0	0	2	5	106	0	7
Rewetted bog	0	0	40	84	337	0	26	97	21	114	763	29	553	62	2199
Other modified peatland	131	365	562	1748	1649	816	1292	1418	143	86	2717	112	18065	1817	6954



SM Figure 20b. National Forest Inventory (2023).



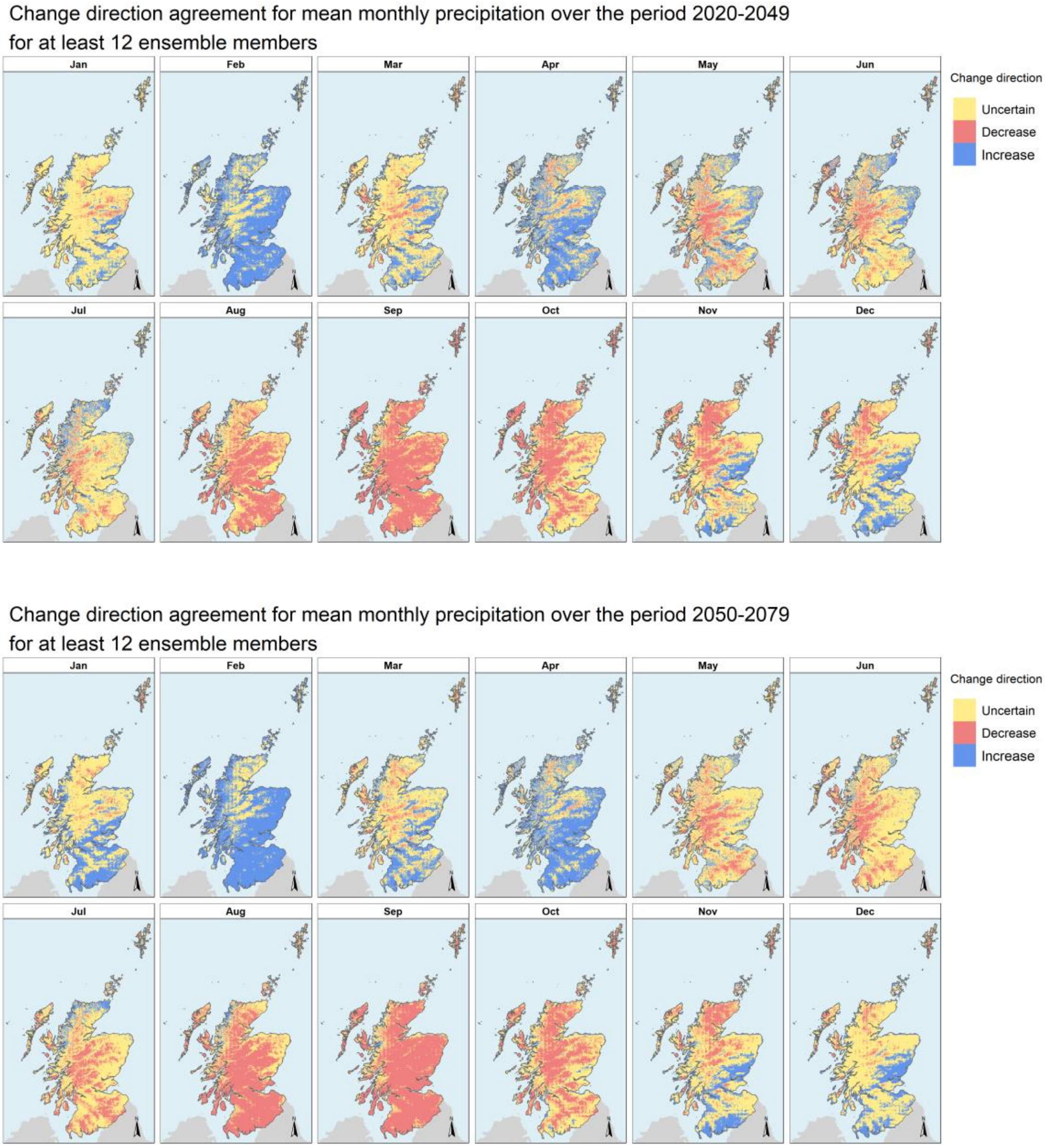
SM Figure 21 UK-CEH Land Cover Map (left) and Space Intelligence SLAM-MAP habitat maps of Scotland



SM Figure 22. Existing riparian woodland (NatureScot data).

NatureScot (2023) Riparian Woodland Scotland.
https://spatialdata.gov.scot/geonetwork/srv/eng/catalog.search#/metadata/ac10398e-a9ec-427f-bd9f-116582e95c0d
"Riparian woodland in Scotland identified using a combination of existing open datasets. Search area is 20m either side of water courses. Includes coniferous and broadleaved woodland, native and non-native."

Climate Projections

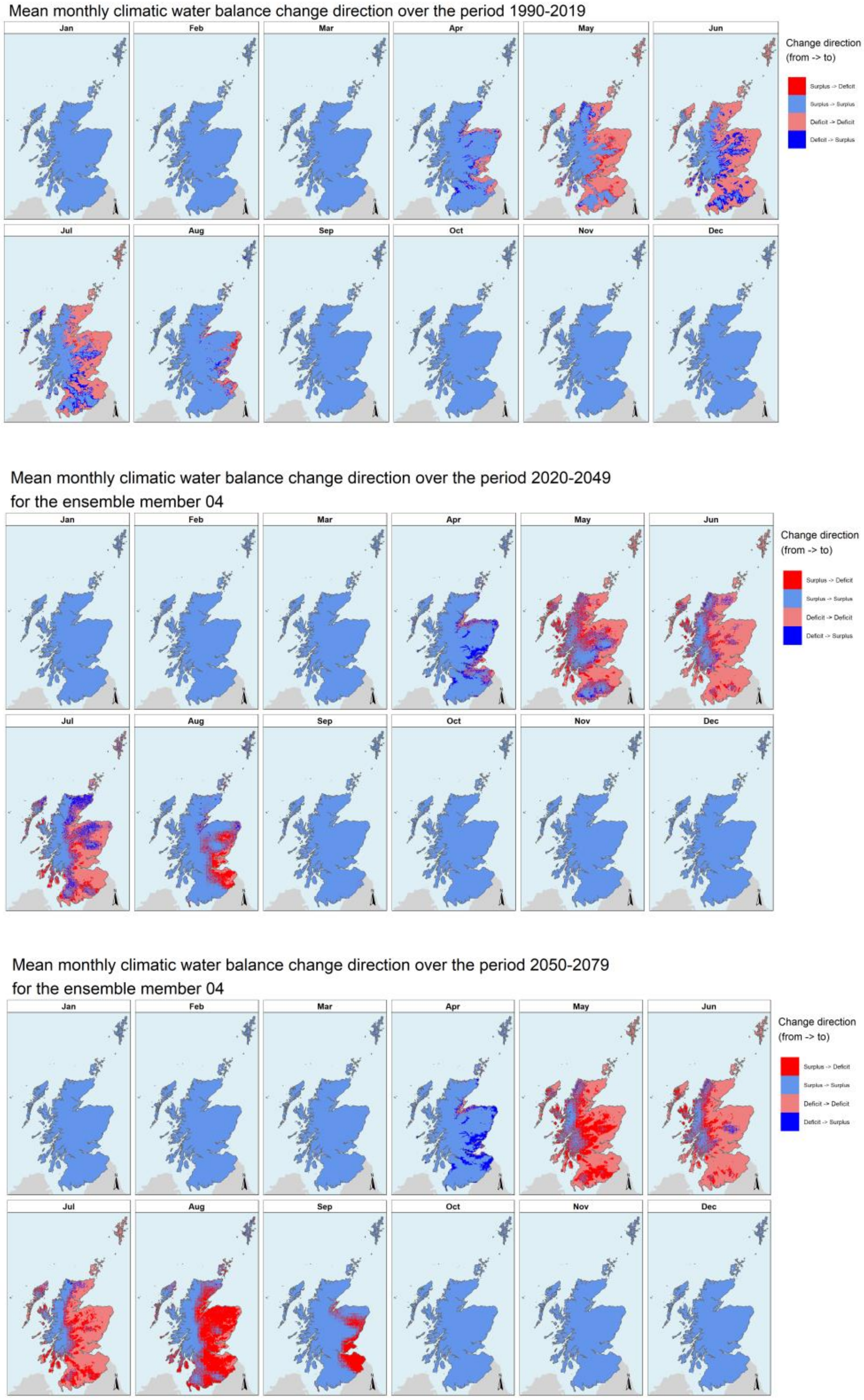


SM Figure 23. Agreement maps for all 12 UKCP18 climate projections on the direction of change in mean monthly precipitation for the 2020 – 2049 (top) and 2050 – 2079 (bottom) periods, compared to the 1960-1989 baseline.

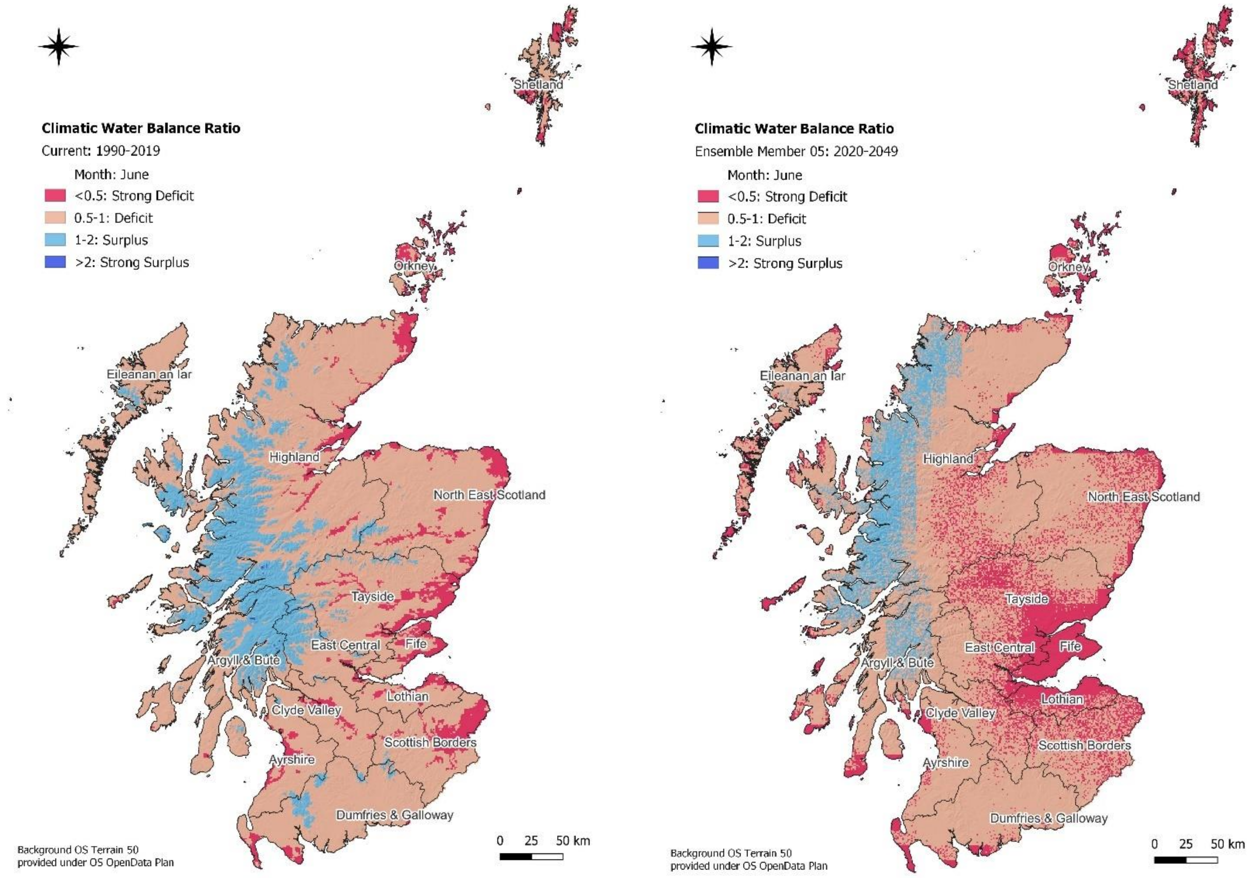
SM Figure 23 shows the agreement in either having an increase or decrease in precipitation for 12 climate projections (UKCP18). This approach provides more confidence in the probabilities of estimated future climates. There is general agreement for most of Scotland that September may experience a decrease in precipitation. Similarly, February is likely to see an increase. Yellow areas in represent locations where there is no agreement between the projections (e.g. some indicate increases, other decreases). For January, there are few areas where there is agreement for the 2020 – 2049 period, but this shifts towards agreement that southern Scotland is likely to see an increase in precipitation.

It is worth noting that the level of agreement between projections increases in the 2050 – 2049 period for some months, e.g. the 'uncertain' (yellow) areas in August and September in Figure 23 are less than for the 2020 – 2049 period, but decreases for others (e.g. June).

Climatic Water Balance (Precipitation – Evapotranspiration)



SM Figure 24. Changes in direction of mean monthly Climatic Water Balance (Precipitation – Evapotranspiration). Top: changes between 1960-198 baseline) and 1990-2019; Middle and bottom: example of changes from baseline and projected 2020-249 and baseline and 2050-2079, respectively (UKCP18 no. 04). Change direction: dark red = surplus to deficit; light red = deficit to deficit; dark blue = deficit to surplus; light blue = surplus to surplus.



SM Figure 25. Climatic Water Balance Ratio for the period 1990-2019 (left) and an example estimated using the UKCP18 (projection 04) for the 2020-2049 period.

SM Figure 24 shows the changes in the Climatic Water Balance indicator (CWB), which is the difference between precipitation and reference evapotranspiration (ET_0). This can be used to indicate whether a location may experience a shift from water surplus to deficit, or deficit to surplus.

The Climatic Water Balance ratios (CWR) provides more information in respect of the quantity of water, and is defined as the ratio of Precipitation (P) to (ET_0):

$$CWB\ ratio = \frac{P}{ET_0}$$

This approach can be used to both identify surpluses and deficits; CWR ≥ 1 denote climatic water surpluses while CWR < 1 denote climatic water deficits, but it also provides the magnitude of these surpluses or deficits; for example, CWR value above 2 indicates a strong or extreme climatic water surplus because precipitation is two times higher than evapotranspiration.

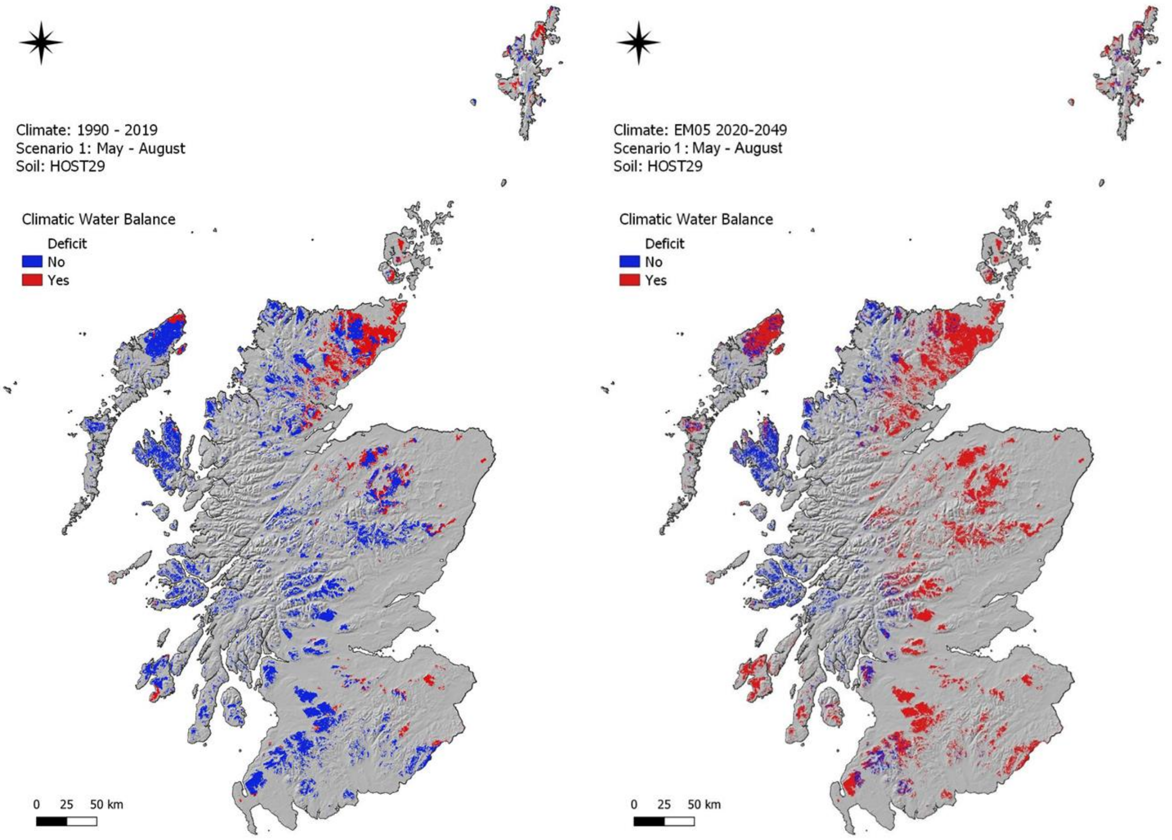
SM Figure 21 uses the following four classes of CWR levels: CWR < 0.5: Severe climatic water stress, precipitation covers 50% of the evapotranspiration demand); CWR between 0.5 and 1 (moderate climatic water stress); CWR between 1 and 2 (moderate climate water surplus); and CWR > 2 ('extreme' climatic water surplus).

For further details see: https://www.hutton.ac.uk/wp-content/uploads/2024/03/Assessment-of-Natural-Capital-asset-exposure-to-current-and-future-meteorological-drought-Report-D21d-D23c.pdf

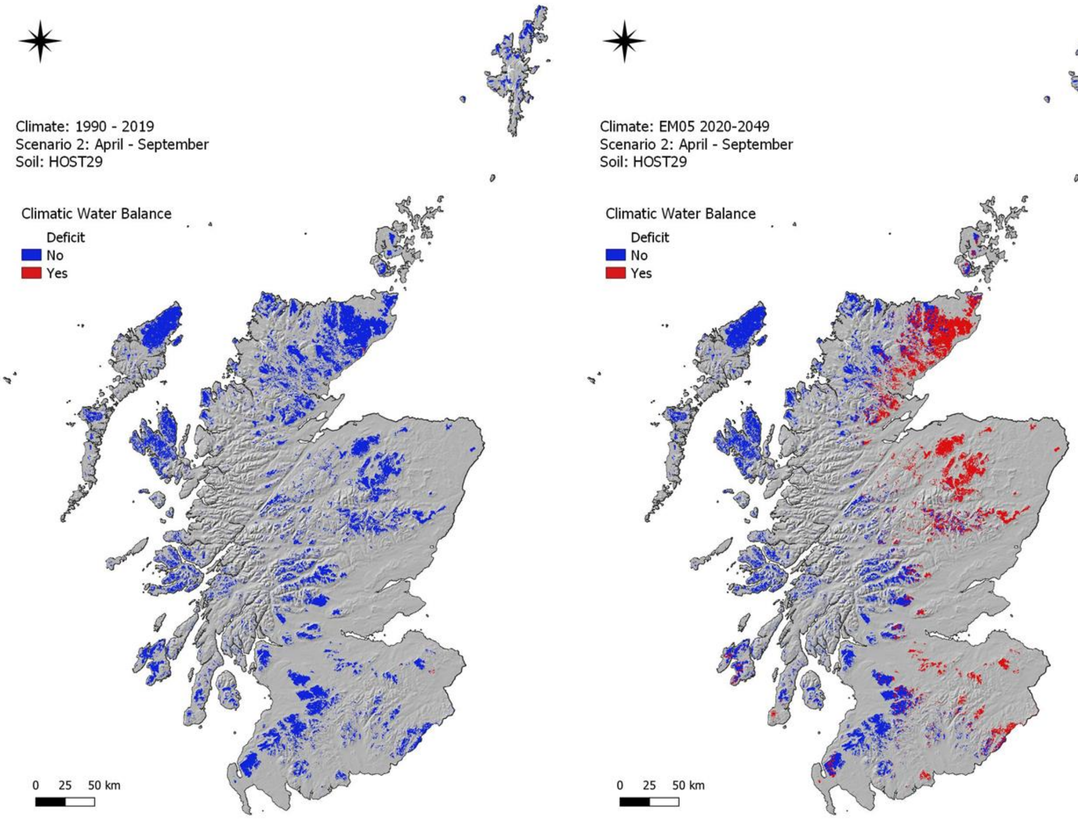
SM Figures 24 and 25 are available for other UKCP18 climate projections.

These CWR layers have been used to assess the exposure of upland blanket peat to observed (1990 - 2019) and future (2020 - 2049) meteorological drought and to assess potential effects on water table levels in relation to regulation of greenhouse gas (GHG) emissions. (Gagkas et al., 2024). Areas of peat soil were derived from a digital soil map of Scotland (Gagkas and Lilly, 2024) translated to Hydrology of Soil Types (HOST) class 29 (Upland Blanket Peat), and covered 10,624 km2 (or ~14% of Scotland's area). Exposure was assessed by spatially overlaying the HOST class 29 map with monthly data layers of CWR calculated using 1 km interpolated gridded observed climatic data and UKCP18 climate projection daily climatic data for the 'high emissions' scenario (RCP8.5). A single future climate scenario, Ensemble Member 5 (EM05), was used, which represents a drier climatic scenario compared to the baseline period (1960 - 1989) in terms of mean annual precipitation.

Based on this analysis, a mapping assessment was conducted to identify areas of upland blanket peat under continuous climatic water deficits (based on observed and future monthly CRW averages) for the May to August (Scenario 1 (S1)) and the April to September (Scenario 2 (S2)) periods (SM Figures 26 and 27, respectively). This analysis found that for the observed period (1990 - 2019), 2,460 km2 (~20% of the upland blanket peat area) was exposed to continuous water stress in the May to August period (S1), and only a small area (13 km2) in the April to September period (S2). However, when the EM05-based future climate (2020 - 2049) was considered, upland blanket peat soil areas under continuous water deficit from May to August and from April to September greatly increased to 7,851 km2 and 4,027 km2, respectively, representing 74% and 38% of all areas, respectively. These comprised of extensive areas of upland blanket peat in the Flow County, the Isle of Lewis, the Cairngorms, and the Southern Uplands, that were projected to be in continuous water stress based on one plausible future climate for S1, with the exception of peat areas in northwestern Highlands, the Isle of Skye, and the Isle of Mull (SM Figure 26). Peat soil areas under continuous climatic water stress for the longer period from April to September were mainly found in the eastern part of Scotland (SM Figure 27).



SM Figure 26. Maps of Upland Blanket Peat (HOST class 29) based on Scenario 1: Continuous climatic water deficit from May to August, for the observed (1990 – 2020) period and future (2020 – 2049) period for Ensemble Member (EM) 05.



SM Figure 27. Maps of Upland Blanket Peat (HOST class 29) based on Scenario 2: Continuous climatic water deficit from April to September, for the observed (1990 – 2020) period and future (2020 – 2049) period for Ensemble Member (EM) 05.

In periods of climatic water surpluses and if there is potential for storage in the peat's saturation zone, the distance from the surface of the soil to the water table can potentially be reduced, with potential positive effects related to the reduction of GHGs emissions. However, prolonged climatic water deficits could lead to further depletion of water in the water table that may favour the release of GHGs from the surface soil layer.

Eroded and degraded peat is more vulnerable to climatic water deficits. Prevention of methane emissions by Sphagnum covering ponds may become reduced if they dry out. Therefore, these results highlighted the importance of restoring and/or maintaining bogs in good condition (i.e., fully saturated) because this can maintain and/or improve the resilience of peat soils to climatic water deficits and improve the provision of their climate regulation services.

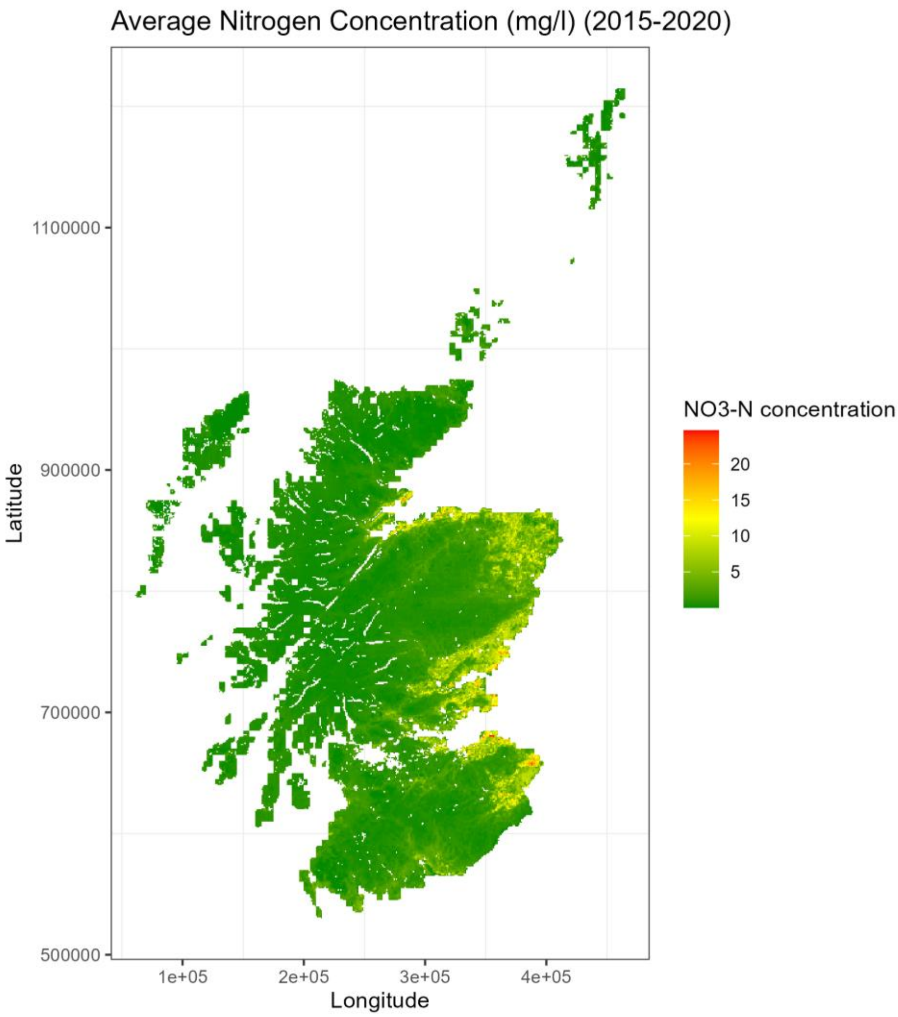
This analysis was based on the climatic projections of a single Ensemble Member (EM05), considered to represent more prolonged dry conditions, but not necessarily the most intense dry ones. Moreover, the results presented here are the means for the period, hence do not represent the extreme individual years. Using a different climate projection would alter the magnitude of climatic water balance shifts presented here, and hence the levels of exposure; however, there is strong agreement between different projections with regards to the direction of change in climatic water balance in Scotland. This provides confidence in the assumption that can be made based on the findings of this analysis.

Climatic Water Balance References:

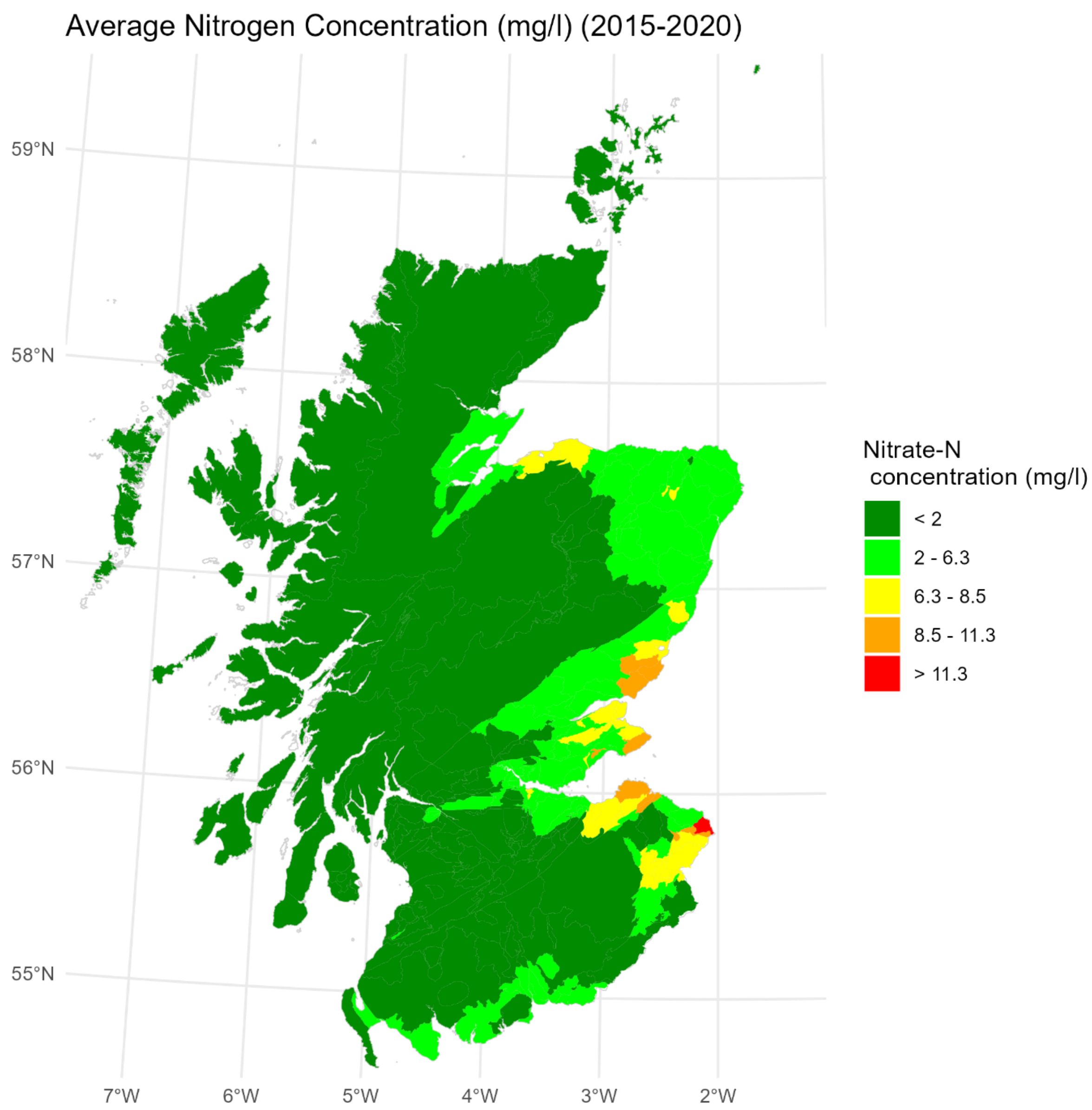
Gagkas Z., Jabloun M., Rivington M., Aitkenhead, M. (2024). Deliverable 2.2a Climate change effects on soil properties and functions: the case of soil water balance. The James Hutton Institute, Aberdeen. Scotland. https://zenodo.org/records/11210904

Gagkas, Z., Lilly, A. (2024) Spatial disaggregation of a legacy soil map to support digital soil and land evaluation assessments in Scotland, Geoderma Regional, 38, Art. E00833. https://doi.org/10.1016/j.geodrs.2024.e00833

Nitrogen concentrations



SM Figure 28. Average Nitrogen Concentration (mg/l) in water courses estimated using the NIRAMS model for the period 2015-2020 at a 1km resolution.



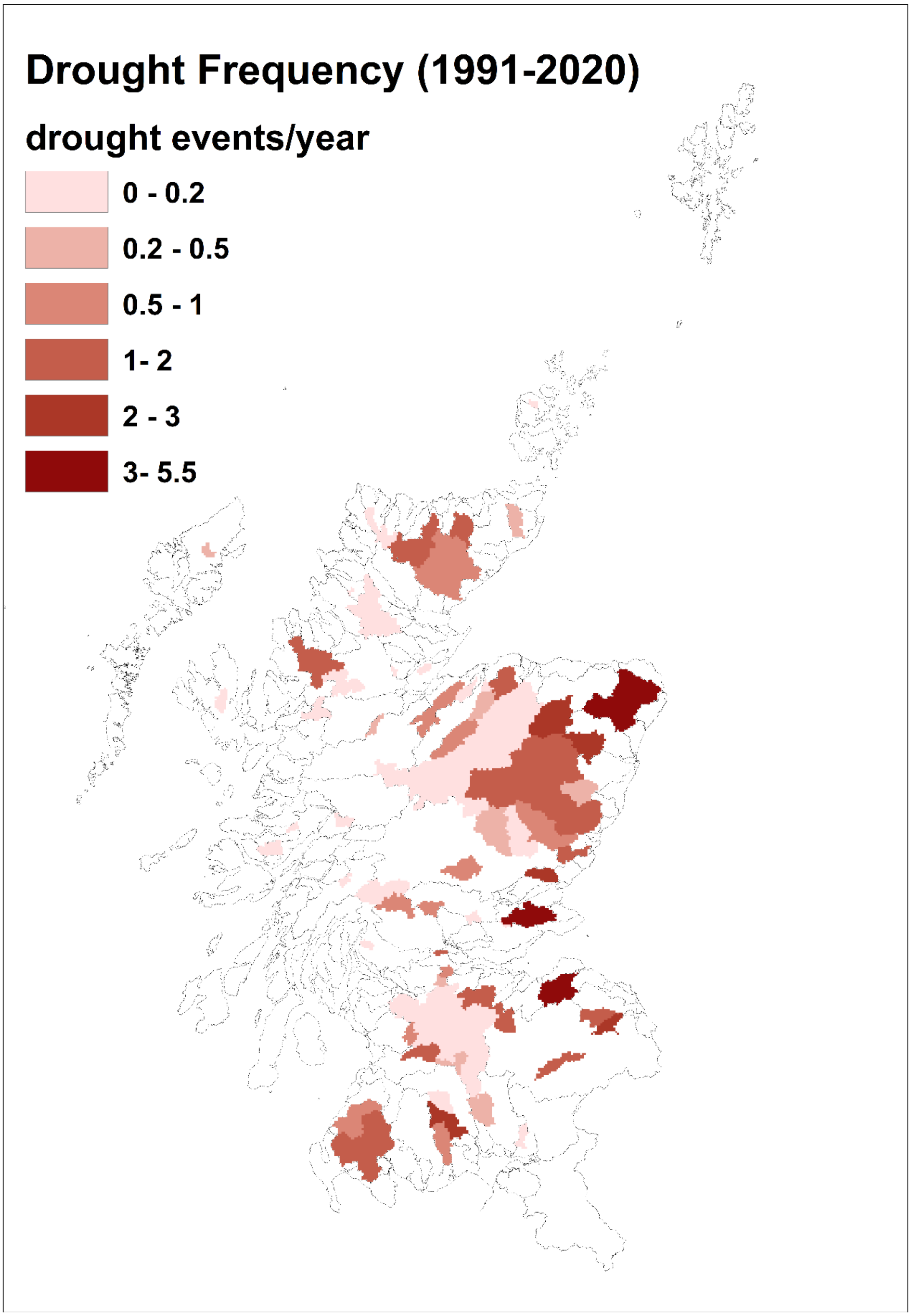
SM Figure 29. Average Nitrogen Concentration (mg/l) in Groundwater Bodies (GWB) estimated using the NIRAMS model for the period 2015-2020.

Drought metrics computed using observed discharge data (RESAS D2-1 WP1)

A dataset of observed daily flow values for 81 hydrometric river level stations, examined for 1991-2020, to identify drought events. Every hydrometric river station had an associated Q95 threshold, which was calculated from the 5^{th} percentile of flow levels for that station during the period 1991-2020. The DRAT methodology assesses five-day mean flow levels for each station and when that value falls below the Q95 threshold, this is deemed low flow. After 30 consecutive days of low flow (below Q95 threshold), the station and its catchment area are said to be in significant water scarcity (drought event).

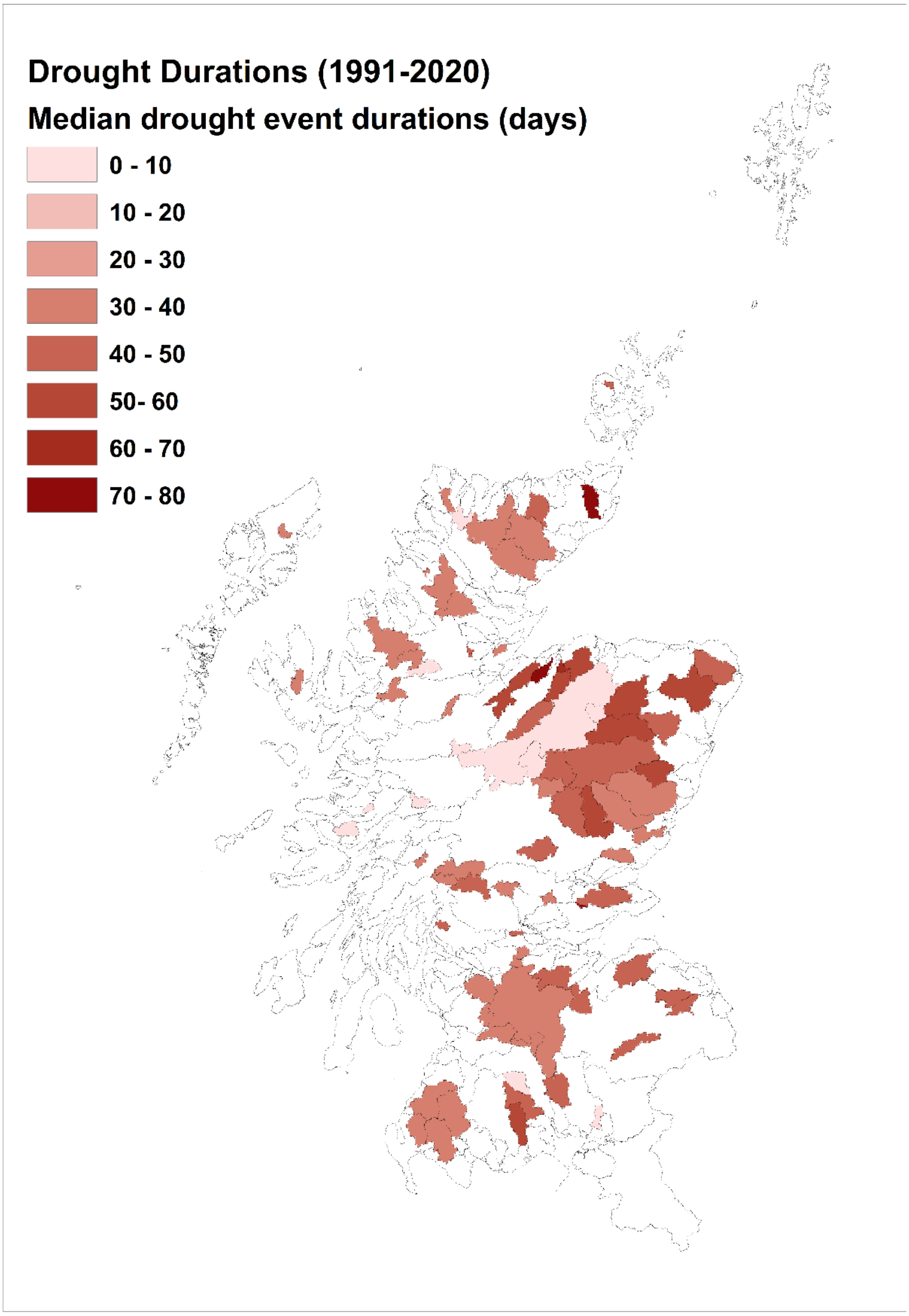
Reference: Glendell M, Schurch N., Frantsuzova A., Butler A., Naha S., Gagkas Z., Adams A. and Macleod K. (2023). Exploring the sensitivity of the Drought Risk Assessment Tool as part of the National Water Scarcity Plan Review in Scotland. The James Hutton Institute and Biomathematics and Statistics Scotland, Aberdeen, UK.

1. Drought Frequency (Number of drought counts (events)/year) at 81 DRAT sites



SM Figure 30. Drought frequency at 81 DRAT sites under scenario- 5 daily mean flow threshold falling below threshold Q95 computed for 30 years in historical period 1990-2020

2. Median Average Drought Durations (days) - Median of average drought duration values for each drought event



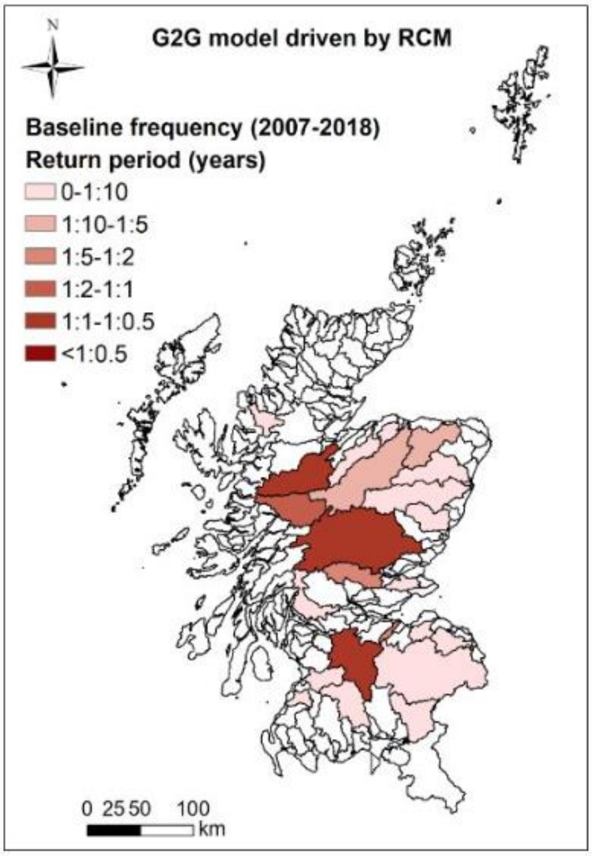
SM Figure 31 Drought Durations at 81 DRAT sites under scenario- 5 daily mean flow threshold falling below threshold Q95, computed for 30 years in historical period 1990-2020

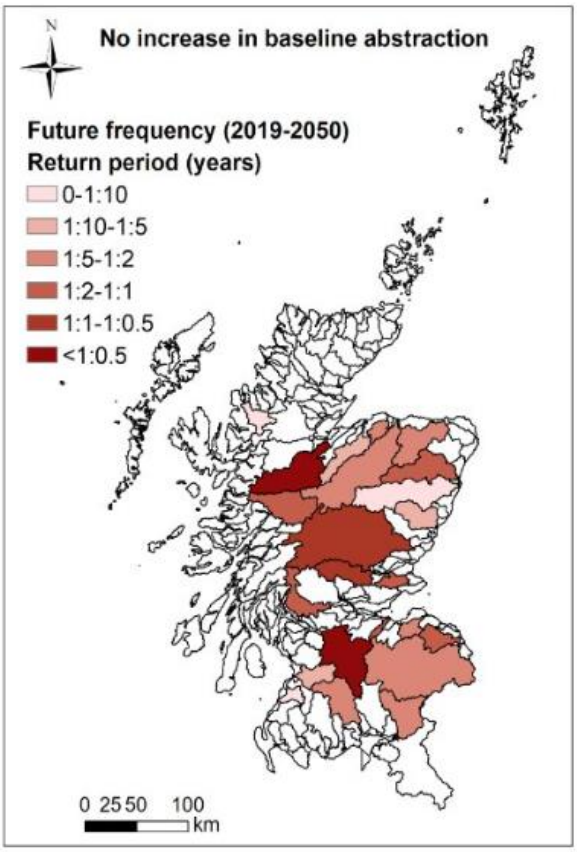
Potential drought frequency and durations based on modelled discharge and reported water use data at 23 catchments in Scotland (HNC/CREW project)

Reference: Miriam Glendell, Kirsty Blackstock, Kerr Adams, Jack Brickell, Jean-Christophe Comte, Zisis Gagkas, Josie Geris, David Haro, Mohamed Jabloun, Alison Karley, Laure Kuhfuss, Kit Macleod, Shaini Naha, Eleanor Paterson, Mike Rivington, Chloe Thompson, Kirsty Upton, Mark Wilkinson, Kirsten Williams (2024). Future predictions of water scarcity in Scotland: impact on distilleries and agricultural abstractors. CRW2023_05. Centre of Expertise for Waters (CREW).

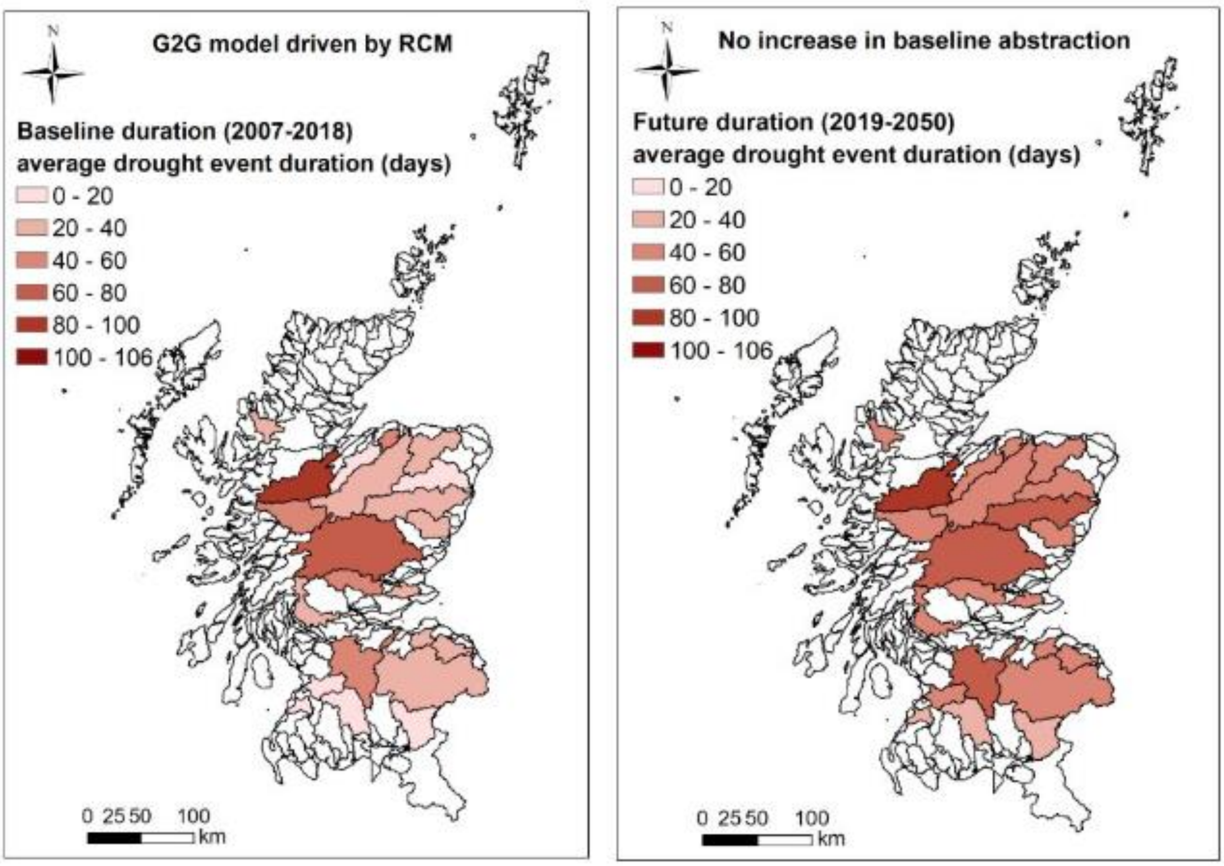
The drought profiling framework was adapted from an existing study to calculate the volume of water available after abstraction in 23 catchments with available abstraction (reported water use data) and modelled discharge data. Low flow events were defined as periods when the volume of available water, following actual abstraction, fell below the long-term Q95 threshold (i.e. flow that occurs less than 5% of the time). Following the drought definition from Scotland National Water Scarcity Plan (SEPA, 2020), we defined drought as an event when flow was below Q95 for 30-days or longer. We then calculated the frequency and duration of drought events for all scenarios across 23 catchments with available data. Frequency was defined as a number of droughts/year whilst Duration is a measure of the average event duration in days.

We found an increase in mean, minimum and maximum frequency and drought duration between the baseline (2007 – 2018) and future periods (2019 – 2050). Mean drought frequency increased from 0.33 to 0.65, while average drought duration increased from 31 to 51 days across the 23 study catchments. Up to 25% increase in historical abstractions is not anticipated to significantly affect future water availability across catchments in Scotland. Therefore, the observed increase in future drought duration and frequency can be primarily attributed to the hydrological model projections of decreased future flows.





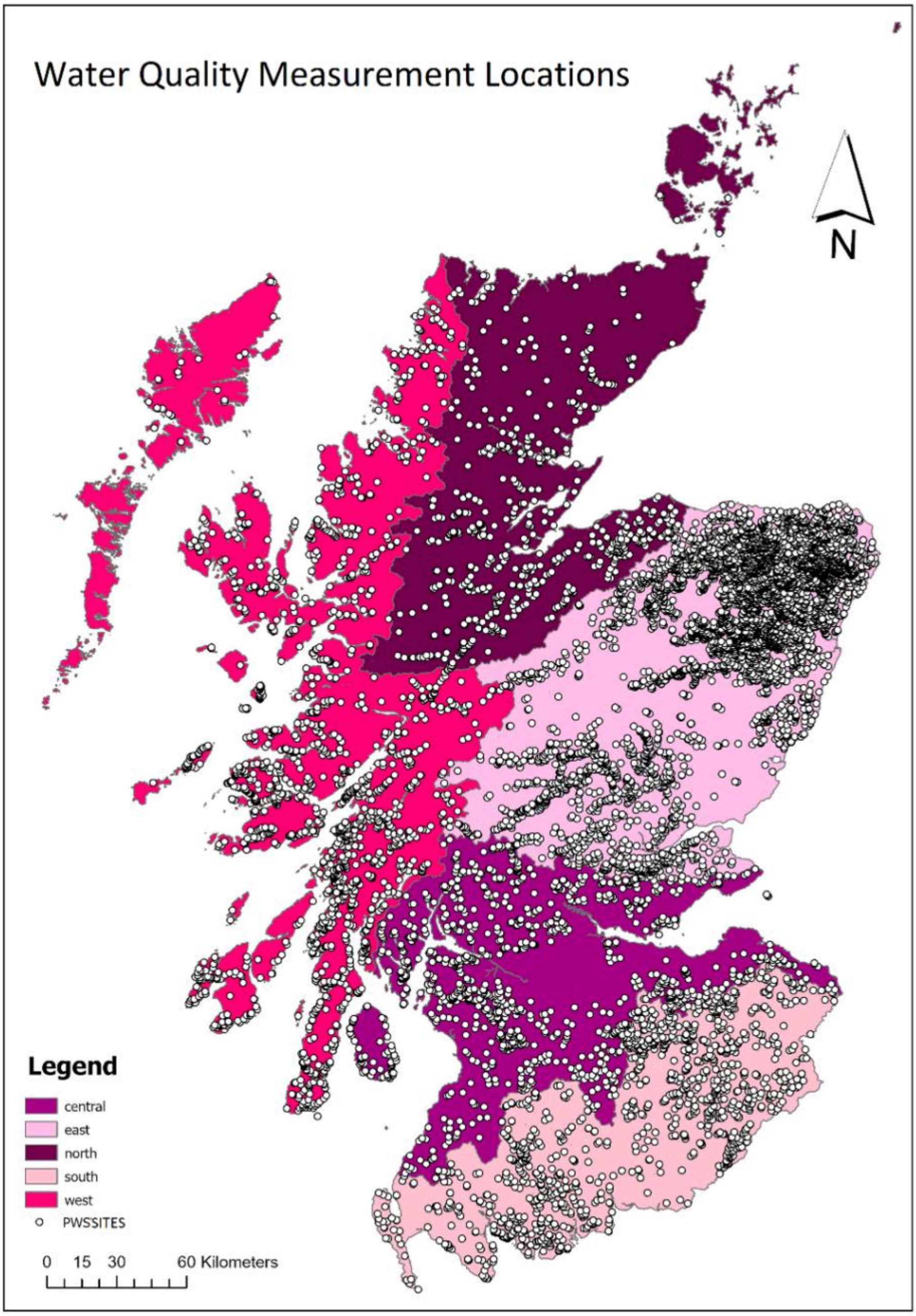
SM Figure 32 Drought frequency extracted from the drought profiling framework for the (left) historical period (2007–2018) driven by Grid-to-Grid (G2G) hydrological model simulated flows using RCM (Regional Climate model projections) and baseline abstractions (right) future (2019–2050) using G2G projected flows and baseline abstractions (reported water use data). Catchments in white were not included in the analysis due to lack of data. (0.1=1:10 years; 0.2=1:5 years; 0.5=1:2 years; 1=1 a year; 2= 2 a year)



SM Figure 33. Average drought duration (in days) extracted from the drought profiling framework for the (left) historical period (2007 – 2018) driven by (Grid-to-Grid hydrological model) G2G model simulated flows using RCM (regional climatic projections) and baseline abstractions (right) future (2019 – 2050) using G2G projected flows and baseline abstractions (reported water use data). Catchments in white were not included in the analysis due to lack of data.

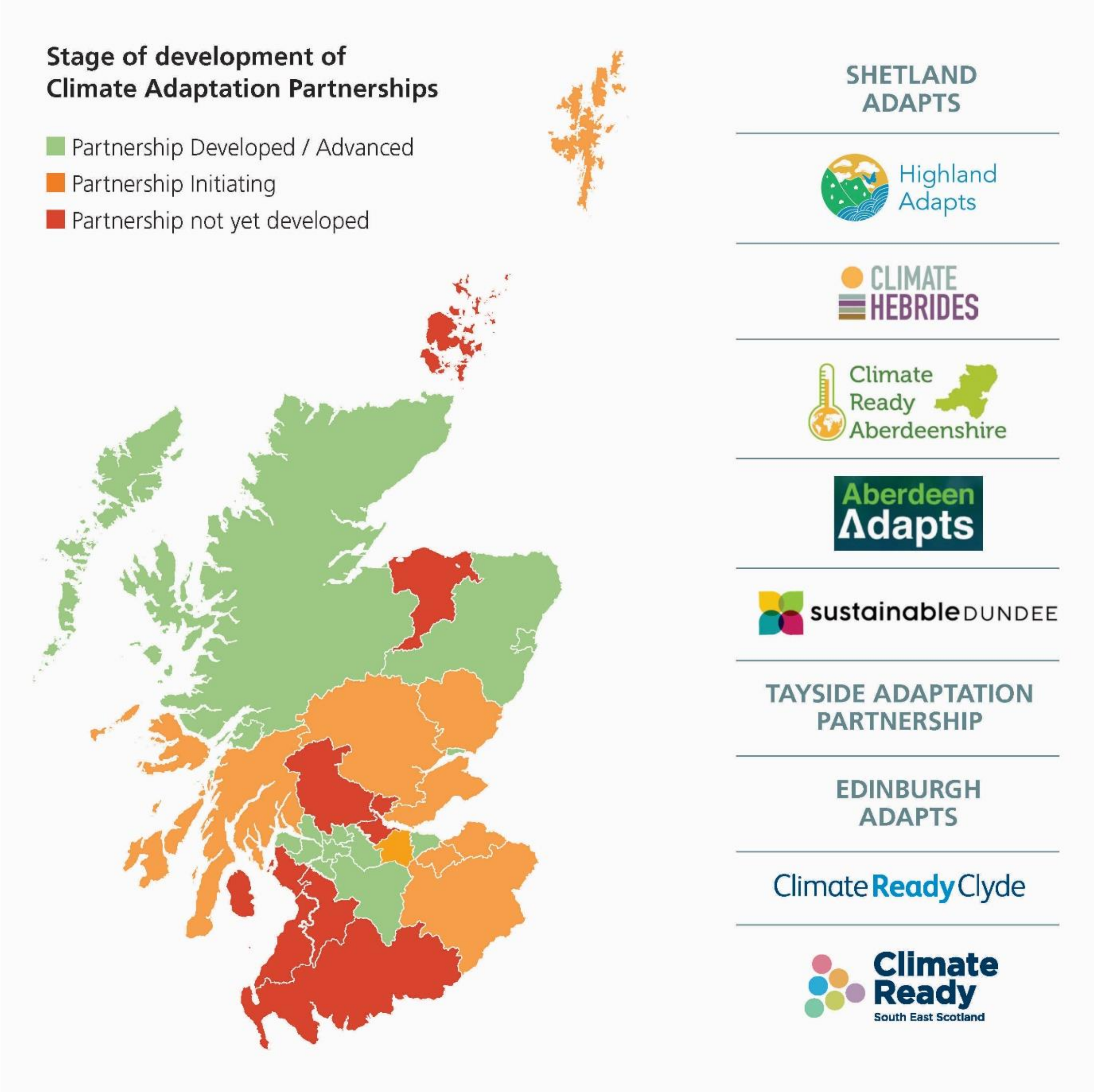
Private water supply locations

Reference: Pawar, S.K. (2024) 'Assessing the impact of Meteorological Droughts on Water Security in Scotland's Private Water Supplies', PhD thesis, University of Dundee.



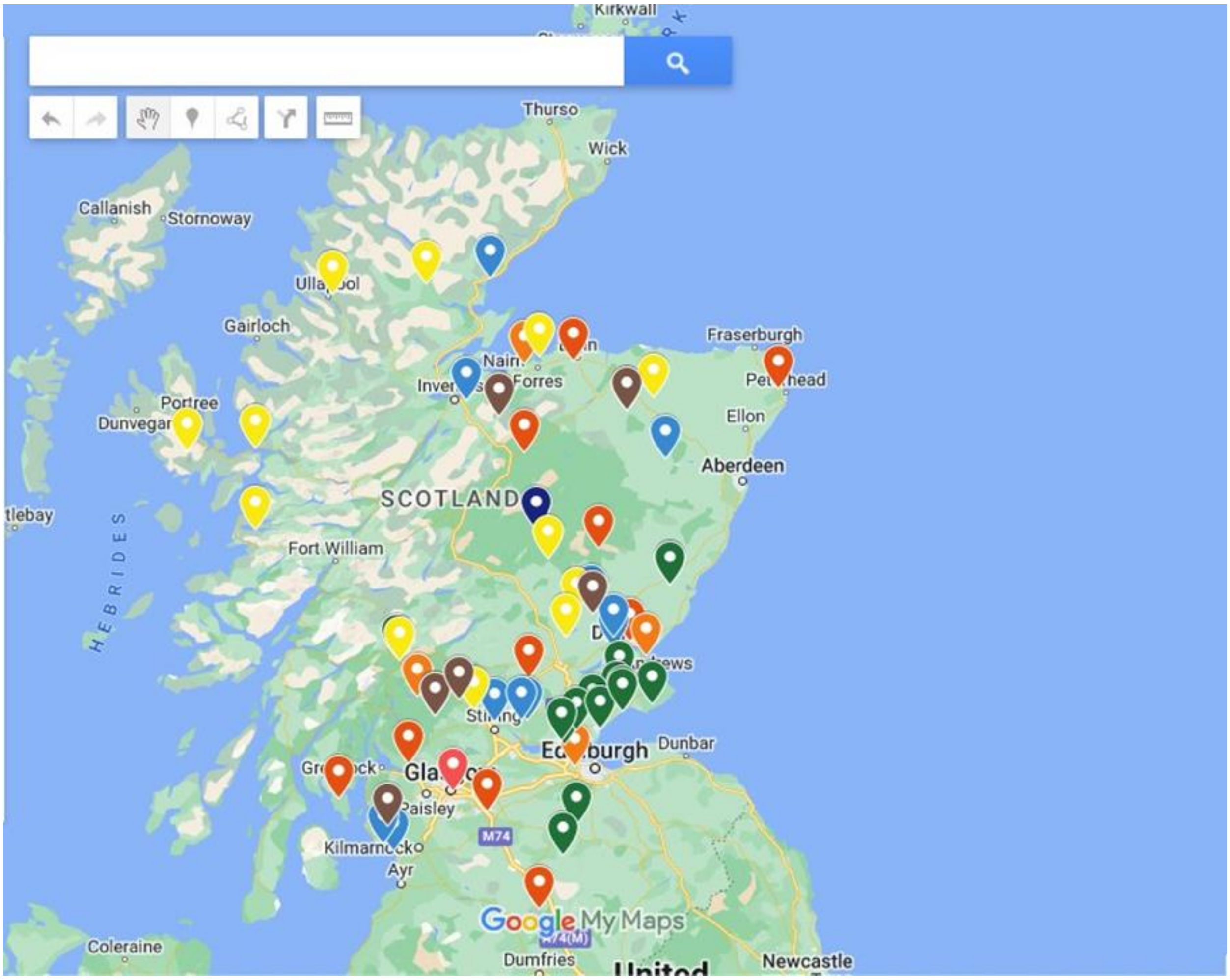
SM Figure 34. Map indicating locations of Private Water Supplies sampled for water quality from 2006-2018 in Scotland with roughly 34,000 sites.

Existing Initiatives (April 2024)



SM Figure 35. Existing Adaptation Partnerships in Scotland and their stage of maturity.

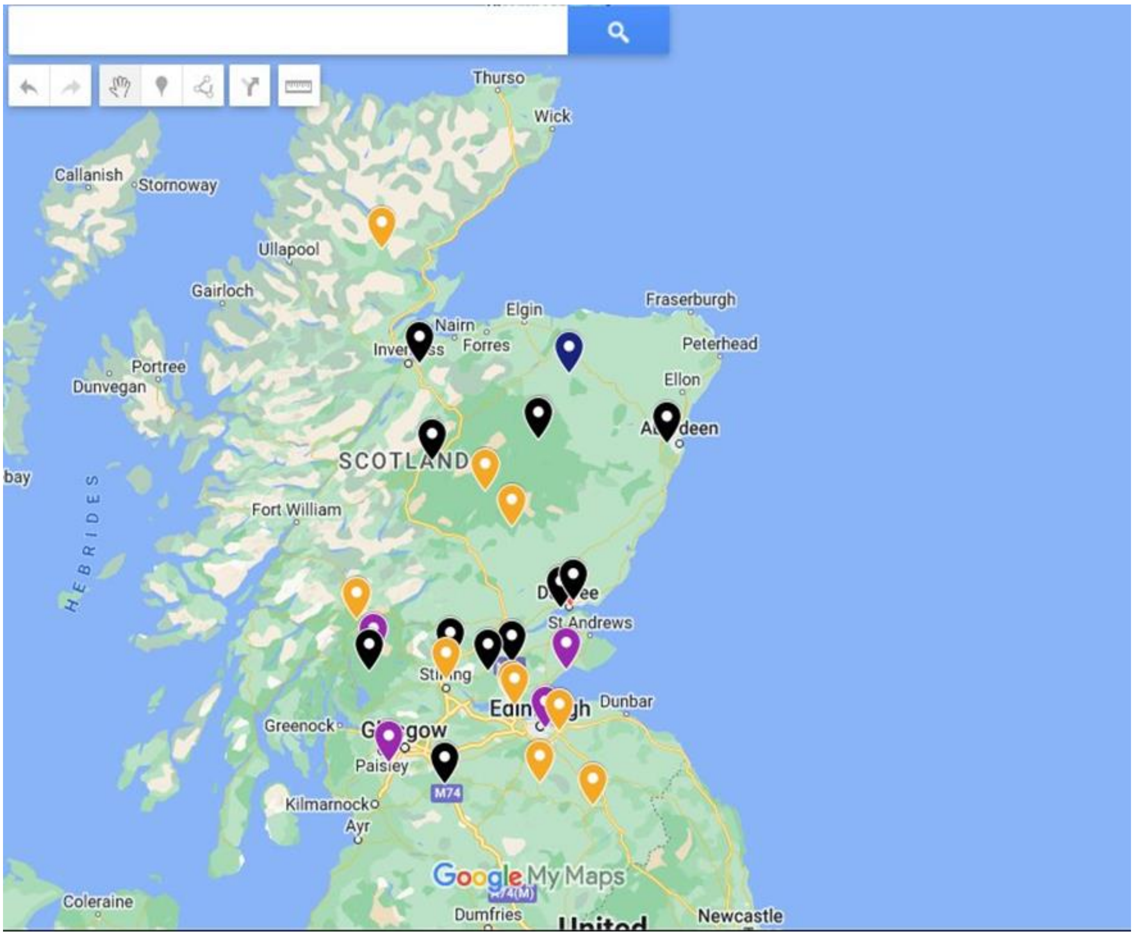
Stakeholder Survey and Interviews



SM Figure 36. Locations where survey respondents identified climate risks. The colours relate to the respondent type / sector. Red - Public body/agency; Blue – Local Authority; Purple – landowner; Green – NGO; Yellow – Rivers Trust

The locations of identified climate risks (SM Figure 36) and nature restoration projects in progress (SM Figure 37) provided by the survey respondents were mapped as far as possible using GoogleMyMaps. This data was made compatible with GIS by converting the longitude and latitude information from the survey respondents to a 12 fig grid ref from Ordnance Survey. The outputs of this were layered onto the GIS map to provide a shared perspective of climate risk, both from a scientific data perspective, and from reflections and experiences of organisations and people on the ground.

* Catchments identified in key informant interviews related to climate risk or areas of proposed or active nature based solution projects were not represented as data points in the spatial maps as they were collated and shared with project partners after the spatial maps were created by JHI. They include climate risks identified in the Clyde (NHS Scotland Assure), the Dee (Scottish Water) and the Forth (Network Rail). This emphasises that the published report serves as a foundation for further conversation with infrastructure providers as a next step.



SM Figure 37. Locations that survey respondents identified that nature restoration projects were already being progressed. Again, colours are representative of respondent type / sector: Purple – Public body / agency; Black – Local Authority; Blue – Landowner; Orange – NGO.

Key caveats for the stakeholder maps

The maps produced of the locations identified through qualitative research are not necessarily wholly accurate, as exact locational data was rarely provided. Instead, they provide a relative distribution of the interpretation of climate risk and nature-based activities to mitigate impacts of those risks from diverse perspectives including NGOs, local authorities, public bodies/agencies and landowners.

The survey data overlay lacks consistency in scale, as locations provided by respondents varied from catchment names to individual sites. In addition, the sample lacks contributions from groups like landowners, several local authorities and infrastructure providers and NGOs/groups known to be delivering nature restoration projects. For many responses, risks were challenging to deduce to single locations. This variance should be considered when interpreting the maps. During follow up conversations on progressing nature restoration, the supplementary data from the survey outputs covering risk and project type as well as descriptive locational information should be used to inform a participatory approach to landscape scale restoration. We recommend NatureScot own this dataset and continues to contribute points of recognised climate risk and known nature-based solutions projects

While rich in information and context that has been shared with NatureScot, the interviews with key informants were limited in pinpointing specific locations of climate risk and adaptation strategies. For many, attempts to associate risk with specific places and assets was an ongoing endeavour. Once priority catchments have been identified and communicated, further conversations with infrastructure providers within priority areas should be encouraged.

Stakeholder Survey Questions

1. Has your organisation identified locations that are vulnerable to the impacts of climate change?
   If you answered Yes, please tell us:
   - How you did this
   - What types of risks you identified
   - Where you identified them (please provide a grid reference or a detailed location description)

2. Has your organisation already explored the potential for nature restoration to reduce identified climate risks? For example, peatland restoration, woodland creation, natural flood management, SuDs schemes/raingardens.

3. Has your organisation identified any priority locations for nature-based climate adaptation?
   If so, where? Please provide a grid reference or a detailed location description.

4. What type of nature restoration do you think is required to address the climate risks your organisation is facing (either identified or anticipated)?

5. Are you already progressing any nature-based climate adaptation projects?
   If so, where? Please provide a grid reference or a detailed location description.

6. If you haven't explored the potential for nature restoration to reduce risks yet, would your organisation be interested in collaborating with others to deliver nature restoration for climate adaptation?
   If yes, who would be the best person to contact about this? Please provide a name and email address.

7. Would your organisation be able to contribute towards the cost of nature restoration in the prioritised locations?

8. What do you think the blockers are to delivering nature restoration in your priority locations? For example, funding, knowledge and skills, awareness of options, policy, regulation etc.

9. What has been the driver for the use of nature restoration to address climate risks? For example, policy / regulation, cost, improvements to place, biodiversity or climate duties.

10. Please provide your name and the organisation you have responded on behalf of
    Name
    Company

Survey respondents

Local authorities

- Stirling Council
- Clackmannanshire Council (x2)
- Aberdeen City Council
- Perth and Kinross Council
- Inverclyde Council
- Midlothian Council
- Aberdeenshire Council
- The Highland Council
- Fife Council
- Dundee City Council
- Glasgow Clyde Valley Green Network (Glasgow City Region)
- North Ayrshire Council

Public bodies / agencies

- The Scottish Parliament
- Historic Environment Scotland
- Forestry and Land Scotland
- SSEN Distribution
- SEPA
- Water Environment Fund (SEPA)
- Scottish Water

NGOs

- Findhorn, Nairn, and Lossie Rivers Trust (x2)
- Bioregioning Tayside
- Learning Through Landscapes
- Tweed Forum
- Loch Lomond and the Trossachs Countryside Trust
- Wester Ross Fisheries Trust
- Morar Salmon Fishery Sub-Board, and Scamadale
- Tweed Forum / Dundee university
- Dee District Salmon Fishery Board
- The Deveron, Bogie and Isla Rivers Charitable Trust
- West Sutherland Fisheries Trust
- Forth Rivers Trust
- The Tweed Foundation
- Fisheries Management Scotland
- Tay Rivers Trust
- Skye and Lochalsh Rivers Trust
- Fife Coast and Countryside Trust
- Kyle of Sutherland Rivers Trust
- River South Esk Catchment Partnership/Angus Council

Landowners

- Edinglassie Estate
- Welbeck Estates

Note: Landowners were not specifically targeted for the survey, though the wide promotion of the survey meant that some did decide to respond to it. Engagement with landowners is a key next step to this project, and they will be involved in the discussions about potential project and partnership development.

Unknown: 6

Survey responses by organisation type: summary information

Priority Landscapes — **Organisation type**

Local authorities (13)

Who submitted a response

- Stirling Council
- Clackmannanshire Council (x2)
- Aberdeen City Council
- Perth and Kinross Council
- Inverclyde Council
- Midlothian Council
- Aberdeenshire Council
- The Highland Council
- Fife Council
- Dundee City Council
- Glasgow Clyde Valley green network
- North Ayrshire Council

Common forms of climate risk

- Flooding (9)
- Erosion (2)
- Nature depletion (3)
- Infrastructure (2)
- Heat in urban areas / lack of shade (2)

Which types of locations have been identified as being at risk?

At various scales:

- Urban areas
- Specific neighbourhoods
- Specific assets, infrastructures and the built environment (bridges)
- Catchment wide
- Shorelines

Common forms of nature restoration

- Tree planting and increasing canopy cover
- Natural flood mgmt.
- Peat restoration
- Woodland creation
- Nature based blue/green infrastructure in urban environments including SuDS
- Habitat connectivity
- Dune restoration

Which types of locations have been identified for nature restoration?

- City regions (districts within city regions)
- Flood prone zones
- Whole catchments

Drivers

Policy & regulation: Strong policy and regulation are leading drivers for nature restoration for LAs. Obligations around climate duties push action.

Cost: Cost-effectiveness plays a key role, with nature-based solutions often seen as the most cost-efficient approach compared to engineered solutions.

Opportunities for collaboration and funding: Availability of funding, such as the Peatland Restoration Fund, and support from organizations like the Green Action Trust, enable collaboration on nature restoration projects. This support helps integrate nature-based solutions alongside traditional methods.

Place-based Improvements: For this group there is a focus on improving local places, with clear evidence showing that nature-based interventions directly benefit communities. This is critical in gaining council and community support for such initiatives.

Priority Landscapes

Organisation type

Public bodies/agencies (7)

Who submitted a response

- The Scottish Parliament
- Historic Environment Scotland
- Forestry and Land Scotland
- SSEN Distribution
- SEPA
- Water Environment Fund (SEPA)
- Scottish Water

Common forms of climate risk

- Flooding (5)
- Drought (2)
- Destabilisation of riverbanks and slopes (2)
- Erosion (coastal) (1)

Which types of locations have been identified as being at risk?

At various scales:

- From bespoke (applicable in areas of high archaeological sensitivity) to community scale to catchment level
- Specific communities: 452 community scale PVAs and 'influencing' areas. Each PVA has been attributed an influencing catchment to embed the catchment / coastal zone approach to flood risk management.
- Specific assets– sites, properties in care, substations

Common forms of nature restoration

- Natural flood mgmt
- Peatland restoration
- Riparian interventions
- Dune restoration

Which types of locations have been identified for nature restoration?

- Rivers
- Coasts
- Parks
- Forests
- Peatlands

Drivers

Duties for public bodies: Key factors include climate change duties for public bodies and public expectation.

Biodiversity: A driving factor, possibly related to conservation goals, regulatory compliance, or sustainability efforts.

Policy & costs: Focus on securing private investment, improving specific locations and balancing priorities like biodiversity and climate change.

Internal policy: Aiming for lower costs than traditional "grey" infrastructure solutions while meeting biodiversity goals and Net Zero carbon targets.

Priority Landscapes

Organisation type

NGOs (20)

Who submitted a response

- Findhorn, Nairn, and Lossie Rivers Trust (x2)
- Bioregioning Tayside
- Learning Through Landscapes
- Tweed Forum
- Loch Lomond and the Trossachs Countryside Trust
- Wester Ross Fisheries Trust
- Morar Salmon Fishery Sub-Board, and Scamadale
- Tweed Forum / Dundee university
- Dee District Salmon Fishery Board
- The Deveron, Bogie and Isla Rivers Charitable Trust
- West Sutherland Fisheries Trust
- Forth Rivers Trust
- The Tweed Foundation
- Fisheries Management Scotland
- Tay Rivers Trust
- Skye and Lochalsh Rivers Trust
- Fife Coast and Countryside Trust
- Kyle of Sutherland Rivers Trust
- River South Esk Catchment Partnership/Angus Council

Common forms of climate risk

- Flooding (12)
- Increase in water temperature (9)
- Loss of biodiversity / nature depletion (8)
- Drought (5)
- Erosion (coastal (2) and river (2) (4)
- Risks to infrastructure

Which types of locations have been identified as being at risk?

Not something restricted to single locations:

- Catchment scale with focus on upper reaches and their impacts downstream
- City centres
- School grounds

Common forms of nature restoration

- River restoration (catchment fertility, improve flow)
- Riparian woodland restoration
- Woodland creation (upland land management, ancient woodland, reduction in browsers)
- Peatland restoration
- Wetland creation
- Management of non-native invasive species

Which types of locations have been identified for nature restoration?

- Upland tributaries.
- Agricultural lands
- Villages
- City centres

Drivers

Specific species protection: Focus on protecting wild Atlantic salmon and the broader fishery, with an emphasis on ecosystem health as an indicator.

Moral responsibility: to address the biodiversity and climate crises.

Community impact and economic considerations: Emphasizing the social and economic impact of not addressing biodiversity and climate needs.

Funding and collaboration: Opportunistic use of various funding streams to support nature restoration projects.

Policy integration and partnership: Successful integration of climate and biodiversity policies through functional, multi-partner collaboration, catchment planning, and land management strategies.

Note: Landowners were not specifically targeted for the survey, though the wide promotion of the survey meant that some did decide to respond to it. Engagement with landowners is a key next step to this project, and they will be involved in the discussions about potential project and partnership development.

Priority Landscapes

Organisation type

Landowners (2)

Who submitted a response

- Edinglassie Estate
- Welbeck Estates

Which types of locations have been identified as being at risk?

At the estate level

- Catchments
- Waterways

Which types of locations have been identified for nature restoration?

- Catchments
- Waterways

Drivers

Urgency: observing changes happening on land

Availability of funding: drives actions like tree planting and blocking ditches. Current funding is believed to be too stringent and doesn't allow for experimentation.

Common forms of climate risk

- Flooding
- Increase in water temperatures

Common forms of nature restoration

- Remeandering of water courses
- Installations of ponds/floodplains to slow water movement
- Riparian woodlands
- Peatland restoration

Priority Landscapes

Organisation type

Unknown (6)

Who submitted a response

NA

Which types of locations have been identified as being at risk?

- Target neighbourhoods
- Urban areas (x2)
- Areas identified through SEPA flood risk mapping

Which types of locations have been identified for nature restoration?

- Rivers
- Urban areas in connection to other projects like active travel programmes and Liveable neighbourhoods

Common forms of climate risk

- Flooding (5)
- Increase in water temperatures
- Poor health outcomes
- Costal erosion
- Biodiversity loss

Common forms of nature restoration

- Peatland restoration (2x)
- Grassland restoration
- Wetland restoration
- SuDS
- Peatland restoration
- Tree planting

Drivers

Key Informant Interview Questions

Section 1: Background information

1.Can you tell us more about you, your role and the organisation you work for. How does your company operate?

2. Where do you operate (geographically)?

3. What general challenges is your organisation facing now? Do you think any relate specifically to climate change?

Section 2: climate risk

1. How do you currently understand climate risk?

2. What are your highest priority risks? How were these identified? Where are they located?

    a. Did you have sufficient information to build your understanding of climate risk?

3. Are these risks known and shared by others within the organisation? How are they used?

4. As an infrastructure operator, we're keen to understand where you have assets or plan to have assets in the near future. We understand some of these locations you cannot share but can you reflect on locations of assets, climate risk and any proposals you have to mitigating these risks?

    a. Are there specific types of geographic areas or landscapes that you believe are vulnerable to climate risks (ie urban areas, specific communities, a specific river)

5. Do you understand the cascading impacts of these risks?

6. Do you report these risks publicly? [Public Bodies Climate Changes Duties Reporting, ISSB]

a. If not, why?

Section 3: Nature based solutions

We are particularly interested in understanding how your organisation is prioritising investment in and using nature-based solutions to mitigate climate risks. We define nature based solutions as actions that protect, manage, or restore natural ecosystems.

1. In your organisation, what types of nature restoration / nature-based solutions have been identified?
    a. How many of these have been implemented?
    b. In which types of landscapes have these been implemented?
    c. At what scale?
    d. Are you doing this in collaboration with others? Who?
2. What drives/motivates you to use nature restoration projects to address climate risk? (examples could include improving places, available funding policy/ regulation, cost effectiveness of NbS solutions, concern about a specific species)

3. What are the challenges you face in implementing NbS?
4. How are your climate adaptation and nature projects funded?
5. If your organisation willing to contribute financially to landscape scale nature projects with others?

Section 4: Close

1. What might incentivise more action in this area?
2. Is there anything else you would like to reflect on?

Key Informant Interview organisations:

Scottish Water, Climate Change Adaptation Technical Lead

Scottish Water, Business Strategy and Climate Change Manager

SSE Distribution, Sustainability Analyst

Scottish Government , Sustainability Manager

NHS, Sustainability Manager (Adaptation and Resilience)

Transport Scotland, Climate Change Manager

Network Rail, Weather Resilience and Climate Change Adaptation Strategy Manager

Scottish Gas Networks were invited to interview and initially accepted, however declined as they were unable to agree to the interview consent form conditions.

Key Informant Interviews: summary information

Priority Landscapes

Key Informant Interview 1

Network Rail

Background info

Four delivery units across Scotland (East = Edinburgh, Perth up to highlands) and West (Motherwell and Glasgow, East of)

Working to understand what drainage they have in relation to their infrastructure; what state it is in and how to design it out to anticipate climate change to SEPA guidelines.

They are seeing a change. The challenges is understanding existing system and get it up to a level that's manageable to then be able to identify where resilience is needed.

Understanding of climate risk and areas of vulnerability

686 climate risks identified – most based on performance issues

Agnostic to location. How climate interacted with assets – breaking down the infrastructure into components (ditches, culverts, pipes) - looked at the ways these could be impacted. Downside of this was that it was not spatial.

Now conducting a spatial climate risk assessment from which areas of vulnerability can be identified.

Priority risks and where they have been identified

Flooding, wind, extreme cold, frost & erosion
"There's something at risk everywhere. There wouldn't be a catchment that the rail runs through that isnt a concern."

Cited, Edinburgh to Glasgow Mainline, East Coast Mainline, West Coast Mainline, Perth to Inverness (Highland Mainline), West Highland Line (including branch lines to Oban, Fort William and Mallaig) as well as West Highlands and Bridge of Orchy – routes characterised by bounding steep-sided/mountainous topography and at risk of erosion.

Specific locations of existing investment

Glasgow North Electrics, Blair Atholl to Dalwhinnie, Fife, Perth and Arbroath, Winchburgh Tunnel, Structures East – Edinburgh, E&G, ECML, and Borders, West Coast and Edinburgh to Glasgow Mainlines, Kilmarnock

Reflections of use of Nature based solutions

Early days in efforts to use nature to address challenges. Access poses a challenge. Sometimes NbS needs more land and are not as robust as they are need to be.

Internally pushing designers to consider NbS. Integration is about behaviour/culture change again where they have always focused on fixing the problem inside the railway corridor, they now must think outside of it.

There is a need for good examples of NbS within the network. To promote this takes time. They own very little of the land to needed to implement some of these on. Believe costs can be prohibitive, so working with lineside neighbours and stakeholders must be imperative.

Funding for nature based solutions

In terms of risk, drainage score is very high. Driver would be condition or performance issues that needs rectifying, rather than a climate challenge. NbS work would come from the drainage budget.

Have the appetite but need to prove the business case with recognisable benefit to the organisation.

Incentivising action

The business case for the use of NbS needs to be stronger.

In an engineering firm, internal stakeholders need more technical knowledge and data that demonstrates the success of such interventions to provide reassurance that nature is a suitable and effective alternative to a solution that has already been defined. This collective knowledge and understanding needs to be mainstreamed.

Key driver is safety. If there is any strong concern about network safety, it will not get implemented.

Priority Landscapes

Key informant interview 2 & 3

NHS Assure + Scot Gov

Background info

Part of the climate change, sustainability and environment team of NHS Assure which belongs to National Service Scotland (a specialist national board). Help regional 22 health boards (14 territorial and 8 special boards) update their risk assessments, adaptation plans, guidance for implementing adaptation measures. Currently enhancing their climate mapping tool which boards can access online. Autonomous in a sense but the Scot Gov can encourage them to move in a certain direction. NSS have their own sustainability team.

Scot Gov representative looking at decarbonisation of NHS and infrastructure.

Understanding of climate risk and areas of vulnerability

Each NHS board has identified risks that could impact their assets and service provision, recognising a total of 952 potential climate change impacts across all twenty-two NHS boards. Currently, mitigation is prioritised over adaption, because there are national goals (Scottish Adaption plan). Adaptation its not goal orientated.

Existing climate change risk assessments are very high level – some boards specify specific assets, others haven't. Assessments are subjected to local expertise. Impact scores aren't comparable across boards.

Priority risks and where they have been identified

Flooding, combined climatic effects (high winds, storms), downpours, prolonged periods of heat & c old spells. Organise hazards based on risks to; infrastructure, essential supplies, equipment, access. Risks are managed from a resilience point of view.

More populated areas, greater Glasgow and Clyde (estates and population). Western Isle and Shetland – access is more difficult. There are so many ways to see vulnerability (age of the estate, population, older population, older population and level of complexity) - cannot say which area. Ayshire & Arran score highest on the Average Risk Exposure Score per NHS board (but this is self-reported).

Reflections of use of Nature based solutions

Few focused reflections on NbS. Aware that its effective and beneficial but little evidence on how it builds on existing green spaces and biodiversity targets.

Current priorities include how green networks (walking, cycling) and greenspaces around hospitals are created around hospitals. Referenced the use of SuDS.

Currently working on developing an adaptation planning guidance which might include NbS as an adaptation measure but more evidence on proposed benefits needed.

Funding for nature based solutions

Need to show good value for money.

Incentivising action

"Sometimes it feels like a bit of work here and a bit of work there. A concept at catchment scale will be interesting"

Knowledge and awareness of the potential impacts of climate change and the benefits of implementing adaptation measures can motivate people to start progressing them but more examples are needed.

Seeing examples from other countries is an inspiration.

Priority Landscapes

Key informant interview 4

SSEN Distribution

Background info

Distribution network operators. Deliver power to 3.9 m customers in UK, 792k in Scotland. In Scotland, operate in the north – from about Stirling upward.

Understanding of climate risk and areas of vulnerability

Have a Climate Resilience Strategy but understanding is piecemeal. Worked with the Energy Networks Association to identify 15 direct risks to network assets.

There is a GIS exercise being done with assets and risk register (beyond grid and primary substations to include secondary substations) - in the process of doing this, need to hire skills. Held in a Sharepoint and excel document- identifying sites to do flood risk assessments for. Currently doing this for Scotland- dependent on next round of funding.

Priority risks and where they have been identified

flood risk, river, pluvial and coastal sea flooding.

Top three (with the highest risk rating in 2023 and 2050) include substations affected by river flooding due to increased winter rainfall, by pluvial (flash) flooding due to increased rainstorms in summer and winter and by sea flooding due to increased sea levels and/or tidal surges, followed by overhead line conductors affected by temperature, and underground cable systems affected by increase in ground temperature, reducing ratings.

Grid and primary substations are protected from flood risk. Identifying which ones are high risk sites are from anecdotal evidence - not a thorough assessment done using flood risk maps.

Reflections of use of Nature based solutions

Currently, NbS is mainly being used for carbon reduction. Have 400 hectares of peatland restoration in Scotland. This might change. Target of 129 hectares of woodland creation. 14 hectares of seagrass restoration.

Nature4Networks- a small set of specific distribution assets and use cases such as flood protection for existing primary substations or new substation construction. Experimenting with

- Linear woodlands to screen overhead lines
- Thorny planting around wood poles
- SuDS to prevent assets flooding
- Bioswales to capture oil

Funding for nature based solutions

In current biz plan they do have commitments to NbS which have been funded for but it's challenging to make the business case for NbS to Ofgem. Funding is a quarter of what they were originally asking for. Need to build a strong consumer value proposition to demonstrate how its funded, its role in carbon removal, green job creation, volunteer hours.

Incentivising action

Regulated industry is challenging as accountants don't know how to account for investments in nature. Ofgem are an economic regulator, and processes don't account for social and environmental benefits. There needs to be guidance from Ofgem and IFRS. NbS often lands as an Opex cost neglecting the need for ongoing management and maintenance. Will be publishing their own document on regulatory challenges. Action to ensure procurement services are open and fair is needed to widen the pool of appropriate responses to climate risks.

There are broader nature market challenges – availability of suitable options, additionality is confusing. Theres a lack of skills people, resources and knowledge. This is a new area and there is a lot of learning on the job.

Priority Landscapes

Key Informant Interview 4

Scottish Water

Background info

Working to mainstream climate change adaptation to ensure organisation are taking sufficient new behaviour change in operations and asset investment so that they are prepared for climate change.

Work at a national scale. Manage 400+ water sources across Scotland and 50,000km of water networks

Move beyond catchment partnerships, with small pieces of funding from different sources.

Understanding of climate risk and areas of vulnerability

27 key risks are outlined in the Scottish Water Adaptation Plan based on 2°C and 4°C warming.

Looks at risks on environment (availability and quality of water), assets (performance and reliability), customers and communities (meeting future needs), people (skills and capabilities) and suppliers and interdependencies (global impacts).

Priority risks and where they have been identified

Deteriorating raw water quality, wetter winters that cause flooding, variable rainfall patterns, more frequent storms, sea rise and erosion.

Many risks are spread across the country. Scottish Water have not identified specific geographical hotspots. The east coast is of concern which has been exacerbated by shifts in population from West to East as well as lower rain fall.

Reflections of use of Nature based solutions

Nature based solutions are not new at Scottish Water but it was suggested that current initiatives are not being implemented at the scale or pace required to adapt to climate change impacts.

Two main areas they are undertaking NbS:

1. At a catchment management perspective – providing multiple benefits to protect water quality but also carbon sequestration, biodiversity benefits in open catchments through peatland
2. Separation of stormwater/rainwater out of combined waste water networks through use of blue/green infrastructure in urban environments

Funding for NbS

Trying to make the case through customer financing and government borrowing.

Still experience barriers to making the business case. Hard to outline the certainty of outcome. Lacking information needed or the cost benefit assessment.

Incentivising action

Articulated a strong need for national policy alignment, shared governance and buy in with an alliance from SEPA, Scot Gov, NatureScot and local authorities to agree areas of focus. Without which, there is a risk of fragmented restoration plans that do not deliver strong benefits.

Encouragement to plan over longer time scales. River based management planning is currently looked at in six-year cycles but this is not adequate for climate adaptation. Need to see 25 years out in terms of future climate risk to drive thinking about what needs to change now to make regenerative catchments exist in future.

Build the evidence base of customer benefits and better articulate the multiple benefits achieved by NbS.

Priority Landscapes

Key informant perspective 6

Transport Scotland

Background info

Transport Scotland's Approach to Climate Change Adaptation and Resilience (ACCAR), outlines the key climate risks affecting Scotland's transport system and sets out our strategic outcomes for Road, Rail, Aviation and Maritime transport networks.

Supports the delivery of climate change adaptation as well as aviation and maritime sectors.

Understanding of climate risk and areas of vulnerability

7 key climate risks that relate to transport infrastructure: Risks to infrastructure networks (water, energy, transport, ICT) from cascading failures; risks to infrastructure services from river, surface water and groundwater flooding; Risks to infrastructure services from coastal flooding and erosion; Risks to bridges and pipelines from flooding and erosion; Risks to networks from slope and embankment failure; Risks to subterranean and surface infrastructure from subsidence; Risks to transport from high and low temperatures, high winds, lightning

Priority risks and where they have been identified

Land associated with the Trunk Road Network

The trunk road and motorway network is 3,507 km (2,179 miles) long, including slip roads and roundabouts. It has a gross asset value of over £20.8 billion and represents 6% of the total Scottish road network.

Transport Scotland landscape policy is applicable to both maintenance issues and the delivery of new schemes. Responsible for the preparation and delivery of the following landscape information: a unit-wide landscape strategy; an annual landscape development plan; an annual report

Reflections of use of Nature based solutions

No explicit mention of NbS in climate adaptation plan. Outlines aims to integrate green infrastructure solutions into transport developments related to risks to infrastructure and services from river, surface water and groundwater flooding.

Funding for nature based solutions

Incentivising action

Sustainability Reporting / Climate Disclosure Analysis

Organisation	Amount of land	Have they done some type of publicly available reporting on climate risks?	In this do they share information about areas of risk?	What adaptation measures (if any) do they mention?	Use of nature restoration
Scottish Water	Responsible for 23,000 hectares	**Yes** TCFS https://www.scottishwater.co.uk/-/media/ScottishWater/Document-Hub/Key-Publications/Annual-Reports/Scottish-Water-Annual-Report-2024.pdf (pg 39) https://indd.adobe.com/view/d63df175-559e-4ec7-a2b5-8227596a710e (pg 11)	Loch Katrine		None explicitly outlined in TCFD but Biodiversity report published in line with duty under Natural Environment Act 2011 details plan for nature restoration focused on natural capital https://www.scottishwater.co.uk/-/media/ScottishWater/Document-Hub/Key-Publications/Energy-and-Sustainability/211223Biodiversityreport23FINAL.pdf

SSEN Distribution		**Yes** 15 risks identified – mainly risks to assets due to temperature increases, drought and flooding https://www.ssen.co.uk/globalassets/library/climate-change-adaptation-docs/ssen-distribution-fourth-climate-change-adaptation-report.pdf Environmental report: https://www.ssen.co.uk/globalassets/library/environment-report-2024/ssen-distribution---annual-environmental-report-2024--final-web-v17.pdf https://www.sse.com/sustainability/	No but developing spatial (GIS) maps of risks of assets to flooding		Yes but specific to carbon removal - aim to plant 258 hectares of native woodland and restore 522 hectares of peatland in our licence areas, which are expected to remove up to 65,000 tCO2e by 2045 Now working to Identify where there are issues faced by networks which could be addressed by a Nature-based Solutions (NbS) approach. https://www.ssen.co.uk/about-ssen/sustainability/#:~:text=We%20have%20an%20ambitious%20sustainability%20strategy%20outlining%20our,own%20environmental%20impact%20in%20a%20transparent%2C%20credible%20way Nature4Networks - Ofgem innovation fund exploring the use of nature-based solutions to safeguard electricity networks (https://smarter.energynetworks.org/projects/10105122/)

Historic Environment Scotland		**No** Climate adaption plan to be developed	No		Noted as a driver in survey response Nature restoration mentioned in Climate Action Plan in which is key part of KPI 5 Increasingly lead the sector in climate change action' in Annual Report.
Forestry and Land Scotland	9% of Scotland	**No** A full strategic climate change risk assessment for FLS has not been carried out Last published Annual sustainability report in 2021 - https://forestryandland.gov.scot/media/iabkzx0r/fls-annual-sustainability-report-2020-2021.pdf	No		
Scottish Power Energy Networks (SPEN)		**Yes** 35 risks were identified, which have been separated out depending on the asset or assets the risk is impacting. https://www.spenergynetworks.co.uk/userfiles/file/Climate-Resilience-Strategy-RIIO-T3-Business-plan-SP-Energy-Networks.pdf	Possibly? Need more info In the short term, SPT will work with local climate adaptation partners to identify five priority areas and develop project plans by the end of 2027 for	Organised by three types (soft, green and hard)	Yes and budgeted for https://www.spenergynetworks.co.uk/userfiles/file/SP_Energy_Networks_Action_Plan_for_Nature.pdf

			implementation by the end of 2031 – Refer to the SPEN T3 Environmental Action Plan In the future we plan to carry out location specific assessments to take in to account the variety of risks that are impinging on our assets		
Network Rail		**Yes** https://www.networkrail.co.uk/wp-content/uploads/2024/12/Network-Rail-4th-Adaptation-Report-Dec-2024.pdf https://www.networkrail.co.uk/wp-content/uploads/2022/01/Network-Rail-Third-Adaptation-Report-December-2021.pdf	No - but developing spatial analysis to be delivered in March	https://www.networkrail.co.uk/wp-content/uploads/2024/04/Scotlands-Railway-CP7-Climate-Ready-WRCCA-Plan.pdf	

Transport Scotland (regional transport partnerships)		Most Transport Partnerships and IJBs have not undertaken a risk assessment or only with respect to a single issue. This may be due to corporate adaptation risks being addressed by the host body taking responsibility for addressing direct risks to occupied estate and shared assets and services (Public Bodies Climate Changes Duties Reporting 22- 23)	No		
NHS Scotland		**Yes** https://www.nss.nhs.scot/media/5784/asr500-002-report-of-ccras-and-ap-v1-jan-25.pdf	No	Weather monitoring and temperature management to the implementation of nature-based solutions	
Scottish Gas Networks		**Yes** 43 potential risks pertaining to asset management and physical security, health & safety and environment & climate change https://www.sgn.co.uk/sites/default/files/media-entities/documents/2022-01/SGN-ARP3-1221_0.pdf	Northeast coast of Scotland (sea level rise) Across Scotland (flooding)		https://www.sgn.co.uk/news/improving-and-protecting-biodiversity-our-sites

Local authorities		While every local authority has carried out some form of risk assessment and 53% of the sector has done so to a comprehensive or advanced degree, nearly half (47%) of local authority reports indicate that only single-issue risks have been considered, i.e. flooding. (Public Bodies Climate Changes Duties Reporting 22- 23)	Not enough data	Not enough data	

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