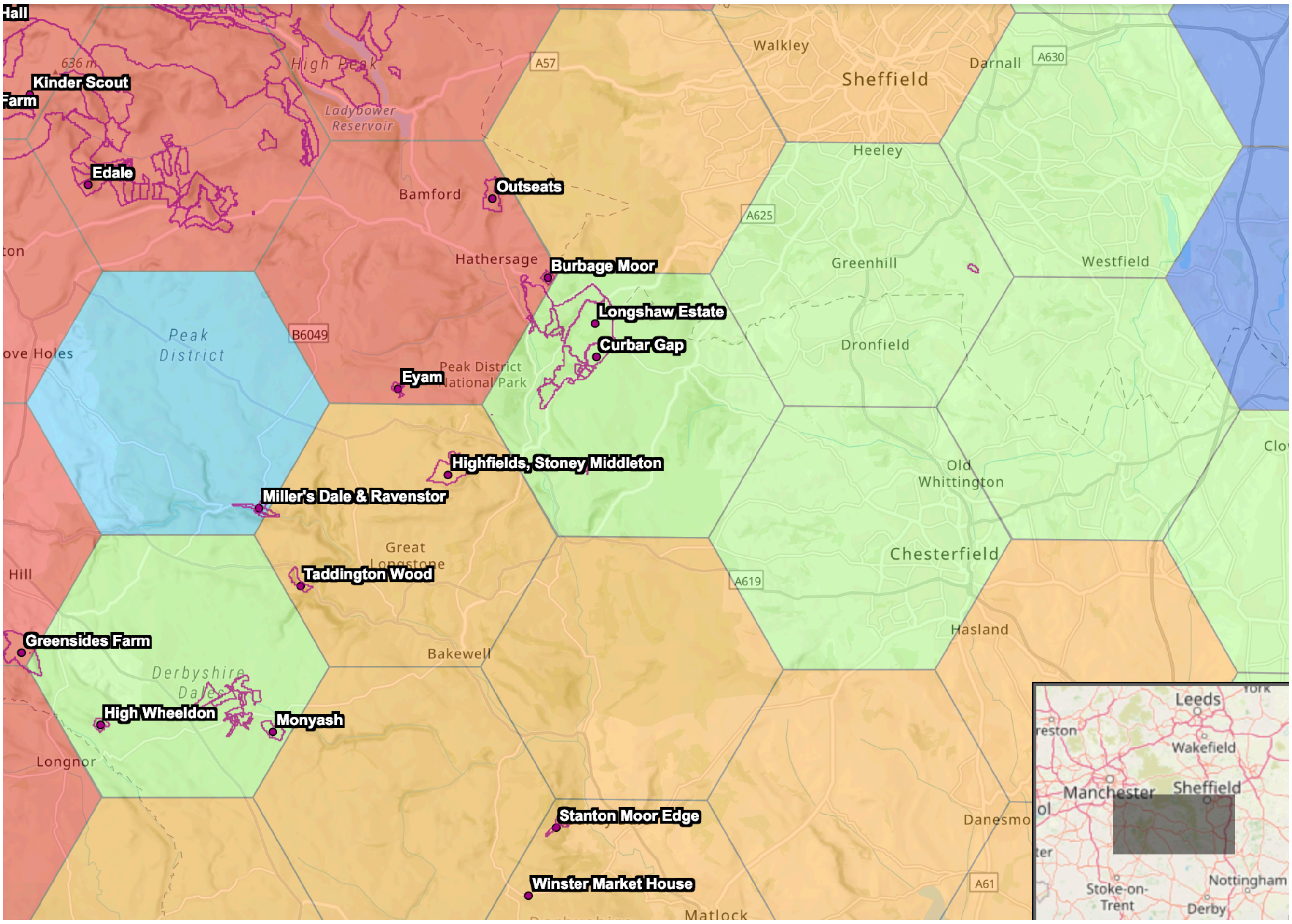
Historic England

Mapping Climate-Related Hazards to Historic Sites

Joshua Deru, David Dowding, Emily Crowe, Hannah Fluck

Discovery, Innovation and Science in the Historic Environment



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SUMMARY

This project aims to build upon an initial climate risk mapping project ([*Phase 1.0*]) commissioned by the National Trust in 2020. *Phase 1.0* mapped six key climate hazards to heritage sites (Overheating & Humidity, Storm Damage, Slope Failure, Flooding, Shrink-Swell, and Coastal Risk) across England, Wales and Northern Ireland.

Led by a consortia of UK heritage organisations[1], *Phase 1.5* seeks to expand and develop these initial pilot maps by including a number of additional hazards and datasets, as well as expanding the maps to include the entire United Kingdom. The project has been created primarily for internal GIS teams looking to assess climate risk to heritage sites, but has been designed with capacity for further builds such as additional datasets, higher data resolutions, and open-source public viewing platforms.

The analysis has been performed using Geographic Information System (GIS) Mapping, combining climate, geomorphological and hydrological data in relation to a set of defined hazard thresholds – described fully in *Section 2.0: Methodology*. The key final output is a set of hexagonally gridded ('HexGrid') GIS risk maps, detailing the risks posed by each of the hazards identified. These have been uploaded to a shared google drive in the form of GIS shapefiles[2].

This report provides a summary of the methodology, a guide to using the data, and recommendations for implementation as part of a climate adaptation and mitigation strategy. Specifically for Historic England (HE), this report also summarises the key findings resulting from assessing heritage assets on the National Heritage List for England (NHLE) in the context of the risk maps. This data can be used to inform national, regional and local priorities for climate.

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[1] Cadw, Historic Environment Division NI, Historic Environment Scotland, Historic England, the National Trust and the National Trust for Scotland

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1.0. INTRODUCTION

This project, referred to hereafter as *HEN Climate Risk Mapping Phase 1.5*, aims to build upon an initial climate risk mapping project (***Phase 1.0***) commissioned by the National Trust in 2020. *Phase 1.0* mapped six key climate hazards to heritage sites (Overheating & Humidity, Storm Damage, Slope Failure, Flooding, Shrink-Swell, and Coastal Risk) across England, Wales and Northern Ireland.

Led by a consortia of UK heritage organisations[3], *Phase 1.5* seeks to expand and develop these initial pilot maps by including a number of additional hazards and datasets, as well as expanding the maps to include the entire United Kingdom. The project has been created primarily for internal GIS teams looking to assess climate risk to heritage sites, but has been designed with capacity for further builds such as additional datasets, higher data resolutions, and open-source public viewing platforms.

The analysis has been performed using Geographic Information System (GIS) Mapping, combining climate, geomorphological and hydrological data in relation to a set of defined hazard thresholds – described fully in *Section 2.0: Methodology*. The key final output is a set of hexagonally gridded ('HexGrid') GIS risk maps, detailing the risks posed by each of the hazards identified. These have been uploaded to a shared google drive in the form of GIS shapefiles[4].

This report provides a summary of the methodology, a guide to using the data, and recommendations for implementation as part of a climate adaptation and mitigation strategy. Specifically for Historic England (HE), this report also summarises the key findings resulting from assessing heritage assets on the National Heritage List for England (NHLE) in the context of the risk maps. This data can be used to inform national, regional and local priorities for climate adaptation and mitigation.

2.0. METHODOLOGY

2.1. Hazards Assessed

A longlist of desired hazard indicators, additional to those used in *Phase 1.0.,* was provided by the heritage bodies. This longlist contained three types of indicators:

Basic single indicators – Raw values calculated from one dataset. E.g. Average monthly temperature for each grid cell.

Event threshold indicators – Frequency with which a basic single indicator surpasses an agreed event threshold. E.g. Number of days per month where average monthly temperature surpasses 25°C for each grid cell

[3] Cadw, Historic Environment Division NI, Historic Environment Scotland, Historic England, the National Trust and the National Trust for Scotland
[4] Contact joshua.deru@3keel.com to request access

Compound indicators – Aggregated values calculated from multiple datasets E.g. Drought frequency.

The full list of indicators, refined by a process of scoping and feasibility assessment, is shown in *Appendix 1: List of Datasets and filenames*.

2.2. Parameters

Data was assessed for two time periods: a **baseline** period and a projected **future** period, which were agreed as 1981-2010 and 2060-2080, respectively[5]. For existing datasets which did not include these exact ranges, the nearest possible date range was selected.

Data was normalised to a set of 5km grid hexagons covering the United Kingdom, as described in *Section 2.3: GIS Methodology*. For datasets excluding certain parts of the UK, gaps were addressed by sourcing an alternative local or regional dataset, developing a proxy value, or inserting a blank value, in that order of preference.

2.3. GIS Methodology

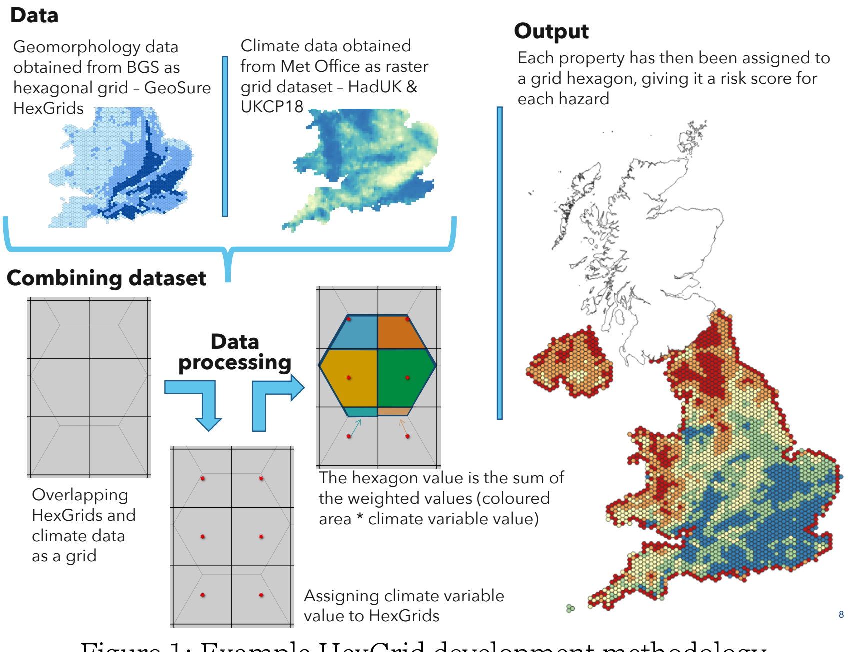


Figure 1: Example HexGrid development methodology

The GIS methodology used in *Phase 1.5* is the same as for *Phase 1.0*: In order to align the various datasets used, a set of 5km grid hexagons (HexGrids) was defined across the United Kingdom (including Scotland, this time). All datasets were then

[5] Note that these differ from the original time periods used in *Phase 1.0*. (2020-2025 and 2060-2065).

overlaid on to these HexGrids, and attributes were re-apportioned to the HexGrid grid layout based on area-weighted values, as shown in Figure 1 above.

The 5km grid was selected based on the lowest common resolution available in existing data, to avoid provision of a false sense of precision. The steps taken during the conversion of input datasets to HexGrids for the GIS analysis are outlined in Figure 2.

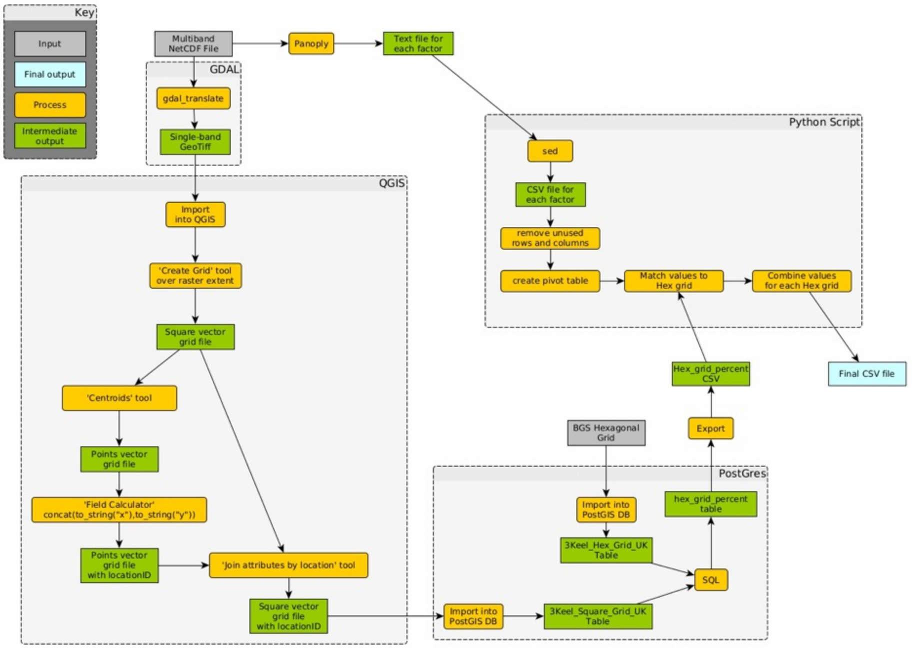


Figure 2: HexGrid conversion process flowchart

3.0. RESULTS

The key final output is a set of hexagonally gridded ('HexGrid') GIS risk maps, detailing the risks posed by each of the hazards identified. These have been uploaded to a shared google drive in the form of GIS shapefiles[6]. A number of mapped shapefile outputs have been presented below, with further discussion provided in the *Discussion* section.

[6] Contact joshua.deru@3keel.com to request access

Figure 3: Average daily max temperature, hottest month, in baseline scenario

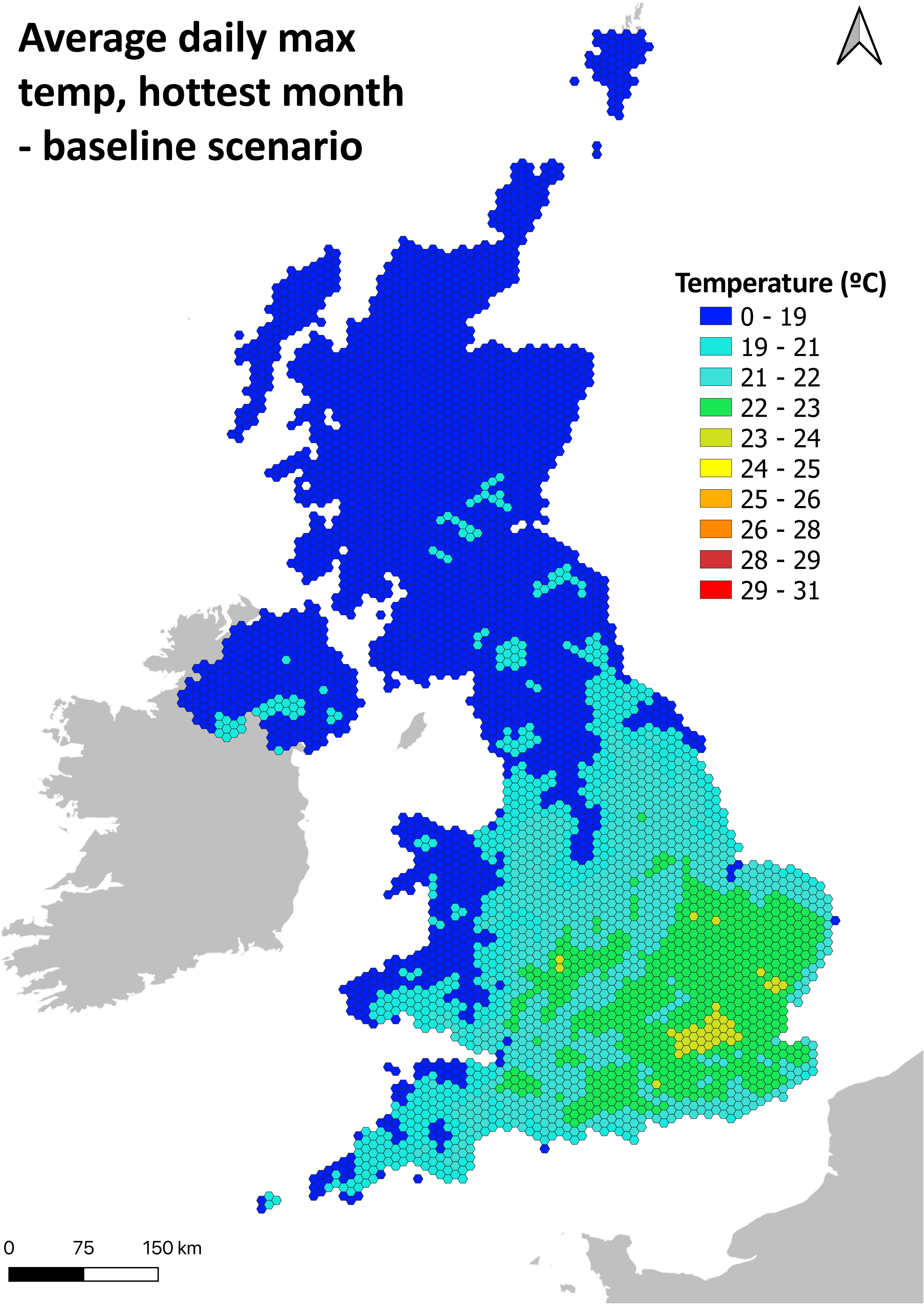


Figure 4: Average daily max temperature, hottest month, in future scenario

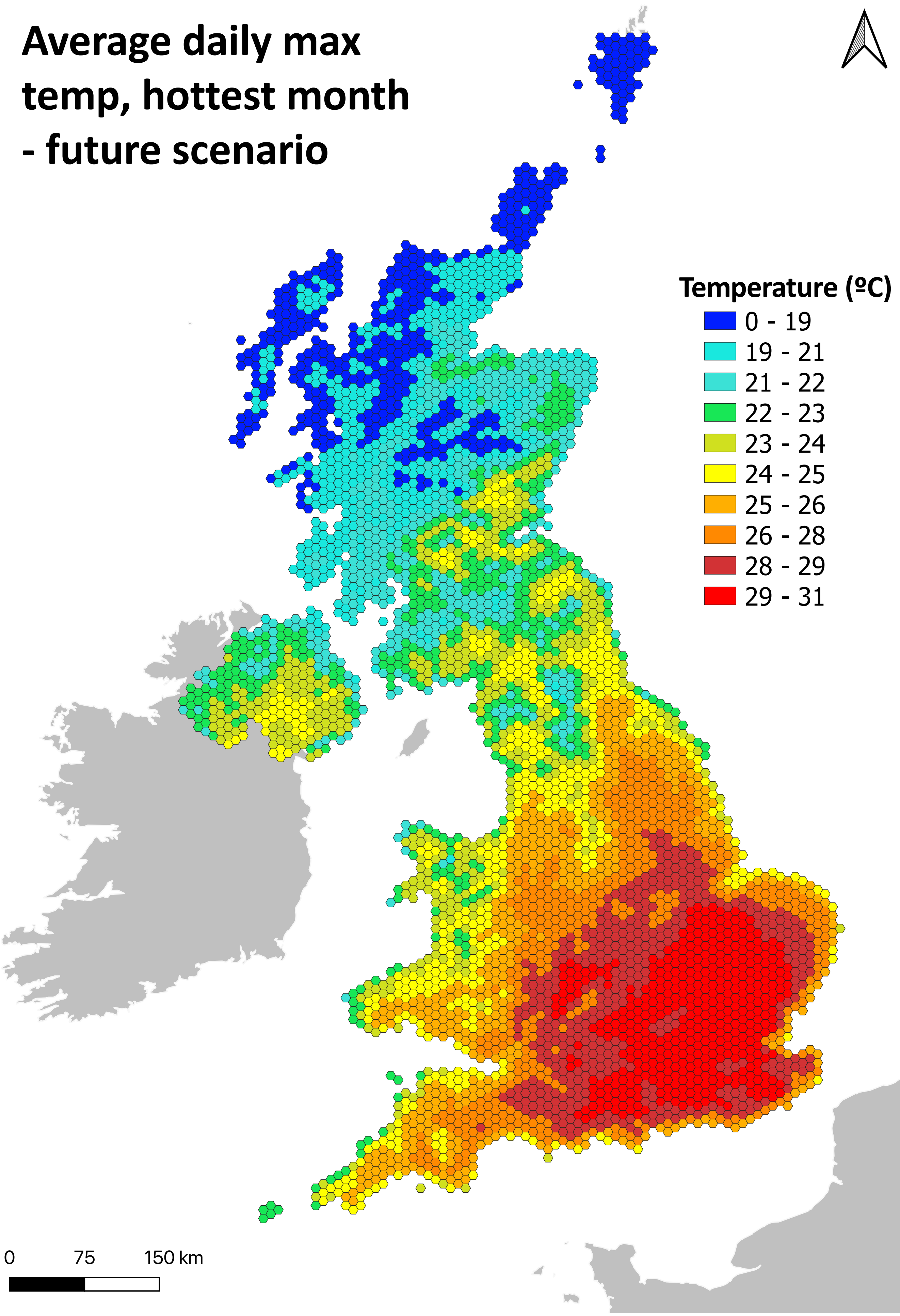


Figure 5: Average daily min temperature, coldest month, in baseline scenario

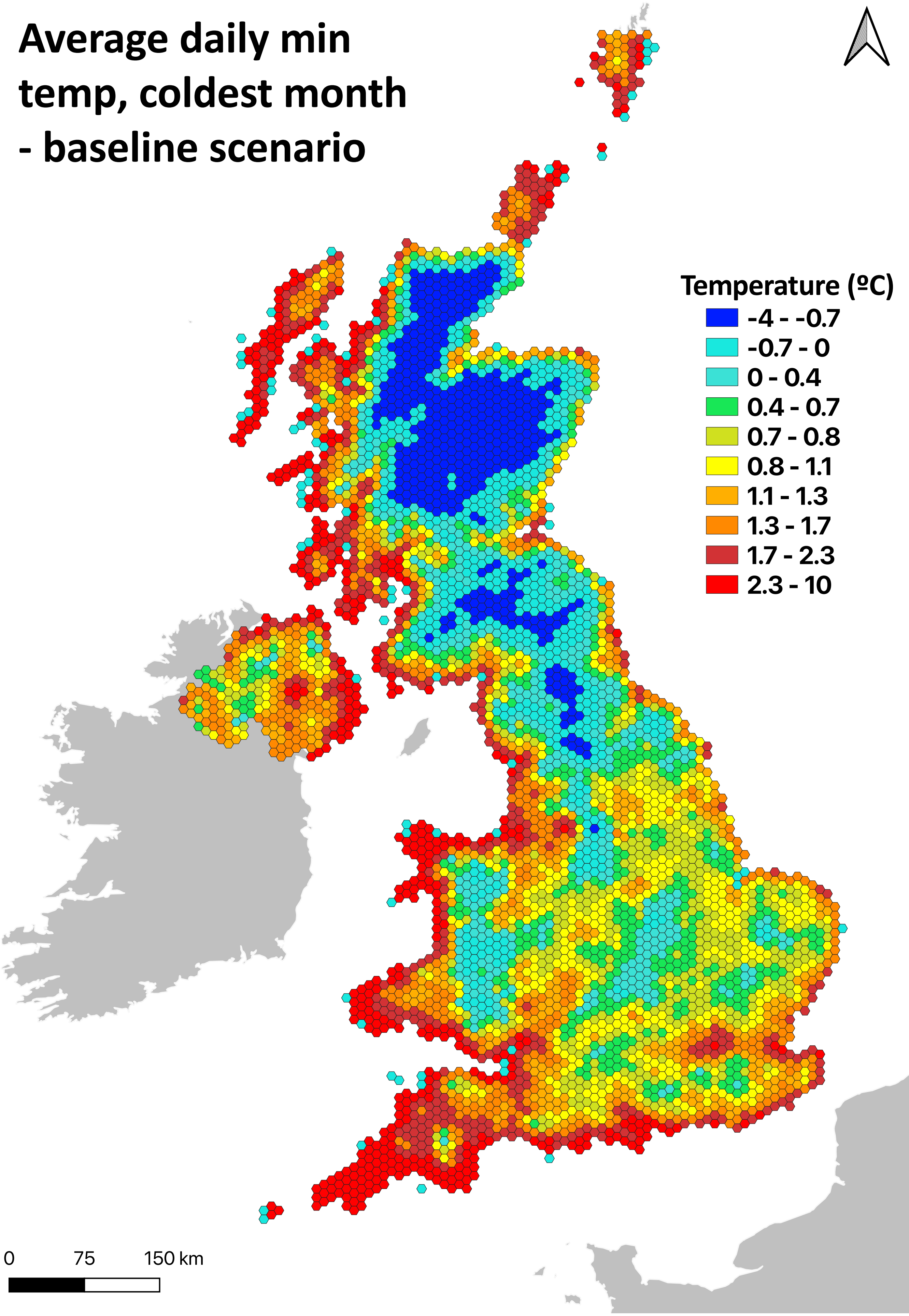
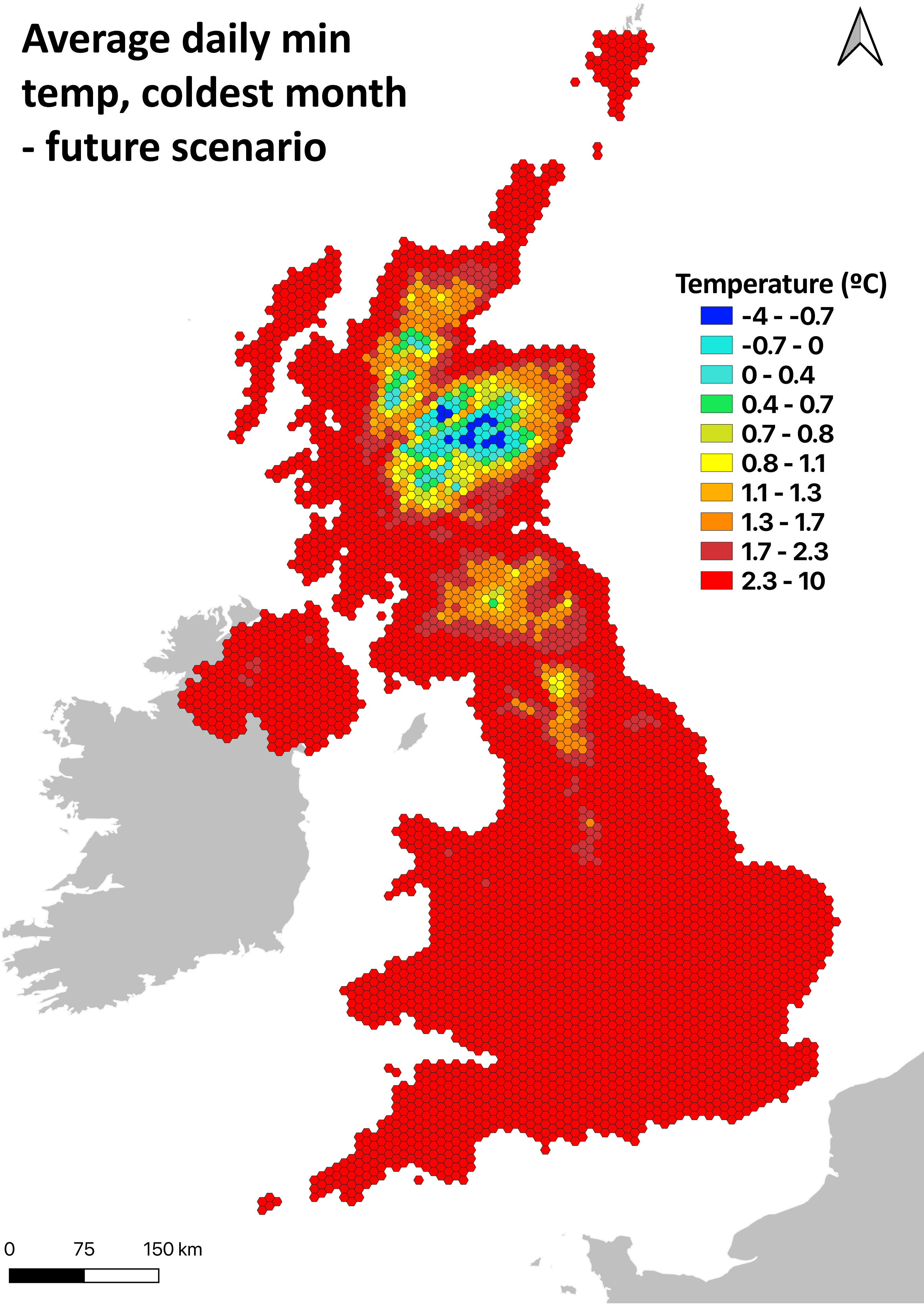


Figure 6: Average daily min temperature, coldest month, in future scenario



3.1. Temperature: Relevance for Designated Heritage Assets

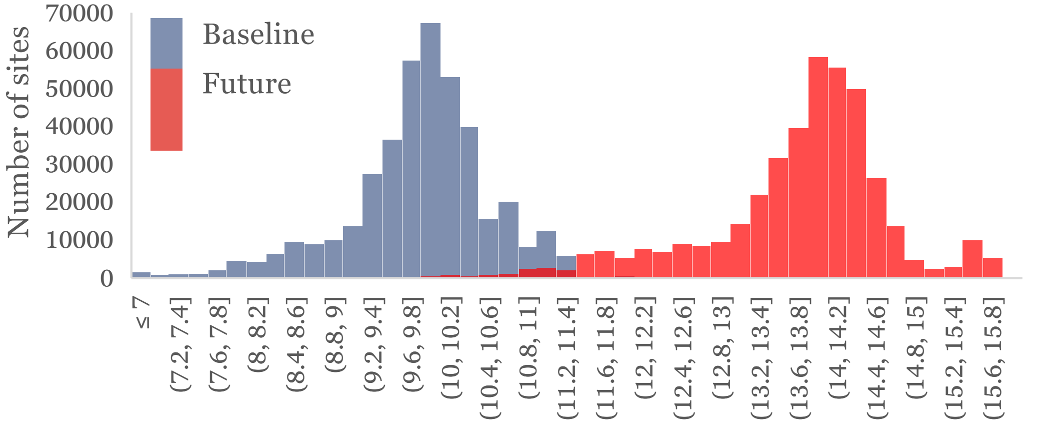


Fig 7: Average daily mean temperature, entire year, by site (ºC)

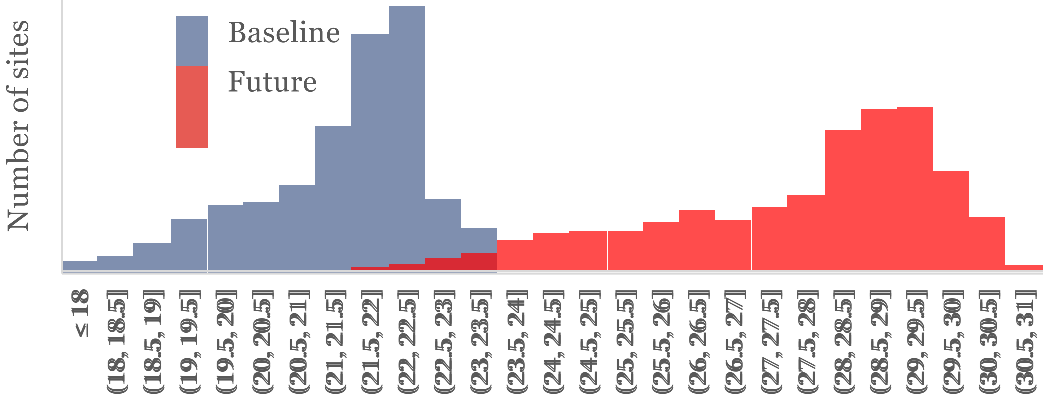


Fig 8: Average daily max temperature, hottest month, by site (ºC)

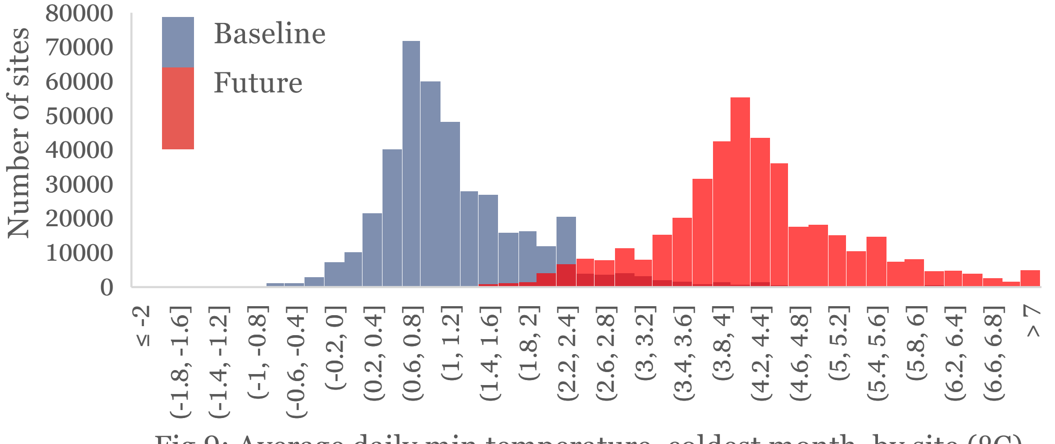


Fig 9: Average daily min temperature, coldest month, by site (ºC)

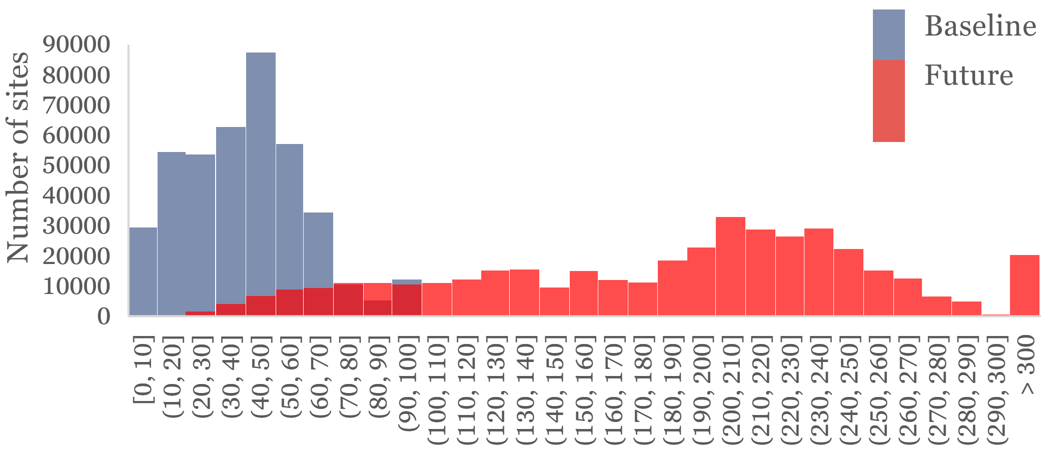


Fig 10: Cooling Degree Days (ºC, relative to 22ºC), by site

Figures 7-10 (top to bottom): *Histograms by site, in baseline and future scenarios, of : 7) average daily mean temperature for entire year, 8) average daily maximum temperature for hottest month, 9) average daily minimum temperature for coldest month, and 10) cooling degree days (day-by-day sum of the mean number of degrees by which the air temperature is > 22 ºC.)*

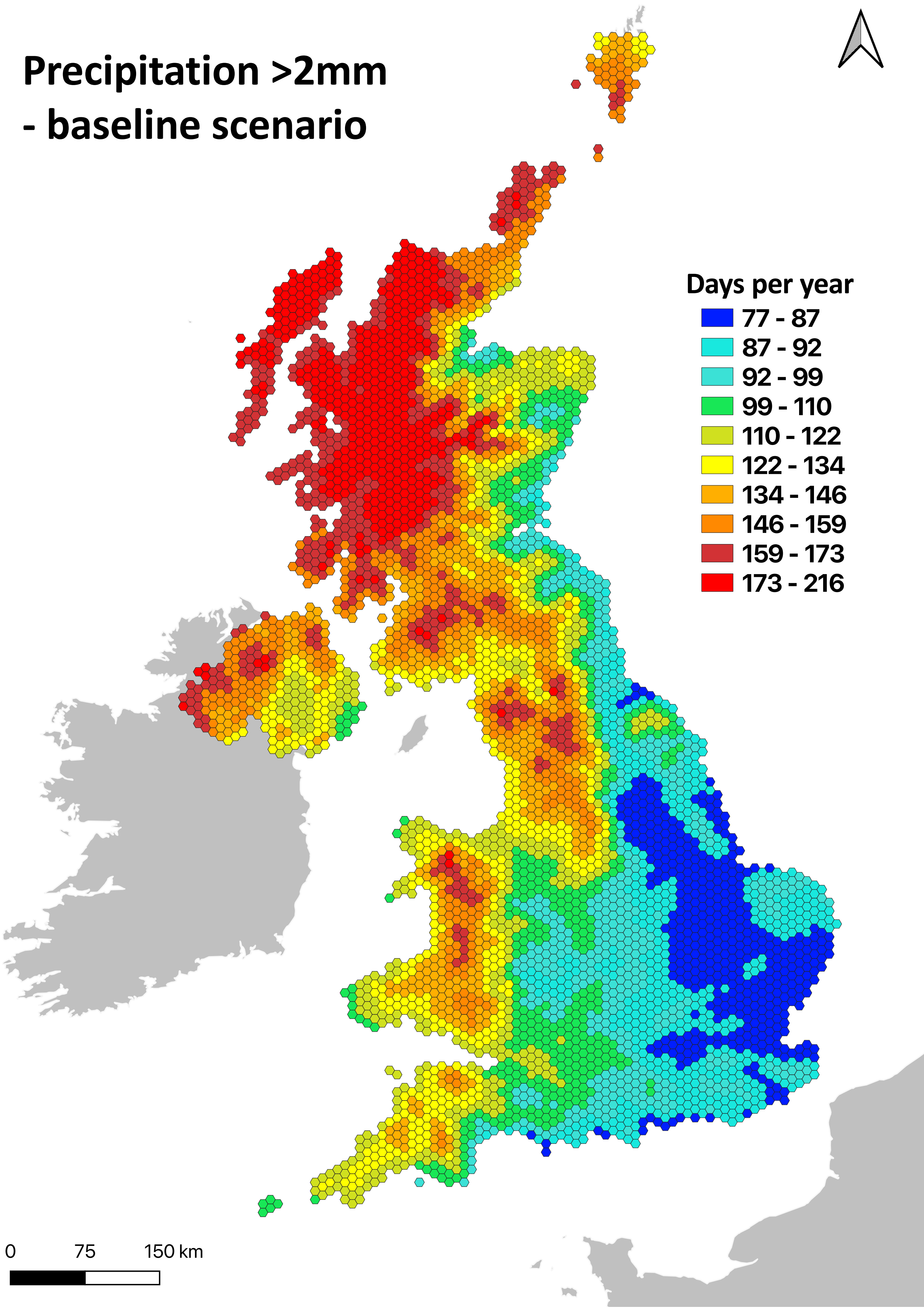
Figures 3-9 show an across-the-board increase in temperatures experienced at NHLE sites, with minimum, mean and maximum temperatures rising approximately 3-7 degrees on average.

This corresponds to similar changes in Cooling, Heating and Growing Degree day values for NHLE sites, with the most stark change shown in Figure 10 above. Cooling Degree Days, which are the day-by-day sum of the mean number of degrees by which air temperature exceeds 22ºC (i.e. representing an approximation of the amount of cooling required in average UK buildings) rise by 367% from the baseline to future scenario.

Growing Degree Days (day-by-day sum of the mean number of degrees by which air temperature exceeds 5.5ºC) similarly rise 673%, while Heating Degree Days decrease in number due to the milder winters experienced.

These effects are particularly pertinent for NHLE properties as the South East of England is projected to face the highest temperatures, in both the baseline and future scenarios.

Figure 11: Number of days per year with >2mm precipitation, in baseline scenario



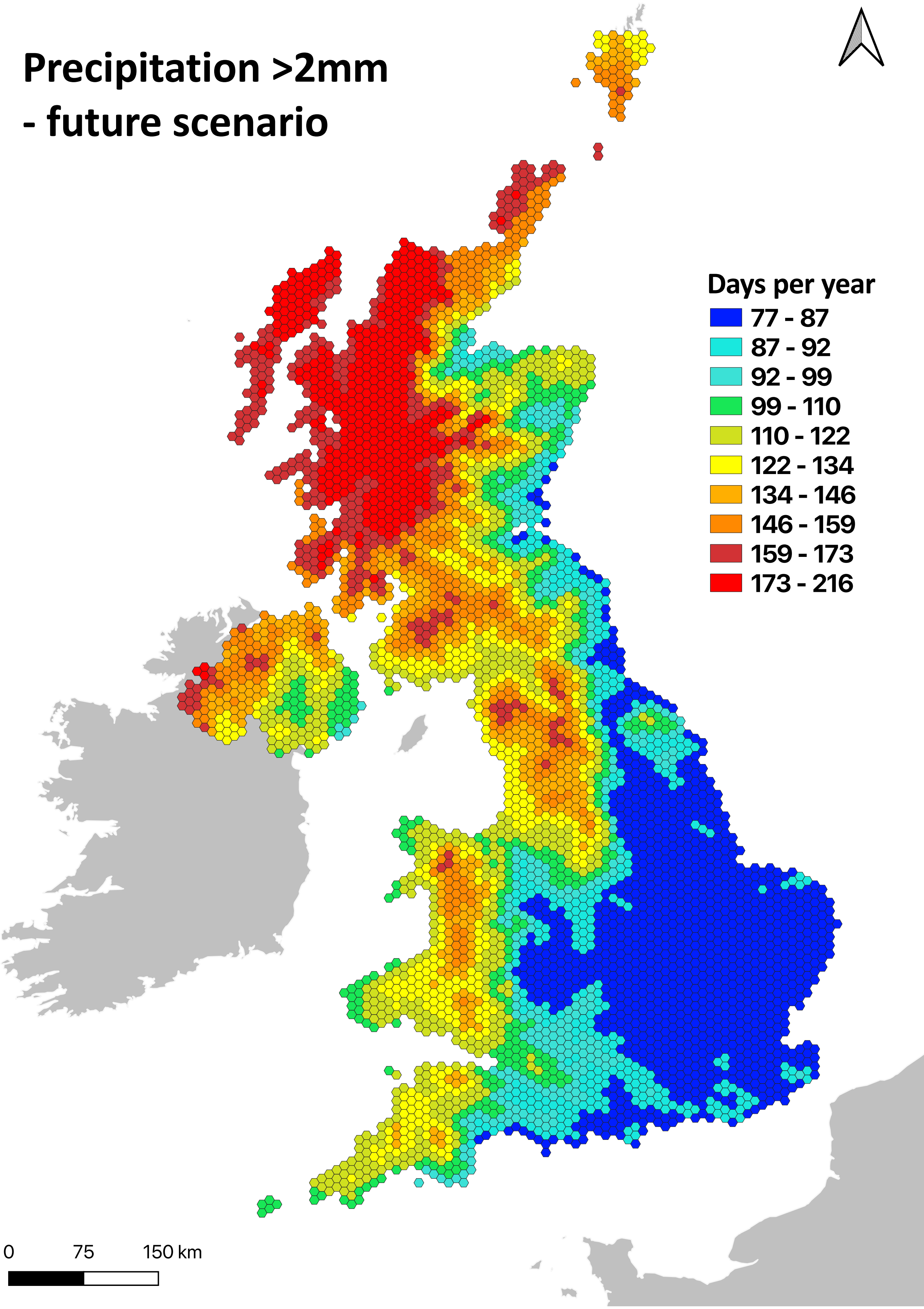

Precipitation >2mm
- future scenario
Days per year
77 - 87
87 - 92
92 - 99
99 - 110
110 - 122
122 - 134
134 - 146
146 - 159
159 - 173
173 - 216
0
75
150 km

Figure 13: Number of days per year with >50mm precipitation, in baseline scenario

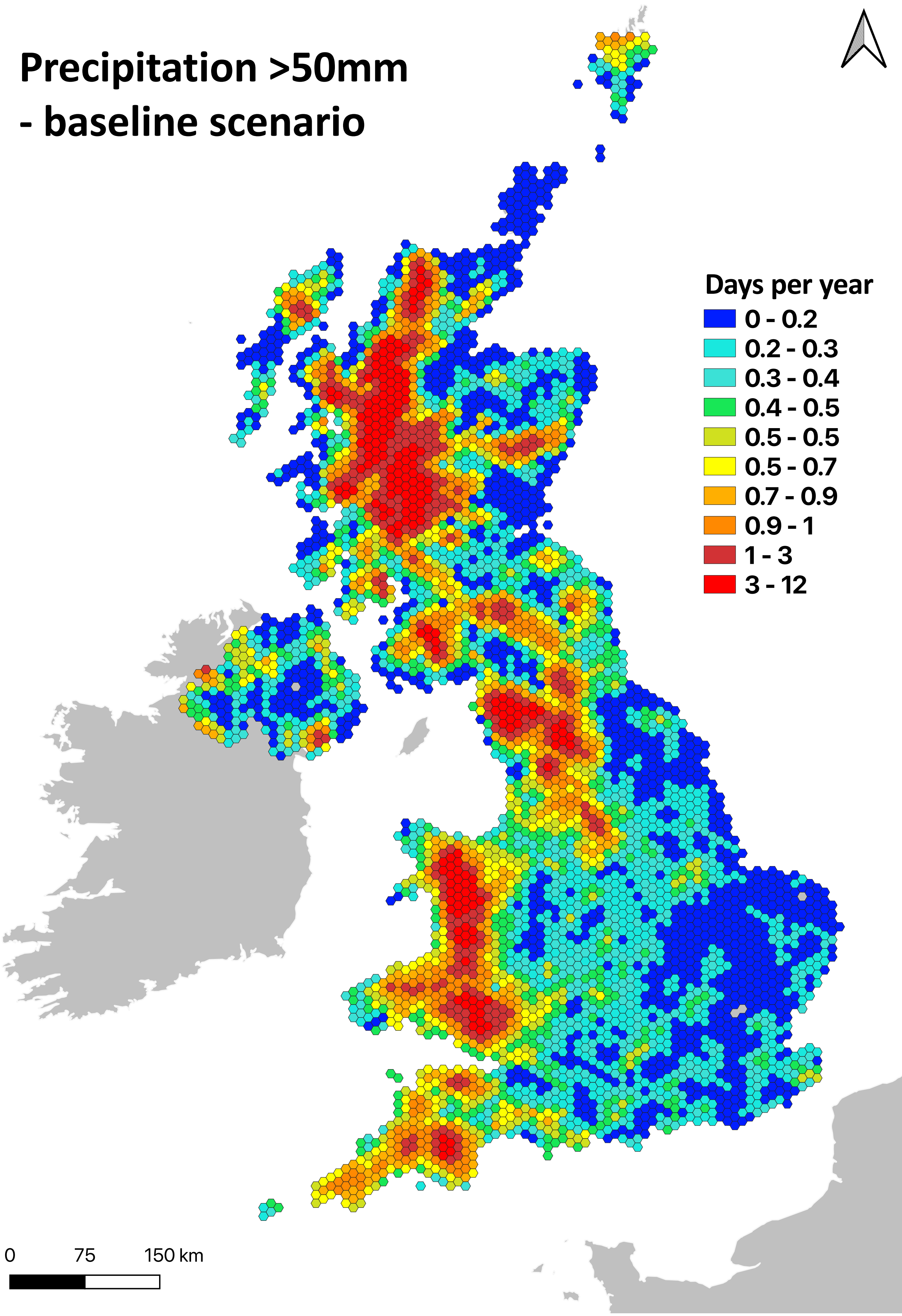
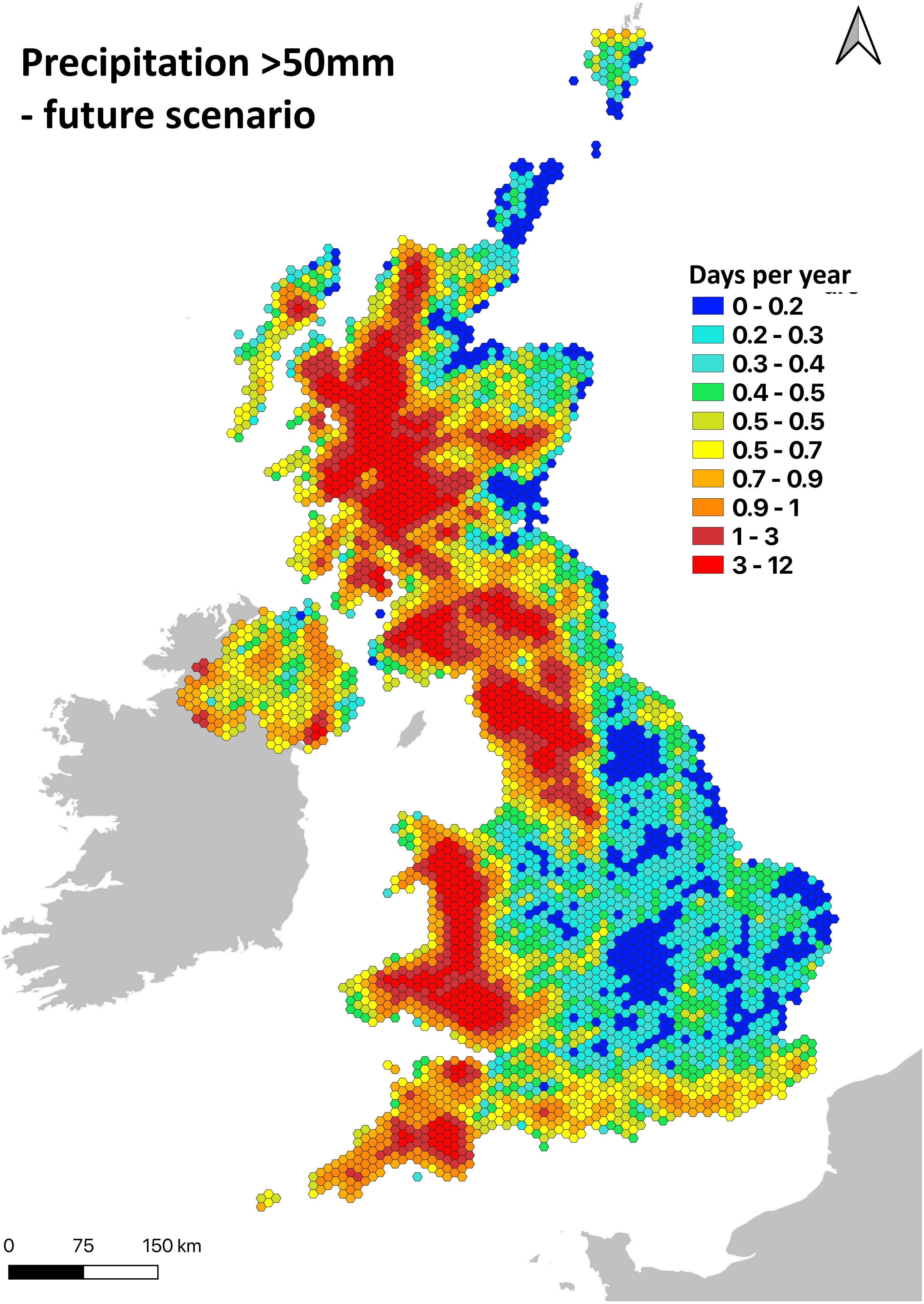


Figure 14: Number of days per year with >50mm precipitation, in future scenario



3.2. Precipitation: Relevance for Designated Heritage Assets

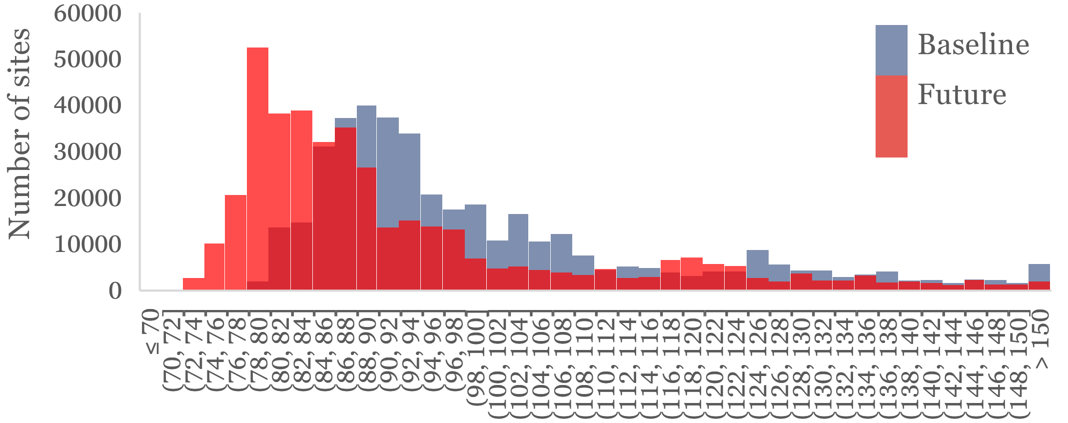


Fig 15: Days per year with >2mm precipitation, by site

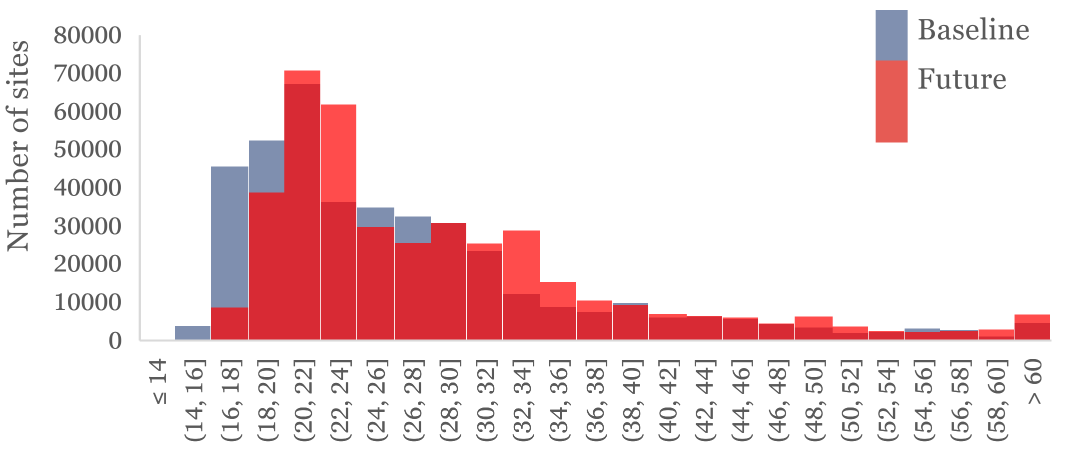


Fig 16: Days per year with >10mm precipitation, by site

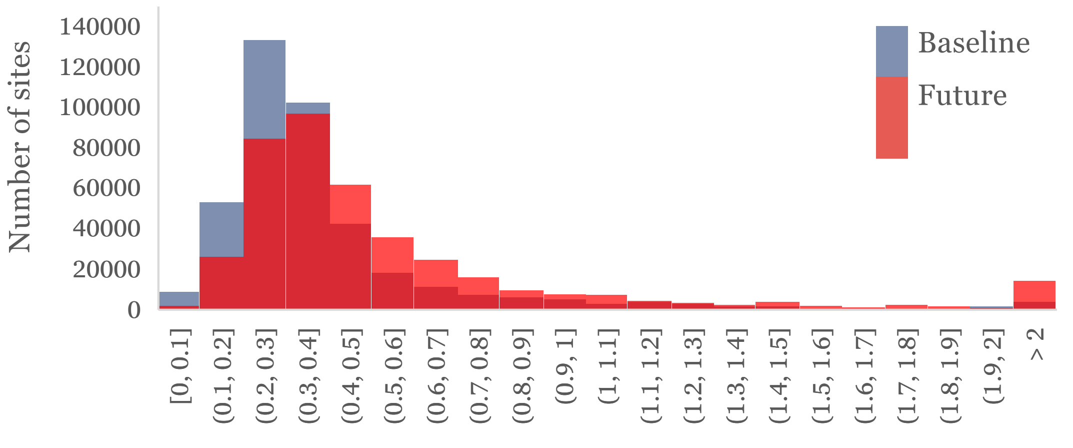


Fig 17: Days per year with >50mm precipitation, by site

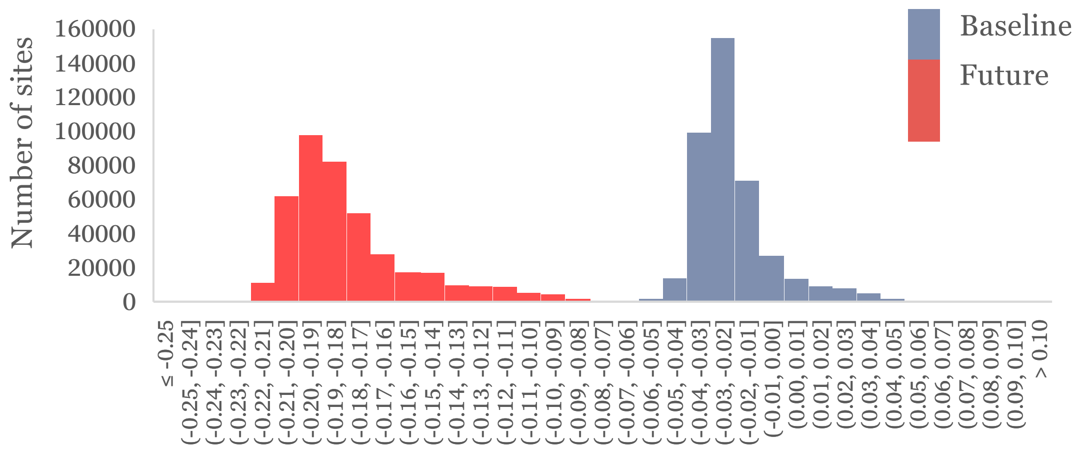


Fig 18: SPEI Drought Index value, by site (more negative value = higher drought risk)

Figures 15-18 (top to bottom): *Histograms by site, in baseline and future scenarios, of : 15) number of days per year with >2mm precipitation, 16) number of days per year with >10mm precipitation, 17) number of days per year with >50mm precipitation, and 18) SPEI Drought Index value, where more negative values represent higher drought risks (-0.99 - 0.99 = "near normal" drought risk).*

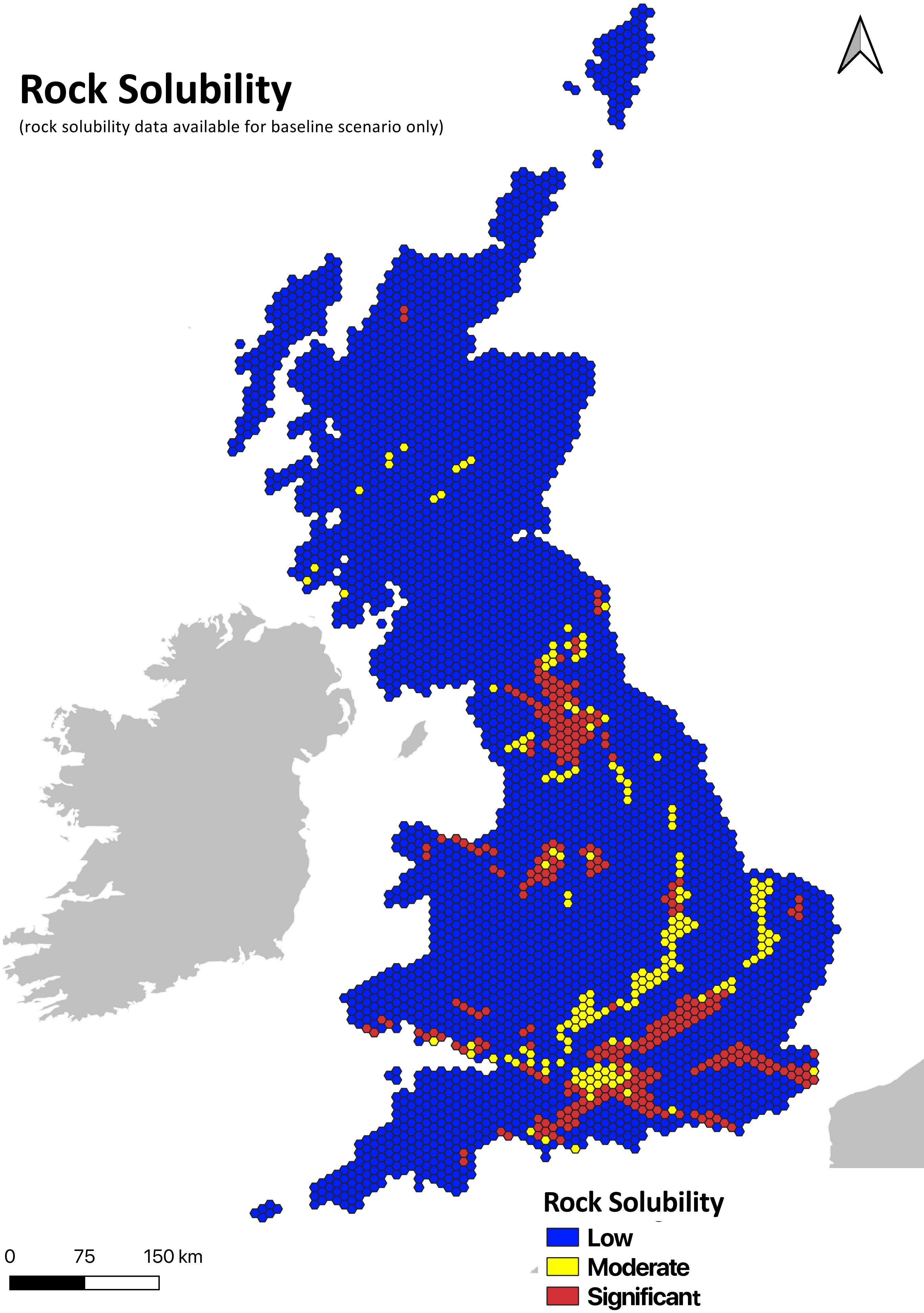
NHLE sites are projected to experience increases both in the number of days with no precipitation (Figure 15 shows a decrease in the number of days with >2mm precipitation), and the number of days with heavy precipitation (Figure 17 shows an increase in the number of days with >50mm precipitation). This aligns with Met Office projections of increases in extreme weather such as drought and flooding[6].

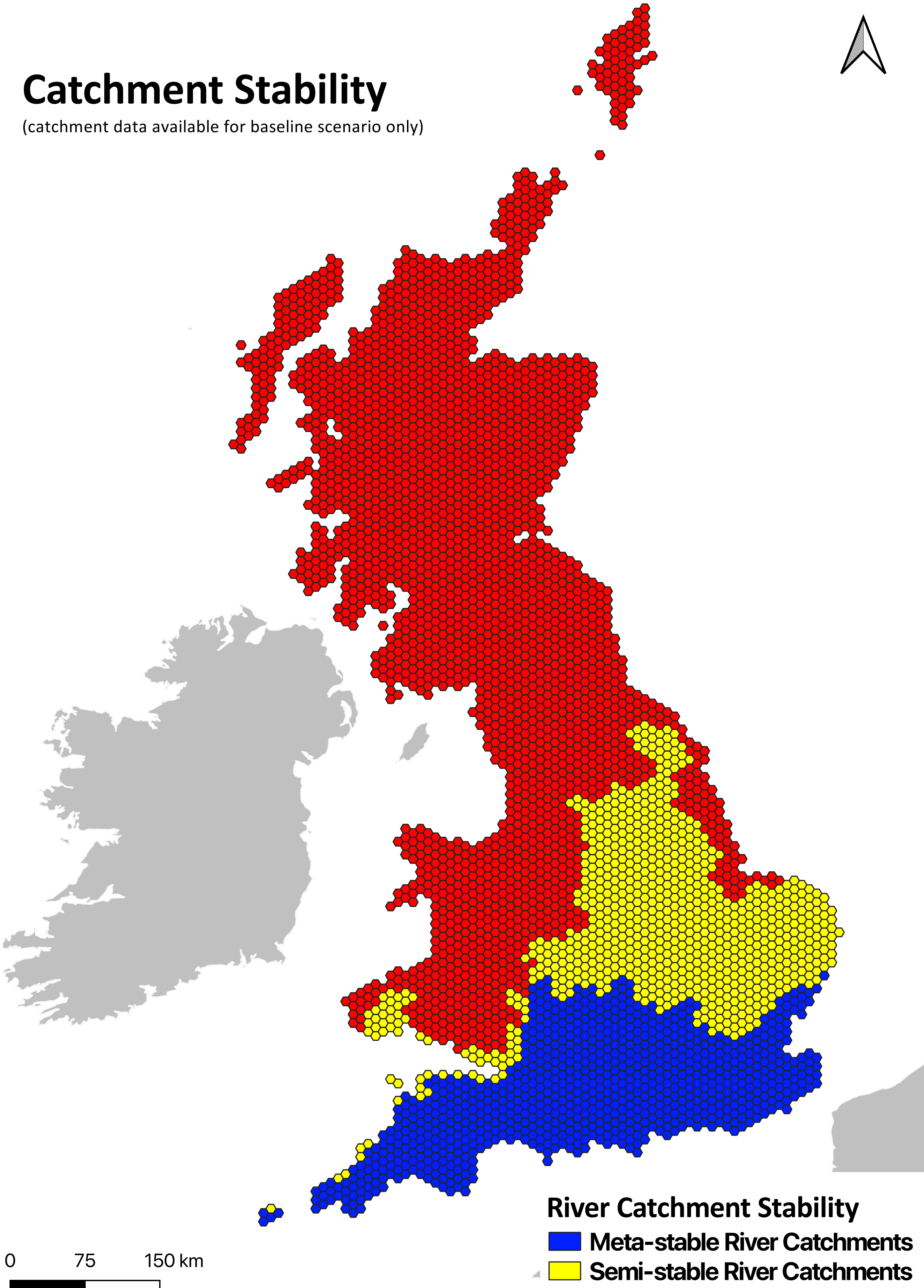
Total levels of precipitation are projected to decrease, with an average 8% decrease across NHLE sites, from baseline to future scenarios. This corresponds with the decrease in SPEI drought index values seen in Figure 18 – decreasing SPEI index values represent an increased drought risk, although the range of [-0.22, -0.09] seen for NHLE sites still falls within the 'near normal' category for SPEI drought indicators. Figure 30 shows a map of baseline drought risks.

As such, for NHLE sites, a small increase in localised drought risk will be seen, while the level of increased flood risk is more severe and widespread.

[6] Met Office, 2019, *How is climate linked to extreme weather?*, https://www.metoffice.gov.uk/weather/climate/climate-and-extreme-weather

Figure 19: Potential for dissolution within geological deposit




Catchment Stability
(catchment data available for baseline scenario only)
0
75
150 km
River Catchment Stability
Meta-stable River Catchments
Semi-stable River Catchments
Unstable River Catchments

3.3. **River Scour:** Relevance for Designated Heritage Assets

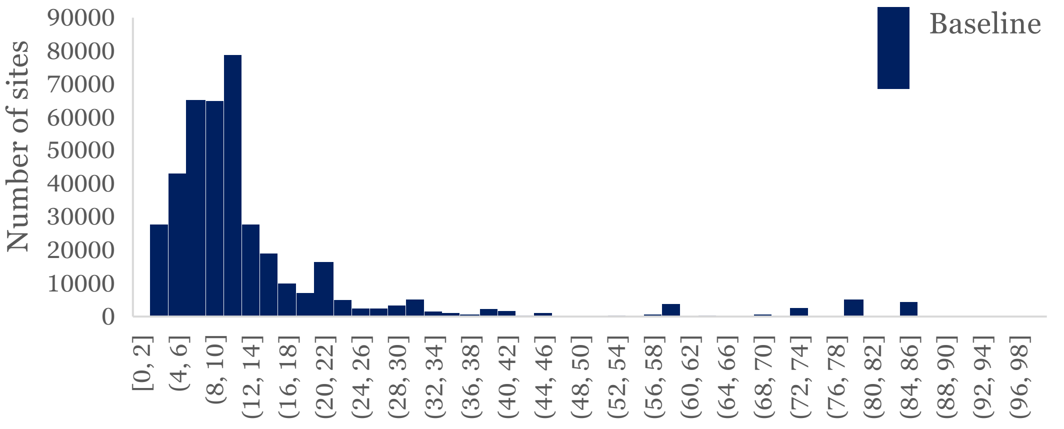


Fig 21: % urban coverage of surrounding area, by site

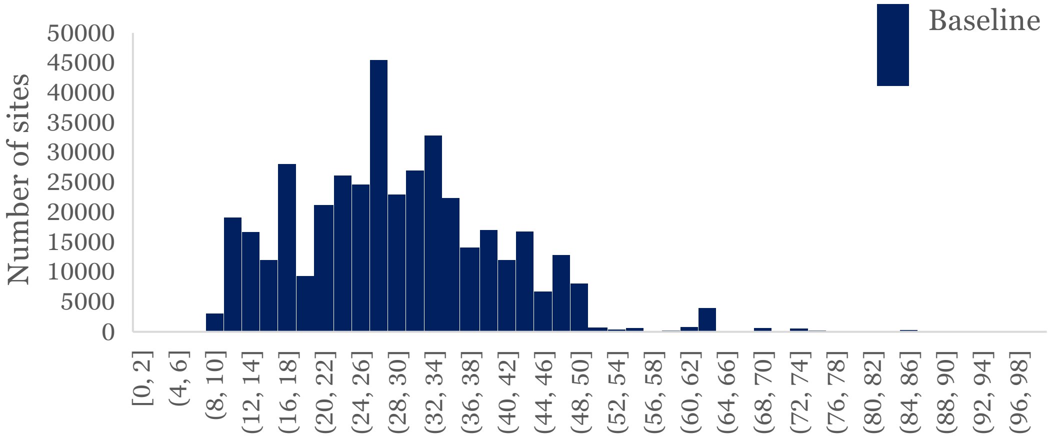
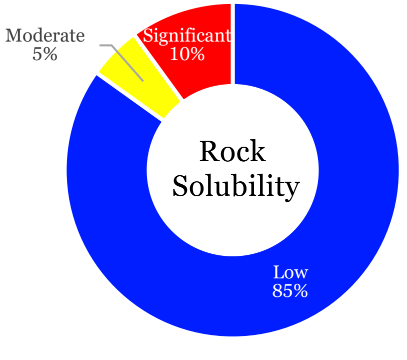


Fig 22: % coverage of flood accommodation space in catchment, by site



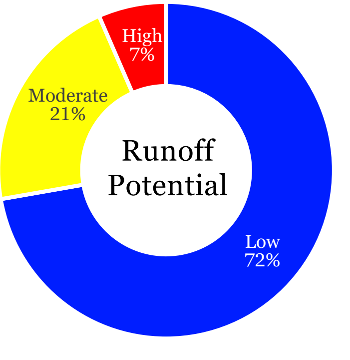
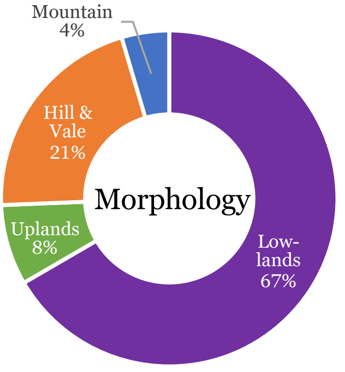


Fig 23 (left): Potential for dissolution within geological deposit, by site
Fig 24 (right): Dominant geological runoff class in catchment, by site



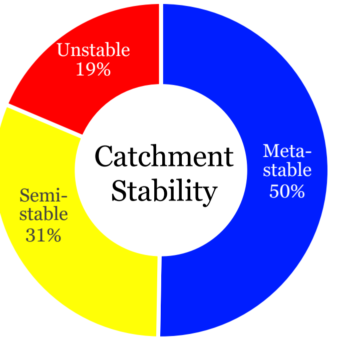


Fig 25 (left): Dominant morphology in catchment, by site
Fig 26 (right): Stability of catchment, by site

Figures 19-26 show underlying data relating to risk of river scour, in the baseline scenario. Insufficient data was available to cover a future scenario, and input data did not include data for Northern Ireland.

Rock solubility is generally low across most of England, with regions of moderate and significant solubility present in central Southern and Northern England (see Figures 19 and 23). Bands of soluble rock also run East to West in the South-East.

Figures 21-22 show the relative percentage coverage of sites within each category, with the majority of sites found in areas of 4-20% urban coverage (with exception of a number of sites in highly urban areas e.g. London), and a corresponding 10-50% flood accommodation space.

Figures 24 and 25 show runoff potential and morphology, with 72% of sites in areas of low runoff potential (defined as *Low overland flows, unless ground is excessively dry or saturated*) and 67% of sites in lowlands – both of which increase likelihood of flooding.

In terms of river scour and catchment stability, 81% of sites are in areas of meta-stable or semi-stable river catchments, with the remaining 19% of unstable catchments generally found in the West Midlands and the North of England.

Figure 27: Number of days per year with underlying groundfrost, in baseline scenario

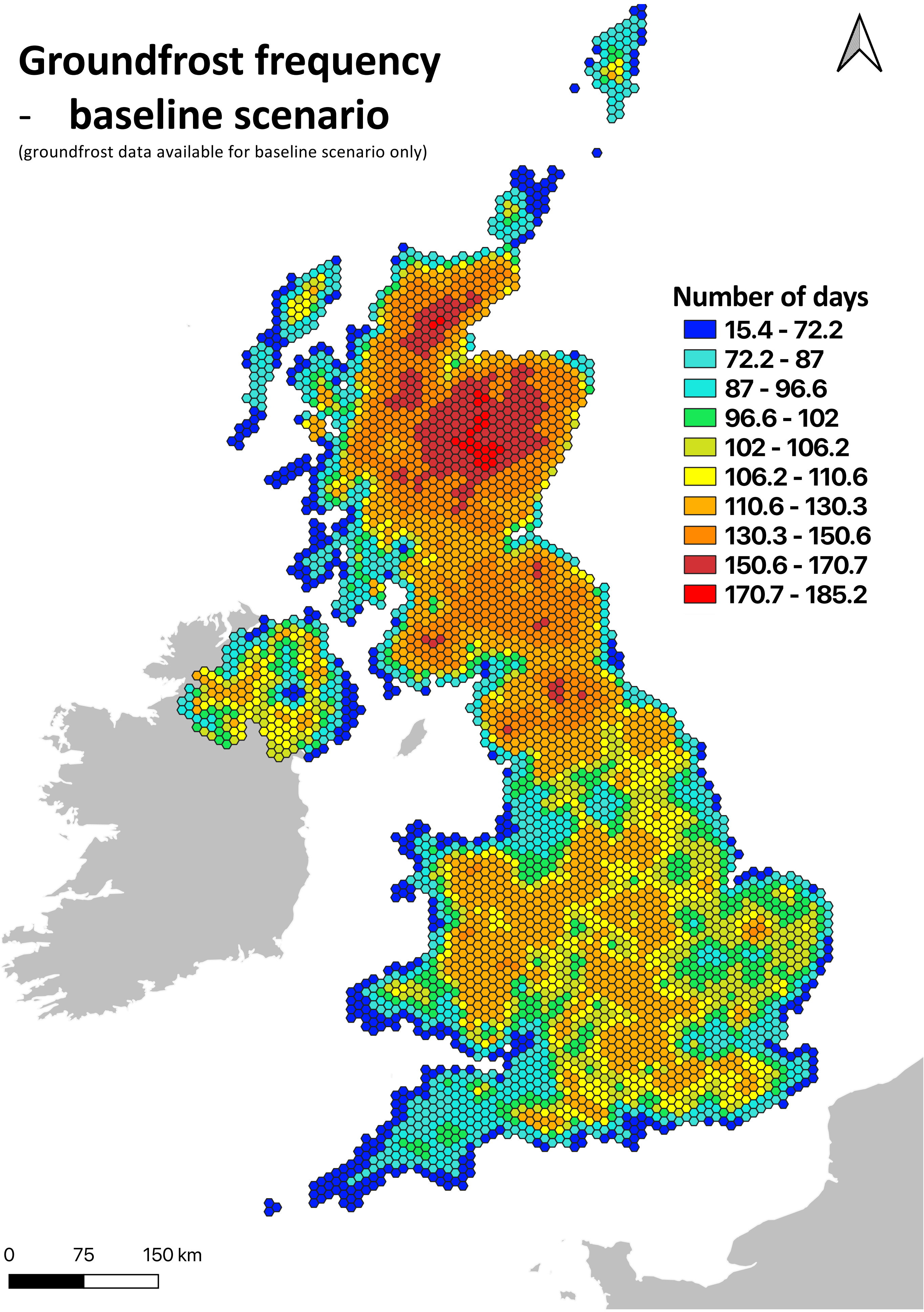


Figure 28: Number of sunshine hours per year, in baseline scenario

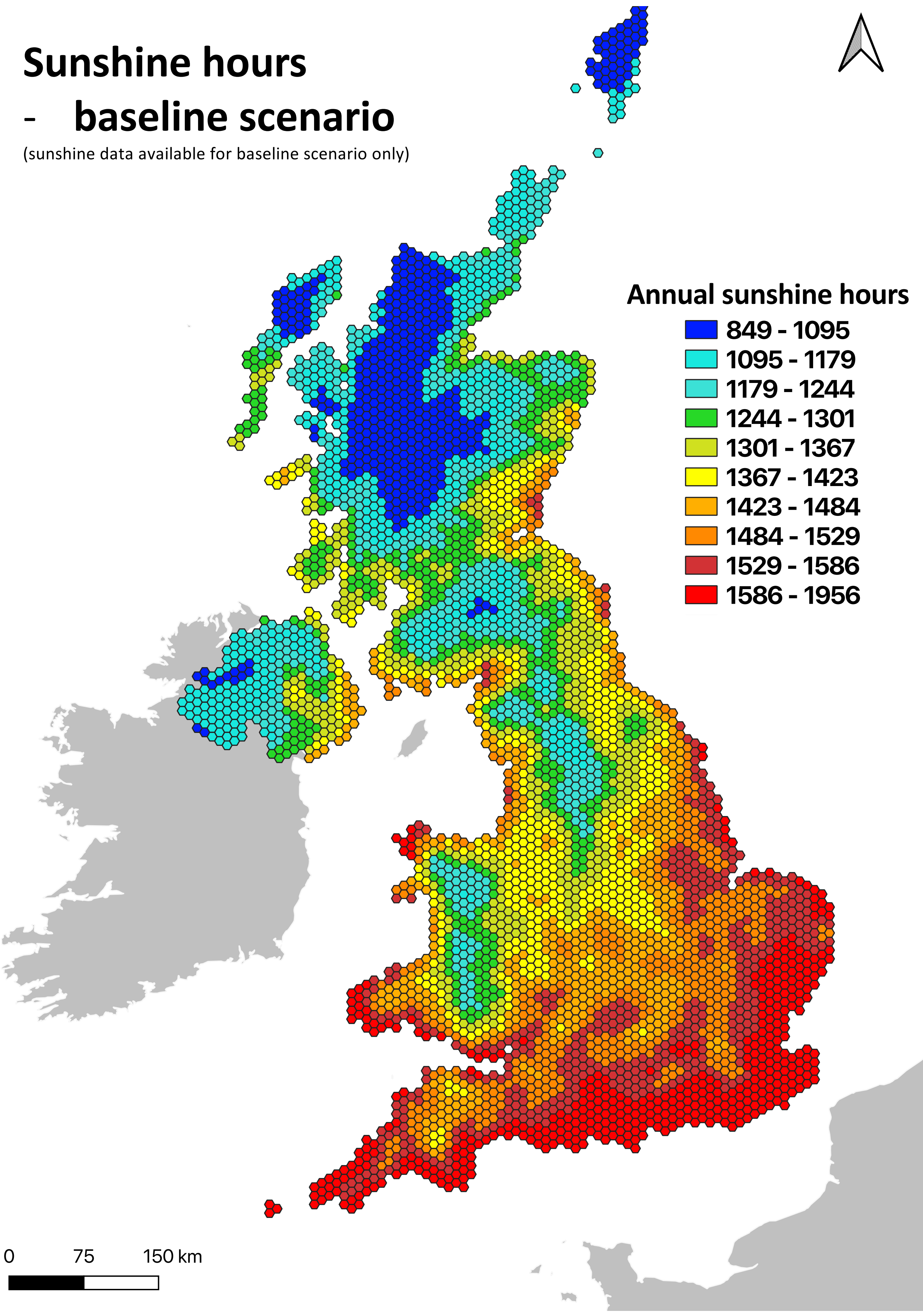
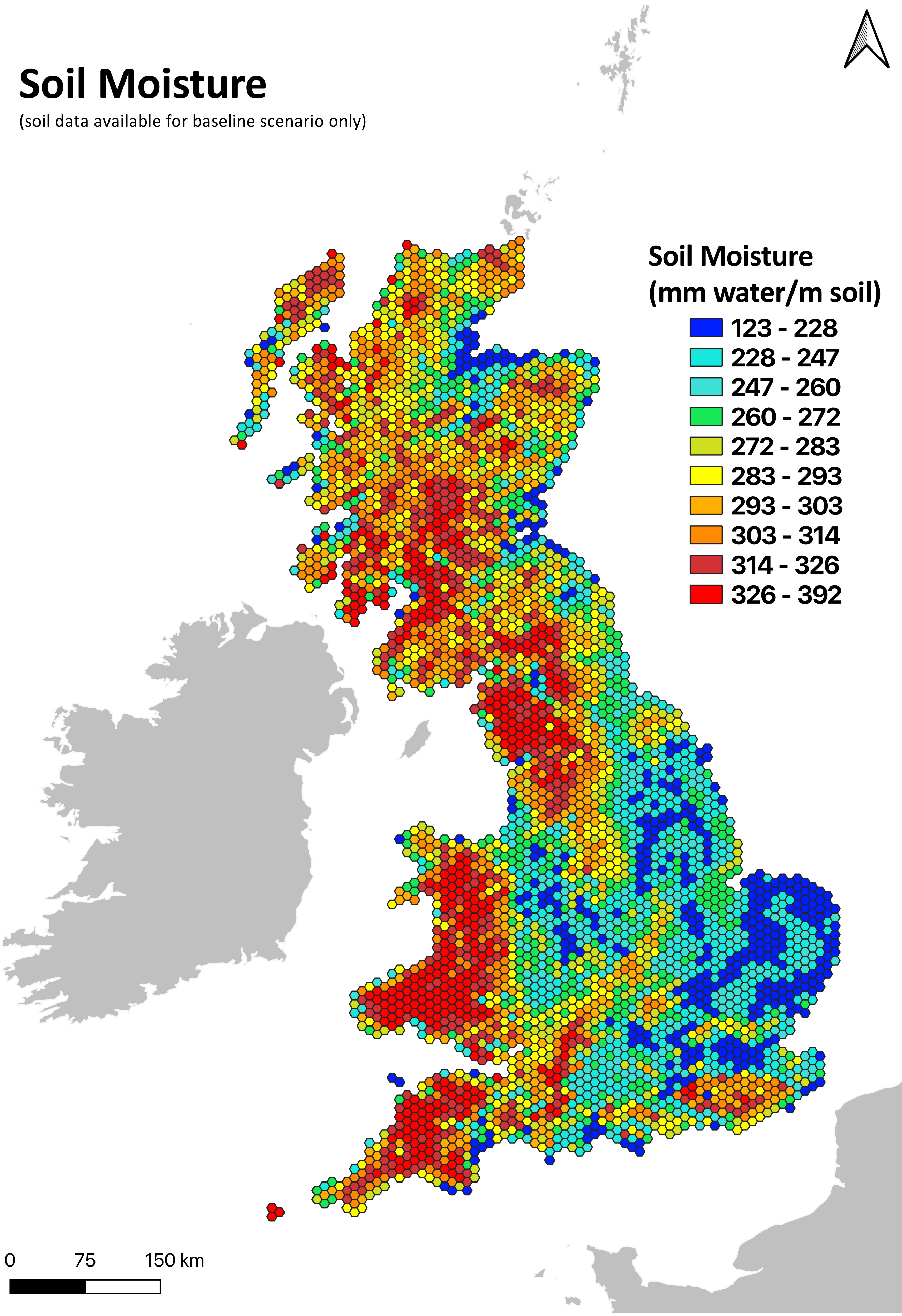
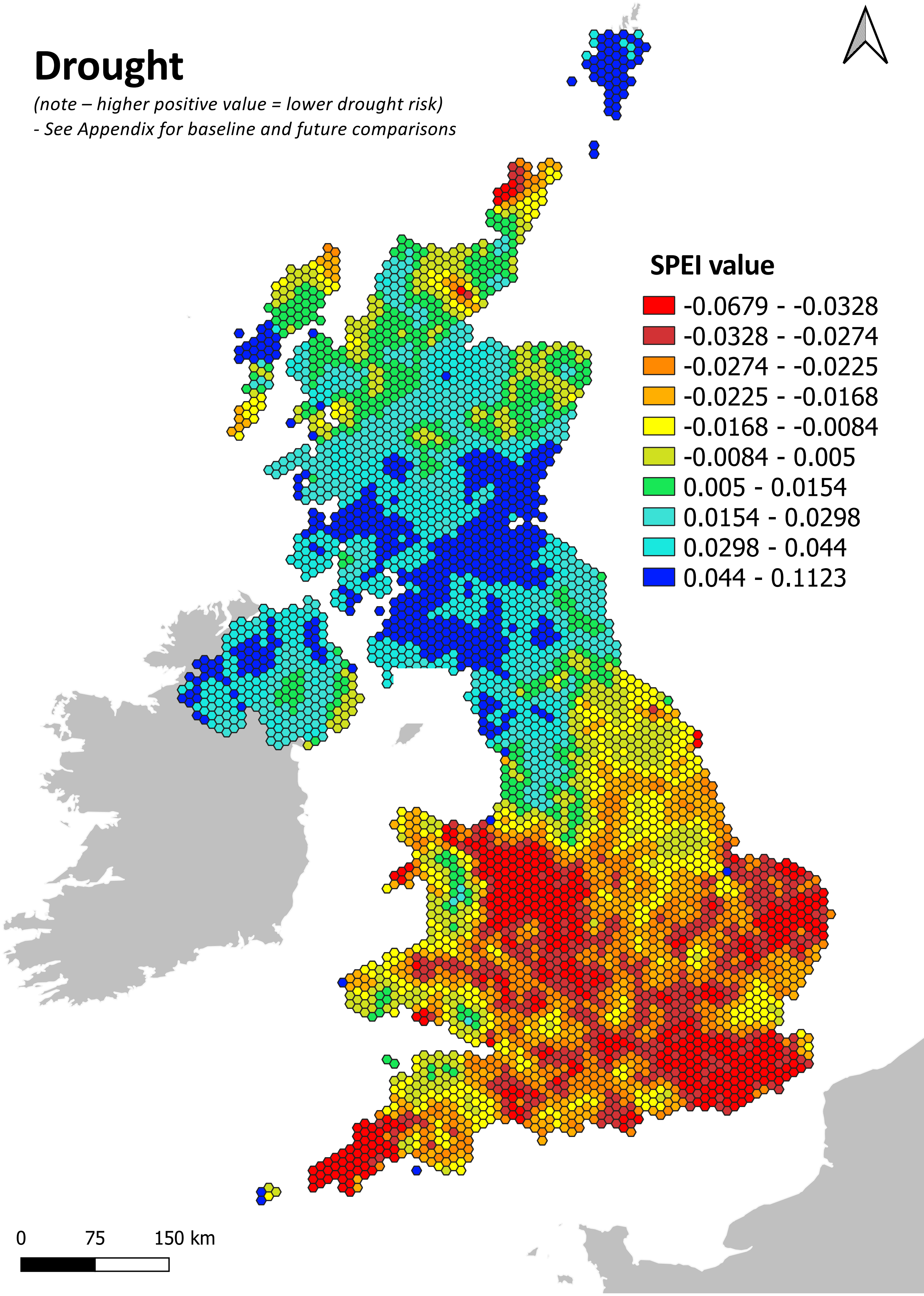


Figure 29: Underlying soil moisture (mm water per m soil), in baseline scenario




Drought
(note – higher positive value = lower drought risk)
- See Appendix for baseline and future comparisons
SPEI value
-0.0679 - -0.0328
-0.0328 - -0.0274
-0.0274 - -0.0225
-0.0225 - -0.0168
-0.0168 - -0.0084
-0.0084 - 0.005
0.005 - 0.0154
0.0154 - 0.0298
0.0298 - 0.044
0.044 - 0.1123
0
75
150 km

3.3. Historic England Phase 1.0 Risks

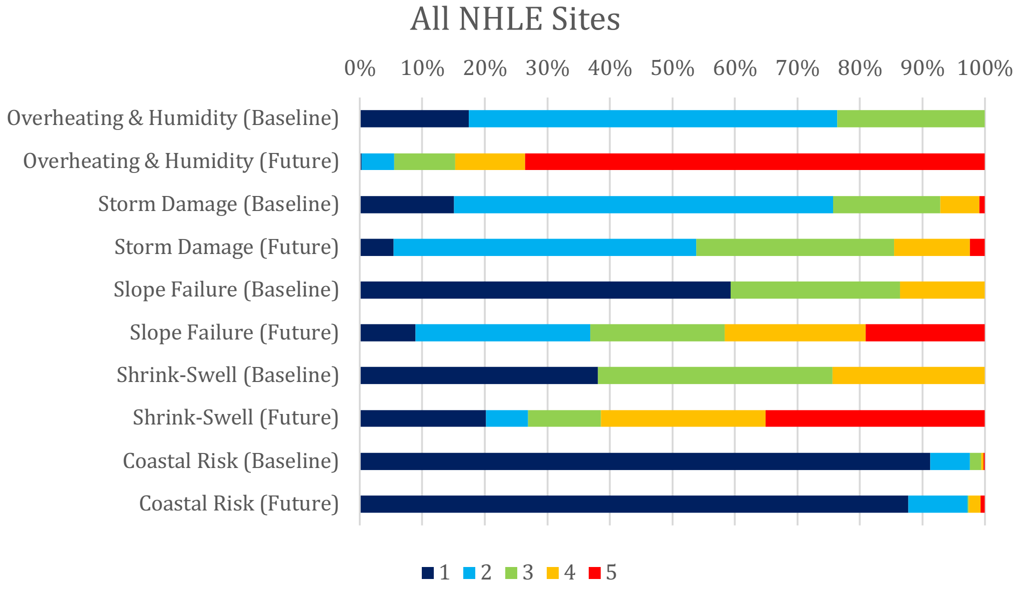


Figure 31: Percentage of heritage assets on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

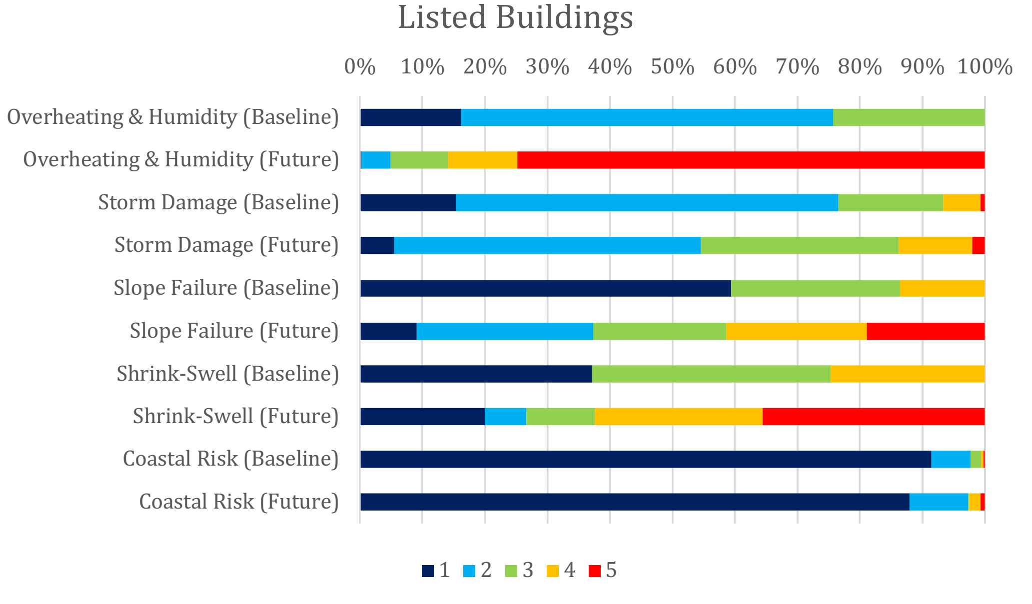


Figure 32: Percentage of Listed Buildings on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

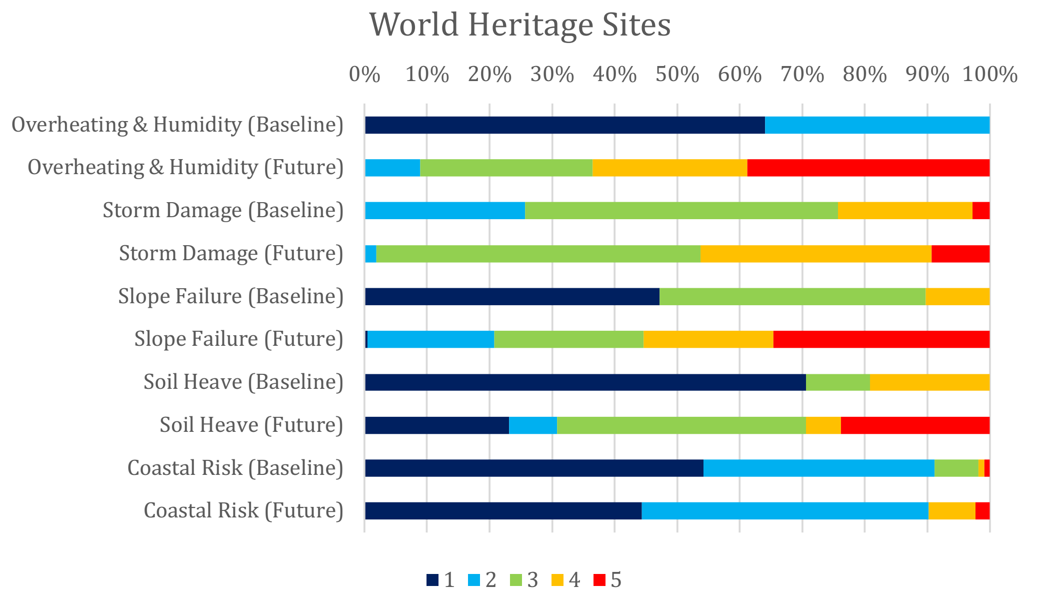


Figure 33: Percentage of World Heritage assets on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

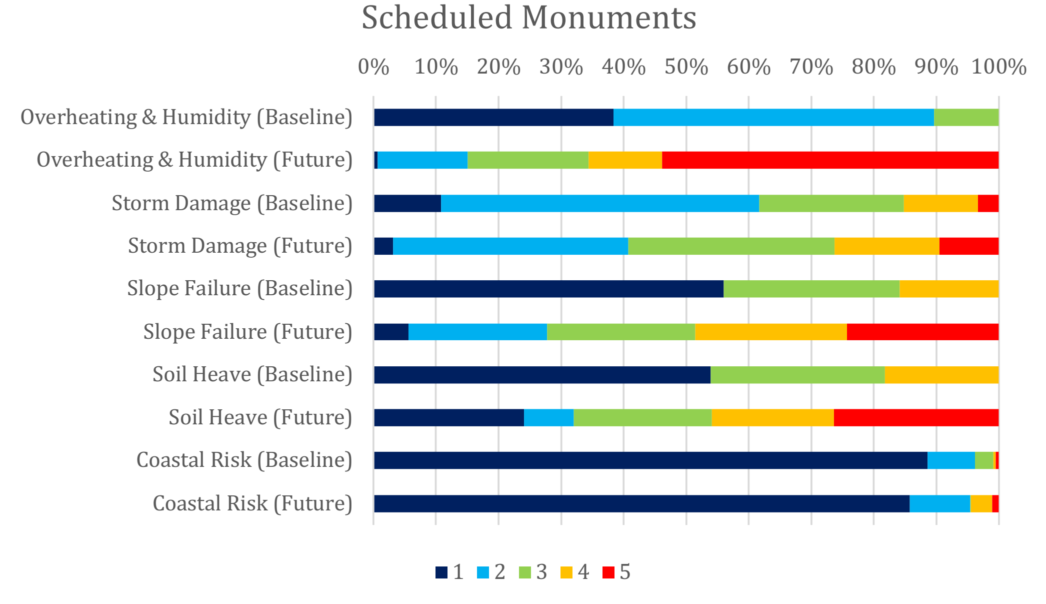


Figure 34: Percentage of Scheduled Monuments on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

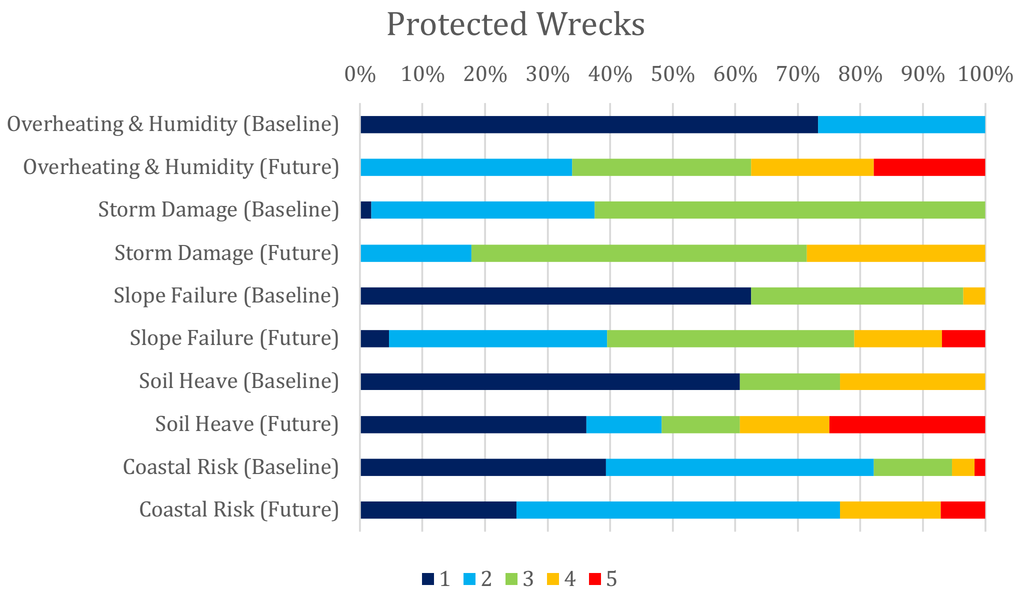


Figure 35: Percentage of Protected Wrecks on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

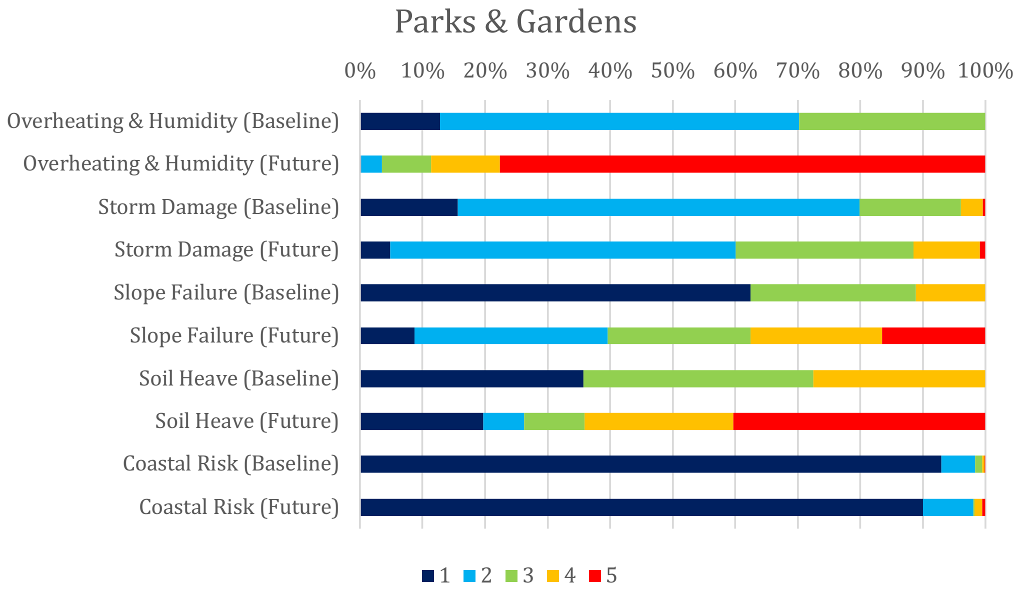


Figure 36: Percentage of Parks & Gardens on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

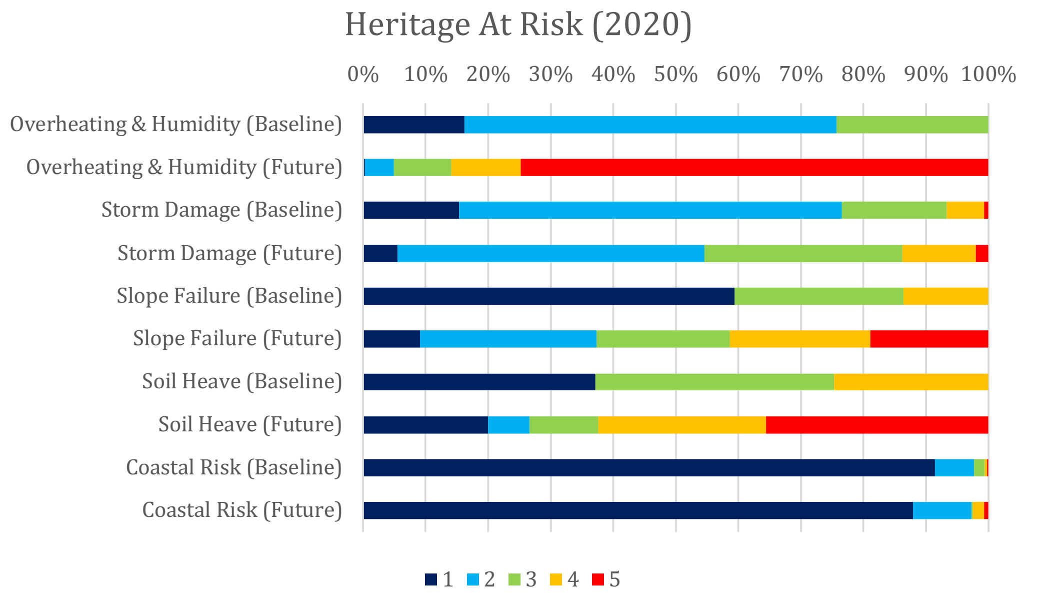


Figure 37: Percentage of 2020 'Heritage At Risk' assets on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

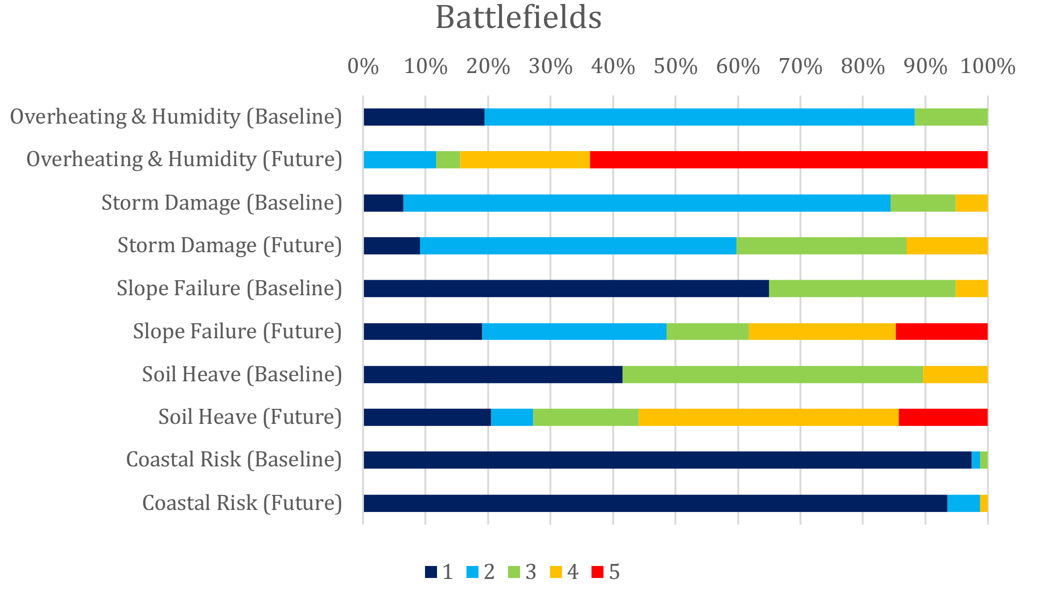


Figure 38: Percentage of Battlefields on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

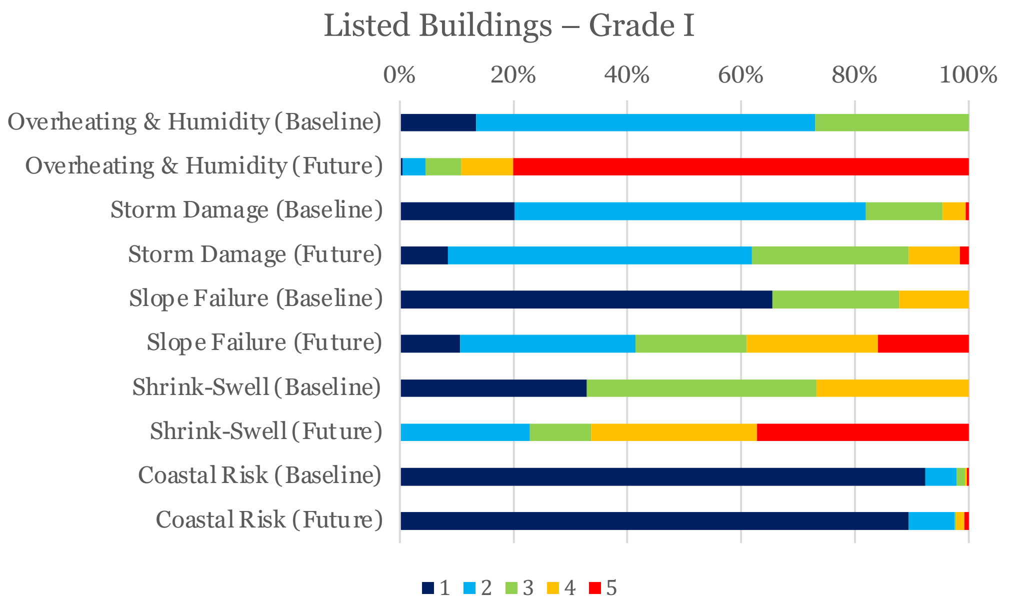


Figure 39: Percentage of Grade I Listed Buildings on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

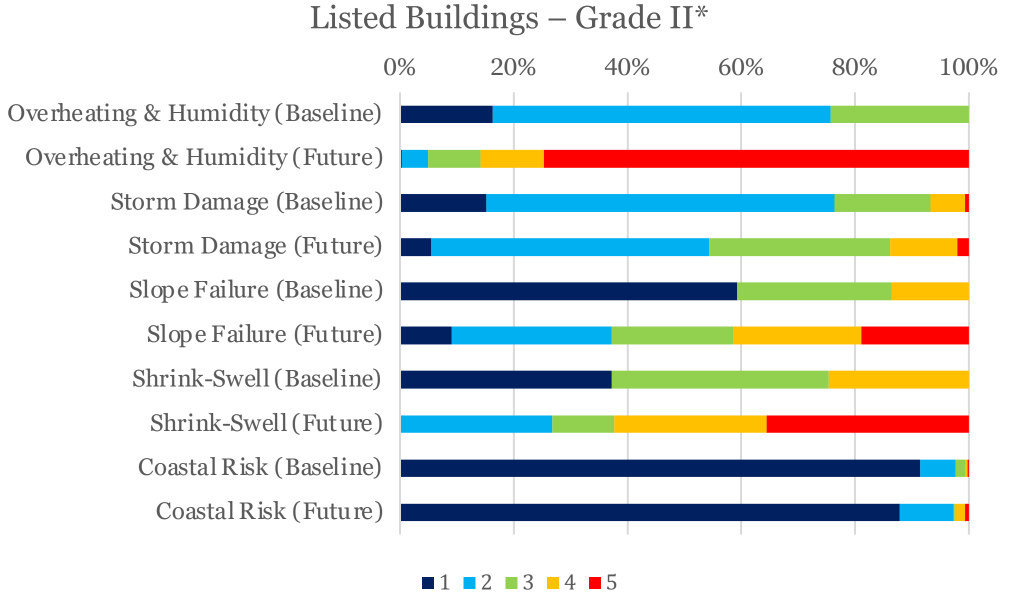


Figure 40: Percentage of Grade II* Listed Buildings on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

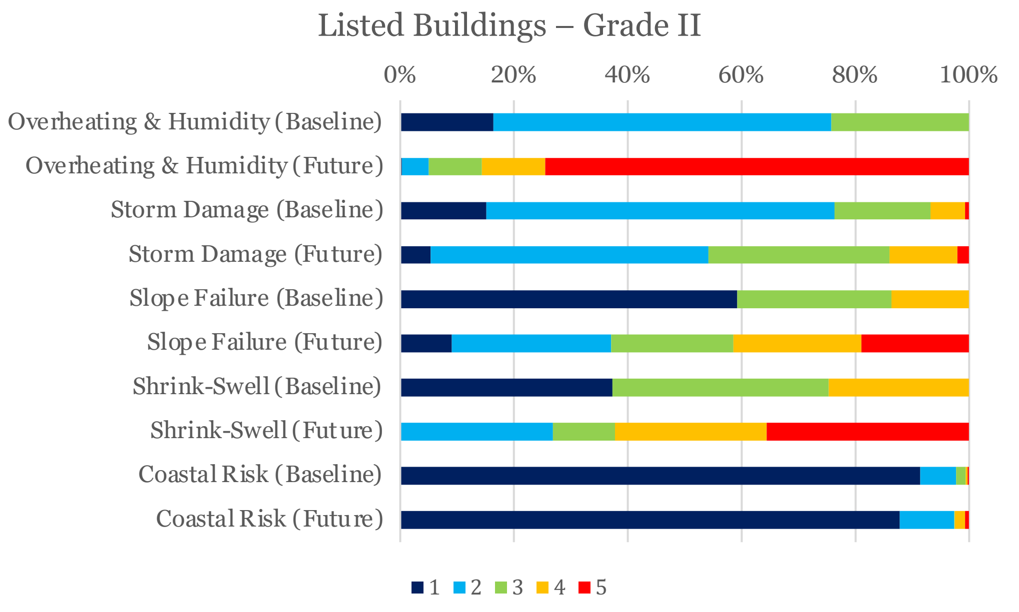


Figure 41: Percentage of Grade II Listed Buildings on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

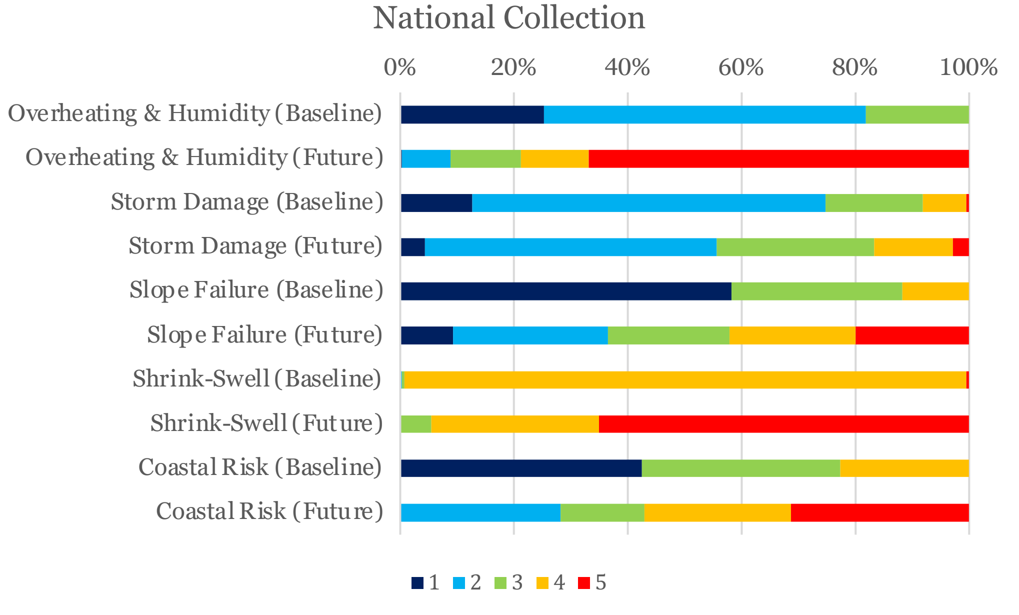


Figure 42: Percentage of National Collection Sites on the National Heritage List for England (NHLE) at risk from Phase 1.0 indicators (1 = lowest, 5 = highest)

4.0. DISCUSSION

4.1. Phase 1.0 Indicator Update

Trends shown across Phase 1.0 indicators are largely similar to those identified in the first phase of the work, with an overall increase in risk seen for the majority of sites and risks:

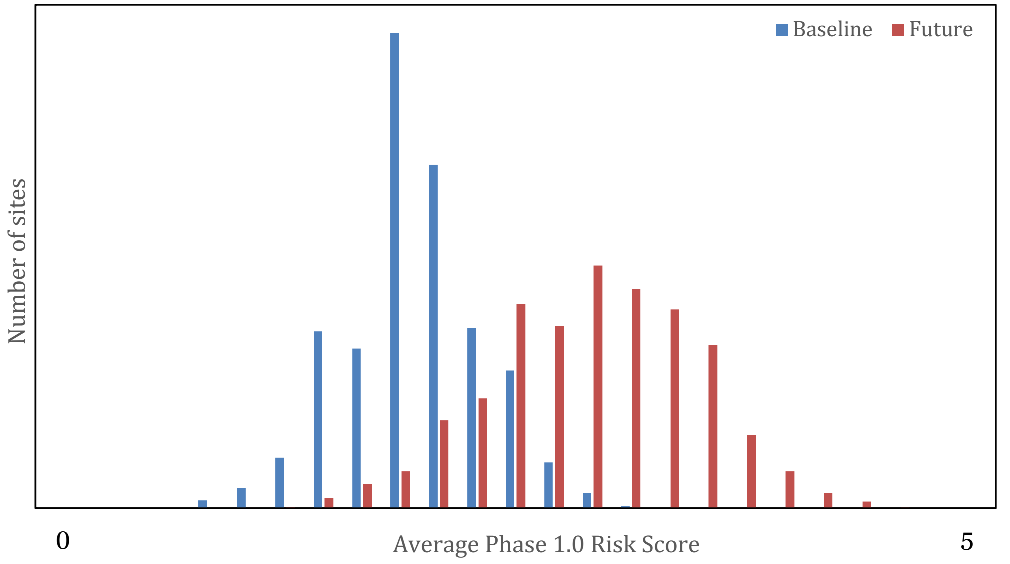


Figure 43: Figure showing average risk scores of heritage assets on the National Heritage List for England (NHLE) across all Phase 1.0 indicators

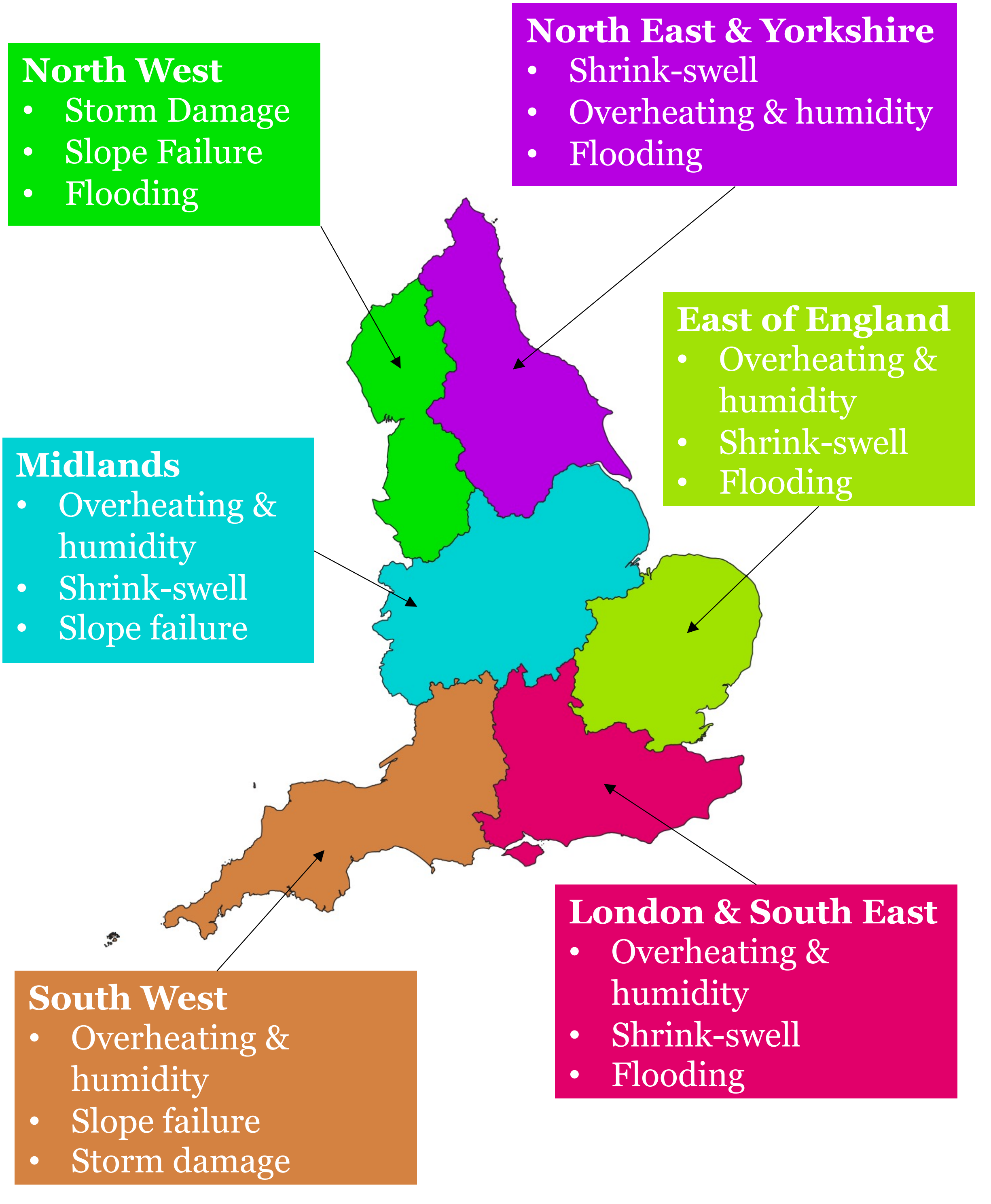


Figure 44: Map of key climate hazards within each region of England

Figure 44 above shows the key hazards related to each region of the UK. Key themes and general trends replicated from Phase 1.0 are shown in the excerpt below:

The climate risk analysis highlights several important developments in background risk to Historic England's assets. General trends seen are similar to those shown in Phase 1.0, and can be summarised as follows:

1) An across-the-board intensification of climate driven risks
Climate-linked risks show a generally deteriorating situation towards 2070. This means that any site or region currently suffering damage or losses as a result of any of these risk factors should assume that, without mitigation action, the risks of further damage or loss will increase over time.

2) Overheating & humidity becoming more widespread and more intense
This risk is in part to visitor numbers, and is relevant to properties where high temperatures make it unsafe for visitors and staff to remain indoors, or where very hot weather is likely to put visitors off. There is also a risk to building materials and contents, with high temperatures increasing risks to building fabric (e.g. lead buckling and timber cracking). This pattern of increasing risk will be especially marked towards the South and East of England, but serious impacts may be expected north well into Yorkshire, and inland parts of SW England.

3) Slope failure / landslips becoming more likely and more widespread
This risk applies to any built or buried structures that may be damaged or destroyed by slope failure. It also applies to properties and locations that may become cut off to visitors or site managers as a result of disruption to transport infrastructure. The risk analysis shows notable increases in the likelihood of slope failure across hilly and western parts of the country, covering: the Lake District, throughout the Pennines, and in parts of the South West – notably around the Mendips and Dorset.

4) Shrink-swell intensifying and expanding out from existing high-risk zones
Shrink-swell creates risks to the structural integrity of historical features, as the ground underneath them moves and flexes the structure. The risk of damage from shrink swell arises as an interaction between underlying soil types and climatic conditions. Our analysis shows an increase in risk, and an extension of area of risk, along and around areas that are currently impacted.

Trends are fairly consistent across all site types, with the exception of Protected Wrecks and World Heritage Sites, which have higher proportions of coastal locations, and thus higher risk from coastal erosion and flooding.

4.2. Phase 1.5. Implications

Figures 3-30 show the regional variations in Temperature, Precipitation, Drought, River Scour and Other Indicators in baseline and future scenarios (where data is available).

Figures 3-10 show an overall trend of increasing temperatures, with minimum, mean and maximum temperatures increasing, as well as frequency of >25°C and >30°C days – particularly in SE England, but also in general across the UK. Data provided in Phase 1.5. of the climate risk mapping work allows for increased usability, and regional determination of risk. In Appendix 2 (Figure 49) for example, the use of a 25°C threshold and gradation scale allows for increased resolution in temperature variations in Scotland, highlighting variations in overheating risk in central and north Scotland relative to more southern Scottish regions.

Figure 10 shows the corresponding increase in cooling degree days required in the future scenario.

Figures 11-18 show the intensification of both drought and heavy rainfall, with the number of days with rainfall above 2mm decreasing, while the number of days with rainfall above 50mm increases – i.e. there are more dry days, but also more *very* wet days. This aligns with the results of the storm damage analysis performed in Phase 1.0, as shown in Figure 45 below.

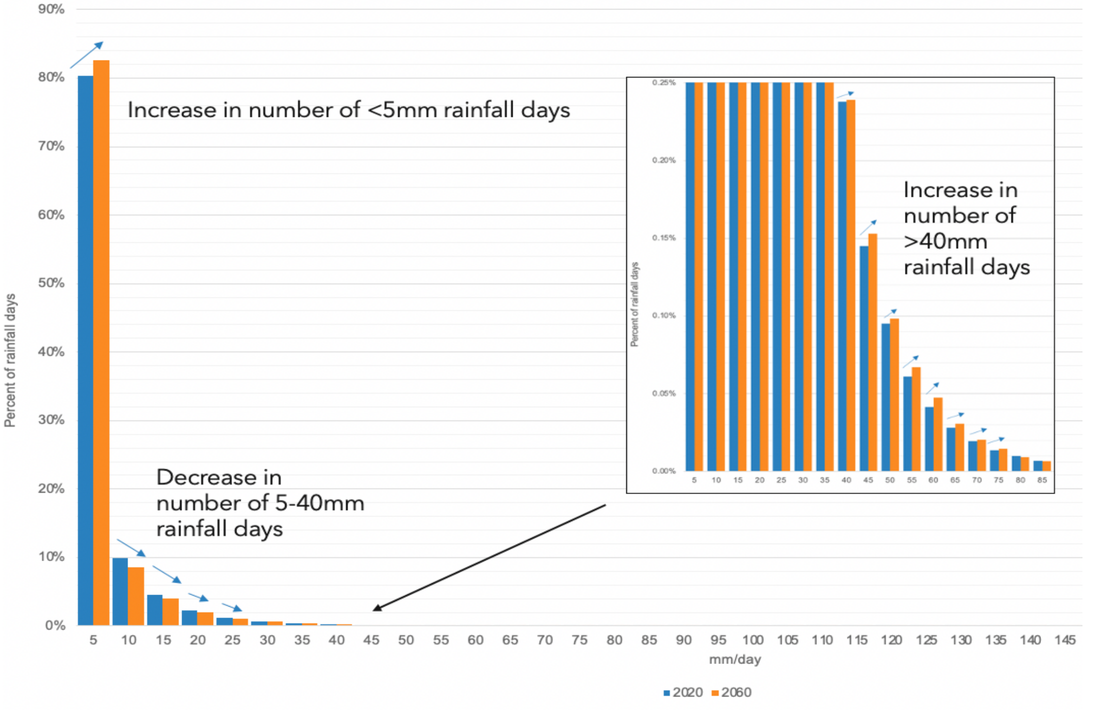


Figure 45: 5-Year Histogram of daily rainfall amounts, from Phase 1.0.

Figure 20 shows the current risk related to river scour in Great Britain (data for future scenarios and Northern Ireland were not available) – with catchment stability highest in the South, and lowest in the North, of England. Figures 19-26 also show regional variations in other contributing factors to river scour.

Figures 27-30 show a number of other risk indicators, with groundfrost, sunshine hours and soil moisture generally aligning with their parallel indicators of min temperature, mean temperature and precipitation respectively.

4.3. Implementation & Data Use

Phase 1.0 Updates

Updated Phase 1.0. data can be used and implemented as described in the following excerpt from the original report:

As well as providing a strategic picture of changes to climate linked risks to historic properties across the organisation, the Hexgrids used in our analysis can be used to provide a localised background risk profile for individual assets.

The background risk profile could be used, in conjunction with site analysis, to provide a consistent screening and mitigation planning framework; in essence, flagging potential risk factors that may become a problem for a property.

Screening would follow the basic logic set out below, and illustrated in Figure 46:

1. *Risk level*
   The background risk level for a site can be obtained from the HexGrid in which it is located. This provides current and projected background risk against each of the seven risk categories.

2. *Relevance to asset*
   Background risk refers to risk independent of site characteristics. The second part of any analysis therefore looks at the extent to which the risk is relevant, given the type, condition and location/context of the asset

3. *Plan status*
   In very simple terms, the analysis should use background risk combined with asset characteristics to evaluate the adequacy of any mitigation plans that are in place. This evaluation should be done in relation to current risk, and future projected risk

4. *Required action*
   In essence, this is about ensuring that plans are in place which respond both to current and projected impact relating to each risk category at the property in question. Clearly, where plans are inadequate either at current or future risk levels, then further planning, investment and action would be required if deemed appropriate.

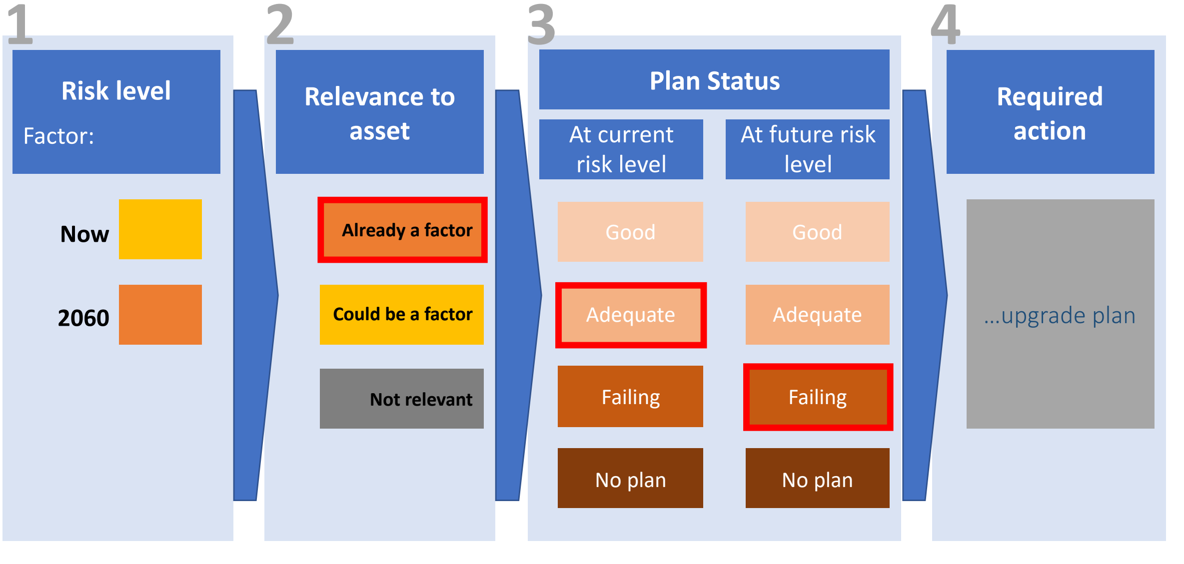


Figure 46: Basic logic for integrating background risk profile analysis into site management planning

Phase 1.5 Uses

With the addition of Phase 1.5. data, the increased data granularity and threshold data availability allows for a number of other uses:

- **Integrating with existing risk management systems -** Where existing systems and frameworks are already in use, raw data can be extracted and used straight from the risk maps, to fit into these systems. For example, for organisations with risk management plans for >30°C or >50mm rainfall days, data on increased frequency of these events can be used to plan for future fiscal and infrastructural needs.

- **Detailed site analysis –** while acknowledging the limitations of the data and its intended use as a flagging tool rather than precise planning tool, data can be used to provide context and develop more detailed site plans, combining local expertise with wider climate information – see the National Trust's Blickling case study[7].

- **Integration into public climate hazard tool –** Updated data from the Phase 1.5. analysis can now be used to update and expand the public tool for mapping climate risks.

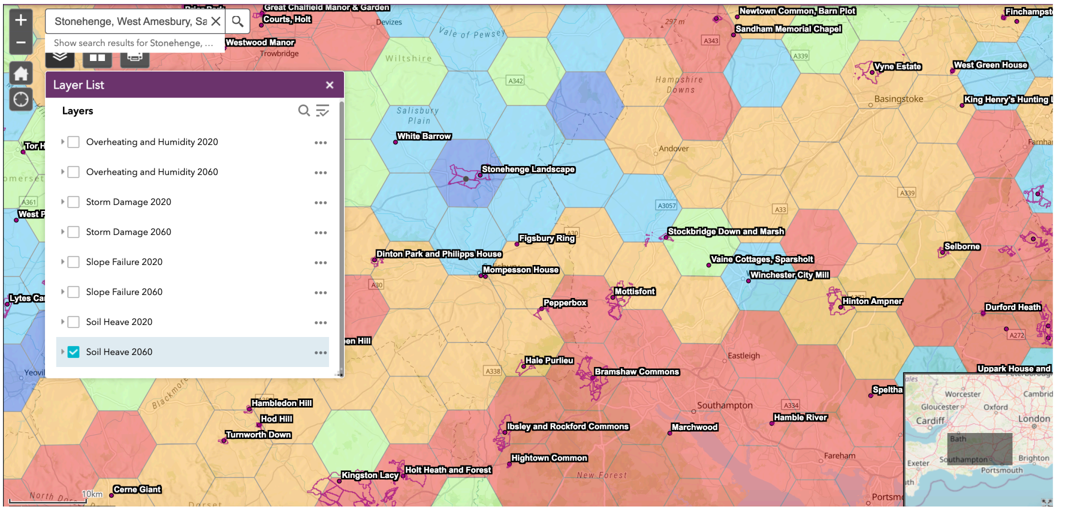


Figure 47: Screenshot from public tool for climate hazard mapping

[7] Available upon request

CONCLUSIONS & NEXT STEPS

Phase 1.5. confirms the intensification of climate hazards to historic sites in the UK, underlining the continued need to develop understanding of, and responses to, climate hazards across the heritage sector.

For Historic England in particular, key hazards include across-the-board increases in temperature & humidity-related risks (overheating, damage to sites, drought), increases in heavy rainfall in the South West and North West of England, and local intensification of landslide and shrink-swell risks in existing geomorphological hotspots.

Recommendations for next steps include:

1) An organisational or sector-wide climate risk screening system for heritage assets
Developing a common system for screening sites against climate risk, and checking the adequacy of mitigation plans. Having a common system for picking up and acting on climate-derived risk achieves two things: (1) it provides a consistent level of technical support and policy signal to regional site managers and teams, helping ensure adequate action is taken, and (2) it helps in tracking, monitoring, and directing activity and investment at a strategic level.

2) Best practice development for key risk categories
Managing certain key categories of risk are going to become an increasingly familiar part of site management. It will make sense to identify these, and proactively develop and share solutions. This may be achieved through internal 'centres of excellence' and/or collaborations with specialist partner organisations.

3) Strategic investment planning
Clear patterns of risks, in terms of type and regional focus, are emerging. Combined with coordinated site-screening this should start to help develop an understanding of where and how to place strategic investment in developing resilience to climate-linked risks.

4) Continued work with Heritage partners to develop the approach as a common resource across the UK
HE is already engaging and collaborating with agencies across the UK to develop and further deploy this work. The ambition could be to build in additional datasets in order to provide an increasingly accurate picture, to provide a commonly accessible interface for site managers, and to develop action and implementation plans so that site managers can readily obtain background risk profiles for the locations of their heritage assets, wherever they are in the UK.

APPENDIX

Appendix 1: List of Datasets and filenames

Filename	Source	Description	Period	Region
BGS_CollapsibleDeposits.gpkg	BGS GeoSure	Low, Moderate and Significant risk of hazard as defined by BGS	Historic	GB only
BGS_Landslides.gpkg	BGS GeoSure	Low, Moderate and Significant risk of hazard as defined by BGS	Historic	GB only
BGS_ShrinkSwell.gpkg	BGS GeoSure	Low, Moderate and Significant risk of hazard as defined by BGS	Historic	GB only
HRi_above_60_future.gpkg	MET Office	Number of days per year with Relative Indoor Humidity (for average building) above 60%	Future	GB & NI
HRi_above_60_past.gpkg	MET Office	Number of days per year with Relative Indoor Humidity (for average building) above 60%	Historic	GB & NI
HRi_above_100_future.gpkg	MET Office	Number of days per year with Relative Indoor Humidity (for average building) above 100%	Future	GB & NI
HRi_above_100_past.gpkg	MET Office	Number of days per year with Relative Indoor Humidity (for average building) above 100%	Historic	GB & NI
HRi_under_10_future.gpkg	MET Office	Number of days per year with Relative Indoor Humidity (for average building) below 10%	Future	GB & NI
HRi_under_10_past.gpkg	MET Office	Number of days per year with Relative Indoor Humidity (for average building) below 10%	Historic	GB & NI
HRi_under_40_future.gpkg	MET Office	Number of days per year with Relative Indoor Humidity (for average building) below 40%	Future	GB & NI
HRi_under_40_past.gpkg	MET Office	Number of days per year with Relative Indoor Humidity (for average building) below 40%	Historic	GB & NI
pr_above_7.6_future.gpkg	MET Office	Number of days per year with >7.6mm precipitation	Future	GB & NI
pr_above_7.6_past.gpkg	MET Office	Number of days per year with >7.6mm precipitation	Historic	GB & NI
pr_above_15_future.gpkg	MET Office	Number of days per year with >15mm precipitation	Future	GB & NI
pr_above_15_past.gpkg	MET Office	Number of days per year with >15mm precipitation	Historic	GB & NI
pr_above_40_future.gpkg	MET Office	Number of days per year with >40mm precipitation	Future	GB & NI
pr_above_40_past.gpkg	MET Office	Number of days per year with >40mm precipitation	Historic	GB & NI
pr_above_50_future.gpkg	MET Office	Number of days per year with >50mm precipitation	Future	GB & NI
pr_above_50_past.gpkg	MET Office	Number of days per year with >50mm precipitation	Historic	GB & NI
pr_annualprecipitation_future.gpkg	MET Office	Total annual precipitation	Future	GB & NI
pr_annualprecipitation_past.gpkg	MET Office	Total annual precipitation	Historic	GB & NI
pr_percentiledifference_1st_99th_future.gpkg	MET Office	Difference between 1st and 99th percentile of daily precipitation	Future	GB & NI
pr_percentiledifference_1st_99th_past.gpkg	MET Office	Difference between 1st and 99th percentile of daily precipitation	Historic	GB & NI
pr_percentiledifference_5th_95th_future.gpkg	MET Office	Difference between 5th and 95th percentile of daily precipitation	Future	GB & NI
pr_percentiledifference_5th_95th_past.gpkg	MET Office	Difference between 5th and 95th percentile of daily precipitation	Historic	GB & NI

pr_under_0.5_future.gpkg	MET Office	Number of days per year with <0.5mm precipitation	Future	GB & NI
pr_under_0.5_past.gpkg	MET Office	Number of days per year with <0.5mm precipitation	Historic	GB & NI
sfcWind_average_windspeed_future.gpkg	MET Office	Average daily windspeed	Future	GB & NI
sfcWind_average_windspeed_past.gpkg	MET Office	Average daily windspeed	Historic	GB & NI
snw_above_2.6_future.gpkg	MET Office	Number of days with >2.6 cm snowfall	Future	GB & NI
snw_above_2.6_past.gpkg	MET Office	Number of days with >2.6 cm snowfall	Historic	GB & NI
tas_average_temperature_future.gpkg	MET Office	Average daily mean temperature	Future	GB & NI
tas_average_temperature_past.gpkg	MET Office	Average daily mean temperature	Historic	GB & NI
tas_percentiledifference_10th_90th_future.gpkg	MET Office	Difference between 10th and 90th percentile of daily mean temperature	Future	GB & NI
tas_percentiledifference_10th_90th_past.gpkg	MET Office	Difference between 10th and 90th percentile of daily mean temperature	Historic	GB & NI
tasmax_above_30_future.gpkg	MET Office	Number of days with daily max temperature above 30 degrees celsius	Future	GB & NI
tasmax_above_30_past.gpkg	MET Office	Number of days with daily max temperature above 30 degrees celsius	Historic	GB & NI
wdr_over_56.5_future.gpkg	MET Office	Number of days per year with wind driven rain index above 56.5	Future	GB & NI
wdr_over_56.5_past.gpkg	MET Office	Number of days per year with wind driven rain index above 56.5	Historic	GB & NI
wdr_over_100_future.gpkg	MET Office	Number of days per year with wind driven rain index above 100	Future	GB & NI
wdr_over_100_past.gpkg	MET Office	Number of days per year with wind driven rain index above 100	Historic	GB & NI
wsgmax10m_above_27_future.gpkg	MET Office	Number of days per year with daily max speed of wind gust at 10m height over 27 m/s	Future	GB & NI
wsgmax10m_above_27_past.gpkg	MET Office	Number of days per year with daily max speed of wind gust at 10m height over 27 m/s	Historic	GB & NI
wsgmax10m_above_31_future.gpkg	MET Office	Number of days per year with daily max speed of wind gust at 10m height over 31 m/s	Future	GB & NI
wsgmax10m_above_31_past.gpkg	MET Office	Number of days per year with daily max speed of wind gust at 10m height over 31 m/s	Historic	GB & NI
Average_Monthly_Min_Temperature	MET Office	Daily minimum temperature, averaged per month	Historic/Future	GB & NI
Average_Monthly_Sunshine	MET Office	Daily total sunshine hours, averaged per month	Historic	GB & NI
Average_Monthly_Temperature	MET Office	Daily mean temperature, averaged per month	Historic/Future	GB & NI
Dissolving_Rocks	BGS GeoSure	Low, Moderate and Significant risk of hazard as defined by BGS	Historic	GB only
Drought	CEH	Standardized Precipitation Evapotranspiration Index (as defined by CEH) - https://spei.csic.es/	Historic/Future	GB data only, with values extrapolated for NI
CatchmentStability.gpkg	BGS GeoScour	Catchment Stability, as defined by BGS GeoScour - https://www.bgs.ac.uk/download/geoscour-user-guide/	Historic	GB only
FloodAccommodation.gpkg	BGS GeoScour	Flood Accomodation, as defined by BGS GeoScour - https://www.bgs.ac.uk/download/geoscour-user-guide/	Historic	GB only

Geological_Runoff_Potential.gpkg	BGS GeoScour	Geological Runoff Potential, as defined by BGS GeoScour - https://www.bgs.ac.uk/download/geoscour-user-guide/	Historic	GB only
Morphology.gpkg	BGS GeoScour	Morphology, as defined by BGS GeoScour - https://www.bgs.ac.uk/download/geoscour-user-guide/	Historic	GB only
Urban_Coverage_LargePercent.gpkg	BGS GeoScour	Large Urban Coverage, as defined by BGS GeoScour - https://www.bgs.ac.uk/download/geoscour-user-guide/	Historic	GB only
Urban_Coverage_SmallPercent.gpkg	BGS GeoScour	Small Urban Coverage, as defined by BGS GeoScour - https://www.bgs.ac.uk/download/geoscour-user-guide/	Historic	GB only
Average_Annual_Groundfrost	MET Office	Average annual days with groundfrost	Historic	GB & NI
Average_Annual_Sunshine	MET Office	Average annual sunshine hours per day	Historic	GB & NI
Average_Monthly_Days_Over25	MET Office	Average number of days over 25 degrees celsius, per month	Historic/Future	GB & NI
Average_Monthly_Days_Over30	MET Office	Average number of days over 30 degrees celsius, per month	Historic/Future	GB & NI
Average_Monthly_Days_PR_Over2mm	MET Office	Average number of days over 2mm precipitation, per month	Historic/Future	GB & NI
Average_Monthly_Days_PR_Over10mm	MET Office	Average number of days over 10mm precipitation, per month	Historic/Future	GB & NI
Average_Monthly_Days_PR_Over50mm	MET Office	Average number of days over 50mm precipitation, per month	Historic/Future	GB & NI
Average_Monthly_DegreeDays >> growing	MET Office	Average number of growing degree days per month	Historic/Future	GB & NI
Average_Monthly_DegreeDays >> heating	MET Office	Average number of heating degree days per month	Historic/Future	GB & NI
Average_Monthly_DegreeDays >> cooling	MET Office	Average number of cooling degree days per month	Historic/Future	GB & NI
Average_Monthly_Groundfrost	MET Office	Average number of days with groundfrost per month	Historic	GB & NI
Average_Monthly_Max_Temperature	MET Office	Average daily max temperature, by month	Historic/Future	GB & NI
Overheating & Humidity	Multiple	1-5 ranking for likelihood of Overheating & Humidity hazard event, as defined in methodology report (1 = <1 annual hazard event, 5 = >15 annual hazard events)	Historic/Future	GB & NI
Storm Damage	Multiple	1-5 ranking for likelihood of Storm Damage hazard event, as defined in methodology report (1 = <1 annual hazard event, 5 = >15 annual hazard events)	Historic/Future	GB & NI
Slope Failure	Multiple	1-5 ranking for likelihood of Slope Failure hazard event, as defined in methodology report (1 = <1 annual hazard event, 5 = >15 annual hazard events)	Historic/Future	GB & partial NI data
Flooding	Multiple	1-5 ranking for likelihood of Flooding hazard event, as defined in methodology report (1 = <1 annual hazard event, 5 = >15 annual hazard events)	Historic/Future	GB & partial NI data
Shrink Swell	Multiple	1-5 ranking for likelihood of Shrink Swell hazard event, as defined in methodology report (1 = <1 annual hazard event, 5 = >15 annual hazard events)	Historic/Future	GB & partial NI data
Coastal Risk	Multiple	1-5 ranking for likelihood of Coastal Risk hazard event, as defined in methodology report (1 = <1 annual hazard event, 5 = >15 annual hazard events)	Historic/Future	GB & NI

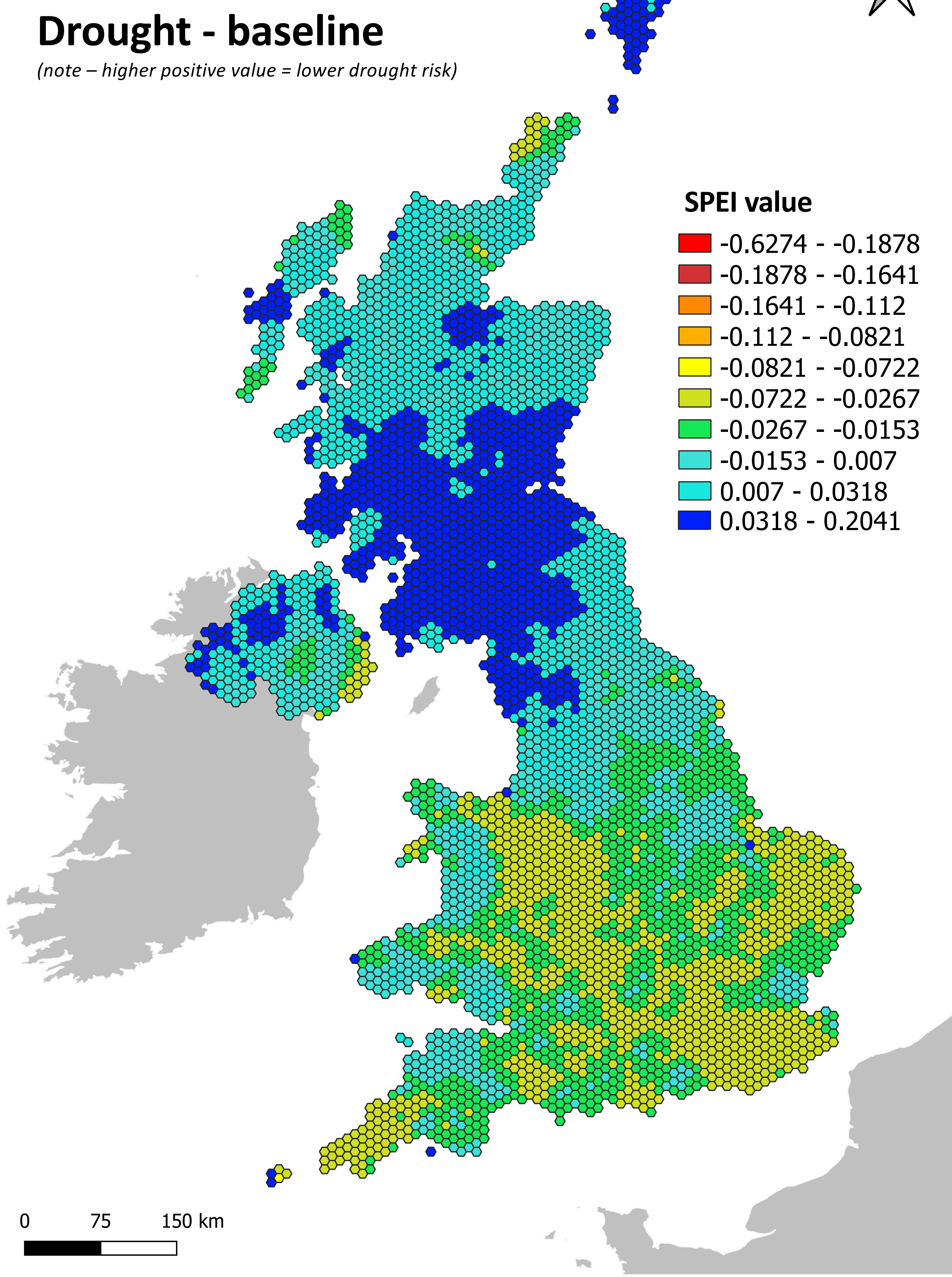
Figure 48: Tabulated list of datasets and filenames

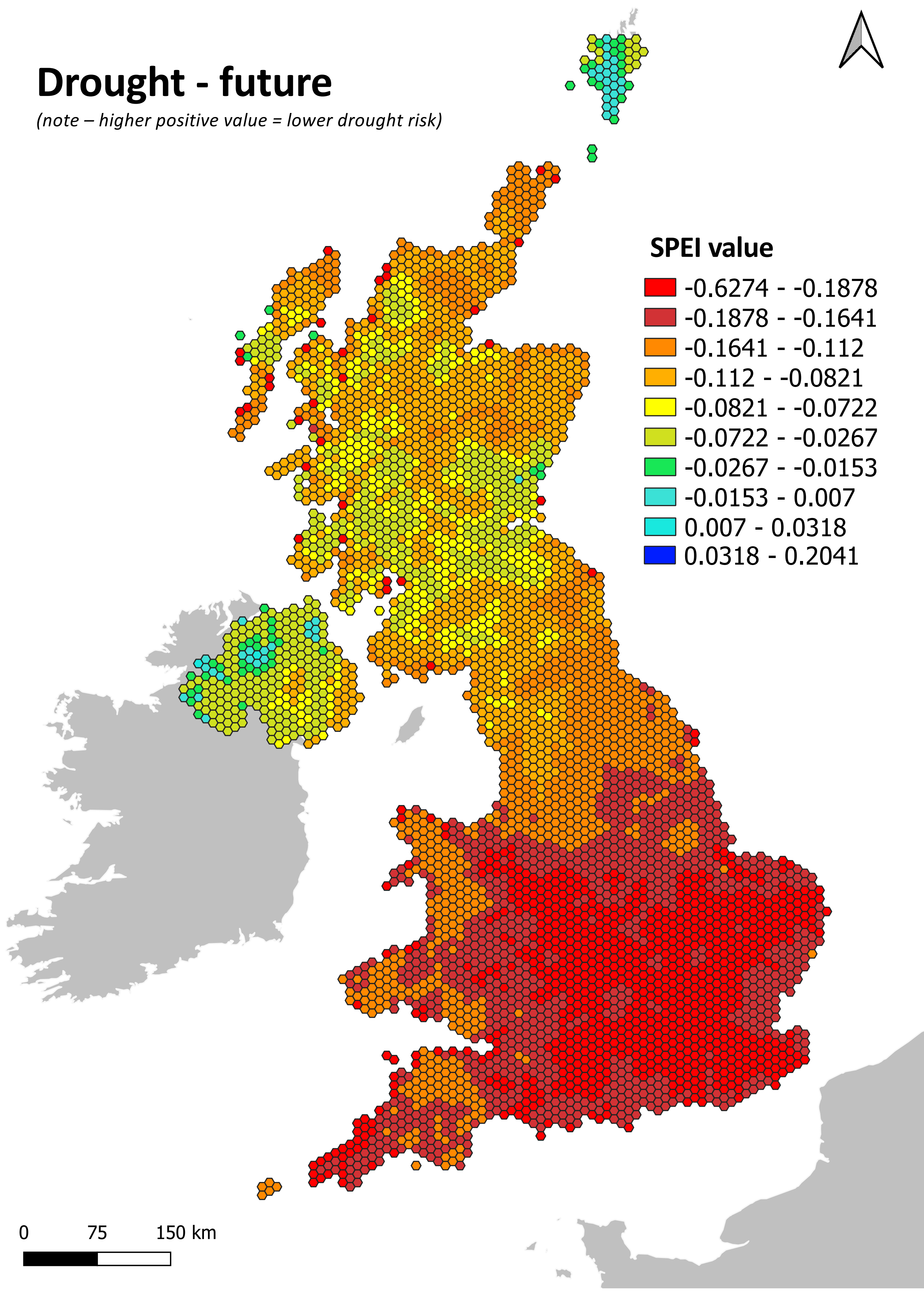
Appendix 2: Tabulated values for Phase 1.0 hazards

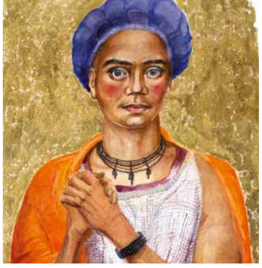
Hazard	Score	Battlefields		Heritage At Risk		Listed Buildings (All)		Listed Buildings (Grade I)		Listed Buildings (Grade II*)		Listed Buildings (Grade II)		National Collection		Parks And Gardens		Protected Wrecks		Scheduled Monuments		World Heritage Sites		Total	
		Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future	Baseline	Future
Overheating & Humidity	1	19%	0%	25%	1%	16%	0%	13%	0%	14%	0%	16%	0%	25%	0%	13%	0%	71%	2%	38%	1%	73%	2%	17%	0%
	2	69%	12%	54%	8%	59%	5%	60%	4%	61%	4%	59%	5%	57%	9%	57%	3%	29%	27%	51%	14%	22%	37%	59%	5%
	3	12%	4%	21%	14%	24%	9%	27%	6%	25%	8%	24%	9%	18%	12%	30%	8%	0%	31%	10%	19%	5%	29%	24%	10%
	4	0%	21%	0%	15%	0%	11%	0%	9%	0%	11%	0%	11%	0%	12%	0%	11%	0%	21%	0%	12%	0%	13%	0%	11%
	5	0%	64%	0%	64%	0%	75%	0%	80%	0%	77%	0%	75%	0%	67%	0%	78%	0%	19%	0%	54%	0%	19%	0%	74%
Storm Damage	1	6%	9%	12%	4%	15%	6%	20%	8%	17%	6%	15%	5%	13%	4%	16%	5%	2%	0%	11%	3%	1%	0%	15%	5%
	2	78%	51%	58%	49%	61%	49%	62%	53%	61%	51%	61%	49%	62%	51%	64%	55%	38%	19%	51%	38%	39%	17%	61%	48%
	3	10%	27%	20%	27%	17%	32%	14%	27%	16%	30%	17%	32%	17%	28%	16%	28%	60%	58%	23%	33%	29%	36%	17%	32%
	4	5%	13%	9%	14%	6%	12%	4%	9%	5%	10%	6%	12%	8%	14%	3%	11%	0%	23%	12%	17%	21%	29%	6%	12%
	5	0%	0%	2%	6%	1%	2%	1%	2%	1%	2%	1%	2%	0%	3%	0%	1%	0%	0%	3%	9%	10%	17%	1%	2%
Slope Failure	1	65%	19%	61%	7%	59%	9%	65%	11%	61%	10%	59%	9%	58%	8%	62%	9%	67%	5%	56%	6%	39%	5%	59%	9%
	2	0%	29%	0%	29%	0%	28%	0%	31%	0%	30%	0%	28%	0%	23%	0%	31%	0%	35%	0%	22%	0%	18%	0%	28%
	3	30%	13%	27%	24%	27%	21%	22%	20%	27%	20%	27%	21%	30%	18%	26%	23%	29%	40%	28%	24%	36%	16%	27%	21%
	4	5%	24%	11%	22%	14%	22%	12%	23%	12%	22%	14%	22%	12%	19%	11%	21%	4%	14%	16%	24%	25%	28%	14%	23%
	5	0%	15%	0%	17%	0%	19%	0%	16%	0%	18%	0%	19%	0%	17%	0%	16%	0%	7%	0%	24%	0%	34%	0%	19%
Shrink-Swell	1	42%	20%	46%	22%	37%	20%	33%	0%	37%	0%	37%	0%	0%	0%	36%	20%	58%	33%	54%	24%	75%	38%	38%	20%
	2	0%	7%	0%	7%	0%	7%	0%	23%	0%	26%	0%	27%	0%	0%	0%	7%	0%	11%	0%	8%	0%	13%	0%	7%
	3	48%	17%	29%	16%	38%	11%	40%	11%	39%	11%	38%	11%	0%	5%	37%	10%	17%	13%	28%	22%	15%	24%	37%	12%
	4	10%	42%	25%	21%	25%	27%	27%	29%	24%	28%	25%	27%	95%	28%	28%	24%	25%	15%	18%	20%	9%	12%	24%	26%
	5	0%	14%	0%	33%	0%	36%	0%	37%	0%	35%	0%	36%	0%	63%	0%	40%	0%	27%	0%	26%	0%	13%	0%	35%
Coastal Risk (Baseline)	1	97%	94%	90%	86%	91%	88%	92%	89%	92%	89%	91%	88%	42%	0%	93%	90%	35%	19%	89%	86%	80%	73%	91%	88%
	2	1%	5%	7%	11%	6%	9%	6%	8%	6%	8%	6%	10%	0%	28%	5%	8%	46%	56%	8%	10%	12%	19%	6%	9%
	3	1%	0%	2%	0%	2%	0%	1%	0%	2%	0%	2%	0%	35%	15%	1%	0%	13%	0%	3%	0%	7%	0%	2%	0%
	4	0%	1%	0%	2%	0%	2%	0%	2%	0%	2%	0%	2%	23%	26%	0%	1%	4%	17%	0%	3%	0%	7%	0%	2%
	5	0%	0%	0%	1%	0%	1%	0%	1%	0%	1%	0%	1%	0%	31%	0%	0%	2%	8%	1%	1%	1%	1%	0%	1%
Total #of sites		77		5366		379133		9328		22066		347739		1103		2208		52		20675		214		407725	

Figure 49: Tabulated values for Phase 1.0 hazards (Figures 31-42)

Appendix 3: Drought Maps




Drought - future
(note – higher positive value = lower drought risk)
SPEI value
-0.6274 - -0.1878
-0.1878 - -0.1641
-0.1641 - -0.112
-0.112 - -0.0821
-0.0821 - -0.0722
-0.0722 - -0.0267
-0.0267 - -0.0153
-0.0153 - 0.007
0.007 - 0.0318
0.0318 - 0.2041
0
75
150 km



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