Perth and Kinross Council

Climate Change Risk and Opportunity Assessment

Technical Report

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1. Introduction

Scotland's climate is already changing. Over the last century temperatures have increased, sea levels have risen, and rainfall patterns have changed, with increased seasonality and more heavy downpours. These changes are projected to continue and intensify over the coming decades, and we can expect future changes in climate to be far greater than anything we have seen in the past.

These changes are already impacting people and places across Scotland. Perth and Kinross has already been experiencing flooding and wildfires. Taking early action to adapt to these events will therefore help increase resilience and reduce risks.

The Climate Change (Scotland) Act 2009[1] places a legal duty on public bodies such as Perth & Kinross Council (PKC) to adapt to the impacts of climate change. Statutory climate change reporting requirements also include a provision for public bodies to report on how they are contributing to national objectives for climate change adaptation and resilience as set out in the current Scottish Climate Change Adaptation Programme (SCCAP).

As part of this commitment, PKC have commissioned Arup to develop their first Climate Change Risk and Opportunity Assessment (CCROA) and risk and opportunities register, in response to the increasing risks and impacts of current and future climate change on the local authority area and its assets and operations. This will build on the work already being undertaken by the council's Climate Action Plan and the community resilience groups.

1.1 Reporting

This report provides a detailed overview of the findings of the first CCROA produced for Perth and Kinross. The report is accompanied by a risk and opportunity register, which provides more narrative on the scoring of each individual risk. The aim of this assessment is to better understand both the risks and opportunities which climate change poses to the local authority area. The scope of this CCROA includes key risks and opportunities for the people of Perth and Kinross, the geographic area of Perth and Kinross, and specifically for Perth and Kinross Council as an organisation. The assessment considers a wide range of changes to the climate which will occur between now and the end of this century.

This report provides an overview of how climate is likely to change in Perth and Kinross as well as what impacts both positive and negative which these changes will bring. Therefore, this work is primarily focused on both direct and indirect physical risks and opportunities posed by climate change. These risks will inform adaptation plans. Transitional risks are an important consideration for climate change mitigation plans. Transitional risks are risks inherent in changing strategies, policies or investments as society and industry work to reduce its reliance on carbon and impact on the climate. As this assessment is primarily focussed on informing adaptation to climate change, transitional risks are only discussed in relation to this where appropriate. However, risks which climate change directly impacts mitigation plans were assessed at a high level and are included in this assessment, i.e., how a changing climate might limit or enhance efforts to meet net zero plans.

The CCROA is focused on and divided by key sectors, namely, agriculture, infrastructure, natural environment, people, health, and the built environment. The overall approach uses the methodology in the UK Climate

[1] https://www.legislation.gov.uk/asp/2009/12/contents

Change Risk Assessment (2022)[2] (UK CCRA) as a base, tailoring risks to Perth and Kinross and scoring the risks based upon local context, and local vulnerabilities.

This report and the accompanying risk assessment contribute towards Perth and Kinross Council's efforts to meet statutory climate change reporting requirements. These requirements include a provision for public bodies to report on how they are contributing to national objectives for climate change adaptation and resilience as set out in the current five-yearly Scottish Climate Change Adaptation Programme. The Programme, prepared by Scottish Government, responds to the priority risks for Scotland independently identified by the Climate Change Committee (CCC) in the evidence reports of the UK CCRA and covering a range of global warming scenarios.

This study will ensure that policy and decision-makers are informed about the climate risks that will have the greatest impact on Perth and Kinross's society, economy, and environment, enabling creation of evidence-based, future-proof plans. The findings and recommendations in the assessment also provide valuable information on risks and opportunities that need to be addressed.

[2] https://www.ukclimaterisk.org/wp-content/uploads/2021/06/CCRA-Evidence-Report-Scotland-Summary-Final-1.pdf

2. Approach

2.1 Overall approach

This section sets out the overall approach and more detailed methodology used to conduct the CCROA.

To begin with, it was established what the climate hazards could be. To do this, the most recent climate projections (UKCP18) were used to help identify the magnitude and nature of hazards induced by climate change for Perth and Kinross. This process is described in detail below (Section 2.2).

Following this, risk and opportunities were identified which were or could be a result of climate change. To do this the UK CCRA and the accompanying national summary for Scotland were used as a basis to understand the wide range of risks Perth and Kinross might face. Initially, a long list of risks was assessed for their relevance to Perth and Kinross, those deemed not relevant were removed, and additional risks specific to Perth and Kinross were added. An Assessment was then undertaken to better understand the current local context and specific vulnerabilities within Perth and Kinross. This enabled us to assess the magnitude of the risk. This assessment was undertaken via desk-based research, literature study and stakeholder consultation, including a stakeholder workshop.

Finally, the risks were scored on their impact and likelihood, allowing for prioritisation of the risks.

These three key steps are presented in more detail in Sections 2.2 to 2.5 below.

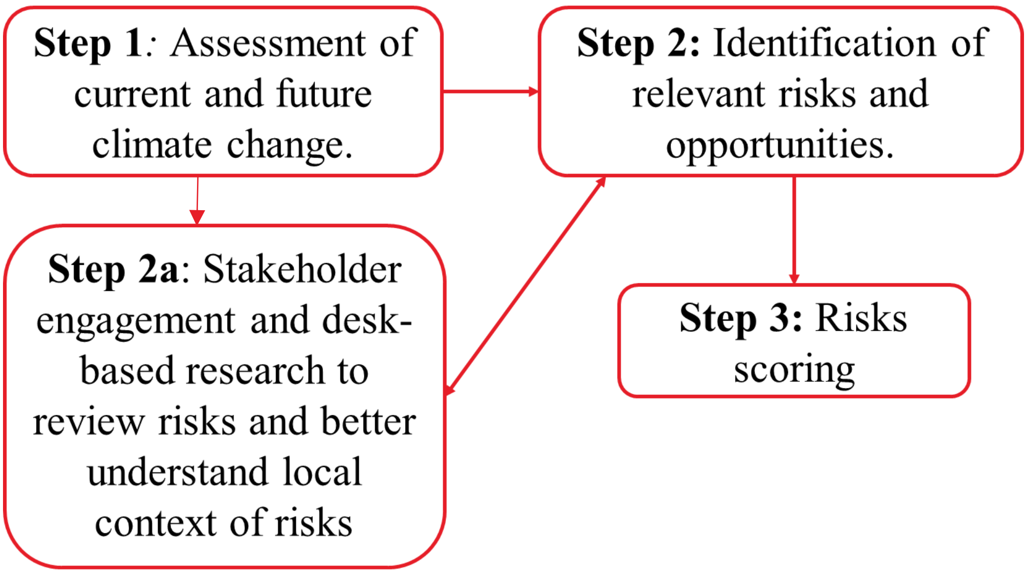

Figure 1: Flowchart showing overview of methodology.

2.2 Step 1: Assessment of current and future climate

The aim of this step was to understand what the current evidence tells us about climate change will alter key climate variables within Perth and Kinross. The main sources of information were used to assess the current and future climate; the most recent climate change projections for the UK, and a literature survey which focused on climate change in Perth and Kinross and its impacts.

Climate projections are informed predictions of the future climate based on climate models. The UKCP18, published in 2018 by the MET Office Hadley Centre, is the most recent in a series of climate change projections for the UK. UKCP18 contains a set of tools for assessing how the UK climate is likely to change both on the land and in surrounding seas.

The projections cover multiple different climate variables. In this assessment the variables used were:

- Temperature (minimum, maximum and average).
- Precipitation.
- Snowfall.
- Wind.
- Sea level and storm surge.

These variables are provided for different timescales, with averages across the different months and seasons. For this assessment, seasonal averages for both winter and summer were analysed.

The variables are also available for different emissions scenarios and future time periods. These UKCP18 datasets are based on probabilistic changes in future climate and an assessment of modelled uncertainties providing estimates of different future climate outcomes and their relative probabilities. These are provided across all representative concentration pathways (RCPs). RCPs are future scenarios including potential changes in population, economic development, and types of mitigation of greenhouse gases. This assessment has used the probabilistic projections at regional level under the RCP8.5 (high climate change) and RCP 2.6 (low climate change). RCP2.6 corresponds to an increase in global mean surface temperature of 1.6℃ and RCP8.5 corresponds to an increase of 4.3℃.

The probabilistic projections are provided at 25km scale and covered the whole of Perth and Kinross. In addition, some 12km local data was also used. Although this was only available at RCP 8.5, it did provide useful insights to very localised patterns of change.

The Scottish Environmental Protection Agency (SEPA) have produced flood maps. These SEPA flood maps were also used to analyse flooding risks due to coastal, river, and surface water flooding. SEPA flood maps are based on climate change projection data from 2009 (CP09). The methodology is discussed further below. Other data sources used to inform the flooding analysis include SEPA's information on flood risk management and flood risk management plans, as well as PKC's local information regarding flood risk management. The 2^{nd} National Flood Risk Assessment (NFRA2) was also used to help quantify the risk posed by flooding. It should be noted that as the CP18 projections suggest more severe impacts of climate change compared to CP09, it is likely that SEPA flood maps underestimate flood risk. It is noted that SEPA provide climate change guidance with respect to increased allowances for snowmelt and rainfall for RCP8.5; for consistency of approach, these allowances are not applied in this analysis. For more detailed assessment of how specific variables will be impacted by climate change it is recommended that preliminary work is done to identify the most appropriate allowances to use.

Finally, further evidence was gathered from our literature review, any additional evidence found on change to the climate in Perth and Kinross was collated and used alongside the SEPA maps and the UKCP18 projections.

Once all this information was gathered it was analysed to understand what the key changes to PKC area were, the following key questions of the data were asked:

- **Temporal**: How is the climate likely to change over the century (mid, mid-late and late century)?
- **Range**: What are the possible ranges in the projected variables across different emissions scenarios (differences between 2.6 and 8.5 and worst cases 90th percentiles for 8.5)?
- **Spatial**: What do these changes look like across PKC – where is worst (e.g., highest temperature changes are seen around the city of Perth)?

The results of this step are presented in Chapter 3 and form the basis of the subsequent work on understanding risks.

2.3 Step 2: Risk identification

The next step used the evidence of change to the climate to Perth and Kinross produced in step 1, to identify both risks and opportunities. Initially a long list of risks was assessed for their relevance to Perth and Kinross, those deemed not relevant were removed, and additional risks specific to Perth and Kinross were added. An assessment was then undertaken to better understand the current local context and specific vulnerabilities within Perth and Kinross to enable an assessment of the magnitude of the risk. This was done via desk-based research, literature study and stakeholder consultation. The stakeholder engagement took place in two forms: a stakeholder workshop and short interviews with key stakeholders. Here, risks were reviewed, and discussion took place on how they might impact Perth and Kinross given local context.

The risks were then placed into key sectors, these sectors roughly follow those set out in the UK CCRA, with some alterations made to suit the needs of Perth and Kinross Council and the local context. Risks were divided into the following sectors:

- People, health, communities, and the built environment.
- Natural environment.
- Infrastructure.
- Business and industry (including analysis of P&K's key industry/sectors).
  - Tourism and cultural heritage.
  - Agriculture.
  - Forestry.
  - Salmon fishing.
  - Construction.

Finally, an additional assessment was undertaken which identified the risks directly to PKC as an organisation (Chapter 8: *Risks to Perth and Kinross council*). The council is central to many key services within Perth and Kinross, and its assets and operations have been included in the assessment.

2.4 Step 3: Risk scoring

Once all risks were identified, a high-level assessment of the potential risks, their impacts, the likelihood of the risks occurring, and the response needed by the council was undertaken. Each risk was assessed according to the likely impact of the risk occurring and the likelihood of that risk occurring, this assessment was based on the best available data at the time. The same criteria were used for both risks which were specific to Perth and Kinross Council as an organisation and those which impacted wider Perth and Kinross. The specific criteria are shown in table 1 below.

Table 1: Risk scoring criteria.

Numeric score	Impact Score (1 Low - 3 High)	Likelihood Score (1 Low - 3 High)
1	Low impact risks would include: Financial impact Cost estimated at under £1 million. Social impact Up to than 10% of the population of PKC impacted. Health impact	Low likelihood refers to a situation where the risk is unlikely to occur either due to specific characteristics of Perth or Kinross. Or the change in climate required to make the risk occur is an extreme case and only viable later in the century.

Numeric score	Impact Score (1 Low - 3 High)	Likelihood Score (1 Low - 3 High)
	Low impact would mean some inconvenience to people. Some minor health impacts for a smaller proportion of the population. Environmental impact Only small environmental impact – no significant damage, no protected areas or species impacted and or small geographic area impacted	
2	Medium impact risks would include: Financial impact Cost estimated of over £1 million and up to £10 million. Social impact More than 10% and less than 50% of the population of PKC impacted. Health impact Medium impact would mean significant inconvenience to people. Some major health impacts for a smaller proportion of the population. Or minor health impacts to a large proportion of the population. Environmental impact Only small environmental impact – some environmental damage, no protected areas or species impacted but a medium or multiple geographic area impacted	Medium likelihood, climate change required for the risk is likely to occur below RCP 8.5. There are some vulnerabilities inherent in Perth and Kinross that makes the risk more likely to happen
3	High impact risks would include: Financial impact Cost estimated of over £10million. Social impact 50% or more of the population of PKC impacted. Health impact High impact would mean significant inconvenience to many people. Major health impacts to a significant amount of those impacted and/or some mortality. Environmental impact Largescale environmental impact – significant environmental damage, protected areas or species impacted, and or a large geographic area impacted.	Only a small amount of climate change is needed for the risk to occur. Or risk is already happening and will be enhanced by climate change. Specific characteristics make Perth and Kinross particularly prone to the risk occurring.

An overall risk score was then calculated using the impact and likelihood scores:

Impact x Likelihood = Overall risk score

The overall scores were then categorised as high, medium, or low, shown in Table 2 below:

Table 2: Risk scoring matrix.

Impact/Likelihood	1	2	3
1	1	2	3
2	2	4	6
3	3	6	9

The risk score was then considered with the climate change evidence and specifically when in the century the risks would materialise. Taking the two together a high-level categorisation of the council's response was given to each risk. The following categories were used:

- ***Action needed.*** This risk is already existing or will materialise within the next 15 years.
- ***Monitor risk***. No immediate action required, but regular review of impact and likelihood required.
- ***No current action needed***.

If there was a lack of evidence on either the impacts of the risk, its likelihood or Perth and Kinross vulnerability to the risks, the risks were also flagged as ***Needs further research / understanding***.

2.5 Limitations of the assessment

- The risks scoring was based on available evidence gathered and the judgement of consultants and stakeholders who took part in the assessment, interviews and workshop. A detailed quantitative assessment of each individual risk was beyond the scope of this project.
- The categorisations of the council's response are based on a high level and evidence-based assessment, though this categorisation system is subjective to some extent and should be used with caution. All risks pose some threat for Perth and Kinross and all risks should therefore be considered in adaptation plans; this assessment is simply intended to offer some guidance on prioritisation. Moreover, some responses take many years to implement, and so the Council should on a regular basis re-assess these risks.
- Some risks were identified and flagged as *Needs further research / understanding*. This was based on the evidence which was available to Arup at the time, and similar categorisations in the UK CCRA. This was done to offer some prioritisation of research needed. For risks not flagged, the council should still be looking for new evidence, and take any opportunities for enhance the current evidence. No risk is fully understood, due to the nature and complexity of climate risks.

3. Climate change in Perth and Kinross

3.1 Introduction

This chapter summarises the key findings of the analysis of climate projections for Perth and Kinross. This chapter aims to provide information on multiple climate variables, how they will change across the century, the possible variation in these changes with different climate scenarios and how these changes may be different across the geographic area of Perth and Kinross.

3.2 Changes to precipitation

To understand how precipitation will change due to climate change, three variables which measure precipitation in different ways were used:

- **Precipitation rate anomaly (%)** – This refers to the amount of precipitation (rain, sleet, snow) falling as mm per day and is given as a % change from a baseline which is the season volume average between 1981-2000.
- **Maximum 1-day total precipitation –** This refers to the amount of precipitation (rain, sleet, snow) falling in mm in 24 hours.
- **Maximum 5-day total precipitation** – This refers to the amount of precipitation (rain, sleet, snow) falling in mm in 120 hours.
  - 1- or 5-day precipitation is based on an analysis of statistical extremes; so, considers the statistical likelihood of different volumes of precipitation over 1 day or a 5-day period.

3.2.1 Precipitation rate anomaly

Changes to the precipitation rate anomaly for Perth and Kinross are different for both winter and summer. In general, more precipitation is projected to occur during the winter months with less precipitation occurring during the summer months.

Figure 2 shows how the total precipitation is projected to change for the winter months. These changes are based on a baseline which consists of the average precipitation in winter between 1981-2000. This baseline was on average 471mm (ranging between 200 and 1039mm across Perth and Kinross.) The areas with the highest winter precipitation currently are in the East of the local authority.

In Figure 2, the orange represents the average change across all of Perth and Kinross, (The geographic area of Perth and Kinross spans 19, 25km grid cells). This shows that for all climate scenarios, between now and 2080, on average Perth and Kinross will receive more precipitation during the winter months. Under a high emissions scenario of RCP 8.5, by 2080, on average Peth and Kinross will have a **20%** increase in precipitation during the winter months. However, by 2080, some locations in Perth and Kinross are expected to receive more than a **40%** increase during the winter months. The increased in winter precipitation projected under a high emission scenario are almost double that of a low emission scenario.

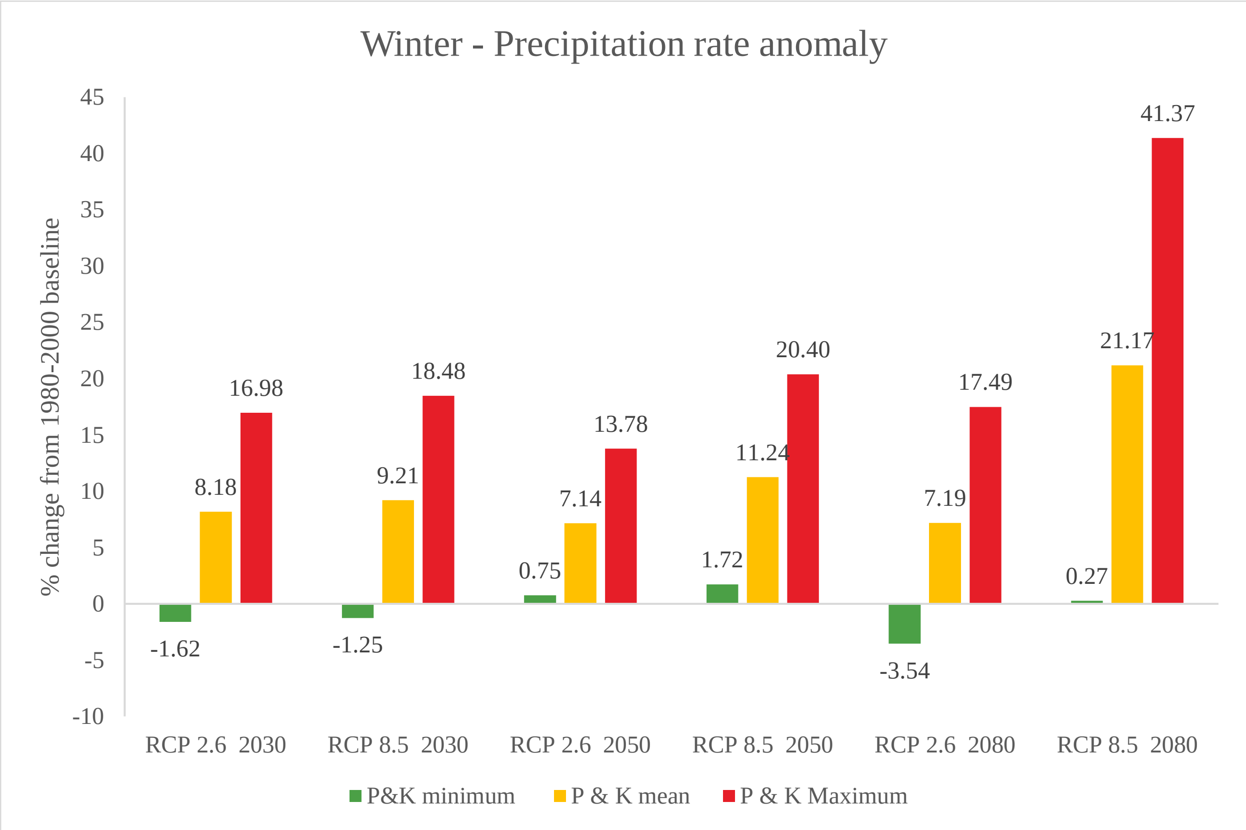

Figure 2: Graph presenting the predicted change to the precipitation rate anomaly (%) based on a 1981-2000 baseline. All data is averaged across the geographic area of Perth and Kinross. This graph shows the change under both high (8.5) and low emissions scenarios (2.6) and how it changes across the coming century. The variable is summarised by three metrics, maximum (red), mean (amber) and minimum (green) precipitation rate anomaly. All data is taken from the 50th percentile of the projections.

Figure 3 illustrates some of this spatial variation in the amount of change in winter precipitation which are expected under a high emission scenario. Red areas indicate where the greatest change in winter precipitation is projected to occur. By 2080 onwards, the highest changes are in the very south and east parts of the local authority which includes the city of Perth, Kinross and areas between Perth and Dundee. Areas with lower changes to rainfall are in the north and west. Particularly low changes are projected for parts of the Cairngorm mountains located within Perth and Kinross. The spatial variation is significant for this variable. By 2080 there is projected to be an almost 35% difference in the change to winter precipitation across the local authority. When comparing to the baseline it is the areas that traditionally receive the least rain where the greatest change is projected to occur.

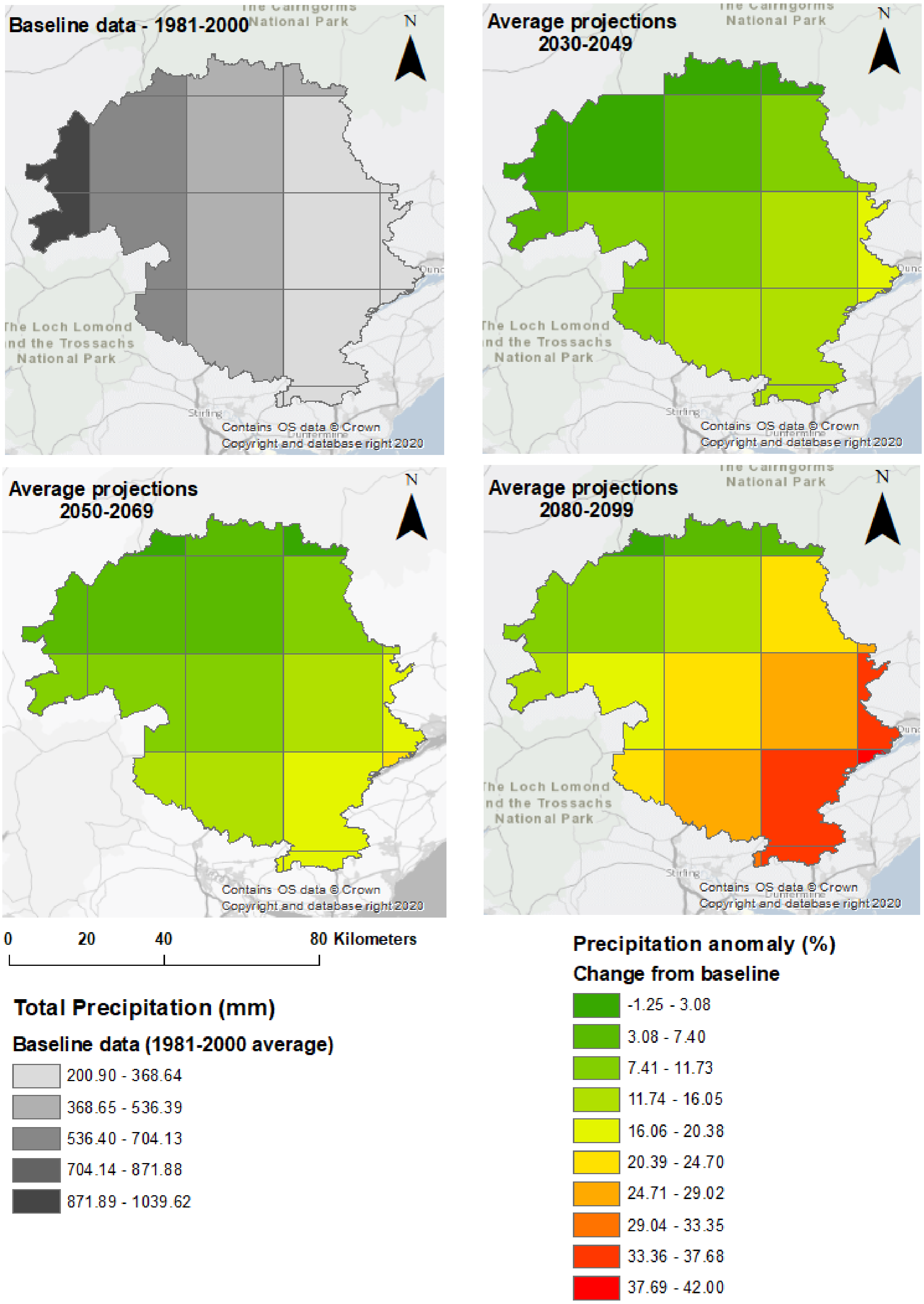

Figure 3: Changes in winter total winter precipitation across Perth and Kinross. The top left map contains the baseline data for total winter precipitation, an average taken form 1981-2000. The other three maps show the projected change across the century. These maps are for RCP 8.5 are taken from the 50th percentile of projections.

3.2.2 1 and 5-day total precipitation

In comparison to other climate change variables, baseline data for 1 and 5-day, is not easily available and can only be derived from individual datasets. Therefore, a baseline was calculated but this was for a single point in Perth with was used to represent Perth and Kinross, rather than the average across all of Perth and Kinross like the projection data. Moreover, the baseline data is a year-round measure where as the projection data used is specifically summer and winter data. Though this provides come context for the changes that are projected it does not give a directly comparable baseline as for the other variables where baselines are presented.

For context the year-round baselines for Perth are as follows:

- 1-day total precipitation = 33.9mm
- 5-day total precipitation = 79.5mm

Figure 4 shows 5-day total precipitation, averaged across Perth and Kinross, for the 50th percentile in winter, for RCP2.6 and RCP8.5. The graph shows that short-term prolonged intense precipitation is expected to increase in both warming scenarios. The increase is much larger for the high-emissions scenario, with a projected increase by 2100 of almost 50mm across five days when compared to the baseline for Perth. The increase for RCP2.6 is much lower, although given that the region already experiences issues with flooding, this suggests that existing issues will not improve due to climate conditions and will require further intervention elsewhere.

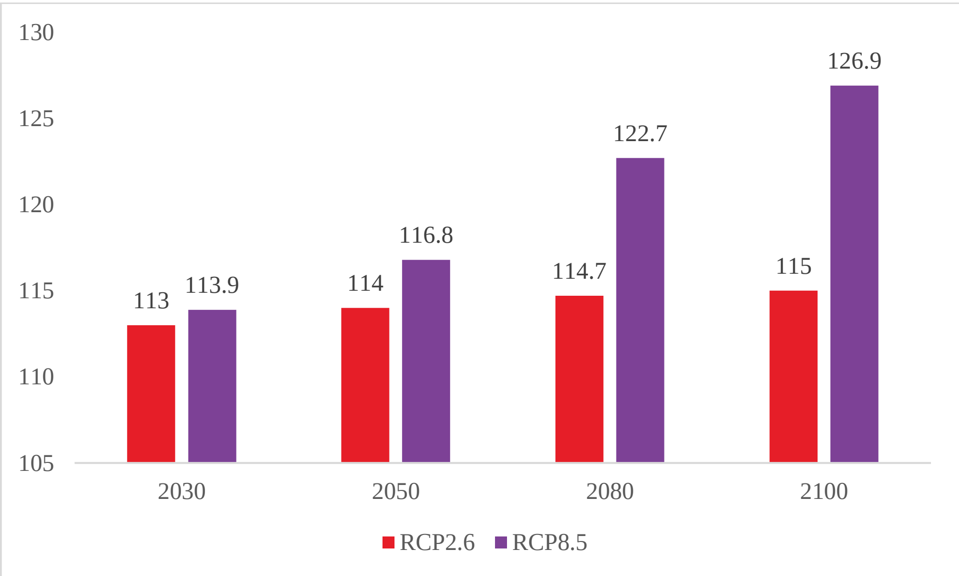

Figure 4: 5-day total precipitation, averaged across Perth and Kinross, for the 50th percentile in winter.

Figure 5 shows 1-day total precipitation, averaged across Perth and Kinross, for the 50th percentile in winter, for RCP2.6 and RCP8.5. The conclusions for the 1-day total precipitation are like the 5-day total precipitation analysis; short-term intense precipitation is expected to increase in both emissions scenarios. It is expected that this will exacerbate existing issues with flooding.

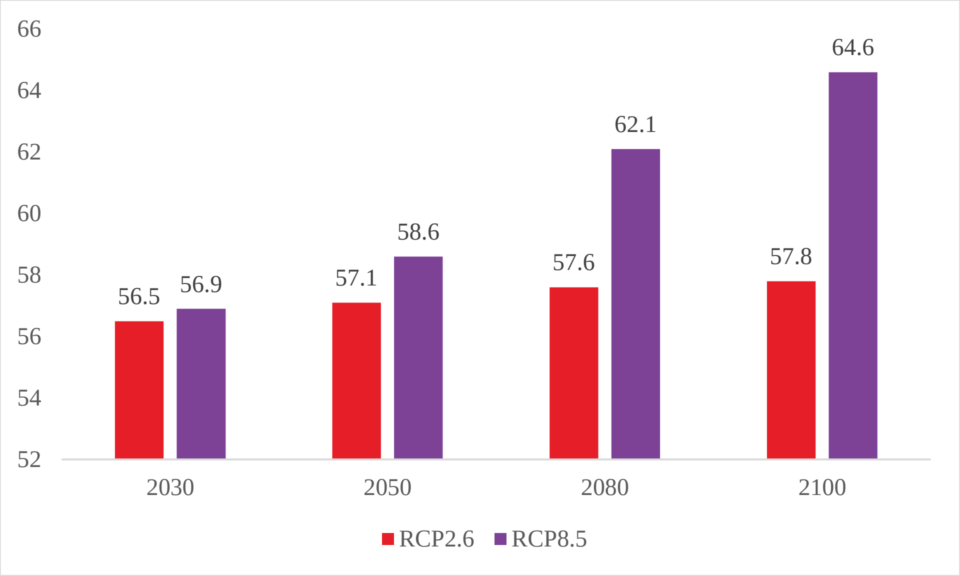

Figure 5: 1-day total precipitation, averaged across Perth and Kinross, for the 50th percentile in winter.

Figure 6 shows 5-day total precipitation, averaged across Perth and Kinross, for the 50th percentile in summer. The graph shows the absolute change in projected short-term rainfall is quite small. Figure 6 shows that the overall intensity of rainfall remains similar; combined with the projections from Figure 8 showing that summers are drier on average. When drier summers are combined with the expected temperature increase, this will likely also lead to drier ground. This means the risk of flash flooding is increased as the ground is less able to absorb water and surface water flooding may become more frequent and severe, particularly in urban areas.[3]

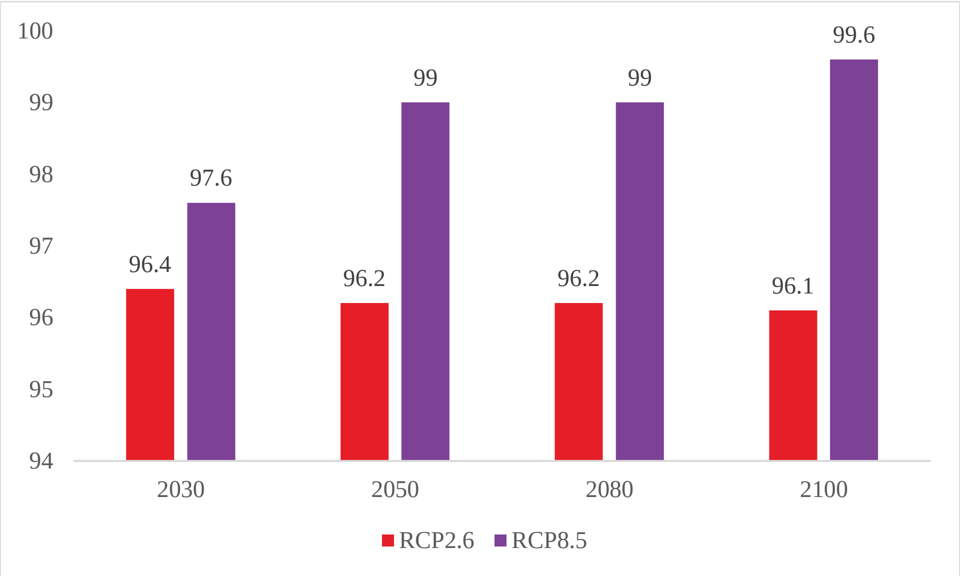

Figure 6: 5-day total precipitation, averaged across Perth and Kinross, for the 50th percentile in summer.

Figure 7 shows how the precipitation rate anomaly is projected to change for the summer months. This shows that under all scenarios across the century all areas of Perth and Kinross are projected to receive less precipitation. By 2080, under a high emissions scenario this is a reduction of more than **26%** on average for

[3]Met Office, UK, and Global extreme events – Heavy rainfall and floods. Available online at: UK and Global extreme events – Heavy rainfall and floods - Met Office

Perth and Kinross and in some areas nearly as much as **35%** less than what was observed between 1981 and 2000. Again, differences occur when comparing the high and low emissions scenarios, for example under RCP 2.6 by 2080 the projected decreases in Precipitation are around 17% on average, this rises to 33% under RCP 8.5.

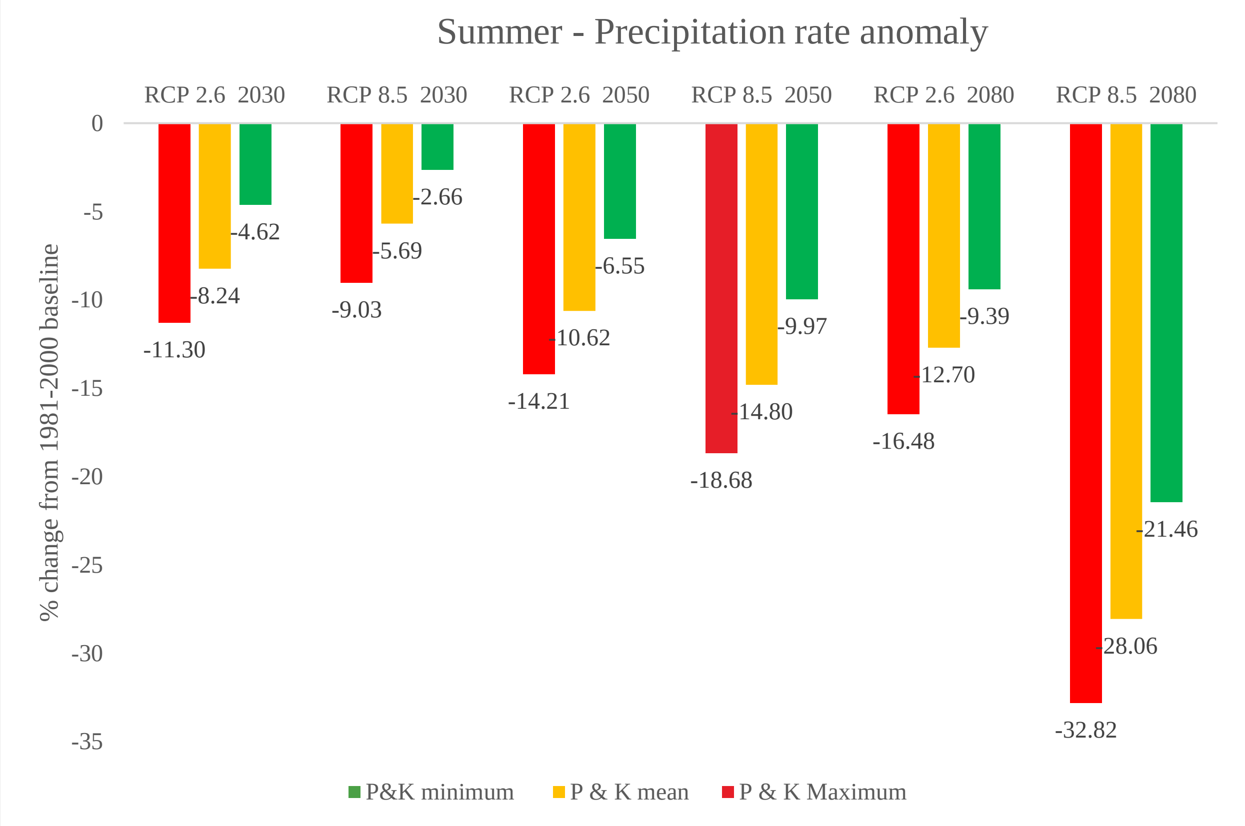

Figure 7: Graph presenting the predicted change to the precipitation rate anomaly (%) based on a 1981-2000 baseline. All data is averaged across the geographic area of Perth and Kinross. This graph shows the change under both high (8.5) and low emissions scenarios (2.6) and how it changes across the coming century. The variable is summarised by three metrics, maximum (red), mean (amber) and minimum (green) precipitation rate anomaly. All data is taken from the 50th percentile of the projections.

Figure 8 shows precipitation rate anomaly for summer and how it is projected to change across this century mapped across Perth and Kinross. Firstly, in comparison to winter precipitation, the spatial variation in expected change is less. The baseline map shows that more summertime precipitation currently falls in the west compared to the east, where areas around Perth and the mouth of the Tay reserve receives as little as half of the amount the west receives.

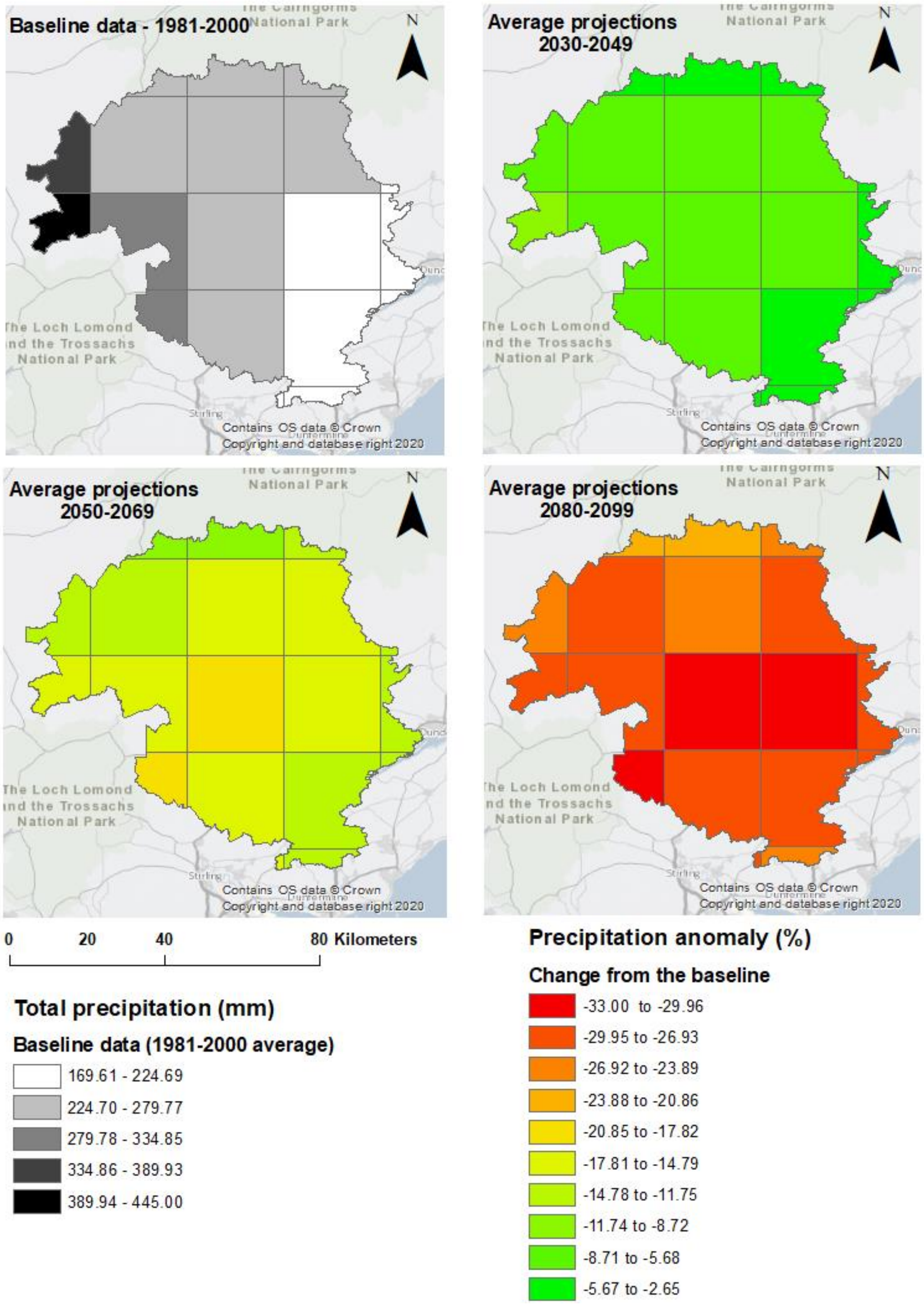

Figure 8: Contains four maps illustrating how the total summer precipitation is projected to change and how this varies across Perth and Kinross. The top left map contains the baseline data for total winter precipitation, an average taken form 1981-2000. The other three maps show the projected change across the century. These maps are for RCP 8.5 are taken from the 50th percentile of projections.

3.2.3 Changed to precipitation key messages.

- Changes to total precipitation are seasonal in nature, winter precipitation is expected to increase, summer precipitation will decrease.
- This means a risk of more flooding in the winter months, especially if rivers, drainage systems become overwhelmed.
- This is compounded by rainfall intensity (measured with the 1- and 5-day totals) also increasing. This specifically can cause drains to be overwhelmed and water to sit on the ground causing problems, especially after periods of drought when water is less easily absorbed.
- More rain rather than snow (*discussed later in Section 3.6*) during the winter also has knock-on implications for river flow in the spring.
- Drier summers run the risk of drought, this is particularly important to consider for hydroelectric generation, agriculture, and the possible changes it will bring to biodiversity.

3.3 Changes to temperature – winter

Figures 9-11 plot the projected minimum, mean and maximum winter temperatures for Perth and Kinross. These values are averages from all the projection readings across Perth and Kinross and provide an overview of how the three winter temperature variables are changing across the century. The baseline data for these projections is also displayed to help contextualise this change.

All three temperature variables increase across the century for both low and high emissions scenarios. As expected for all three temperature variables, there is a greater increase under a high emissions scenario than under the low emissions scenario.

Figure 9 shows the projected changes to the winter minimum temperature. The baseline from 1981-2000 was -0.87℃. The winter minimum temperature is projected to rise to above 2℃. The increases under a low emissions scenario are much smaller, however, by 2080 the average minimum winter temperature for Perth and Kinross is projected to be above 0℃ even under RCP 2.6.

Figure 10 shows the projected changed to the mean winter temperature, here the baseline from 1981-2000 was 1.79℃. Under a 2.6 emissions scenario the mean across Perth and Kinross only rises to just above 2.5℃ by 2080 In contrast, by 2080 under a high emissions scenario by 2080 the average temperature from the baseline more than doubles, from 1.79℃. to 4.6℃.

Figure 11 shows the projected maximum winter temperatures, here the baseline between 1981-2000 was 4.48℃. Again, the rise under a low emission scenario is small. However, under a high emissions scenario by 2080 the average maximum winter temperature across Perth and Kinross is projected to rise by just under 3℃.

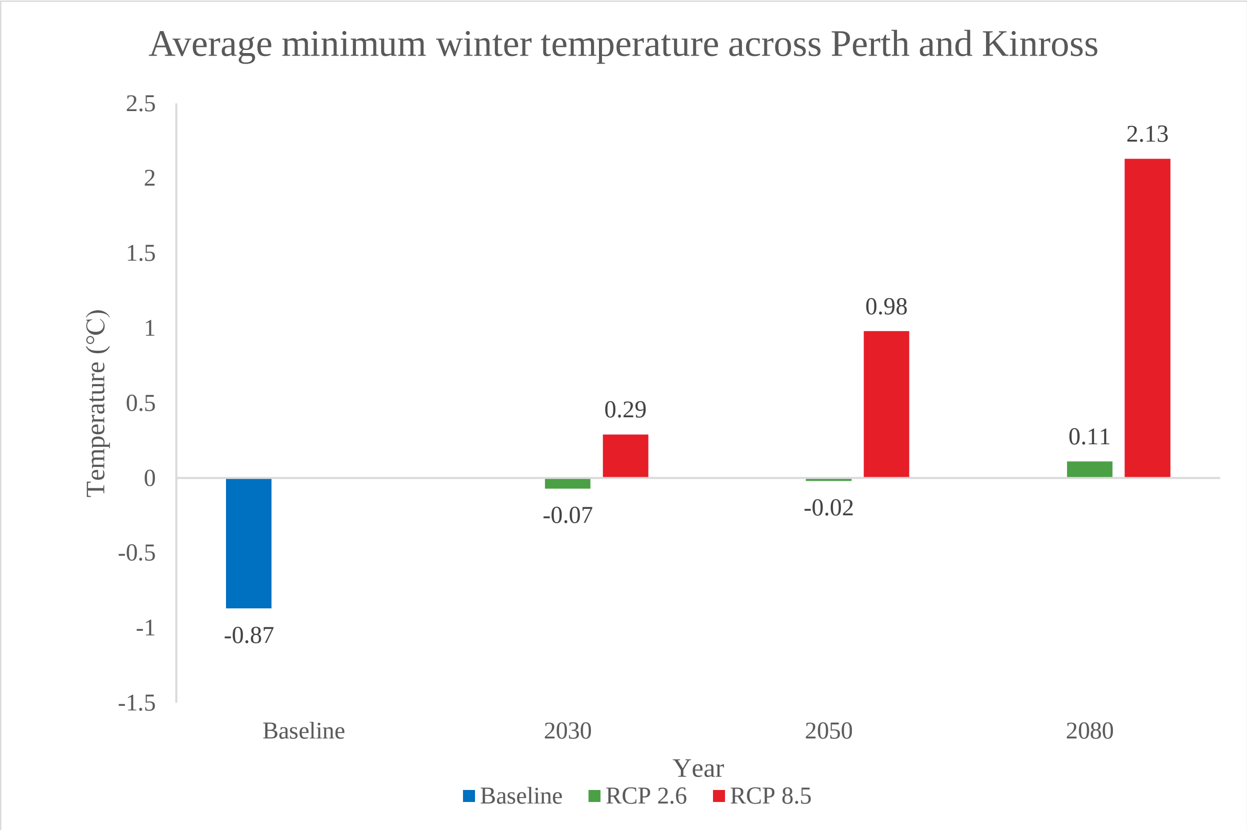

Figure 9: Graph showing the projected average minimum winter temperatures (Dec, Jan, Feb), for both RCP 2.6 and RCP 8.5 against a baseline (average for 1981-2000). These values are extracted from 25km data and averaged for the geographic area of Perth and Kinross. All values are taken from the 50th percentile of projections.

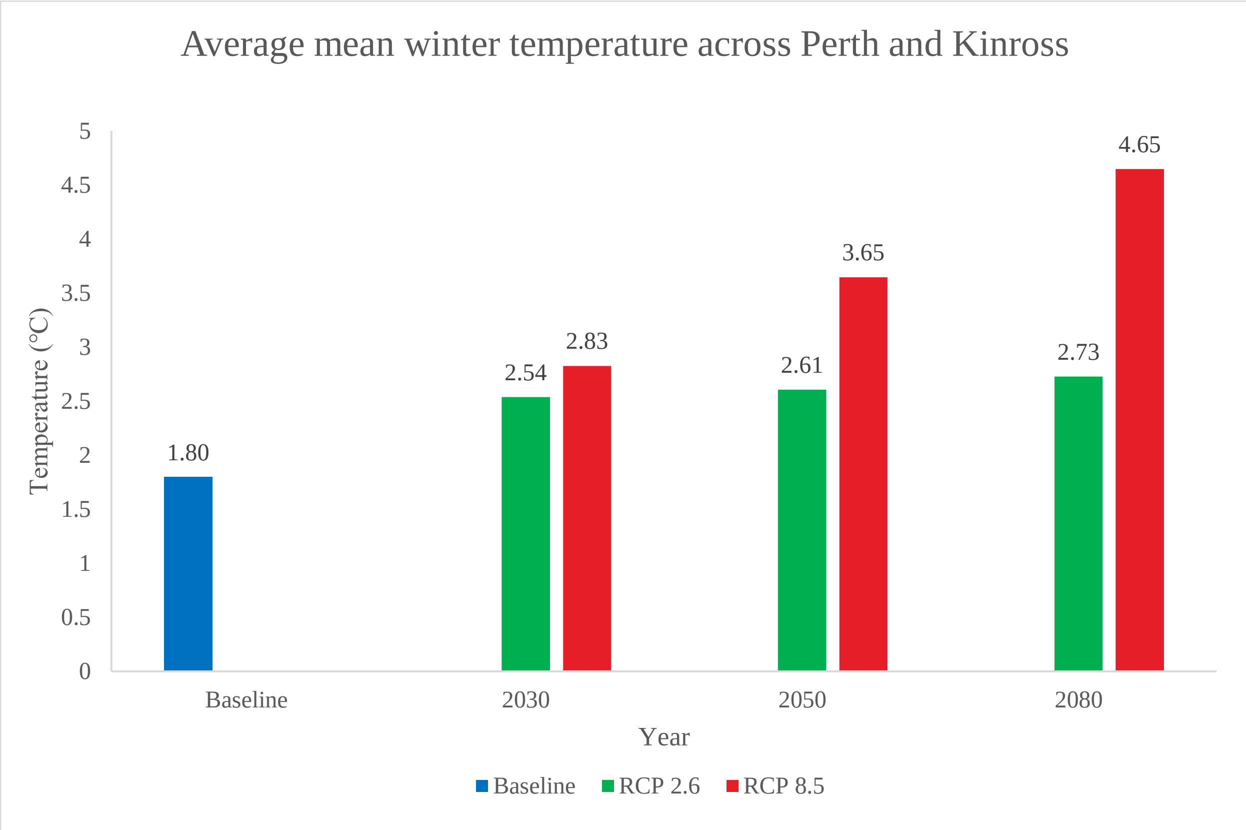

Figure 10: Graph showing the projected average mean winter temperatures (Dec, Jan, Feb), for both RCP 2.6 and RCP 8.5 against a baseline (average for 1981-2000). These values are extracted from 25km data and averaged for the geographic area of Perth and Kinross. All values are taken from the 50th percentile of projections.

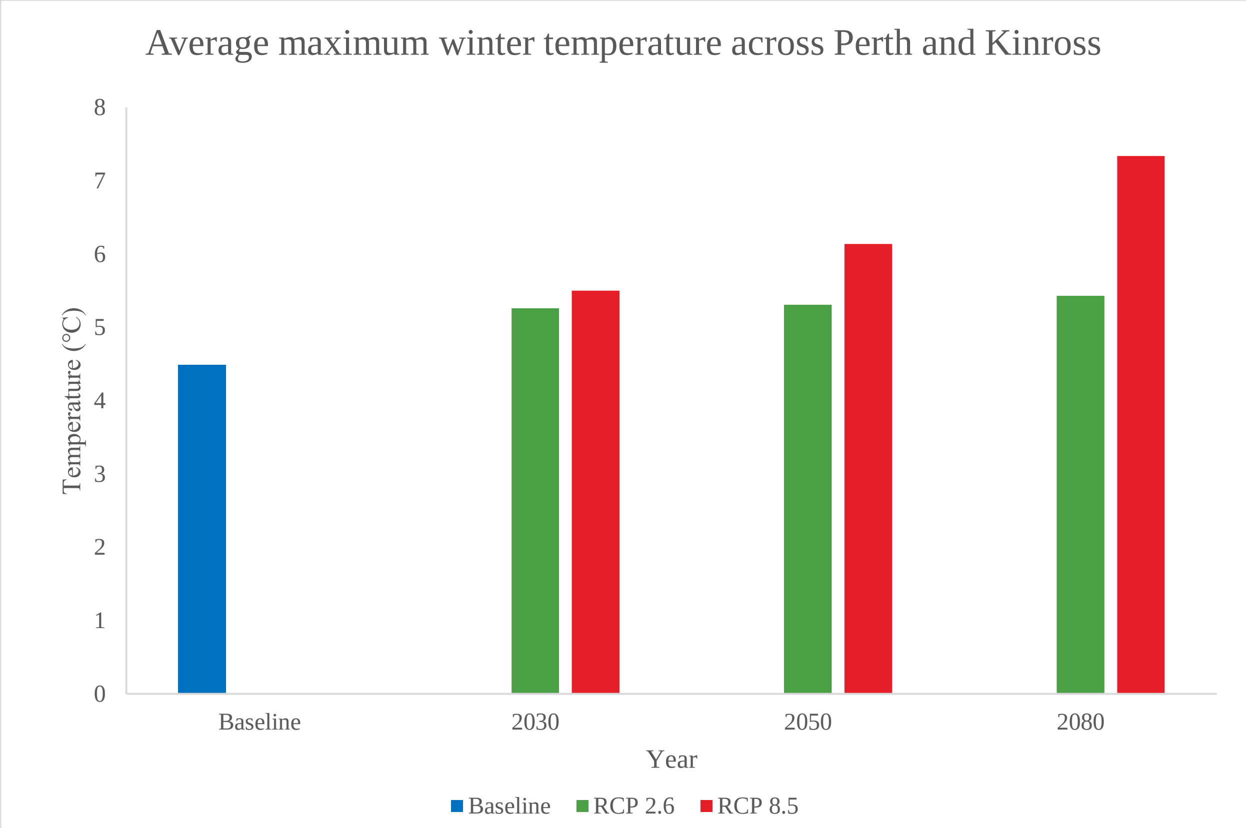

Figure 11: Graph showing the projected average maximum winter temperatures (Dec, Jan, Feb), for both RCP 2.6 and RCP 8.5 against a baseline (average for 1981-2000). These values are extracted from 25km data and averaged for the geographic area of Perth and Kinross. All values are taken from the 50th percentile of projections.

The above three graphs provide an overview of how on average the temperature is likely to change on average for the whole of Perth and Kinross. Actual figures across Perth and Kinross vary. Figure 12 to 14 map the spatial distribution of projected changes to temperature for 2080 under a high emissions scenario, to illustrate spatial differences in projected change. These show the absolute change as opposed to the absolute temperature values.

Figure 12 shows the changes to the winter average minimum temperature under RCP 8.5 for the years 2030, 2050 and 2080. By 2080 nearly half of the geographic area of Perth and Kinross this change is over 3℃. The change in winter minimum temperature is expected to be most pronounced in the north of the city of Perth, east towards Dundee, and south of Kinross. Other areas with the highest change are into the Cairngorms National Park North of Blair Atholl and near Rannoch station.

Spatial patterns for the mean temperature are similar as shown in Figure 13. For the maximum temperature shown in Figure 14, by 2080 the northern areas of Perth and Kinross are projected to increase by 2.77-3.16℃. This includes parts of the Cairngorms, Rannoch Moor and Loch Rannoch.

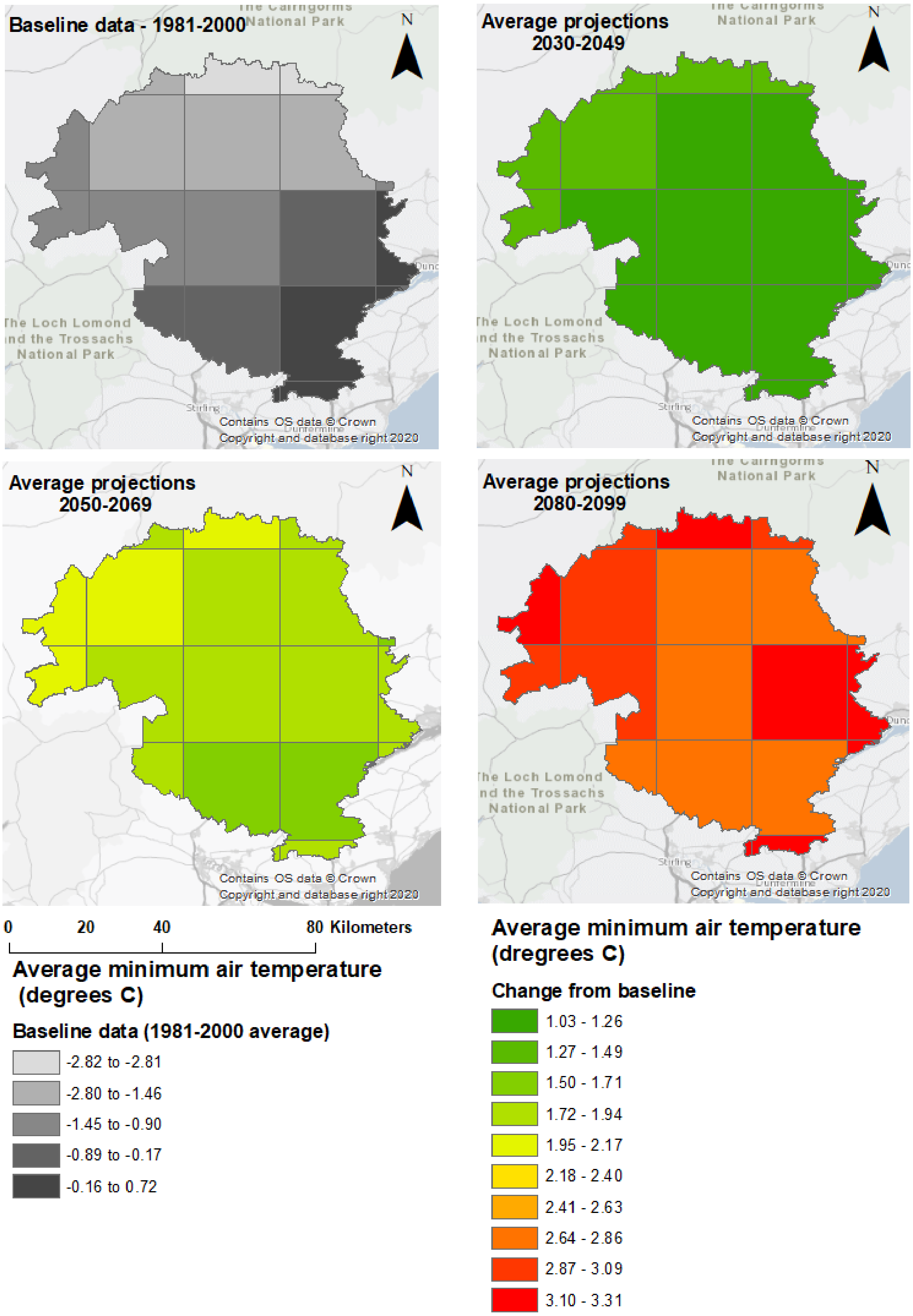

Figure 12: Maps illustrating the spatial distribution of the projected changes to the average minimum winter (Dec, Jan, Feb) temperature for 2040, 2050 and 2080 under RCP 8.5 and the spatial distribution of the baseline temperature for comparison. All values are taken from the 50th percentile of projections. The baseline map displays absolute averaged observations of temperature, whereas the projection map displays absolute change to the baseline temperature.

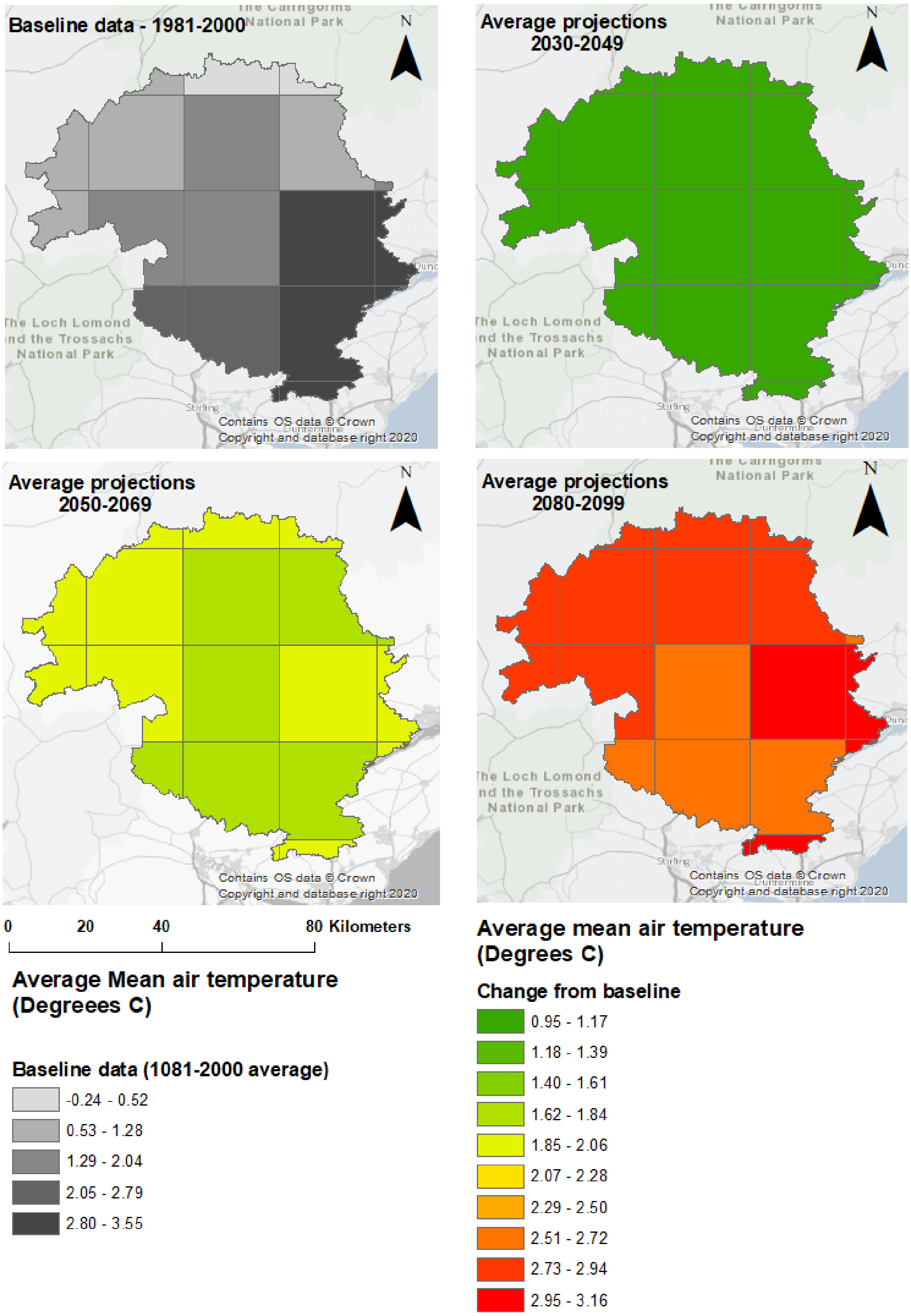

Figure 13: Maps illustrating the spatial distribution of the projected changes to the average mean winter (Dec, Jan, Feb), for 2030, 2050 and 2080 under RCP 8.5 and the spatial distribution of the baseline temperature for comparison. All values are taken from the 50th percentile of projections. The baseline map displays absolute averaged observations of temperature, whereas the projection map displays absolute change to the baseline temperature.

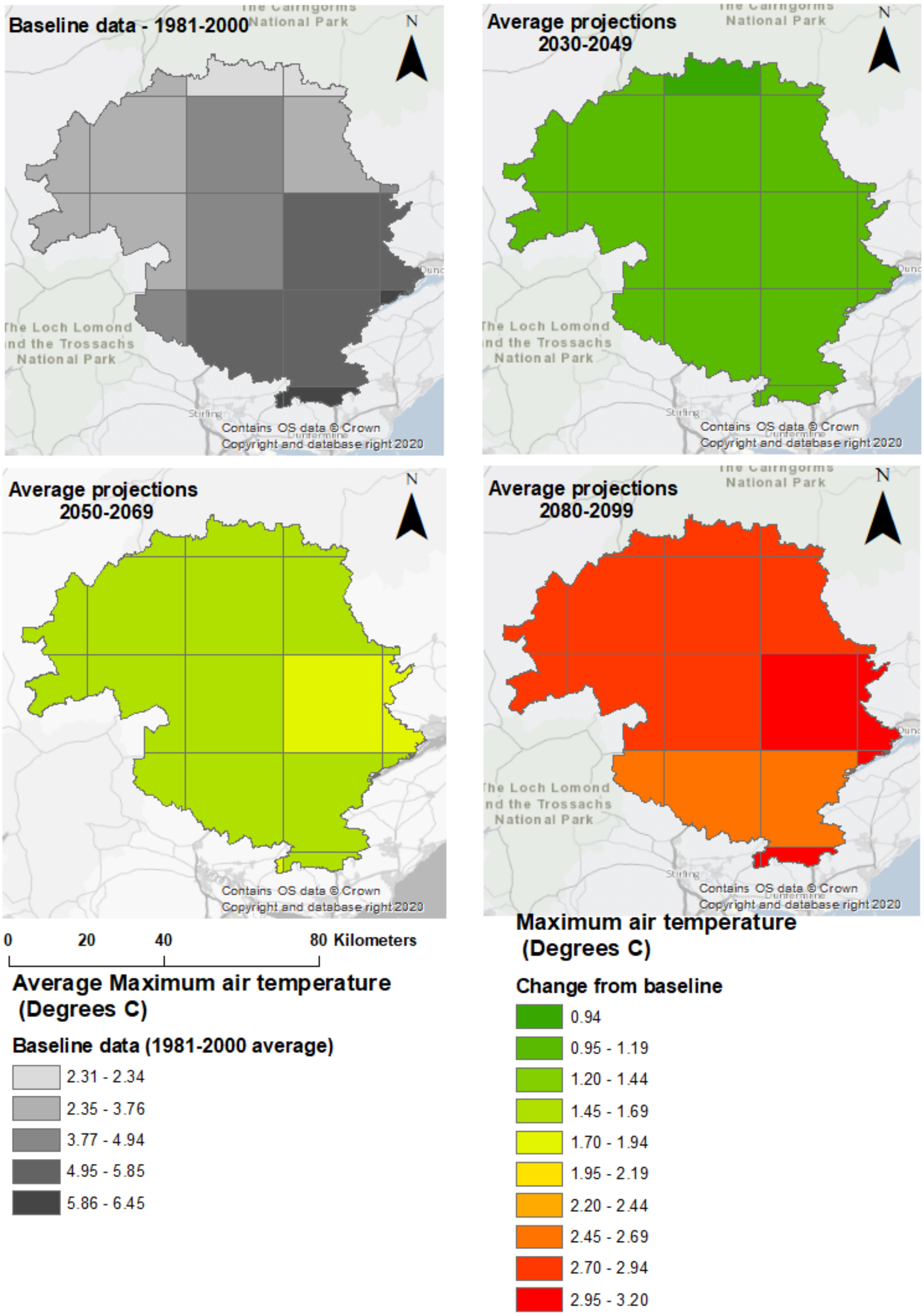

Figure 14: Maps illustrating the spatial distribution of the projected changes to the average maximum winter (Dec, Jan, Feb), temperature for 2030, 2050 and 2080 under RCP 8.5 and the spatial distribution of the baseline temperature for comparison. All values are taken from the 50th percentile of projections. The baseline map displays absolute averaged observations of temperature, whereas the projection map displays absolute change to the baseline temperature.

3.4 Changes to temperature – summer

Figures 15 to 17 show how the projected minimum, mean and maximum summer temperatures (averaged across Perth and Kinross) change across the century. All three graphs are split by emissions scenario to illustrate the range of possible future change. Again, the 1981-2000 baseline upon which these projections are also provided for reference and all three graphs show averages across Perth and Kinross the geographic are of Perth and Kinross.

All three metrics show similar patterns both across the century and when comparing emissions scenarios, for all temperature variables. Summertime temperature will rise in Perth and Kinross under both high and a low emissions scenario, in comparison to the baseline. The temperature change is lower for the low emissions scenario as expected. Under the low emissions scenario, by 2080 the minimum summer temperature is projected to rise by 1.24 ℃, the mean by 1.33℃, and the maximum by more with a 2.35℃. Those projections under a high emissions scenario show average temperature could rise by up to 4.18℃ for the minimum summer temperature, 4.38℃ for the mean, and 4.73 ℃ (an absolute temperature of 21.13℃) for maximum temperatures. As these are average figures, localised extremes could be higher; this is discussed further below.

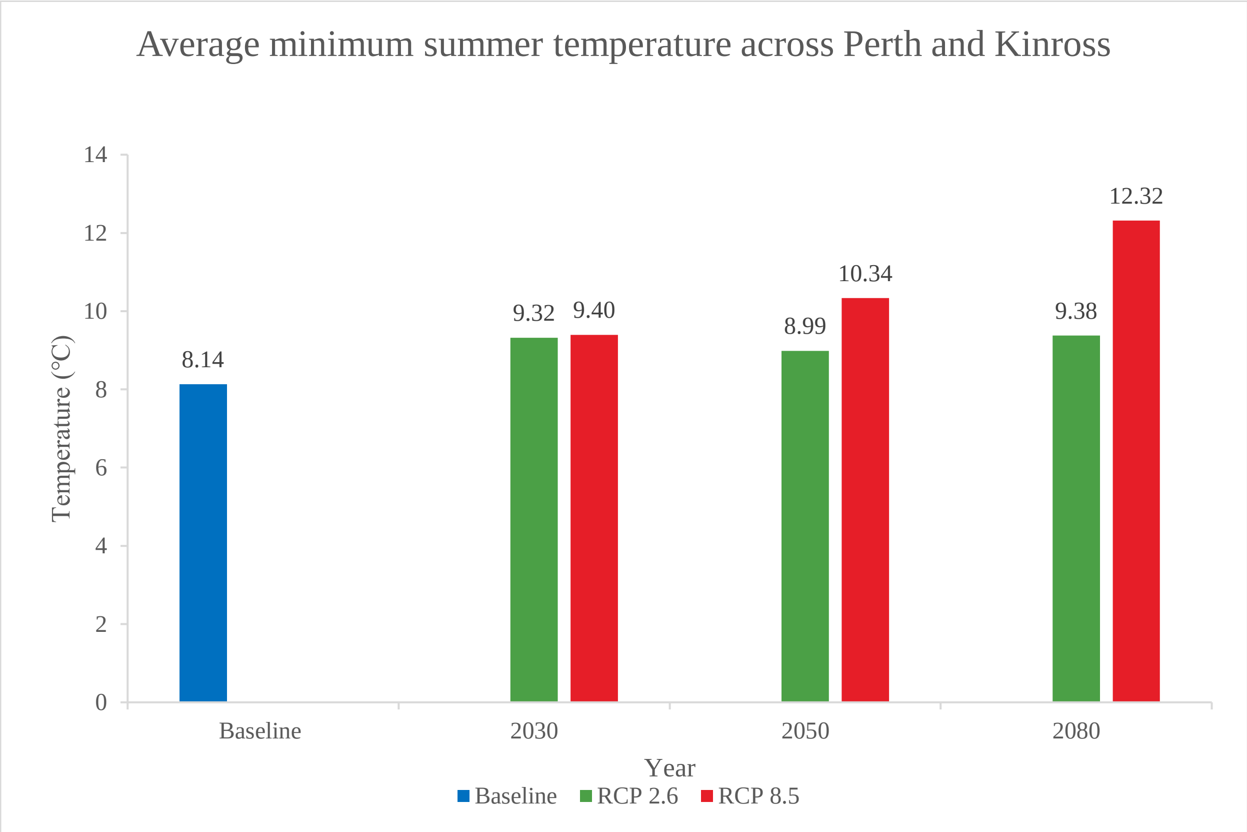

Figure 15: Graph showing the projected minimum summer temperatures (Jun, July, August), for both RCP 2.6 and RCP 8.5 against a baseline (average for 1981-2000). These values are extracted from 25km data and averaged for the geographic area of Perth and Kinross. All values are taken from the 50th percentile of projections.

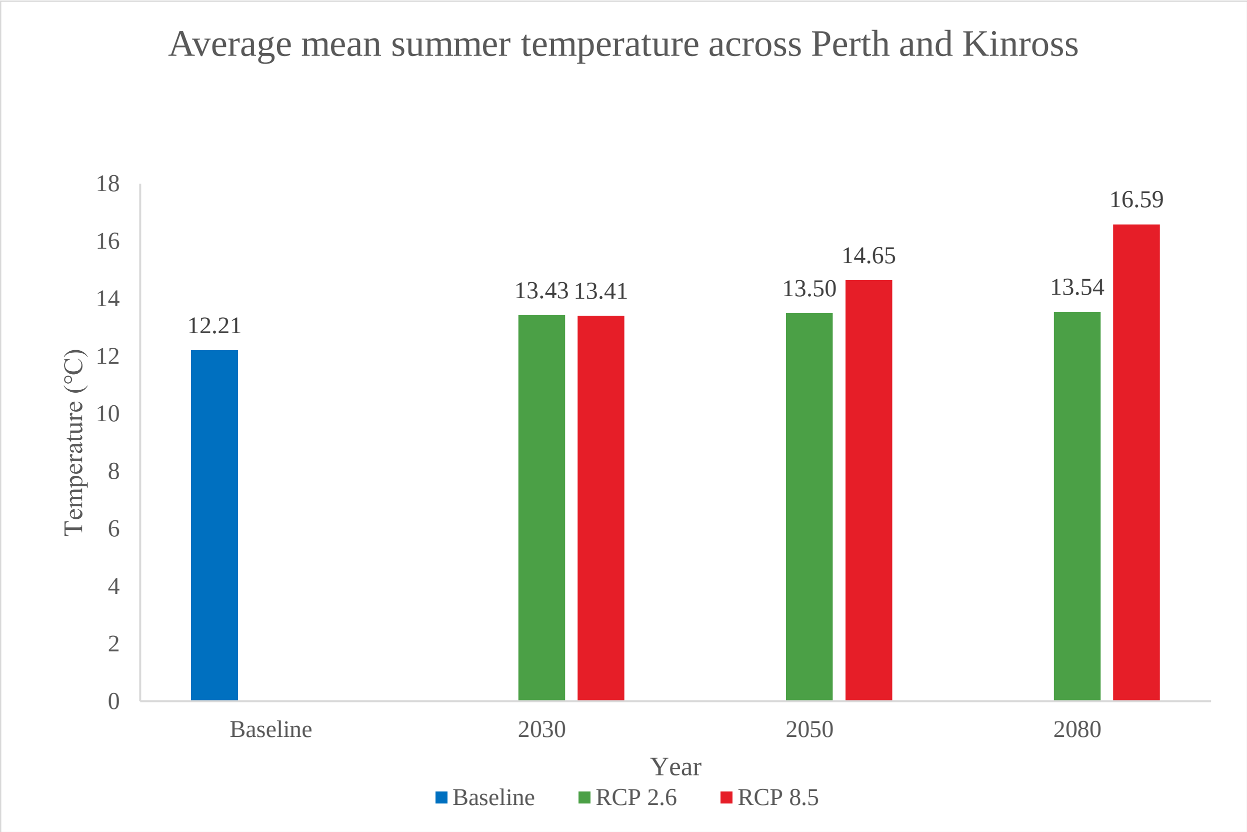

Figure 16: Graph showing the projected average mean summer temperatures (Jun, July, August), for both RCP 2.6 and RCP 8.5 against a baseline (average for 1981-2000). These values are extracted from 25km data and averaged for the geographic area of Perth and Kinross. All values are taken from the 50th percentile of projections.

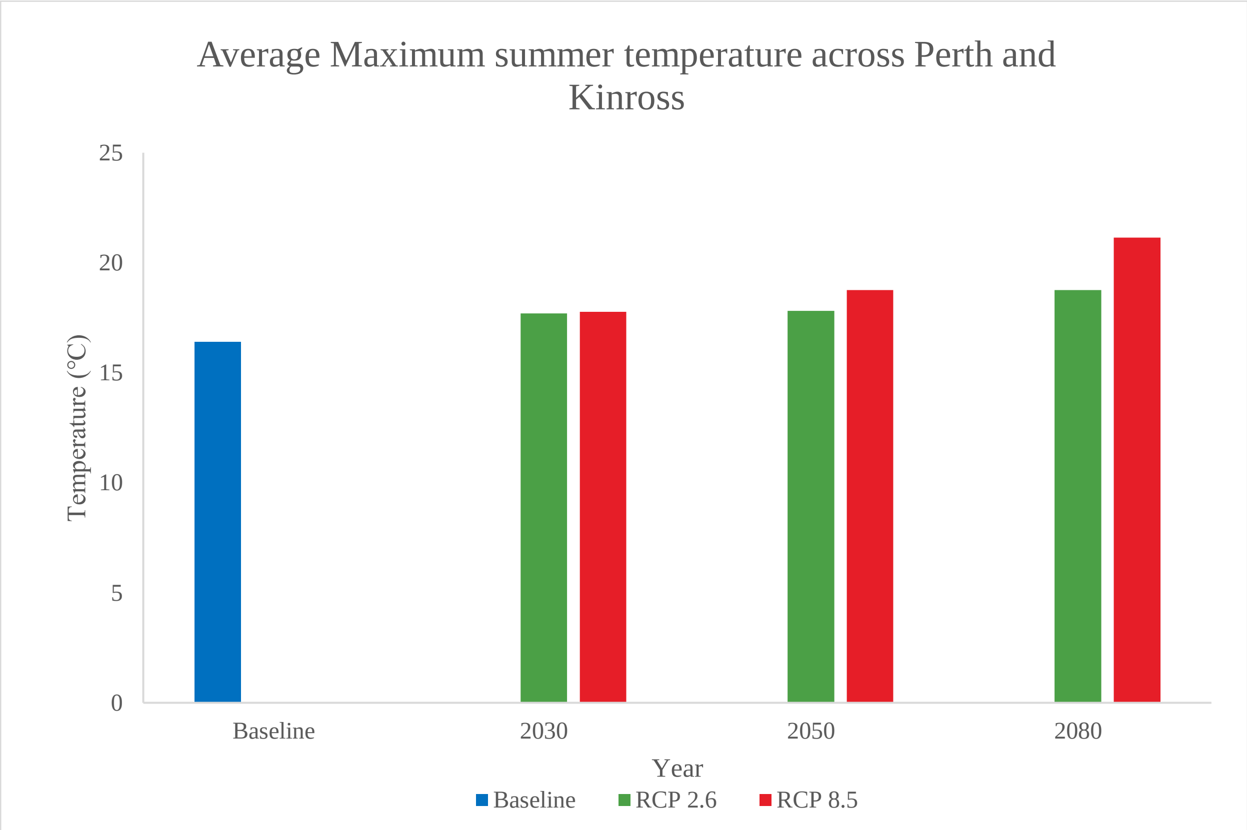

Figure 17: Graph showing the projected average maximum summer temperatures (Jun, July, August), for both RCP 2.6 and RCP 8.5 against a baseline (average for 1981-2000). These values are extracted from 25km data and averaged for the geographic area of Perth and Kinross. All values are taken from the 50th percentile of projections.

The above three graphs provide an overview of how summer temperatures are likely to change on average for the whole of Perth and Kinross. Actual figures across Perth and Kinross vary. Figures 18, 19 and 20 map the spatial distribution of projected changes to temperature for 2030, 2050 and 2080 under a high emissions scenario, to illustrate spatial differences in projected change. These show the absolute change as opposed to the absolute temperature values.

Figure 18 maps the range in the projected change to the summertime minimum temperature. The range of projected change is 4.01℃ to 4.47℃, which is a relatively small range. The location with the largest absolute change covers the northern part of the city of Perth. In contrast with changes to the winter temperature the most northern parts of the local authority show the lowest levels of change. This spatial patten is repeated for the mean and maximum air temperature, shown in Figures 19 and 20. For both the northern part of the city of Perth again shows the highest levels of change at 4.79℃ and 5.23℃.

Increases in temperature in both the spring and the summer result in the accumulated temperature, which is the measurement of the degree of warmth for plant growth throughout the growing season. This is discussed more in Chapter 7.

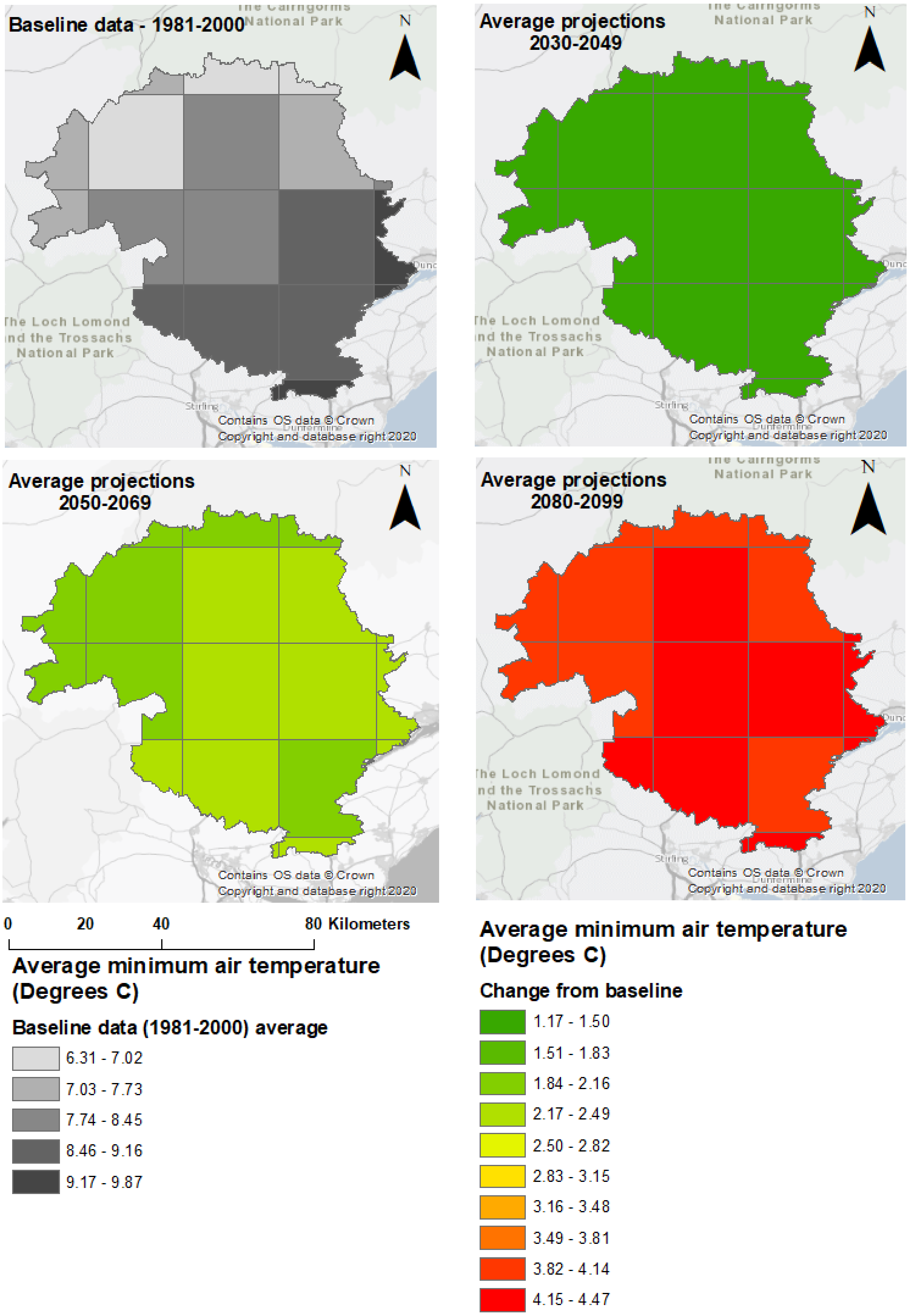

Figure 18: Maps illustrating the spatial distribution of the projected changes to the average minimum summer (Jun, July August), temperature in 2030, 2050 and 2080 under RCP 8.5 and the spatial distribution of the baseline temperature for comparison. All values are taken from the 50th percent percentile of projections. The baseline map displays absolute averaged observations of temperature, whereas the projection map displays absolute change to the baseline temperature.

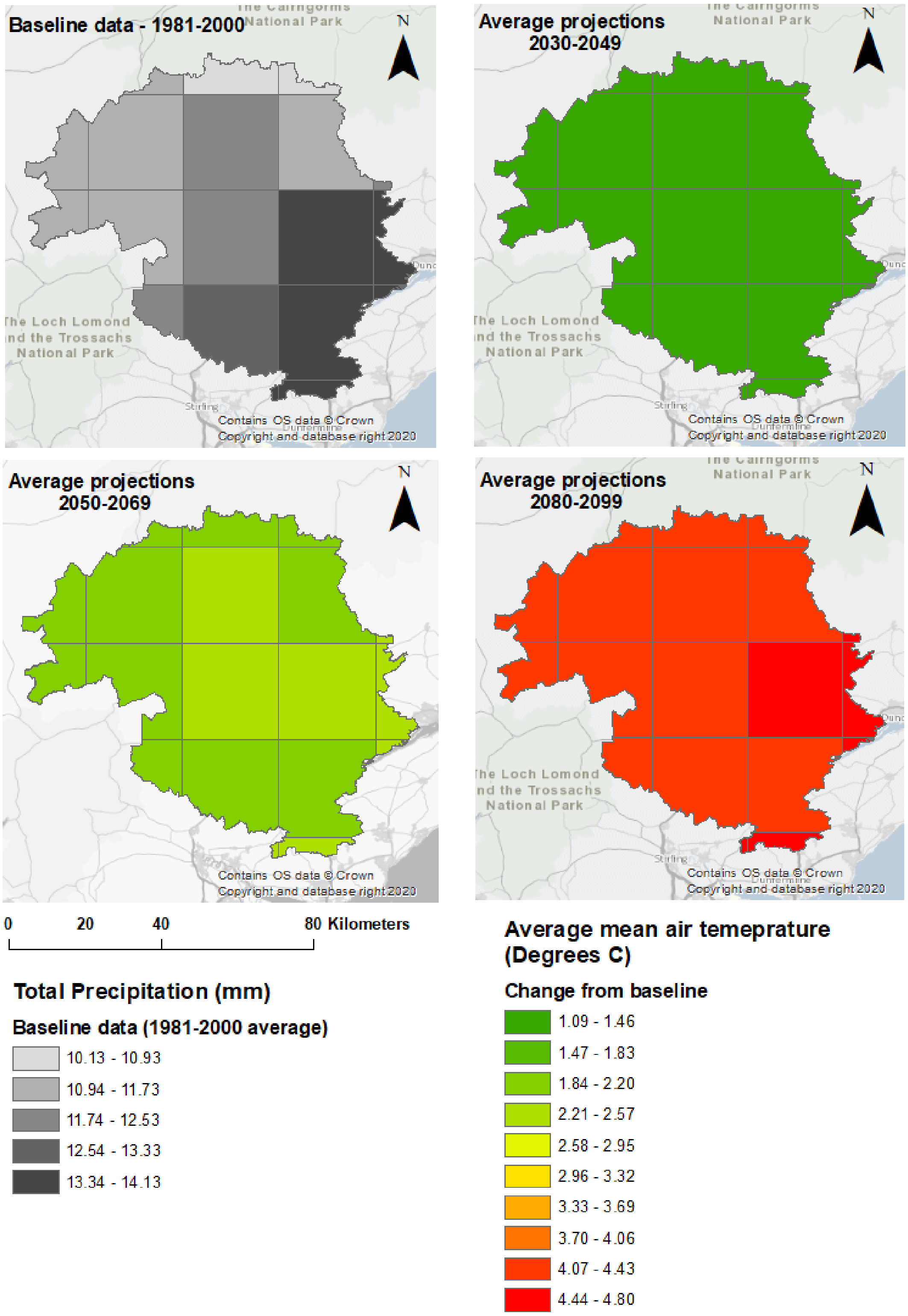

Figure 19: Maps illustrating the spatial distribution of the projected changes to the average mean summer (Jun, July August), temperature in 2030, 2050 and 2080 under RCP 8.5 and the spatial distribution of the baseline temperature for comparison. All values are taken from the 50th percent percentile of projections. The baseline map displays absolute averaged observations of temperature, whereas the projection map displays absolute change to the baseline temperature.

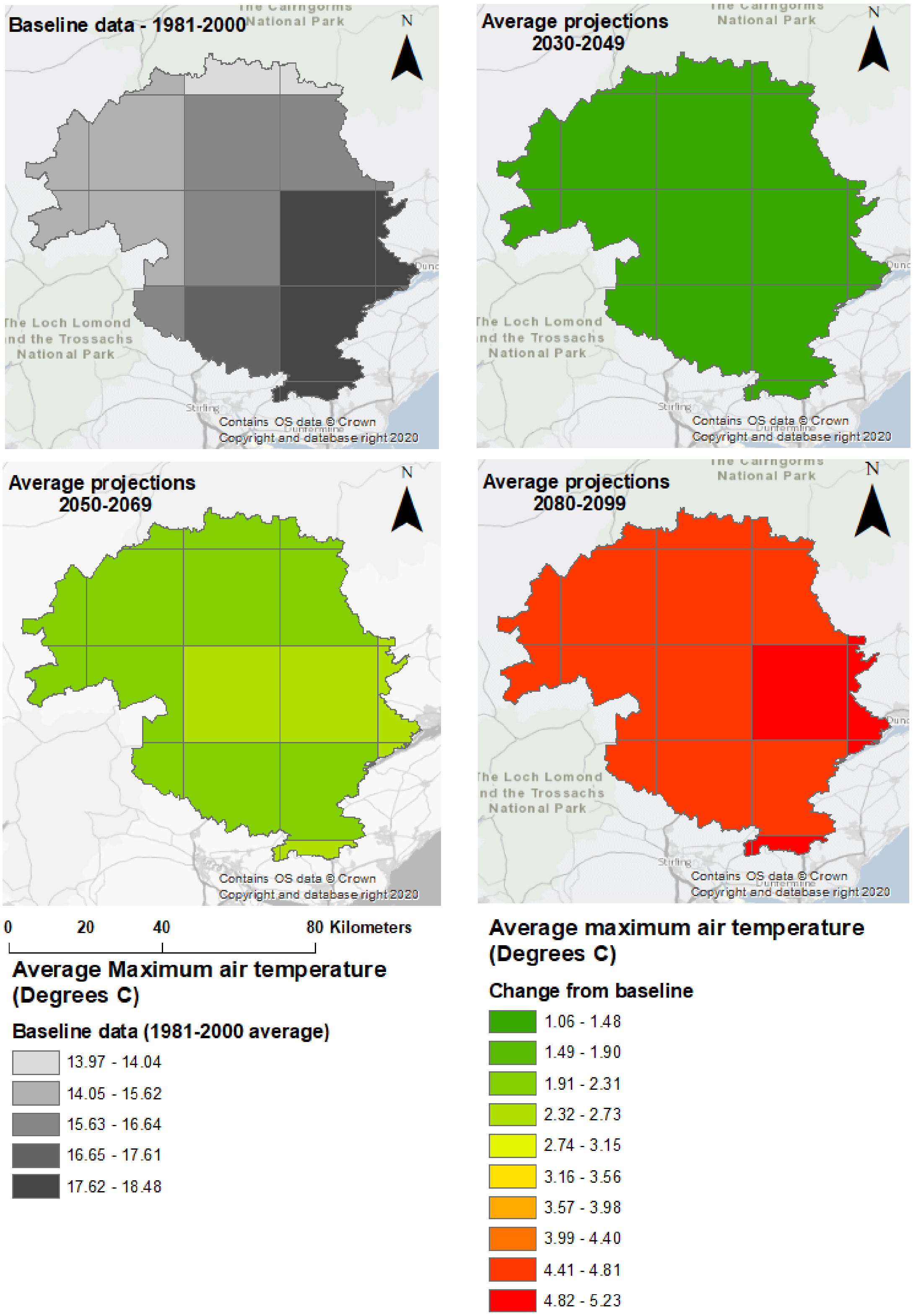

Figure 20: Maps illustrating the spatial distribution of the projected changes to the average maximum summer (Jun, July August), temperature in 2030, 2050 and 2080 under RCP 8.5 and the spatial distribution of the baseline temperature for comparison. All values are taken from the 50th percent percentile of projections. The baseline map displays absolute averaged observations of temperature, whereas the projection map displays absolute change to the baseline temperature.

The above maps and graphs show the average maximum summer temperatures and how they are expected to increase. Figure 21 below shows the baseline information and projected data for the average hottest yearly temperatures across Perth and Kinross, under an RCP 8.5 scenario for 2060-2079 (50^{th} percentile). These maps show us that the average hottest yearly temperature will increase significantly in the future, with areas increasing to 28 to 32.5 ℃ peaks by 2080 (a 5-7 ℃ increase). This measure shows the highest temperatures for an average (non-heatwave) year. More extreme temperatures could be reached under heatwave conditions. Extreme heat events of heatwaves occur within natural climate variation.

However, an increase in the frequency, duration, and intensity of these events over recent decades have been observed; the top 10 warmest years for the UK since 1884 have occurred since 2002. In contrast, none of the coldest years have been recorded in this century. The summer of 2018 included multiple heatwaves; the Met Office have analysed the UKCP18 and showed that a summer as exceptionally warm as 2018 was very unlikely (less than 10% chance) in the recent past (1981-2000), but that warming so far had increased the chance to between 10-20%[4]. Moreover, by the mid-century, summers like 2018 are expected to occur as often as not (with about a 50% chance). By the end of the century the probability could increase to over 90% likelihood under a high greenhouse gas emission scenario.

[4] https://www.metoffice.gov.uk/research/climate/understanding-climate/uk-and-global-extreme-events-heatwaves

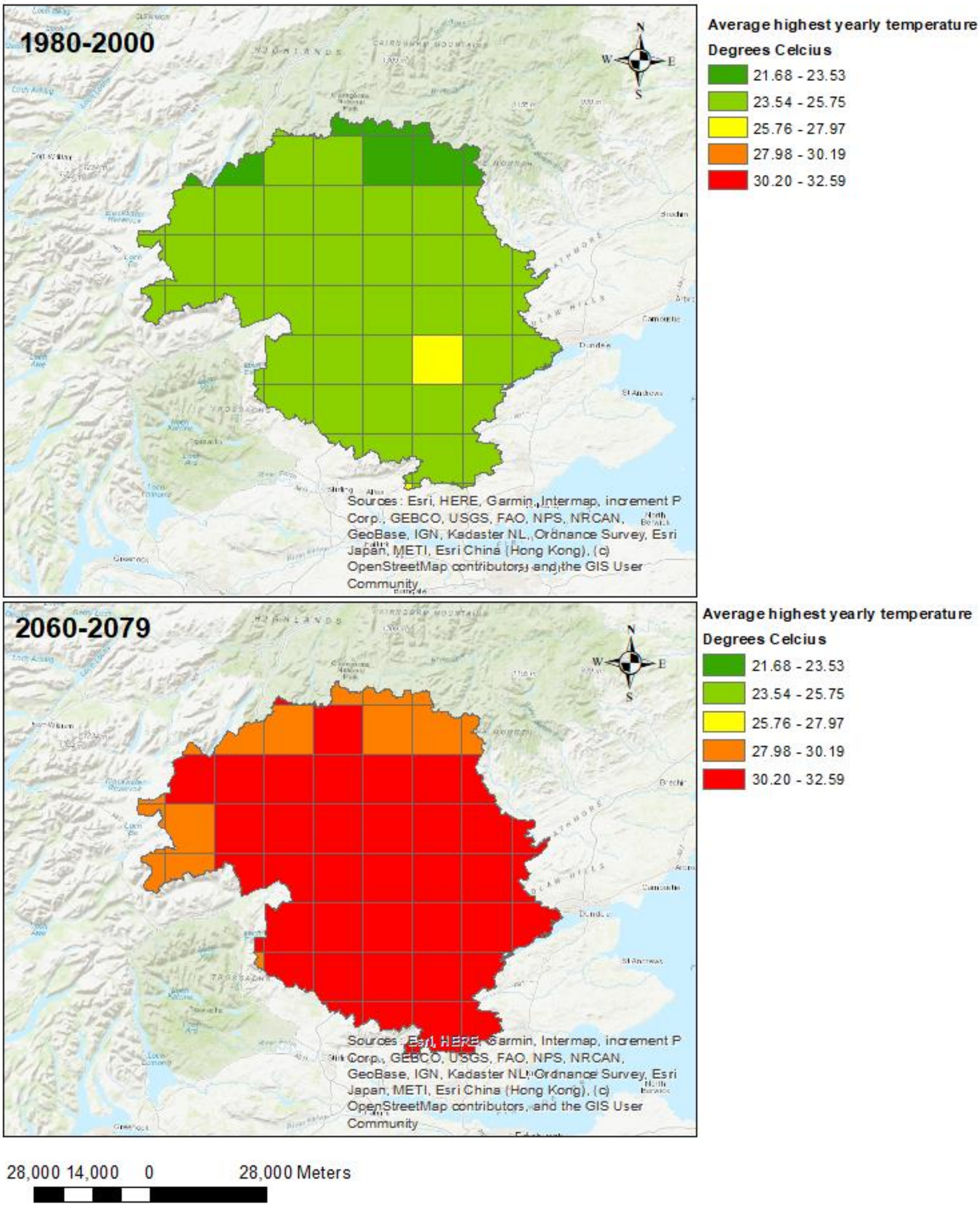

Figure 21 Absolute projections for average yearly highest temperatures in Perth and Kinross for both the baseline time period and projected period of 2060-2079 under RCP 8.5

3.4.1 Changes to temperature key messages

- For all seasons under all scenarios temperatures across Perth and Kinross are projected to increase.
- The mean, maximum and minimum summer and winter temperatures will all increase progressively across the century.

- Winter temperatures rising has a knock-on impact for frost, and snowfall. This has further implications for biodiversity adapted to current temperatures. There are also impacts on run-off, snow cover and increased meltwater.
- Summer temperatures increasing could bring heatwave risks to the population, moreover, some buildings may struggle to maintain a comfortable temperature not being designed for these warmer summers.
- Some benefits may occur due to warmer winters, e.g., less winter heating needed in homes. Warmer summers may also positively impact on both health and tourism.

3.5 Changes to wind

To understand how wind will change due to climate change, the variable "Wind speed anomaly at 10m (ms^{-1})" was used. This refers to the absolute change in wind speed measured in metres per second.

Changes to wind speed for Perth and Kinross vary seasonally. Overall, wind speed is generally expected to increase slightly in the winter months and decrease slightly in the summer. Figures 22 and 23 show how wind speed is projected to change for winter and summer months. The baseline wind speed values for 1981-2000 (6.48 and 4.84 m/s for winter and summer respectively). Figures 22 and 23, show that the overall projected wind speed change is low, with the relative change <5% in all cases. According to the baseline information for both winter and summer the areas with the highest average wind speed are generally in the northeast and western areas of Perth and Kinross, shown in figures 24 and 25.

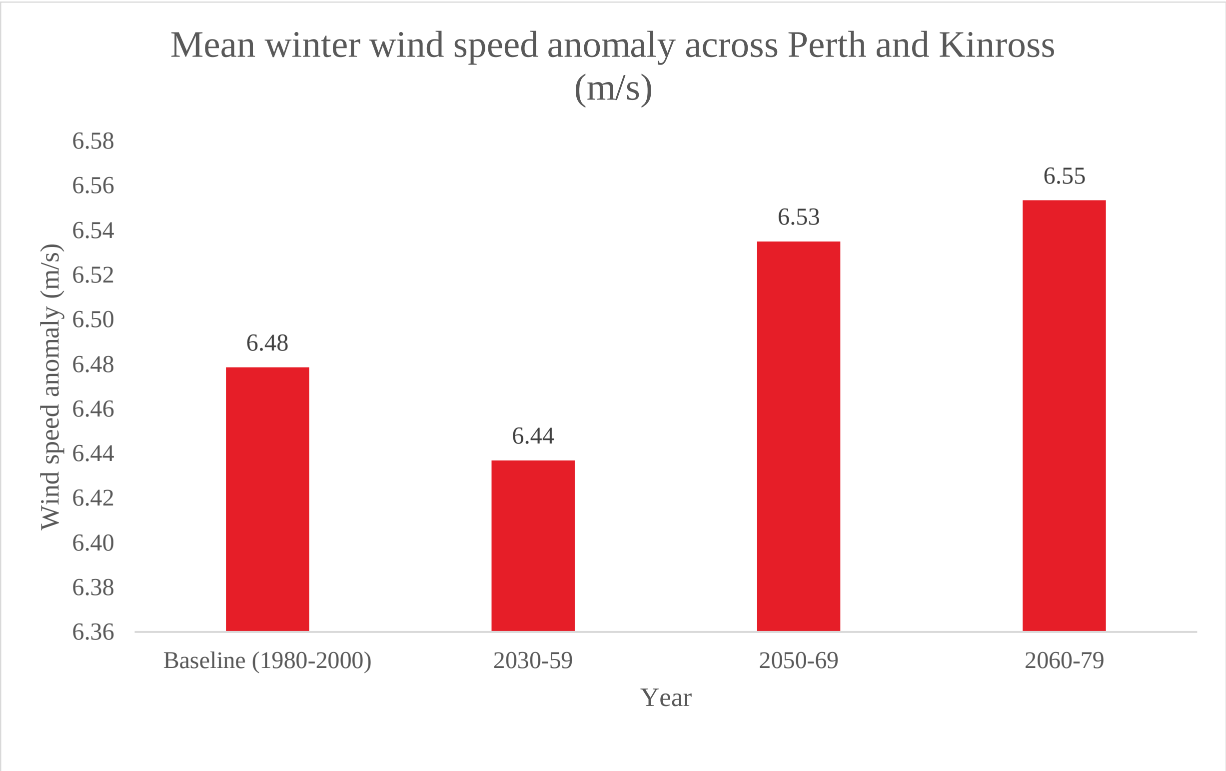

Figure 22: This graph shows the mean wind speed anomaly, averaged across Perth and Kinross for RCP8.5 in winter.

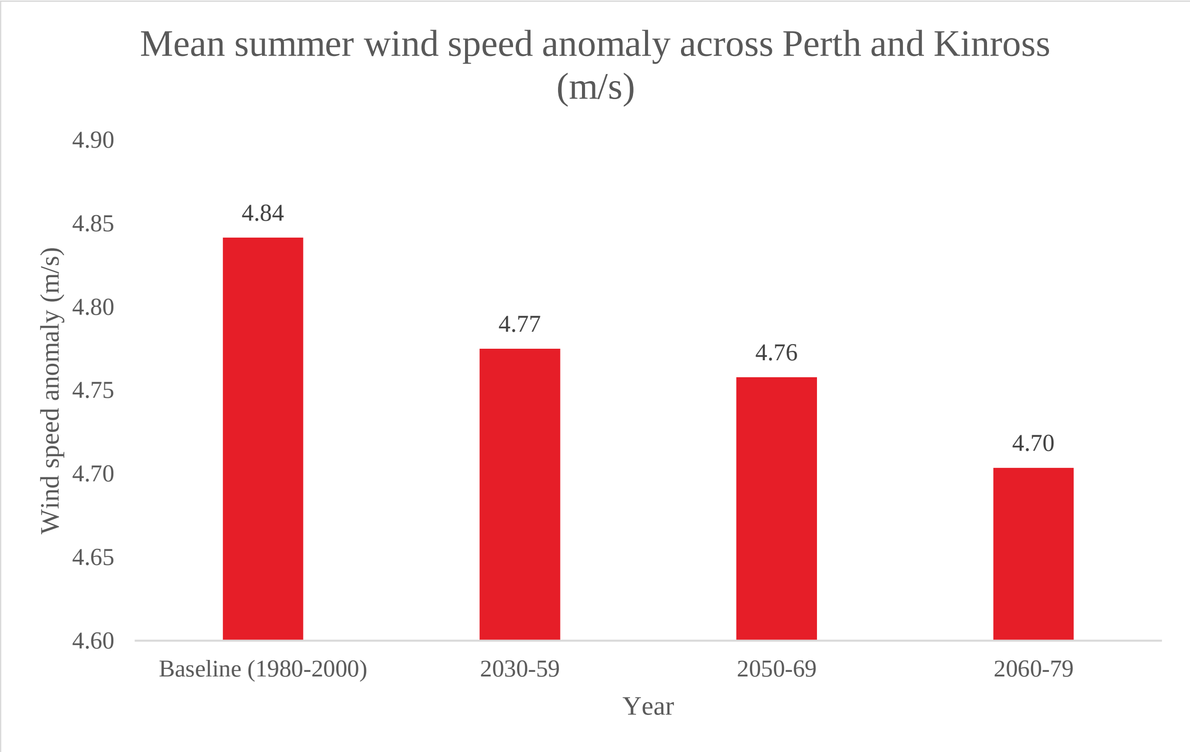

Figure 23: This graph shows the mean wind speed anomaly, averaged across Perth and Kinross for RCP8.5 in summer.

Figure 24 illustrates the spatial variation in the change in mean wind speed anomaly expected under a high emission scenario in winter. Generally, these maps show that under the 2030-2049 projections mean the wind speed anomaly actually decreases slightly with a greater decrease generally seen in the Eastern part of the local authority. For both 2050-2069 and 2060-2079 this becomes a small increase compared to the baseline. With larger increases seen on more Southern and Westerns regions. The areas of lowest change are to the East of the region, including Perth and Blairgowrie, which are expected to see a decrease in wind speed. However, the range in values is low across the local authority, indicating that this spatial variation is not extreme.

Figure 25 illustrates the spatial variation in the projected change in mean wind speed anomaly under a high emission scenario for the summer months. These maps show that the projections suggest a reduction in wind speed, this reduction increases gradually with time. The three maps suggest that the general spatial patterns show lower decreases in the Western parts of the Local Authority. However, again the range in values for the change from the baseline are low across the local authority.

The current understanding of the impacts of climate change in the UK is that “there are no compelling trends in storminess when considering maximum gust speeds over the last four decades,” and “there is little evidence that climate change is affecting storms.”[5]

[5] UK and Global extreme events – Windstorms - Met Office

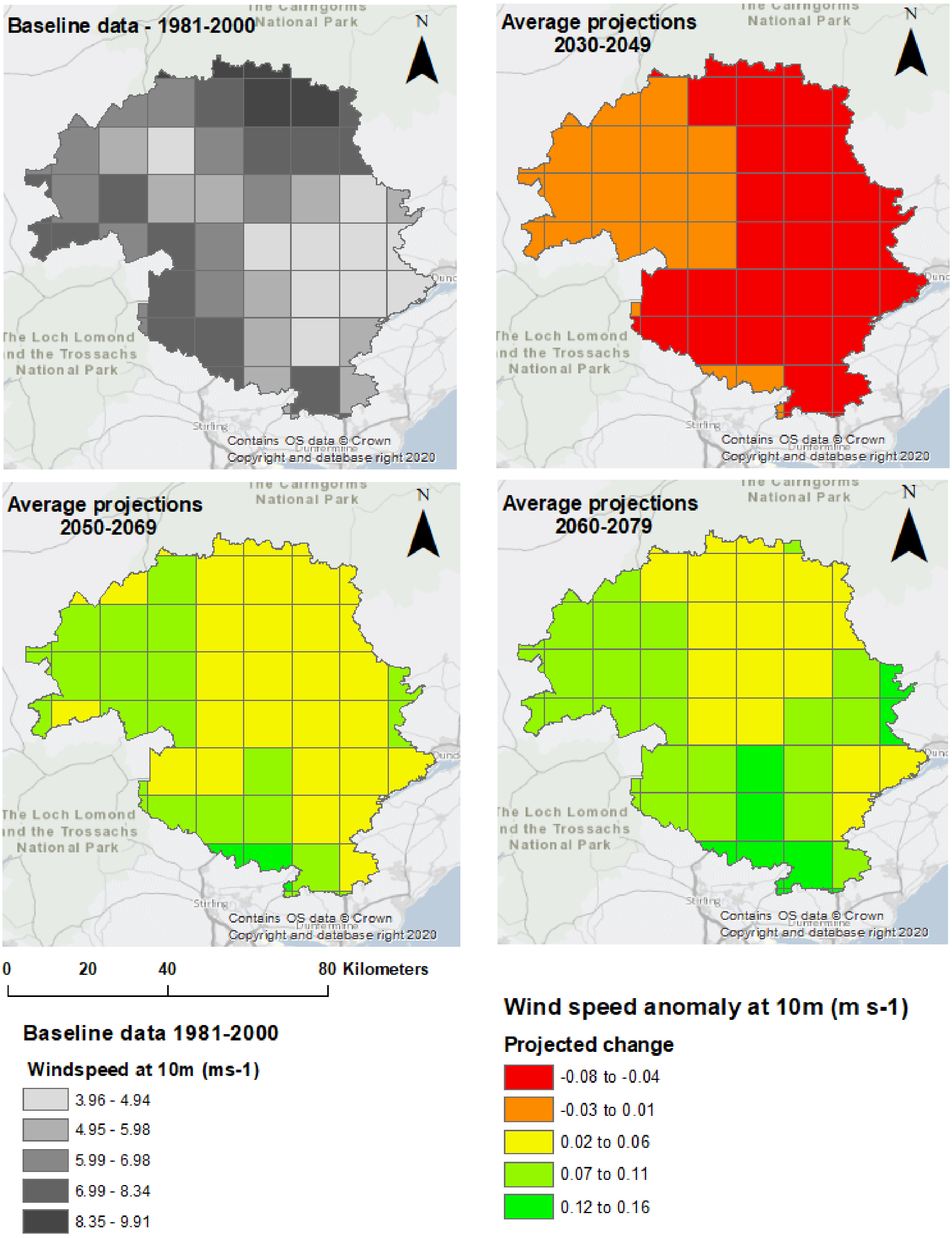

Figure 24: Spatial variation in change in wind speed, for RCP8.5, during the winter months (December, Jan and Feb).

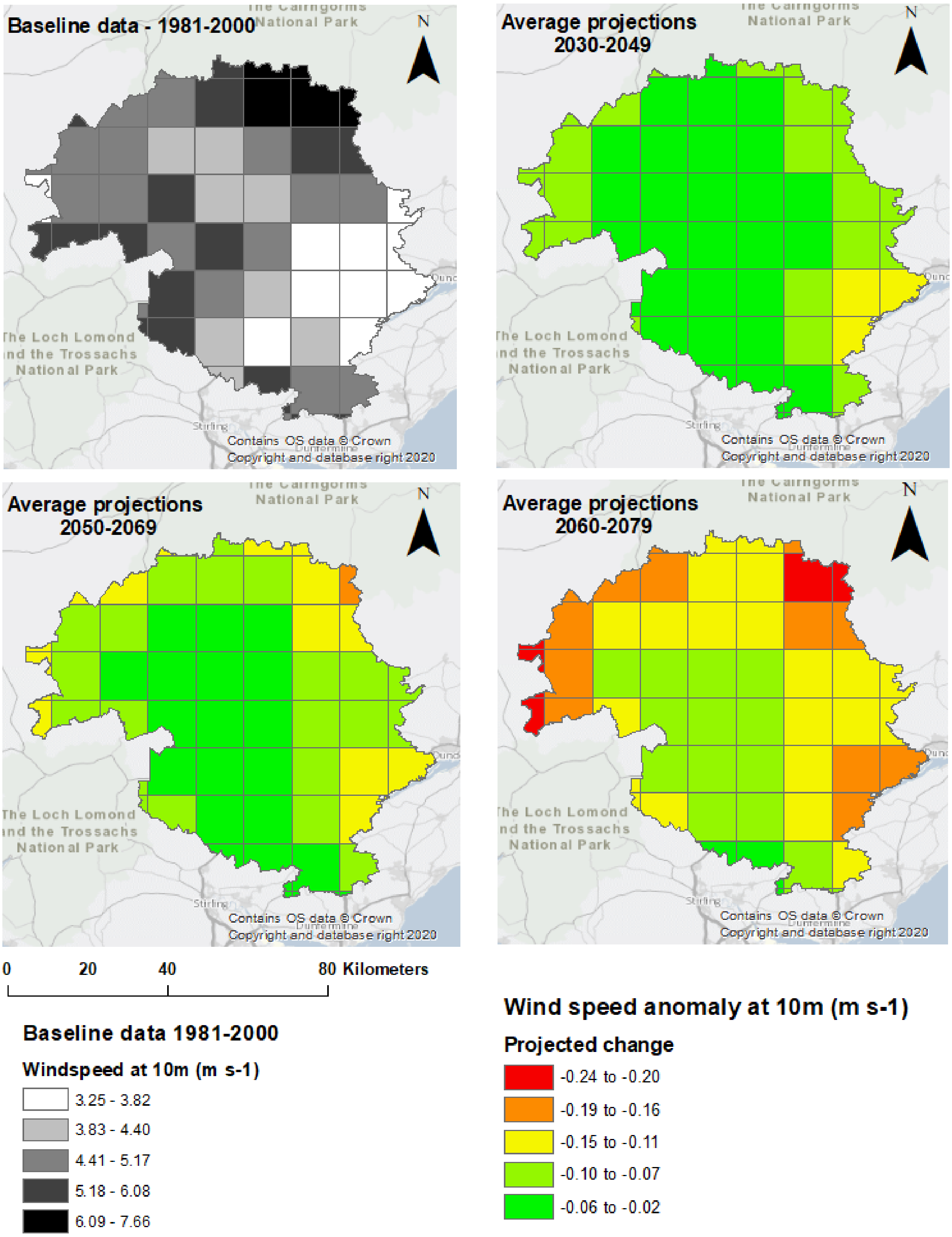

Figure 25: Spatial variation in change in wind speed, RCP8.5, in summer (June, July, august).

3.5.1 Changes to wind key messages

- Changes to wind speed for Perth and Kinross vary seasonally. Overall, wind speed is expected to increase slightly in the winter and decrease slightly in the summer.
- However, wind projections have more uncertainty within the projections than other areas, so the full picture is not clear.

3.6 Changes to snow

In this section data from the UKCP18 local climate projects for snowfall was used to understand how snowfall and snow lying on the ground will change. UK observed snow depth is not well covered. The UK Met Office has a relatively dense network of rain gauges, but these do not distinguish rainfall and snowfall[6]. The projections are based on physical models where snowfall metrics are projected forward and backwards, and as matching real-life observation data is not available. The baseline data is calculated by back projecting the UKCP18 snowfall variables and taking the mean across the entire area of Perth and Kinross.

3.6.1 Snowfall flux anomaly

Snowfall flux is defined as falling snow measured in mm's per day and includes all snow regardless of whether it remains frozen on the ground or melts immediately. Figure 26 shows a projected major decrease in snowfall, increasing progressively through the century, with a projected average decrease of nearly 90 percent by 2079, relative to a 1981-2000 baseline. Figure 28 shows the spatial variation in snowfall flux across Perth and Kinross. The areas of largest decrease are in the lower-lying areas in the southwest of the region, up to a maximum of almost 90% decrease by 2079. The areas of least decrease are in the north-eastern and north-western regions, although even these regions are projected to see a decrease of greater than 50% by 2079.

[6] https://www.ukri.org/wp-content/uploads/2021/12/091221-NERC-LWEC-WaterReportSource11-SnowHistoryProjected.pdf

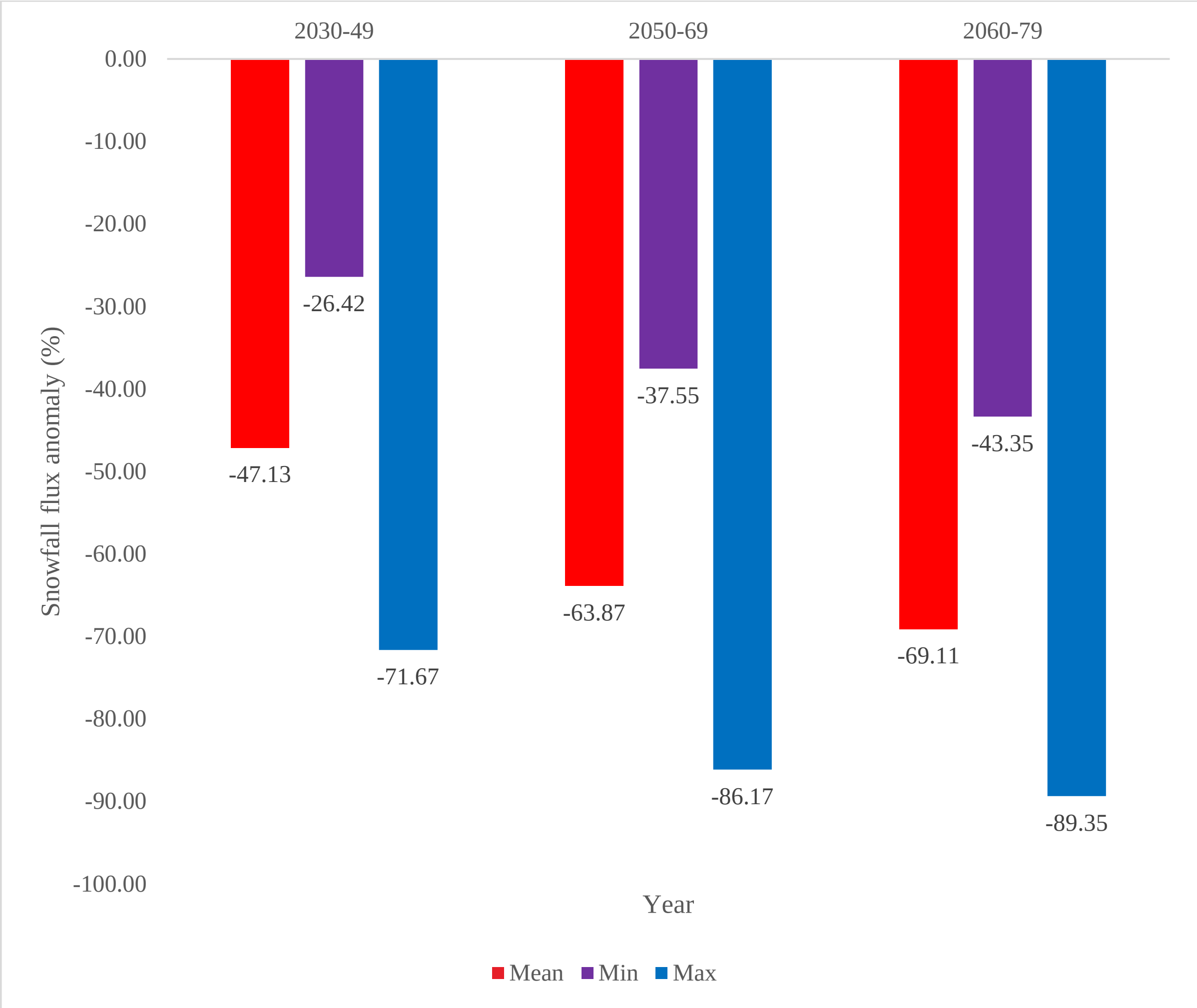

Figure 26: This graph shows the percentage change in winter snowfall, averaged across Perth and Kinross for RCP8.5 in winter (the 50th percentile is shown here). The percentage change is relative to a 1981-2000 baseline.

3.6.2 Surface snow anomaly

Surface snow is defined as snow that remains frozen on the ground once it has fallen. For example, the surface snow reading for a given day could be positive even if it had not snowed that day, if residual snow remains from earlier snowfall.

Figure 27 shows that there is expected to be a major reduction in surface snow relative to a 1981-2000 baseline. The calculated baseline surface snow in winter across the entire region of Perth and Kinross is approximately 4.6 mm. As this is an average, the figures below show an expected decrease of greater than this; this is due to the spatial variation. Figure 29 shows the spatial variation of the surface snow decrease. Surface snow is projected to decrease across the entire region, but the areas of greatest decrease are in the northeast and northwest (upland) regions of Perth and Kinross. The decrease of surface snow is greatest in the northeast corner and is projected to be above 25mm. The projected decrease is least in the south-eastern part of the region (lowland areas including Perth); decreases in this region are in the range of 1.3 to 4.53mm. The overall trend is for areas that currently receive the most snow to see the biggest decreases in absolute terms.

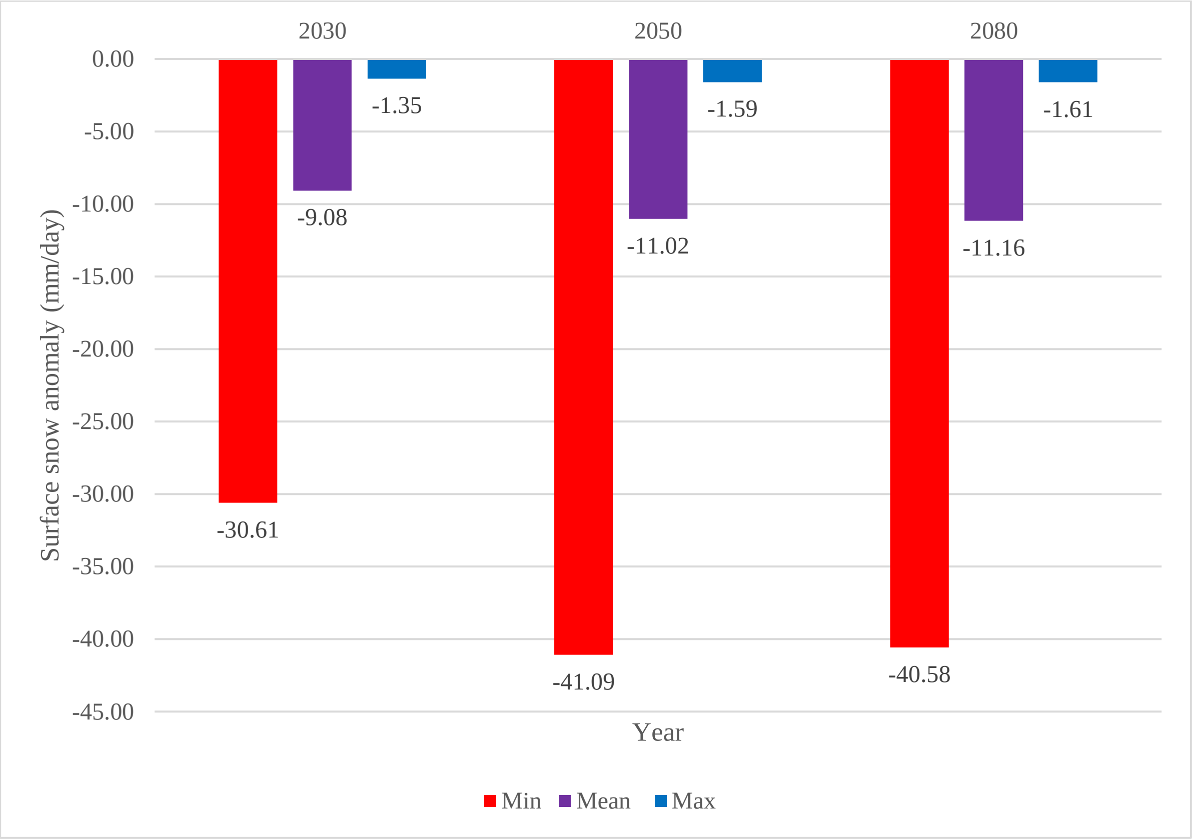

Figure 27: This figure shows the surface snow anomaly in mm per day, averaged across Perth and Kinross for RCP8.5 in winter (the 50th percentile data is shown here). The absolute change is relative to a 1981-2000 baseline.

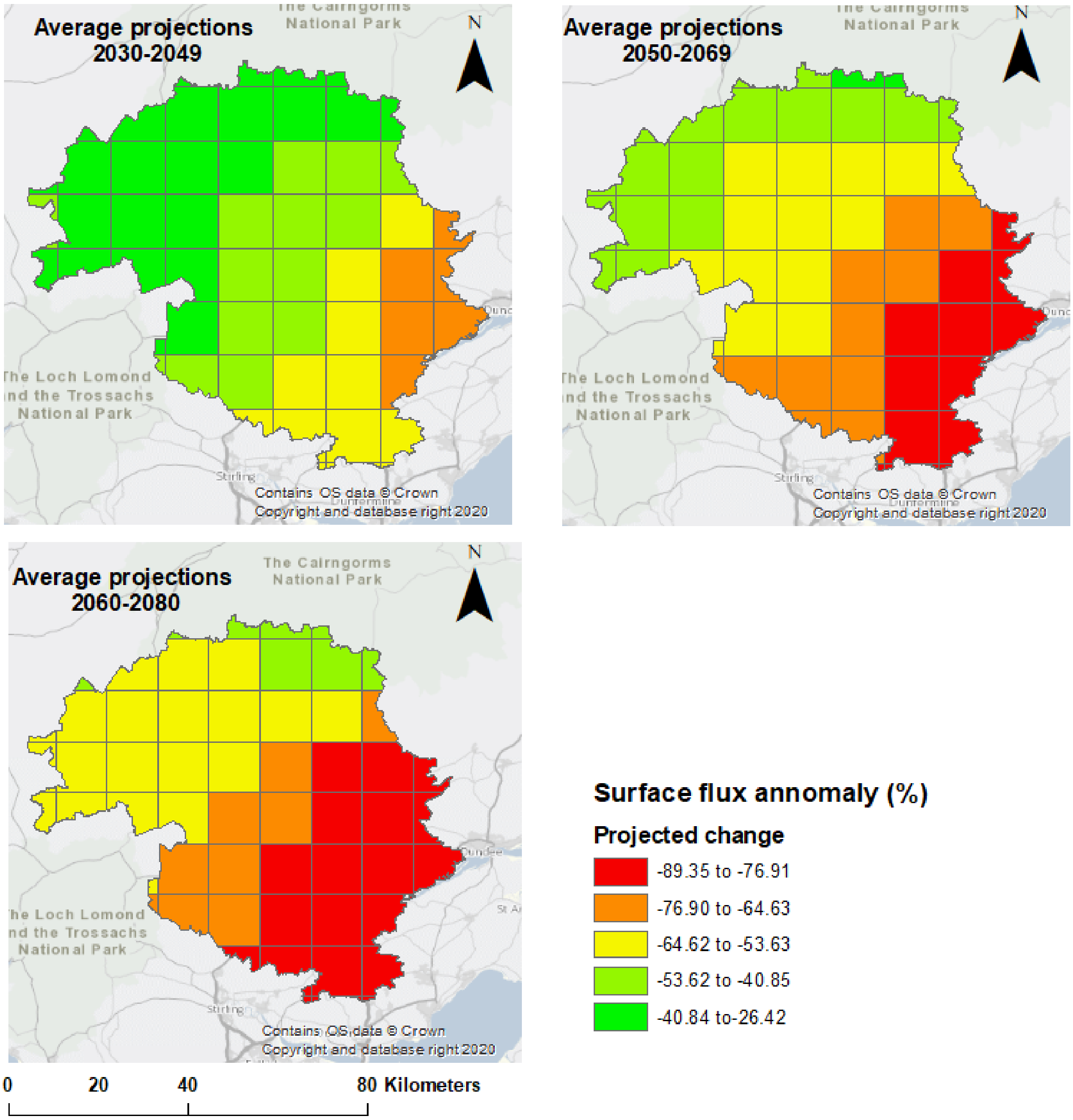

Figure 28: Spatial variation of snowfall flux % change, RCP8.5, during the winter.

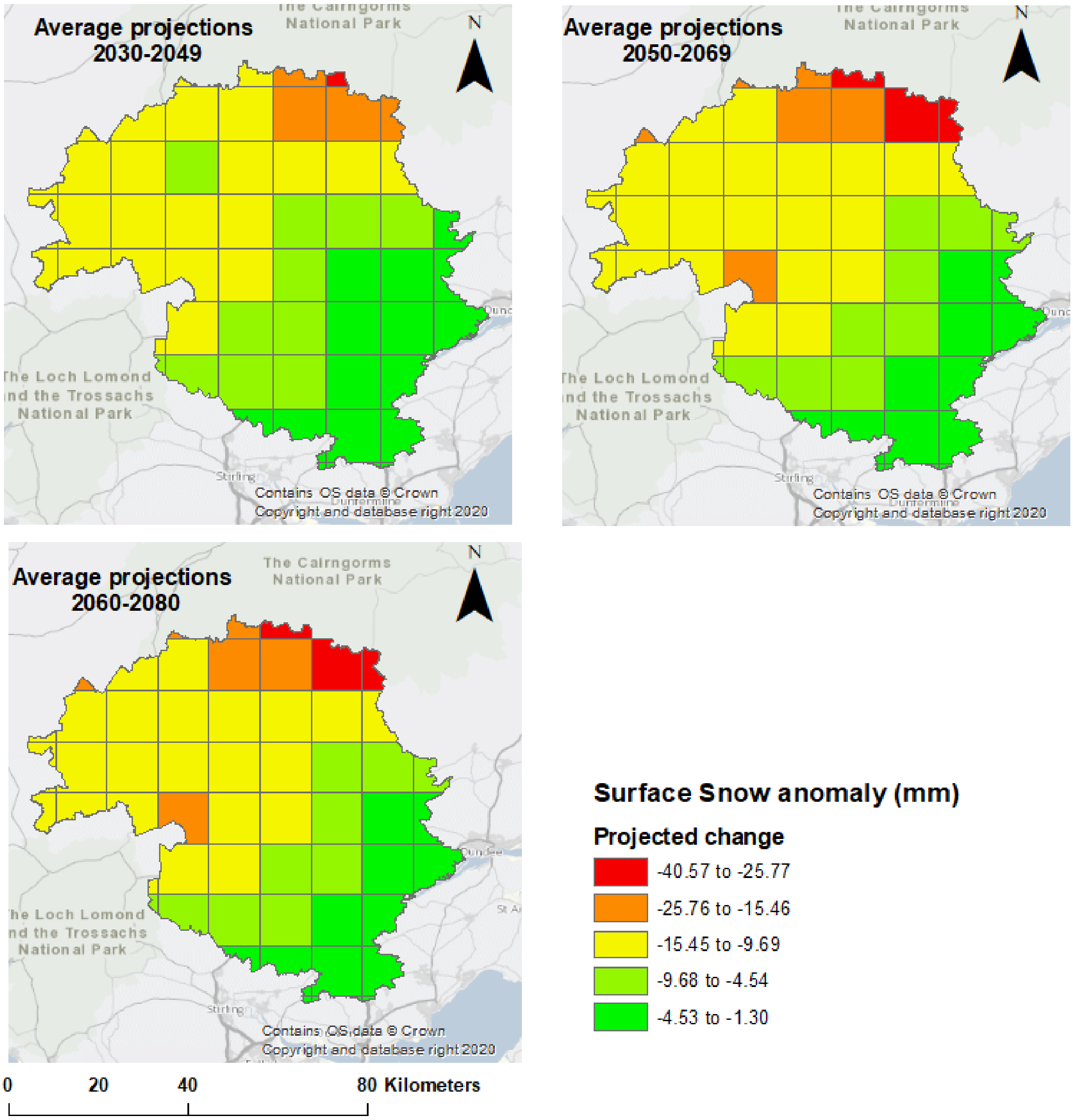

Figure 29:Spatial variation of surface snow anomaly, RCP8.5, in winter.

3.6.3 Snow key messages

- The expected reduction in snowfall may affect industries in Perth and Kinross, such as skiing at Glenshee.
- Decreased snowfall and snowmelt may also put stress on water supplies. It may also affect river flows where rivers are fed by meltwater, and place stress on salmon which struggle when water temperature

rise[7]. However, higher temperatures may lead to more rapid snowmelt and increase the possibility of flooding at certain times.

- There may also be ecological effects caused by disruption to normal natural patterns. An example of this may be insects that historically die in colder winters, which allow trees to recover. Less snowfall may mean insects and fungi can thrive for longer.[8]
- Decreased snowfall also means a decrease in surface albedo (the ability of the Earth to reflect solar radiation), which forms a feedback loop and can increase temperatures further.
- Snowfall flux decreases the most in low-lying areas including the city of Perth and estuarine regions. The reduction in snowfall flux is lower in upland regions.
- The surface snow anomaly geographic variation is the opposite, with the largest decrease in upland regions. This is expected to be partly due to the overall increase in temperature, and partly due to there being more snow to melt in upland regions.

3.7 Changes to sea level and storm surge

Storm surge levels are adjusted for climate change by applying the expected sea level change to the existing storm surge level; as sea levels are expected to rise due to climate change, this results in a positive offset of existing storm surge data. For example, Figures 29 is shown here for the nearest coastal data point at the mouth of the Tay estuary for RCP2.6.

[7] Marine Scotland Resources to reduce river temperatures and protect Atlantic Salmon (blogs.gov.scot)

[8] We're Getting Less Snow, And It's Having A Big Impact On The Environment, Study Shows - Gothamist

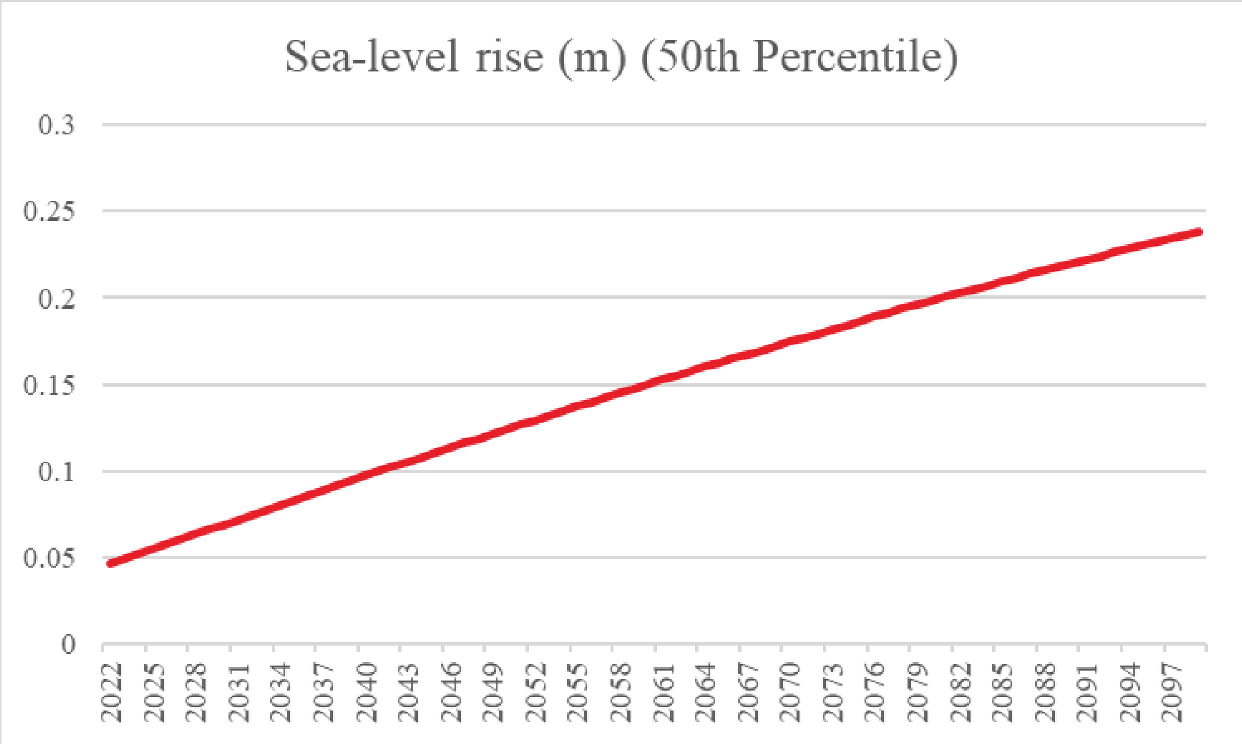

Figure 29: Sea-level rise (50th percentile) for the nearest coastal point to Perth and Kinross, RCP2.6.

Table 3: Absolute change in sea level and absolute height of storm surge. Sea level rise is taken as the 50th percentile of the time mean sea level anomaly.

RCP/Parameter	2022	2030	2050	2080	2100
2.6 – Sea level rise (m)	0.05	0.07	0.12	0.20	0.24
2.6 – Storm surge (m)	3.87	3.89	3.94	4.02	4.06
8.5 – Sea level rise (m)	0.05	0.08	0.18	0.39	0.55
8.5 – Storm surge (m)	3.87	3.90	4.00	4.21	4.37

3.7.1 Sea level and storm surge key messages

There is no consensus on the effect of climate change on storm surge levels. Currently, current storm surge levels are combined with sea level changes.

- The major impacts of sea level rise are seen during high tides and storms, with increased flooding along coastlines and estuaries.[9] This poses a risk to coastal communities.
- P&K does not have open areas of coastline, but sea level rise will affect the Tay Estuary. This will affect tidal areas such as Perth and Invergowrie.

[9] How is climate change affecting coastal flooding in the UK? - Grantham Research Institute on climate change and the environment (lse.ac.uk)

- Sea level rise also increases coastal and estuarine erosion, with associated impacts on land, buildings, and infrastructure.
- Sea level rise may require adaptation or mitigation, which can be expensive, such as new flood defences or nature-based solutions. There are some existing flood schemes such as at Perth and Bridge of Earn which may require adaptation, and other communities may not have flood defences but may require them in the future.
- Rising sea levels may also contribute to coastal squeeze, which is defined as "the loss of natural habitats or a deterioration in their quality caused by man-made structures or human activity."[10]

[10] https://assets.publishing.service.gov.uk/media/6038fadd8fa8f5048f78a5fa/FRS17187_What_is_coastal_squeeze_-_summary.pdf

3.8 Flooding

3.8.1 Context

In June 2009, the Flood Risk Management (Scotland) Act was passed into law. This legislation was intended to modernise flood risk management in Scotland, in line with European Directive 200/60/EC (the Flood Directive). The Scottish Government have provided a national framework for planning policy (Scottish Planning Policy, SPP); flood risk management within local council areas (including Perth and Kinross) is based on this. The approach to flood risk management should be "integrated catchment-wide, sustainable and risk-based."

In practical terms, PKC are obliged to:

- Map relevant bodies of water and SUDS.
- Assess bodies of water for flooding risk.
- If a body of water is a flooding risk, prepare a schedule of clearance and repair works and carry out these works.
- Assist SEPA in preparing the national flood risk assessment (NFRA), flood hazard and risk maps, and flood risk management strategies.
- Prepare local flood risk management plans (every six years).

There are three major types of flooding: fluvial, pluvial, and coastal. Other types of flooding include groundwater, drainage, and infrastructure failure. Flooding can be caused by a combination of these processes.

3.8.2 Flood risk management plans

Flood risk management plans are intended to coordinate flood risk efforts. They are developed by SEPA working with local authorities and other stakeholders. Scotland is divided into 14 local plan districts, with a plan prepared for each. Perth and Kinross is the lead authority for the Tay District, and is involved with three others: Forth, Forth Estuary, and Tay Estuary & Montrose Basin.

FRM plans identify potentially vulnerable areas (PVAs); these are "catchments identified as being at medium to high risk of flooding, and where the impact of flooding is sufficient to justify further assessment and appraisal."[11] The PVAs have specific assessments of the objectives below, as well as additional, location-specific objectives.

The Tay FRM plan estimates that currently there are approximately 13,000 people and 9,000 homes and businesses currently at risk from flooding (Tay FRM does not match PKC boundaries exactly so statistics for PKC may differ). This is expected to increase to 21,000 people and 13,000 homes and businesses by the 2080s as a result of climate change. The annual average damage of these risks is £11.4m. This plan includes the major urban areas of Perth and Kinross, including Perth and Blairgowrie. The plan also identifies 16 actions aimed at managing flood risk:

- Awareness raising.
- Data to support climate resilience.
- Emergency plans/response.
- Flood forecasting.

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[11] Tay_Local_FRM_Plan_Final.pdf (pkc.gov.uk) p37

- Flood warning development framework.
- Future flood risk management planning.
- Guidance development.
- Hazard mapping updates.
- Land use planning – *PKC responsibility*.
- Maintenance – *PKC responsibility.*
- Natural flood management mapping.
- National flood risk assessment.
- National surface water mapping.
- Reservoirs.
- Scottish flood defence asset database.
- Self help.

3.8.3 National flood risk assessment 2 (NFRA)

The NFRA is a tool developed by SEPA to assess the causes and consequences of different types of flooding. At the time of writing, the terms and conditions of use preclude Arup from using the analysis in this report. Arup understands that the NFRA quantifies the risk posed by flooding at a granular level including number of homes and businesses, as well as estimates of damage values – this is also available in the local flood risk management plans, mentioned in the previous section. Input from PKC's flooding team has highlighted that the NFRA states around 9000 homes and businesses are currently at risk in Perth and Kinross, and this is projected to increase to 12,000 due to climate change.

3.8.4 Summary of climate change effect on flooding

The result of increased precipitation and sea level rise will be increased flood risk. The river and coastal flood hazard maps developed by SEPA are based on the UK climate projections 2009 (UKCP09). The emissions scenario is the high emissions scenario, assuming rising greenhouse gas emissions with no action taken to mitigate climate change.

Changes to precipitation and temperature will generally increase flood risk. Higher summer temperatures and an expected increase in short-term high-intensity rainfall will increase the risk of surface water flooding and small/flashy watercourse flood risk. The overall precipitation increase in winter may result in an increased risk of river flooding from longer periods of precipitation.

The latest UKCP18 projections predict an increase in sea level rise. From the Future Flood Maps: Summary document (SEPA): "Initial analysis has indicated that the 95th percentile of the UKCP09 High emissions scenario for 2080 could be considered a proxy for the 50th percentile from the UKCP18 high emissions scenario (RCP8.5) sea level projections for 2100. This suggests that with limited global action to tackle climate change there is a one in two chance the level of sea level rise by 2100 will be higher than that mapped in the future coastal flood maps."

The SEPA maps are a potential underestimate of flood risk as they did not use the latest UKCP18 data in their projections. Furthermore, SEPA maps are a screening tool and do not provide a site-specific assessment of flood risk. SEPA's climate change guidance[12] provides detail on uplifts that should be applied for different

[12] climate-change-guidance.pdf (sepa.org.uk)

types of flooding with regard to (e.g.) peak river flows, peak rainfall intensity, and sea level rise. These allowances can differ from the UKCP18 projections; for example, the suggested sea level rise allowance for the Tay River Basin by 2100 is projected as 0.85m by SEPA, compared to the 0.55m projected by UKCP18. In this work, for consistency, UKCP18 projections are used throughout. However, it should be noted that for more detailed flood-risk and management studies, further study is recommended to use the most appropriate projections. SEPA flood maps are not included in this report as figures due to visibility; analysis from the flood maps is included in later sections of the report. SEPA flood maps can be found online[13].

SEPA prepares climate change allowances for flood risk assessment in land use planning guidance, and a version 2 was adopted March 2022.[14] This update was informed by the more recent UKCP18. This SEPA guidance provides decision makers across Scotland with the predicted implications of future climate change on flood risk. It provides a prediction of anticipated change in peak river flows, peak rainfall intensity, and sea level rises caused by future climate change. SEPA's March 2022 guidance increased the previous uplifts from 20 % across all variables to peak river flows (53%), peak rainfall intensity (39%), and sea level rises due to future climate change.

For an example of how it is used in practice, Perth and Kinross Council's Flood Risk and Flood Risk Assessment supplementary guidance requires that the level of Property Finished Floor Levels (FFL) must be a minimum of 600mm above the 0.5% AP (200-year) design peak flood level (and the design flood level must include the appropriate climate change allowance). The SEPA Climate Change allowances for Flood Risk Assessment in Land use Planning Guidance version 2 provides the allowances required for climate change and informs the applicant's flood risk assessment and their proposed development. National Planning Framework 4 (NPF4) was adopted in February 2023. This provides planning policy for at-risk areas, and defines at-risk areas being future flood risk areas which SEPA has provided 2080 mapping to support.

[13] Flood maps | Scottish Environment Protection Agency (SEPA)

[14] Informing this update, a 2020 study commissioned by the Environment Agency (and contributed to by SEPA to ensure outputs covered Scotland) was carried out by the UK Centre for Ecology and Hydrology to assess the impact of climate change on fluvial flood peaks.

3.9 Conclusions

The high-level conclusions for the Perth and Kinross regions can be summarised as hotter, drier summers, and warmer, wetter winters.

The average temperature is expected to increase in all scenarios, with significant increases in summer temperatures under the high emissions scenario. This is expected to occur alongside reduced precipitation in summer, though the short-term intense rainfall level is similar to current conditions. This means that summer precipitation is expected to be high-intensity, short-duration bursts.

The temperature rise in winter is also expected to occur alongside an increase in precipitation, although more of this precipitation is expected to take the form of rain as snowfall is expected to decrease.

Overall, the effect of sea level rise and storm surge is expected to be limited in the region as there is a small area of coastline. However, tidal regions are likely to be affected, and sea level rise affects estuarine regions.

Flooding is an issue that currently affects Perth and Kinross, and climate change is expected to affect the extent of this, with preliminary analysis showing public facilities are likely to be affected. SEPA flood maps regions show likely to be affected, noting that these are likely to be an underestimate of the extent of affected areas.

In most cases the spatial variation in climate projections across Perth and Kinross is not significant (with some exceptions, such as winter precipitation). All impacts associated with these changes will be assessed on the maximum and the mean for the council area as a whole.

The overall conclusion is that the effects of climate change on the region are expected to be of a similar type to the rest of the UK, with some factors expected to affect Perth and Kinross less, such as hotter summers. However, other areas where Perth and Kinross are currently vulnerable may be exacerbated, such as increased precipitation leading to flooding.

4. Health, communities, and the built environment

This section summarises the evidence regarding the key risks and opportunities that climate change brings to the population of Perth and Kinross. This section specifically focuses on health and wellbeing, as well as risks to the built environment. It covers the risks and opportunities for communities including residential buildings, as well as climate change's impact on key public services namely education, health and social care and the prison service.

4.1 Risks from higher summer temperatures

Table 4: Overview of risks to health and communities from high summer temperatures and scoring.

Code	Risk	Risks score and narrative category	Comments
HCB3	Risks to air quality.	Medium Monitor risk	Poorer air quality due to above ground level ozone. Temperature rises unlikely to have significant impact on air quality until middle of the century.
HCB7	Risks to education from high summer temperatures.	Low Monitor risk – more research needed	Dependent heavily on building type. Need to understand which schools are more at risk. Likely to develop as bigger risk mid-century.
HCB8	Risks to health and wellbeing from high summer temperatures.	Low Monitor risk	Vulnerable people particularly at risk. Risk will develop throughout century so needs to be monitored.
HCB17	Risks to prison services from high summer temperatures.	Low More research needed	Only one prison in Perth and Kinross so low magnitude in terms of impact.
HCB11	Risks to health and social care delivery from high summer temperatures.	Medium More research needed	Unlikely to happen until middle of century, however due to consequences and an already stretched health care system – adaptation needs to be planned now.
HCB12	Risks to building energy demand due to increased temperature.	Low No action needed	Unlikely to happen until later this century.

4.1.1 Direct risks to health from extreme heat

The projected higher summer temperatures and increased occurrence of heatwaves pose multiple health risks to Perth and Kinross. These health risks directly impact upon communities and individuals as well both directly and indirectly increasing pressure on health care services. Heatwaves can result in increased mortality, particularly among the elderly. Though there are currently no specific studies based on mortality in Perth and Kinross, the UK's Climate Chance Risk Assessment (Scotland's national summary) identified that heat related mortality will increase in Scotland to between 70-285 per year by 2050 and 140-390 per year by the 2080s (assuming no population growth). Heat related illness is a further health risk, with those already suffering from chronic illness being the most vulnerable. Heat-related illness includes heat stroke, heat stress or heat exacerbating underlying conditions.

4.1.2 Risks to health from disease (made more prevalent by higher temperatures)

Warmer average summer temperature also brings indirect health risks by increasing the risk of Lyme disease due to producing more favourable conditions for ticks. Lyme disease cases may increase with climate change due to an extended transmission season and increases in person-tick contact. However, non-climate drivers such as agriculture, land use, tourism and populations of animals will also influence how Lyme disease develops, therefore this risk is uncertain. Scotland currently has more reported cases of Lyme disease than elsewhere in the UK, due to higher humidity and high rates of outdoor tourism, both these factors are also likely to increase with climate change. Areas of natural beauty where outdoor tourism is a key industry within Perth and Kinross, are particularly at risk, as that is where the greatest exposure will be. Ticks carrying Lyme disease are more prevalent in grassy and wooded areas[15]. Both landscapes are prevalent in Perth & Kinross. This means many rural areas in Perth & Kinross would have an elevated exposure to this risk. Tourists enjoying these types of area may also have an increased risk due to a lack of awareness of the hazard.

4.1.3 Health and air quality (made more prevalent by higher temperatures and reduced summer precipitation)

Higher temperatures can also interact with air quality, particularly in urban areas, again resulting in health impacts. Warmer temperatures provide more favourable conditions for near ground ozone formation, which can lead to an increase in Nitrogen Dioxide. Recent heatwave events have not been associated with the high levels of ground-level ozone. A reduction in summer precipitation can lead to dryer soils which increase dust levels and Particulate Matter. The air quality within Perth and Kinross is generally good; however, there are a few known hotspots within Perth city centre and Crieff. The main pollutants of concern are Nitrogen Dioxide (NO2) and Particulate Matter (PM10) from vehicle emissions. As mentioned, NO_2 may increase due to increased temperatures and Particulate which could impact existing hotspots. There is air quality monitoring in place, and this should continue.

4.1.4 Risks to buildings functionality and summer energy use

Increases in extreme heat also bring risks to the functioning of buildings both cause buildings to overheat and become uncomfortable for the occupant, as well as the potential for related increases in summer energy use via cooling. This is already impacting building functionality as noted in the stakeholder workshop (e.g., Carpenter House). Along with the domestic stock, health and social care, school and prison service buildings could be impacted. Cooling demand is likely to increase in summer, though this is very dependent on how much households take up mechanical cooling measures like fans and air conditioning. Specific building characteristics are an important modifier of a building’s ability to keep cool. These characteristics include:

- Orientation.
- Age of a building and building materials.
- Types and volumes of glazing on buildings.
- Ventilation.
- The colour and albedo of the walls and roof.

4.2 Exposure and vulnerability assessment of heat on health and communities for Perth and Kinross.

Community councils and community resilience groups play a significant role in understanding and protecting the local community. Therefore, this assessment of exposure and vulnerability is conducted at community council level.

[15] https://forestryandland.gov.scot/visit/activities/walking/check-for-ticks

4.2.1 Exposure to heat

Spatial variation in projected temperatures is discussed in detail in Chapter 3. Areas where summer temperatures and particularly maximum summer temperatures are projected to change most significantly, and where the highest temperatures are found are the areas of the highest exposure. Urban areas are vulnerable during heatwaves due to the Urban Heat Island effect. Perth is the largest urban area within the local authority. Other urban areas include Blairgowrie and Crieff. An urban heat island is a metropolitan or built-up area that is warmer than the rural areas surrounding it. Urban heat islands occur when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat.

Figure 30 presents some exposure analysis which was undertaken at a Community Council scale, the aim being to understand which community councils are most exposed when it comes to extreme heat. The top left map presents projections for 2080 for extreme summer temperature's, under a high emissions scenario. Areas of Perth and Kinross which were in the top 50% of temperatures, according to this map were considered to have higher exposure, shown in the bottom left map. Analysis was then undertaken to understand which Community Councils are located within this area. This is shown in the bottom right map, here Community Councils were categorised as "high risk" if more than 50% of their geographic area lay within the high exposure area, and "Some risk" if more than 25% lay within this area.

Of the 52 community councils 40 have some kind of elevated exposure according to this analysis, with 33 being classed as High risk. Community Councils where heat exposure is likely to be worst are located in the southern half of Perth and Kinross. Community Councils, from Kinross in the south to Blairgowrie and Aberfeldy in the North all have either higher risks or some risk, compared to the other more northern Community Councils where exposure is reduced

The work described above is to help identify where the highest exposure to heat is amongst the Community Councils. This can be used to better understand spatial nature of risks, help community councils to understand their own risk, and to help prioritise adaptation to heat. However, this work should be caveated by the fact that temperatures will increase across Perth and Kinross and heat is likely to still be an issue for all Community Councils even those where future temperatures are lower. Moreover, areas with lower future temperatures may still have many individuals vulnerable to heat.

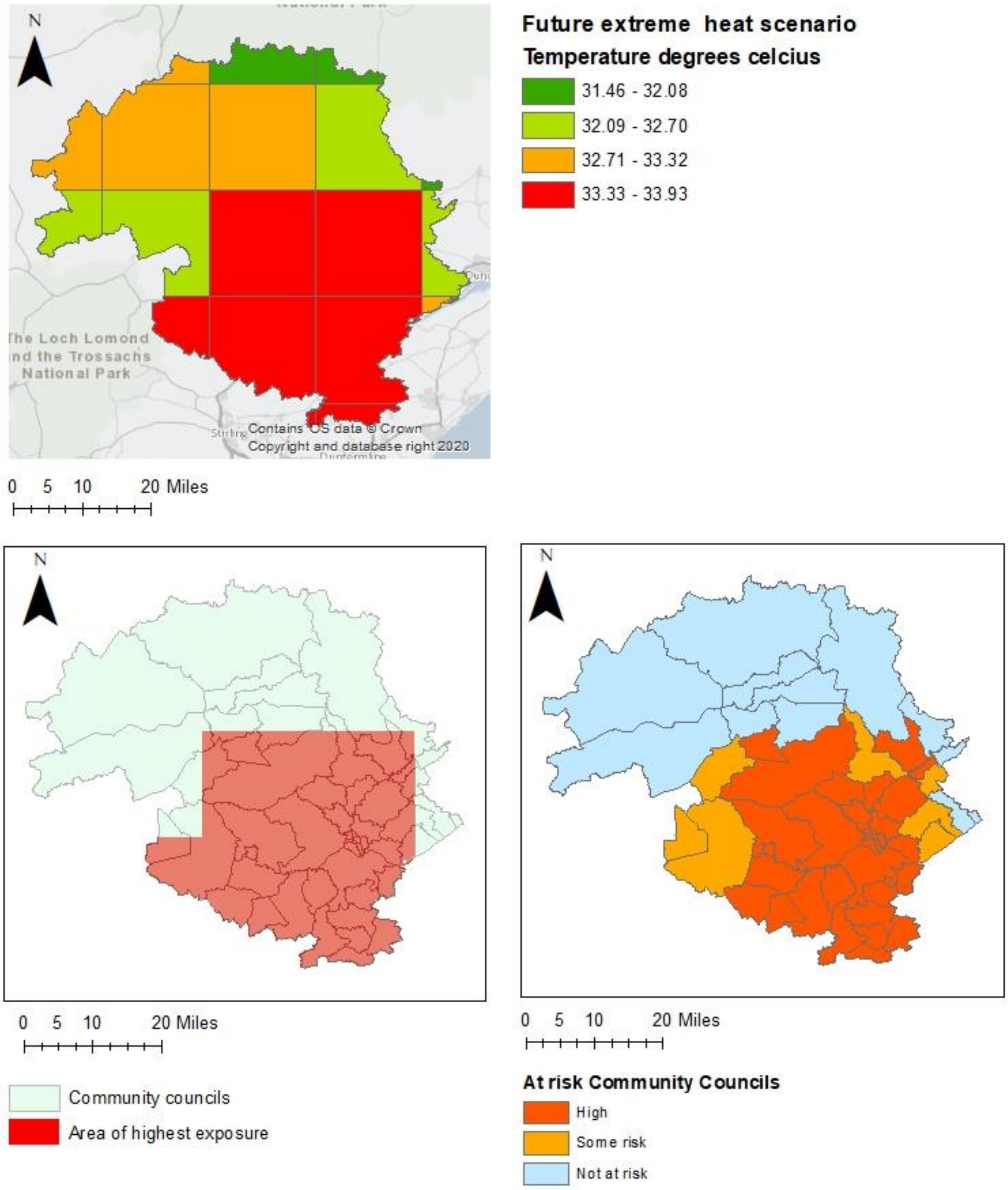

Figure 30 Three maps showing analysis of exposure to heat by community council. Top right absolute maximum temperatures across Perth and Kinross under a high emissions scenario by 2080. Bottom left, hottest 50% locations in Perth and Kinross according to the above map. Bottom right presents the subsequent heat exposure classifications via community Council.

4.2.2 Individual vulnerability to heat

Several characteristics can make individuals more vulnerable to high temperatures.

- Older individuals are more vulnerable to heat, due to specific physiological characteristics. Areas with high concentrations of older people are concentrated towards Perth and the surrounding region.
- Young children are also vulnerable to heat. Areas with high concentrations of young children are dispersed around Perth and Kinross.
- Deprivation can also increase an individual's vulnerability. In Perth and Kinross, deprivation is highly concentrated in urban areas such as Perth and Blairgowrie

- Increase in air pollution will also have an impact on the above-mentioned vulnerable groups.

The most established of these characteristics is older age. Most individuals dying from heat in the UK are above the age of 65. Therefore, the spatial distribution of individuals over the age of 65 was analysed to try and understand where the most vulnerable individuals were located and if these were in areas likely to see the greatest exposure.

Figure 31 shows this analysis, the top right map presents data from the latest Scottish census, showing the number of individuals per data zone. This was converted to Community Councils; the bottom left Map shows this analysis. In this map, community councils which had more individuals over the age of 65 than the average for the whole of Perth and Kinross were highlighted as high risk, and are coloured in red. All those Community Councils with higher-than-average number of people above the age of 65, are located in areas of higher exposure according to the analysis above, apart from Pitlochry and Moulin.

4.2.3 Caveats of this analysis

- Any vulnerability mapping of this kind is simply an overview by community council and does not show exact areas where vulnerable people are. Moreover, there are still some vulnerable people located within areas classed as lower and so these areas should not be ignored.

- The age data is current, and the spatial demographic age distribution of people pattern may change with time.

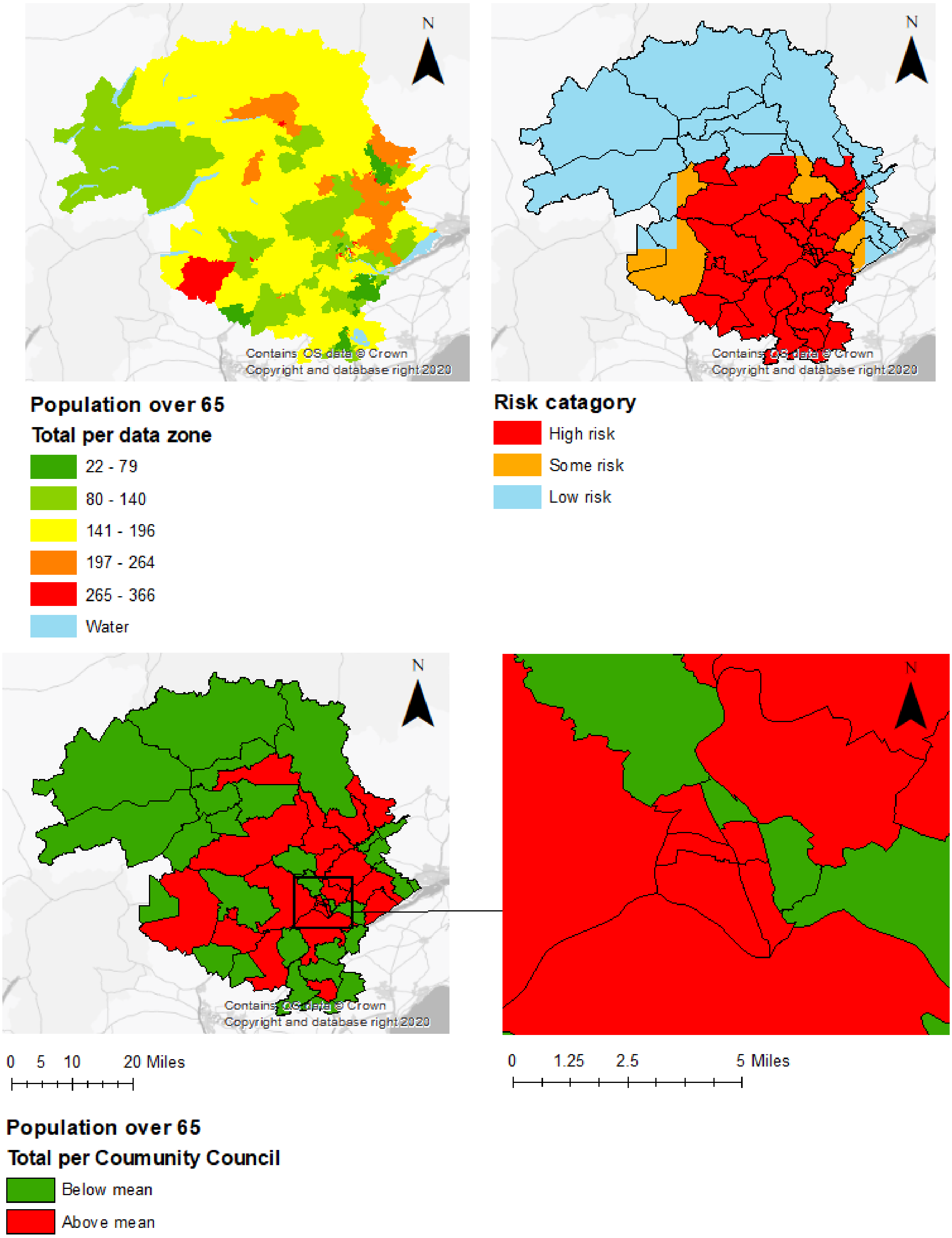

Figure 31: Four maps showing analysis of the spatial distribution of over 65-year-olds. Top left, number of individuals over 65 by Data Zone. Top right is a heat exposure map (described in figure 30). Bottom left, Community councils that have above the average number of over 65-year-olds for Perth and Kinross, bottom right, shows the area of Perth zoomed in.

4.2.4 Community assets and their vulnerability to heat

As mentioned in Section 4.1, it is not only individuals that are at risk, health and social care is also at risk of being impacted by heat. Young individuals are also at risk. Therefore, as part of the spatial vulnerability analysis we also mapped, key health, education, and community assets to understand how many were in areas of high exposure. Below in Table 7, the Community Councils that are classed as high risk for heat exposure, and the number of these key health, education, and community assets which fall into these areas of high exposure. City South has the largest number at 12, with Crieff and Letham at 6 each.

Table 5 Number of education, health and community assets within areas of high heat exposure per Community Council.

Community Council	Hospital	Library	School	Toddler group	Total
Aberfeldy	1	1	1	1	4
Abernethy and District	0	0	1	0	1
Auchterarder and District	1	1	1	1	4
.Auchtergaven	0	0	1	0	1
Blairgowrie and Rattray	1	1	3	0	5
Braco and Greenloaning	0	0	1	0	1
Bridgend, Gannochy and Kinnoull	1	0	0	1	2
Burrelton and District	0	0	1	0	1
Central	0	1	0	3	4
City South	1	0	8	3	12
Coupar Angus	0	1	1	0	2
Crieff	1	1	3	1	6
Dunkeld and Birnam	0	1	1	0	2
Earn	0	0	1	1	2
East Strathearn	0	1	0	0	1
Fossoway	0	0	1		1
Glenfarg	0	0	1	1	2
Kinross	0	0	3	0	3
Letham	0	0	4	2	6

Community Council	Hospital	Library	School	Toddler group	Total
Luncarty, Redgorton, and Moneydie	0	0	2	1	3
Methven	0	0	1	0	1
Milnathort and Orwell	0	0	1	0	1
North Inch and Muirton	0	1	4	0	5
North Muirton	0	0	1	0	1
Scone and District	0	1	1	0	2
Stanley	0	0	1	0	1
Tulloch	0	0	1	2	3
West Carse	0	0	1	2	3
Grand Total	**6**	**10**	**45**	**19**	**80**

4.3 Opportunities from higher summer and winter temperatures

Table 6: Identified opportunities which occur from higher summer and winter temperatures.

Opportunity ID	Opportunity
HCBO1	Opportunities for winter household energy demand.
HCBO2	Opportunities for health and wellbeing from warmer winters.
HCBO3	Opportunities for health and wellbeing from warmer summers.

4.3.1 Lower winter household energy use

Household heating demand dominates energy use in housing at present. Future heating demand is likely to be reduced by climate change due to warmer winters. This would have the benefits of both lowering of fuel poverty and reducing winter CO_2 emission from heating.

4.3.2 Improvements to health from warmer winters and summers

Physical and mental health benefits of increased physical activity (particularly outdoor activity) and contact with nature, are well established. As summer temperatures rise in Perth and Kinross opportunities for more outdoor activities are likely to arise. Increased time outdoors may increase Vitamin D exposure, which is important for bone health and the immune system. It should be noted however that the burden of ill health from cold homes remains significant in Scotland and is a priority for public health and local government action. Population ageing is likely to offset some of the benefit from warmer winters for cold-related mortality.

4.4 Risks from increased precipitation

Table 7: Risks to health and communities from increased precipitation.

Code	Risk	Risk score and narrative category	Narrative
HCB16	Risks to health and social care (physical infrastructure and functioning) delivery from flooding.	Medium More research	There are no hospitals located within any of the flooding extent maps (surface water, river, and coastal). However, there may be GP surgeries and other social care providers, access could also be impacted.
HCB14	Risks to health and wellbeing of individuals from flooding.	High Action needed	Flooding currently occurs to properties and businesses and is expected to increase (21,000 people and 12,000 homes and businesses affected by 2080s) and new ways to support impacted individuals need to be developed.
HCB13	Risks to education from flooding.	Medium Action needed	Action needed for schools in flood zones, some plans need to be in place for displaced students (6 primary schools and nurseries in flood extents).
HCB15	Risks to prison services from flooding.	Medium Action needed	HMP Perth is within the SEPA flood extents and contingency plans need to be in place.
HCB2	Increased damp and condensation in homes.	Medium More research needed	More research is needed to understand the current prominence of this problem

4.4.1 Flooding risks to health and communities

Flooding is the key risk posed by increased precipitation. Flooding presents mental health risks due to the distress and anxiety caused by a flooding event. In extreme cases this could cause physical harm if injury occurred, or subsequent health impacts due to poor sanitation. Long-term impact of damaged assets (e.g., houses) both physically and financially impact individuals. Flooding can also have a detrimental impact on key services, such as health and social care delivery and education. Vital health and social care facilities being out of use would have a detrimental impact on the users and cause cascading impacts of pressure on other facilities. Long-term loss of education facilities can also have a significant impact on children’s (or adults’) learning and place them behind their peers. Data on the scale of potential damages caused by flooding from the Flood Risk Assessment is discussed in Section 3.8.

GIS analysis was conducted to understand which education and hospitals lay within flood zones and which Community Councils this impacted. It found no hospitals lie directly within any flood zones. However, flooding was found to potentially impact schools in several Community Councils. Only river flooding directly impacted schools. The schools impacted, which Community Council it lay within and what kind of flooding that caused it to be at risk are summarised in the table below:

Table 8 Table showing education assets found to lie within river flooding boundaries according to SEPA river flooding maps.

Community Council	School/nursey	Low likelihood	Medium Likelihood	High likelihood	Climate Change included
City South	Inch View Primary School and nursery	Y	Y	N	Y
Central	North Church Toddlers Group	Y	N	N	N
Methven	Ruthvenfield Primary School	Y	N	N	Y
North Muirton	FunTogether at Riverside	Y	N	N	Y
North Muirton	North Muirton Primary School and nursery	Y	N	N	Y
Auchtergaven	Auchtergaven Primary School and nursery	Y	N	N	Y
Dunkeld and Birnam	Royal School of Dunkeld Primary School and nursery	Y	Y	N	Y
Mount Blair	Kirkmichael Primary School and nursery	Y	Y	N	Y

High likelihood means areas with at least 10% change of flooding each year; medium likelihood means areas with at least 0.5% chance of flooding each year; low likelihood means areas with at least 0.1% chance of flooding each year. Climate change included means flood projections have been adjusted based on a high emissions scenario[16].

4.5 Community flood vulnerability

Flooding and associated disruption which may have severe and long-term impacts on society and health. These include emotional and psychological impacts to individuals, which can be long lasting after the event. Physical impacts on health and physical damage to property or assets. The exposure to and impacts of flooding are not uniformly felt across communities. Exposure to flooding across Perth and Kinross is discussed in section 3.8. Flood impacts are a product of socio-economic circumstances, with some areas, communities and individuals being more disadvantaged than others. This inequality is likely to be exacerbated as climate change increases the occurrence and severity of flooding events within the local authority area.

[16] Future Flood Maps - Flood Maps | SEPA

The Joseph Rountree Foundation have investigated community vulnerability to flooding across the UK and developed the flood vulnerability index[17][18]. The Neighbourhood Flood Vulnerability Index (NFVI) provides insight into the social vulnerability of a neighbourhood should a flood occur, based on their susceptibility, ability to prepare, ability to respond, ability to recover and community support. It estimates how far individuals may experience a loss in well-being if exposed to a flood as well as their ability to prepare, respond and recover from a flood (without significant emergency support from the authorities). For this analysis, the NFVI was used to understand where in Perth and Kinross communities are most vulnerable to flooding. Figure 32 shows this analysis. Perth and Blairgowrie are the two locations where the highest vulnerability is found.

There are 32 existing community resilience groups spread across Peth and Kinross, which aim to support communities with climate change impacts. Within Perth and Blairgowrie there are community groups with could support these most vulnerable areas.

[17] Climate just - Neighbourhood flood vulnerability index. https://www.climatejust.org.uk/map

[18] *The new Neighbourhood Flood Vulnerability Index (NFVI) provides insight into the social vulnerability of a neighbourhood should a flood occur. The NFVI combines five characteristics of vulnerability: Susceptibility, ability to prepare, ability to respond, ability to recover, community support – this map focusses more on vulnerability of the community if flooding did occur rather than where flooding is likely to occur. Full details of its construction can be found - http://climatejust.org.uk/map.*

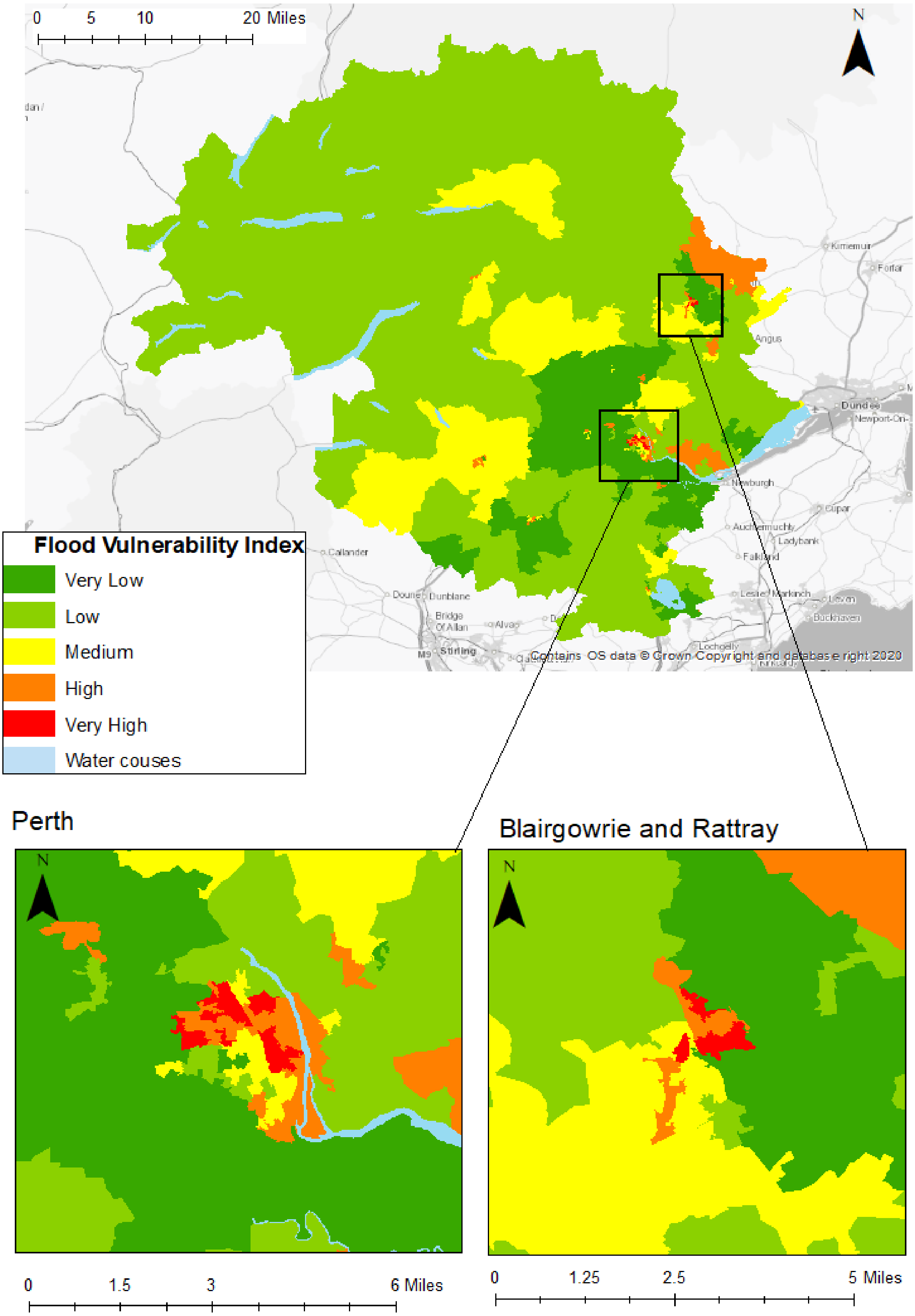

Figure 32: Flood vulnerability across Perth and Kinross, taken from the Neighbourhood Flood Vulnerability Assessment (Joseph Rowntree Foundation). Vulnerability categories refer to the scores across Perth and Kinross, the top 20% being classed as High risk. These maps are by Data Zone.

5. Infrastructure

This section summarises the evidence regarding the key risks and opportunities that climate change brings to infrastructure within Perth and Kinross. The chapter considers several key infrastructure types: water, energy, transport, and ICT systems.

5.1 Risks to infrastructure from higher summer temperatures

The expected increase in Perth and Kinross' summer temperatures is lower than other areas in the UK, however temperatures projected in high climate scenario's later in the century still pose multiple risks to its infrastructure.

Table 9: Risks to infrastructure from higher summer temperatures and scoring.

Risk ID	Risk	Risk score	Risk narrative
I2	Risks to energy from high temperatures.	Medium Monitor risk	Monitor and plan for risk as this may develop rapidly mid- to late century.
I7	Risks to transport from high temperatures.	High Monitor risk	High due to large scale impacts if this risk occurred, need to understand the system and its vulnerabilities better. This is likely to get worse through the mid to late century.
I5	Risks to earth embankment structures (e.g., dams) from High temperatures.	High Monitor risk	High risk due to the impacts if this risk occurred. Existing dams will be monitored.

Heatwaves are likely to cause some increased energy demand both within domestic use and within industry and business. If mechanical cooling is taken up on a large scale in the future this increase could be significant. High temperatures can affect energy systems directly, by reducing electricity generation from thermal generators and increasing the likelihood of faults on the electricity network[19].

High temperatures have a range of impacts for transport infrastructure, such as rail buckling and road surface melt and impacts on bridge bearing and expansion joints. Refer to Section 8.2.2 for further information on this. Infrastructure networks are connected and Perth and Kinross provides the main north south routes for connections to the Highlands and Aberdeen, disruption here would likely have cascading effects on other areas. As temperatures increase though out the decade these impacts will become more prevalent, therefor further research is required to understand the impact on these.

High temperatures may affect earth embankment structures for dams and reservoirs by reducing vegetation on them, reducing their stability. The increase in fluctuating water levels will increase the risk. The non-erodible structures, such as concrete are unlikely to be particularly vulnerable, however, if there are any existing issues associated with cracking or joint movement theses could be exacerbated by the increase in temperatures. Auxiliary structures such as valves or draw off towers may be vulnerable to heat induced expansion[24].

[19] Climate Change Adaptation Report, National Grid Electricity Transmission plc

5.2 Risks to infrastructure from changes to precipitation

Table 10: Risks to infrastructure from changes to precipitation and scoring.

Risk ID	Risk	Risk score	Risk narrative
I18	Risks to infrastructure networks from river and surface water flooding.	High Action needed	Flooding is already an issue, action needed in areas most vulnerable. Water and wastewater infrastructure (sewer networks, reservoirs, flood defences) are likely to need upgrades to deal with intense short-term more intense precipitation and other precipitation changes. Such changes can threaten other infrastructure along the watercourse such as Dams, or ford’s.
I14	Risks to bridges and pipelines from flooding and erosion.	High Action needed	Bridge scour is a major concern currently and is also a concern for greenspace bridges.
I15	Risks to infrastructure networks (water, energy, transport, ICT) from flooding induced cascading failures.	High Action needed More understanding needed	High due to large scale impacts if this risk occurred, need to understand the system and its vulnerabilities better. Cascading failures are by definition high impact as they have impacts on multiple interconnected systems.
I17	Risks to private water supplies from reduced water availability.	High Monitor risk More understanding needed	Though this impacts a small section off the population it is little understood and could have large impacts. The DWQR report (2020)[20] states there are 1657 private water supplies in Perth and Kinross. This risk is already occurring.
I19	Risks to transport and infrastructure networks from slope and embankment failure.	Medium Action needed. More understanding needed	Vulnerability assessment should be undertaken, including importance of the road to local communities, and any existing earth embankments for dams. key physical factors such as ground conditions should also be assessed.
I13	Risks to subterranean and surface infrastructure from subsidence.	Medium Action needed. More understanding needed	Increased precipitation, on average or in short-term intense bursts, poses a risk to above and below ground infrastructure as ground conditions may change suddenly or previous design conditions may no longer be appropriate.
I20	Risks to public water supplies from reduced water availability and quality.	Medium Monitor risk	Currently medium but needs to be monitored due to high impact if this occurred.

[20] pws-annual-report-2020-final.pdf (dwqr.scot)

Risk ID	Risk	Risk score	Risk narrative
I10	Risks to hydroelectric generation from low or high river flows.	Medium Monitor risk	Perth and Kinross have several small-scale hydroelectric generators; this risk is likely to be mitigated by only contributing to a larger grid supply, though the severity of the impact should be assessed in more detail – i.e., are there areas/homes which solely rely on this supply and how much would it impact overall grid supply.

5.2.1 Risks to infrastructure from flooding

The overall effect of climate change is to increase the area affected by flooding, for both river, coastal, and surface flooding. The projected flood extents suggest that at least eleven key facilities (hospitals, libraries, museums, schools including nurseries, primary, secondary, and special) are at risk of flooding.

GIS analysis shows approximately 2000km of roads intersect the projected flood zones at least one point. This does not mean that 2000km of roads are likely to be flooded; for example, if a 10km stretch of road intersects the flooding zone at one point, it will be counted in the analysis. The analysis shows that major roads are at risk of flooding, including the A9, A85, and A91. This could have significant impacts on Perth and Kinross as the A9 is the major A-road connecting Perth to the northeast. Motorways are excluded from this GIS analysis, however the M90 is at risk of surface water and fluvial flooding in places.

The same analysis was conducted for railway lines and stations. Approximately 239km of railway lines intersect flood zones; as above, this does not mean the entire 239km can or will be flooded. However, rail networks are susceptible to knock-on effects of failure, so flooding in small areas can have significant delay effects across the network. The east-west rail line connecting Perth and Dundee via Invergowrie intersects a flood zone. The line going northwest from Pitlochry also intersects a flood zone. This serves to illustrate that critical rail infrastructure across Perth and Kinross is at some risk of flooding.

There will also be effects on other infrastructure such as the six existing flood protection schemes in Perth and Kinross (Perth, Almondbank, Comrie, Milnathort, Bridge of Earn, and Weem). Their original design standard of protection may be reduced, as climate change projections from when they were designed may have changed and are now expected to be more severe; the climate change allowance included in the design may no longer provide the level of protection as was expected at the time of construction. This may require defences to be upgraded or new schemes to be constructed (e.g., the Bridge of Earn flood protection scheme was completed in 2006[21] and climate projects have changed since then). Other infrastructure at risk of flooding includes culverts, drainage systems (such as for roads and sewers), the older drainage systems will not have been designed to take the high flows expected and surface water flooding will occur.

Analysis was done to assess which of the following types of facilities (provided by PKC) are within SEPA flood extents; council housing, council offices, hospitals, libraries, maintained open space, major parks, museums, nurseries, play areas, primary schools, prisons, secondary schools, skate parks and special schools. As noted previously, SEPA flood maps are based on CP09 projections and omission from the results below does not mean facilities are not at risk of flooding.

Table 21 shows some council facilities that are expected to be at risk of different types of flooding. Additionally, 940 council house properties, 707 areas of maintained open space, and 27 play areas are within the projected flood extents. Approximately 160km (318no.) of adopted core paths that are maintained by PKC also intersect the flooding extents. There are also PKC business properties at risk of flooding, for

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[21] PVA_08_17_Full (sepa.org.uk)

example on Shore Road and the Food & Drink Park on Arran Road; further analysis should be done on business properties at risk of flooding to assist with prioritisation and monitoring decisions.

Table 11: Major parks, museums, primary schools, and nurseries within projected SEPA flooding extents including climate change. Note that council housing, maintained open space, and play areas are excluded from the table below for readability.

Name	Facility type	Flooding type
Victoria Park	Major parks	Fluvial
North Inch*	Major parks	Fluvial
South Inch*	Major parks	Fluvial
Community Archive	Museums	Fluvial

* Designed to flood as part of flood protection schemes.

Discussions with PKC have noted the large scale of potential scour issues for bridges. The PKC structure team has identified 440no. bridges across the PKC road network which require a scour assessment. This process will take several years and is a major long-term issue. The results of the assessment will determine required mitigation and repair, meaning that depending on the extent of scour vulnerability this may be a high impact risk for PKC.

5.2.2 Risks to infrastructure from increased precipitation

The impact of increased precipitation on infrastructure is most obviously seen through the effects of flooding. Flooding is already an issue within Perth and Kinross, so the impacts are well known. Changes to precipitation due to climate change may result in flooding increasing in frequency or intensity. The majority of transport infrastructure depends on engineered solutions such as embankments and slope cuttings which can fail if subjected to flooding or persistently high precipitation. Bridge scour has already been recognised as a significant threat currently by Perth and Kinross Council. Intense periods of precipitation along with flashy, steep catchments for many of Perth and Kinross's rivers and streams make some bridges particularly exposed. If bridges were to be compromised near rural communities, particularly where they are single access points across a water course, entire communities could be cut off until repairs are made. The council recognises this threat and is currently undergoing a systematic assessment of the vulnerability to scour of their bridge stock.

A high-level analysis was done using GIS of the current top-10 bridges which require scour assessment, and the effect bridge closure could have. This investigated whether alternate routes are available, without consideration of driving times and road loading capacities. The overall conclusion is that none of the top 10 bridges ranked for scour assessment pose a risk of completely stranding communities, though some of the required diversions are very long and would cause significant disruption; for example, diverting around Victoria Bridge requires skirting the eastern edge of Loch Rannoch. It should also be noted that this analysis is indicative only and does not include factors such as likelihood of diversion road being flooded, or whether HGVs can traverse these roads; in practice, diversions are required to use the same class of road. Input from the PKC team has provided some clarifications to the table below.

NB: a high-risk rating for scour assessment should not automatically assume to imply that a bridge is subject to a high risk of bridge collapse due to river scour action. A high-risk rating for scour implies that the bridge has been preliminarily assessed for various factors and may have a high risk of damage due to scour action as a result of severe rainfall events.

Table 12: Top 10 bridges identified as scour risks and possible diversions in case of failure.

Code	Bridge name	Possible diversion
B8079/05	BRIDGE OF TILT	Diversion via Old Bridge of Tilt or long diversion via A9 Pitagowan
A822/08	CRIEFF	Long diversion via Strowan Road and Lochlane, HGVs would need longer diversion via Comrie or Kinkell (approx. 13 miles)
A827/12	KENMORE	Long diversion via B846 (C-class road) near Keltneyburn – A-class diversion via Crieff, Killin (approx. 70 miles)
A923/12	DUNKELD	Diversion via A9 (C-class road) near Dalmarnock – A-class diversion via Meikleour, Perth (approx. 35 miles)
A93/10	ISLA	Very long diversion via A94 Coupar Angus and A984 – A-class diversion via Dunkeld, Perth (approx. 35 miles)
A93/12	BLAIRGOWRIE	Very long diversion via A923 Coupar Angus
B846/01	ABERFELDY (WADE)	Diversion via A827 – B-class diversion via Tummel, Logierait (approx. 40 miles)
B934/05	FORTEVIOT	Diversion via Broom of Dalreoch
C449/01	BRIDGE OF LYON	Long diversion following River Lyon near Keltneyburn
C450/11	VICTORIA	Very long diversion around Eastern shore of Loch Rannoch

Increase in watercourse flows will also impact the erosion of footpaths adjacent to the watercourses. As stated above there are many kilometres of core paths that follow the water's edge which will be susceptible to erosion and lead to an increase in maintenance requirements.

Dam overflow structures and spillways may also be vulnerable due to increasing frequency and size of flows that might increase debris. Auxiliary structures such as valves or draw off towers may be vulnerable to similar effects and can be prone to other factors such as siltation.[22]

[22] FD 2628 Impact of Climate Change on Dams& Reservoirs May 2013 Atkins

5.2.3 Risks to infrastructure from reduced precipitation

Drier summers can affect groundwater levels and impact private water supplies. This has been known to be an issue in the past so it may be a more significant problem in future. Otherwise, Scotland is expected to remain in water surplus in the period to 2100[23], so reduced precipitation is not expected to pose a high risk overall. If reduced precipitation combined increased temperatures could cause drought in summer, this may pose some risk to Perth and Kinross. This change could potentially put water supplies under stress. If water supplies were to be reduced, cascading impacts could occur. This occurs as other key infrastructure require water. For example, power stations, which if impacted could in turn effect transport, and ICT. With respect to flooding, waterlogging can occur if heavy rainfall follows an extended dry period; this can lead to rapid localised flooding.

5.3 Exposure and vulnerability within Perth and Kinross

- The increased prevalence and intensity of flooding within Perth and Kinross is a risk to the entire area. Urban areas can be severely disrupted by flooding affecting multiple systems such as transport and schools, and rural areas may be highly affected due to the potential of being cut off during extreme weather.
- Perth and Kinross have a significant number of properties using a private water supply. These are not maintained by Scottish Water, and they may be more vulnerable to disruption caused by changes in precipitation, which has already been evidenced.
- There are many small-scale hydroelectric power installations in Perth and Kinross. Periods of decreased precipitation may pose a risk to these in terms of output and to the equipment.
- In terms of transport, urban areas are likely to see a greater temperature increase. Urban areas also have the highest demand on transport infrastructure and any disruption can have significant effects. However, roads in open countryside, which remain in direct sunlight all day may also be vulnerable.
- Although demand is higher in urban areas, rural areas may be at risk of being cut off if transport infrastructure is disrupted. As Perth and Kinross has a high rural population, this risk is more relevant.
- Risks to bridges and other transport infrastructure may be exacerbated in rural areas as they may be the only access route.

5.4 Opportunities for infrastructure

Table 13: Identified opportunities for infrastructure.

Opportunity ID	Opportunity
I12	Increased opportunity for solar thermal energy.
IO1	Increased water resource for hydro energy during the winter.

Higher temperature may make other forms of renewable energy more attractive, such as solar thermal and heat pumps. As mentioned in the previous section, there are various small-scale hydroelectric installations in Perth and Kinross. Wetter periods during the winter months may provide opportunities to increase usage of these, however these benefits may be offset by the drier summers. Increased energy production will also bring an economic benefit.

[23] Is Scotland climate ready? Committee on Climate Change, July 2020

5.5 Conclusions

Overall, flooding is the greatest threat to the infrastructure of Perth and Kinross. Roads and bridges are particularly vulnerable due to flashy basins and steeper terrain. Cascading impacts could also pose a significant threat but need to be better understood. Hydro production within Perth and Kinross could be impacted by changes to hydrology brought on through reduced snowfall and increased seasonality of rainfall. Changes to climate are, however, favourable for renewable energy productions, and if harnessed would relieve pressure from the traditional fossil fuel-based energy system.

6. Business

This chapter considers how changing climatic conditions will impact on business and industry within Perth and Kinross. The focus is primarily on domestic risks and opportunities, both arising directly and indirectly from climate change. However, international risks to supply chains are also covered. This chapter firstly summarises general risks and opportunities to business and industry.

Furthermore, this chapter provides more detailed discussion of specific risks to agriculture, fisheries (salmon production), forestry and tourism. These industries are seen as key to Perth and Kinross and are directly impacted by climate change.

6.1 Risks to business from temperature

Table 14: Identified risks to business from higher temperatures and scoring.

Risk ID	Risk	Risk score	Risk narrative
BI5	Risks to business from reduced employee productivity due to infrastructure disruption and higher temperatures in working environments.	Low Monitor risk Better understanding needed	This not currently a problem, however, should be monitored as it will become more prominent.
BI7	Increased summer running costs due to energy for cooling.	Low Monitor risk	Could become an issue later in the century.

Extreme high temperatures are likely to impact the health, wellbeing, and productivity of employees during extreme heat events. Their ability to commute to work may also be impacted particularly if they are using active travel, working at home in hot, un-airconditioned houses would also impact on comfort and productivity. Some outdoor work may have to be halted if extreme temperatures occur for employees' safety due to an elevated risks of sun stroke. Whilst heat impacts are widely recognised in the context of labour productivity, there is limited evidence on future risks. It is recognised that the impacts of heat vary widely across business sectors, meaning individual business need to do risk assessments on their specific operations and assets.

6.2 Risks to business from increased and reduced precipitation

Table 15: Identified risks to business from precipitation and scoring.

Risk ID	Risk	Risk score	Risk narrative
BI2	Risks to business from flooding.	High Action needed	Business which are within flood zones are vulnerable and should be a priority; the number of businesses at risk is expected to increase (over 1,000 according to NFRA2).
BI4	Risks to businesses from water scarcity (treated supply).	Low No current action needed	Water scarcity not likely to be a large risk in Perth and Kinross. Business on private supplies may be impacted.

Flooding is considered to be the costliest climate hazard for businesses. At present, the annual damages for non-residential properties in Scotland is expected to be £114m, or 17% of total UK damages. Flooding causes significant direct and indirect disruptions, impacting business and infrastructure assets and business continuity.

The projected reduction in summer precipitation could also bring risks to businesses. Businesses use water for many purposes, from cooling and heating, to washing products, dissolving chemicals and as a direct input to products. Moreover, they also use water indirectly through their employees, who use it for drinking, washing and sanitary purposes. As a result, water scarcity has many negative impacts on businesses. It can disrupt business continuity, especially in very water intensive sectors such as food and beverages. If not well managed, risk of water shortage is projected to become material in investment and employment for water-intense sectors. However, water scarcity is not projected to be a prominent risk in Scotland.

6.3 Wider risks impacting Perth & Kinross businesses (supply chain risks and finance)

Table 16: Supply chain risks and scoring.

Risk ID	Risk	Risk score	Risk narrative
BI3	Risks to business from disruption to supply chains and distribution networks.	High Monitor risk Better understanding needed	This could have a profound impact on business which rely on supply chain but is little understood.

Climate change is likely to have more severe impacts on other parts of the world. Weather is a significant cause of supply chain disruption across all sectors, and this could increase with climate change. Climate hazards, such as heavy rainfall and surface water flooding, heating, and high temperatures are the weather types that cause the greatest number of weather-related supply chain disruptions. This causes significant negative impacts on businesses which are not able to continue making their products or offering their services.

Risks also occur from financing of business, where climate change can impact the willingness or ability to lend or invest. Flooding is the most significant risk to the financial system with financial impacts on insurance, mortgages, and investment. Whilst it is not as fully understood as flooding, it is still recognised that storms damage disrupts business infrastructure and therefore negatively impact businesses. Climate change, and increased temperatures in general, impact the financial systems as well, by creating stranded assets, reducing the value of investments, and increasing the cost of capital.

6.4 Opportunities for business

Table 17: Opportunities for business

Opportunity ID	Opportunity
BIO1	Opportunities for business from changes in demand for goods and services

Whilst some products and services will be negatively affected, there is also great opportunity for many businesses to gain an advantage if they can anticipate the changing markets. The warmer weather in Perth and Kinross which climate change is projected to bring could bring several benefits to business, for example lower heating costs in the winter for those indoor and drier and warmer summer for that outdoors. Sectors relevant to PKC such as agriculture, forestry, tourism, and construction have particularly good opportunities for growth and are discussed below.

Another opportunity related to businesses is the creation of more green jobs. The changes in demand and supply chain could result in significant growth for green jobs, with STUC research from 2021 indicating the potential for 131,000-367,000 new green jobs across Scotland over the next 15 years[24].

6.5 Risks and opportunities for key sectors

Section 5.1 to 5.4 presents generic risks that climate change poses to business and industry in Perth and Kinross. This section provides a deep dive into some of the key industries within Perth and Kinross.

6.5.1 Agriculture, forestry, and fishing

Agriculture, forestry, and fishing all rely on nature in different ways, nature is likely to be impacted by climate change (discussed further in Chapter 6). All three sectors are also important to Perth and Kinross's economy, with agriculture employing 8.7% of the population in 2021. All three industries also contribute to both reducing carbon emissions and tackling the biodiversity emergency, and climate change is likely to impact their ability to do so.

Climate change has implications on the viability and productive capacity of agriculture and forestry, notably for crops, livestock, and land management activities. A study from 2008[25] found that the accumulated temperature - the measurement of the degree of warmth for plant growth throughout the growing season - has increased significantly across all regions of Scotland over the last 40 years. Moreover, using the projections of climate change from the UKCP High-emissions scenario, they calculated the future accumulated temperature (AT) for 2050 and 2080. The results highlighted that AT would double for some areas of Scotland, around the eastern lowlands, by the latter part of the century. Climate scenarios also suggest that drought risk is likely to increase in the future, particularly in the east of Scotland. By 2050, events such as low flow in rivers which currently happen once every 40 years could become as common as every 9 years[26]. As well as becoming more common, droughts could potentially last 2-3 months longer than in the past[27].

The increasing hot temperatures, and the accumulated temperature, and the increasing prevalence of droughts are likely to impact the quality of arable land and the yields produced. For example, in the summer of 2018 malt barley supply was impacted by drought severely affecting the distilling and brewing sectors in Scotland, with production at some distilleries halted for several weeks. The whisky industry in particular has a strong presence in Perth & Kinross, so this could be a significant risk. Excess waterlogging also has an impact on yield, and the variability in summer rainfall is increasing the pressures for irrigation. The risk from fluvial flooding is also likely to increase, with significant portions of agricultural land having been impacted already or are at risk in the future.

With increasing hot temperatures, there is opportunity for new crops and species to develop, and for existing ones to potentially move from one region to others which were historically too cold. This has potential to enhance the agricultural and forest productivity. However, assessing the scale of the opportunity is difficult due to the limited evidence. Opportunities, such as longer growing seasons, are possible but are not currently being realised due to adaptation barriers, such as lack of financing to invest in equipment needed or a lack of expertise. Moreover, unreasonably low or very high temperatures can create issues with soft fruit farming or delay ploughing. Perth & Kinross is home to a diverse range of agricultural land. Some agricultural land is amongst the highest quality arable land in Scotland, while the upland regions to the north and west of Perth & Kinross provide land for sheep rearing. There are trends already visible in Perth & Kinross driven by a range of factors including policy and technology, and climate change is likely to affect these going forwards. For example, there has been a notable decline in arable farming areas in upland areas. In wet woodland,

[24] Perth and Kinross Climate Action: Business & Industry. [Available online].

[25] Ray, D. (2008): Impacts of climate change on forestry in Scotland – a synopsis of spatial modelling research. [Available online].

[26] ClimateXChange (2023): Drought impacts on Scotland's farms and forests. [Available online].

[27] Nature Scot (2021): Risk of extreme droughts likely to increase in Scotland. [Available online].

agricultural drainage and over-grazing results in poached soils, changes in the woodland structure and ground flora, and regeneration issues. Increased water abstraction, eutrophication and other forms of pollution also take their toll.

The climate projections for Perth and Kinross suggest higher winter rainfall, and lower but more intense summer rainfall. This comes with an increased flooding risk, agriculture, and forestry, if not managed properly, can contribute to flooding, areas where vegetation is removed no longer slows water as effectively. Moreover, increased precipitation is likely to cause pollutants such as nitrogen from fertilisers can be washed from fields more readily. This would have implications for other environments, nitrogen is a particular problem in freshwater environments. High concentrations can cause “dead zones” within rivers and have serious implications for the ecosystem.

For both agriculture and forestry, changes in minimum and maximum temperatures, precipitation, humidity and even wind direction all have the potential to negatively impact pests, pathogens, and Invasive and Non-Native Species (INNS). This in turn would negatively affect species and habitats, having a potentially severe impact on agriculture. Increased hot temperatures are likely to make it easier for viruses to multiply and spread. The warmer wetter winters may also increase the risks from parasites for livestock.

The forestry industry in Perth & Kinross produces softwoods such as Sitka spruce and Norway spruce. Wood is also used as biofuel. The threats posed by climate change could damage these species and by extension these industries, with similar examples seen in the UK from diseases such as ash dieback. Salmon fishing is another also another nature-based activity, with is prevalent in the River Tay and is important in the economy of Perth and Kinross, the impact climate change has on this is discussed further in Chapter 7.

6.5.2 Tourism

Tourism is also important to Perth and Kinross, in 2021 the accommodation and food service sector employed 11.6% of the population. The warmer winters and hotter direr summer bring a mix of risks and opportunities. For example, in the Cairngorms or other upper regions of Perth and Kinross, the consistency with which favourable snow conditions enable winter sports may be reduced. Conversely an earlier onset of spring and later end of autumn may present other opportunities for outdoor activities, encouraging more tourists to visit during these seasons.

Strongly interlinked with tourism is cultural heritage, Perth and Kinross has many areas of cultural importance. Ranging from buildings of historic importance such as Scone Palace, Blair Castle, Stanley Mills and many historic churches, museums to areas of outstanding natural beauty including the river Tay, Loch Leven, Rannoch Moor, and the Cairngorms national park.

Cultural heritage sites can be impacted by climate-induced flooding, harming buildings, or grounds, through both water ingress and more serious flood damage. In addition, to flooding, increased heavy rain can cause damp, roof logging leakages, and by waterlogging gardens and other archaeological sites. Droughts can impact cultural heritage by leading to desiccation of waterlogged sites, deterioration of deposits, and affecting the long-term resilience of plants and trees, and therefore impacting heritage sites such as parks and gardens.

High temperatures can impact cultural heritage by leading to problems for fabric, building use and for sensitive collections. Moreover, high temperatures increase the demand for air conditioning, which in turn increases problems with condensation and deterioration of sensitive materials. Wildfires are induced by hot, dry weather. Wildfires can impact cultural heritage sites either directly, by destroying them during wildfire events, or indirectly, by changing the landscape management to reduce the risk of wildfires, which in turn may impact cultural heritage.

Additionally, new pests brought by shifts in climate can impact cultural heritage by infecting plants and trees with diseases, by leading to the more rapid deterioration of stone and wood structures, and by increasing the bioturbation of archaeological sites. Tree disease could impact heritage sites with historic gardens.

6.6 Chapter conclusions

- The most prominent individual threat to business in Perth and Kinross is flooding.
- Supply chain risks are the most uncertain and hardest to quantify but could have a significant impact on business which rely on imported materials, such as construction or car industry which are important to Perth and Kinross.
- Heat in the summer is likely to become an increasing threat – particularly for employees that work outdoors.
- Climate change poses multiple risks and opportunities for key industries which are inherently reliant upon nature.
- Opportunities do also arise, for both farming and tourism due to changing summer and winter temperatures, as well for businesses targeting the green economy.
- These risks to business are compounded by the inherent transitional risks (jobs losses and movement, stranded assets, changes in sector governance etc) as Perth and Kinross strive for Net Zero, and though these risks have not be specifically identified in this assessment they need to be considered, due to the additional strain and resource they may put on business and industry.

7. Risks to nature within Perth and Kinross

Climate change will impact the natural environment across Perth and Kinross in a number of ways. This section presents the findings regarding the key risks and opportunities climate change brings for both the terrestrial and freshwater natural environments. Although both agriculture and forestry are intertwined with nature, these were discussed in Chapter 5. This is because agriculture and forestry are key industries within Perth and Kinross.

Habitats and species will suffer or benefit depending on not just climate change but a range of other factors including bioclimatic envelope, interspecies competition, land use pressures and ecological connectivity. Therefore, this chapter aims to describe the general trends and impacts climate change will bring to the natural environment, highlighting these changes with some specific examples, rather than an in-depth study of all of Perth and Kinross's diverse natural landscape.

7.1 Current context for the nature of Perth and Kinross

The Highland Boundary Fault splits Scotland into two distinct landscapes, the lowlands, and the highlands. The fault runs, southwest, from Stonehaven on the east coast to the Isle of Arran on the west coast. This fault traverses through Perth and Kinross from its northeast border, near Blairgowrie and Rattray, to the southwest border and into Stirlingshire. The southern part of Perth and Kinross is dominated by relatively flat and fertile lowlands. In contrast, the north is mountainous, with glacial valleys and lochs (including Loch Tay and Loch Earn) characteristic of the highlands. Add to this the narrow but important intertidal habitats in the Firth of Tay, and predicting the response to climate change becomes an issue of nuance and locale.

Figure 33 illustrates how this topography is reflected in the distribution and diversity of habitats within Perth and Kinross. These habitats support a wide variety of species, many of which are protected locally, nationally, and internationally. Approximately 27.5% of Perth and Kinross is designated under national or international legislation to protect habitats and species.

There are many inland waters and watercourses within Perth and Kinross which support the biodiversity of the area and are key in characterising the landscape. The River Tay is an important watercourse within Perth and Kinross. The river emerges from Loch Tay in the highland area of Perth and Kinross. The river flows into the lowlands, to the city of Perth and from there it flows in an easterly direction towards the Firth of Tay. The Tay has high biodiversity value and is designated as a Site of Special Scientific Interest (SSSI) and a Special Area of Conservation (SAC). The river is internationally recognised for its salmon fishing, and it is designated as a SAC for salmon, otter, lamprey, and freshwater pearl mussel (one of Scotland's most endangered species).

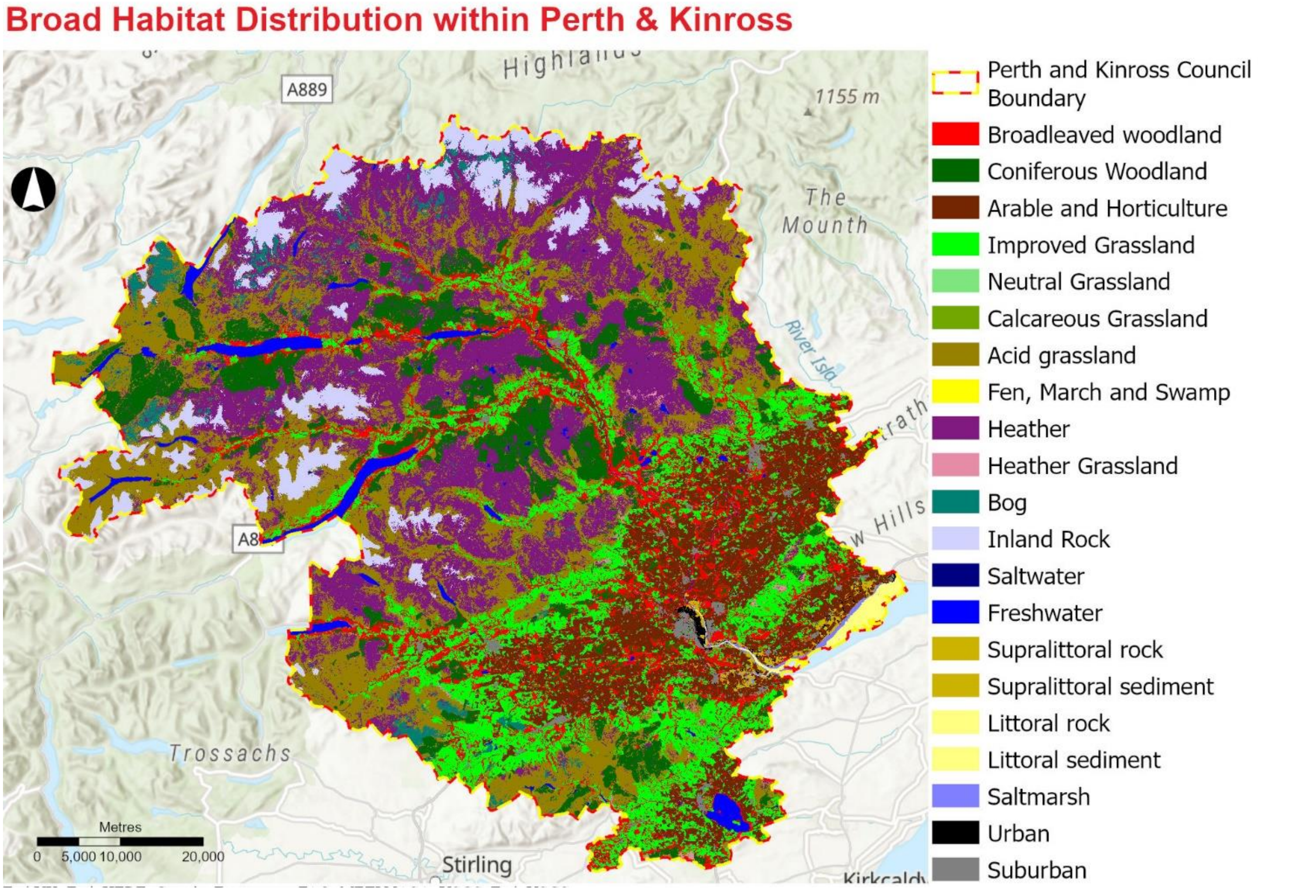

Figure 33: Map of land cover distribution across Perth and Kinross – Land Cover data taken from Land Cover Map 2021 © UKCEH 2022. Contains Ordnance Survey data © Crown Copyright 2007, Licence number 100017572

7.2 Risks and opportunities for terrestrial species within Perth and Kinross

Table 18: Risks and opportunities for terrestrial species within Perth and Kinross and scoring.

Risk ID	Risk	Risk score	Risk narrative
N1	Risks from changing climatic conditions and extreme weather events: Changes to temperature	High Action needed. More understanding needed	Increases in minimum and maximum summer and winter temperatures pose many risks to terrestrial species particularly those already at temperature limits. Extreme heat combined with drought can also include the knock-on impact of wildfires. Action is needed and a better understanding of specific risks and how they might impact the most vulnerable species is also needed.
N10	Risks from changing climatic conditions and extreme weather events: Changes to Precipitation	High Action needed. More understanding needed	Altered hydrology (including water scarcity, flooding, and saline intrusion) and drought could impact terrestrial species and habitats. Action is needed and a better understanding of specific risks and

Risk ID	Risk	Risk score	Risk narrative
			how they might impact the most vulnerable species is also needed.
N11	Risks from changing climatic conditions and extreme weather events: From storm events	High Action needed. More understanding needed	Increases in the frequency and intensity of storm events would impact upon terrestrial species, particularly tree species. Action is needed and a better understanding of specific risks and how they might impact the most vulnerable species is also needed.
N2	Risks to terrestrial species and habitats from pests and pathogens, including Invasive Non-Native Species	High Action needed More understanding needed.	Better understanding of this threat is needed. What, is vulnerable and which pest/pathogens are likely to be the largest threats. The likelihood is very uncertain and difficult to score as climate change is one of many factors leading to this risk.

Opportunity ID	Opportunity
NO1	Opportunities from new species in terrestrial habitats colonisations.

This section focuses on the risks and opportunities climate change poses for species in Perth and Kinross.

Uplands

The peaks and upper slopes of Schiehallion overlooking Loch Rannoch, Ben Lawers, or Beinn a'Ghlo in the Southern Cairngorms support a variety of rare upland plant communities. Nearly the entire British population of Snow Pearlwort (*Sagina nivalis*) occurs on Ben Lawers and half of all known colonies have disappeared over the last 40 years, mainly due to competition from warmth-loving species[28], [29]. The climate space for many montane communities such as alpine willow scrub is predicted to shift uphill by the 2080s[30] with some species having nowhere to go. Modelling on Ben Lawers indicates snow cover will reduce by up to 100% at 130masl and up to 32% at 1060masl by the 2050s leading to a severe reduction in bryophyte dominated snowbed communities[31].

This reduction of snow cover will have consequences for a variety of cold adapted species and the response to it may be complex. The mountain hare (*Lepus timidus*) undergoes a seasonal moult, with its coat changing to reflect the dominant colour of habitats it occupies, white in winter and grey-brown in summer. The timing of this moult is crucial, as a hare out of sync with conditions is much more visible and so particularly vulnerable to predation. There should therefore be a strong selection pressure for the hare spring moult to

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[28] Stroh, P.A. *et al.* (2023) *Plant atlas 2020. volume 2*. Princeton Oxford: Princeton University Press.

[29] *BSBI Plant Atlas 2020 press release Scotland* (2023). Botanical Society of Britain and Ireland. Available at: https://bsbi.org/wp-content/uploads/dlm_uploads/2023/03/BSBI-Plant-Atlas-2020-press-release-Scotland-FINAL.pdf (Accessed: May 10, 2023).

[30] Trivedi, M.R., Morecroft, M.D., Berry, P.M., Dawson, T.P. (2008). Potential effects of climate change on plant communities in three montane nature reserves in Scotland. Biological Conservation 141, 1665-1675.

[31] Trivedi, M.R., Browne, M.K., Berry, P.M., Dawson, T.P., Morecroft, M.D. (2007). Projecting climate change impacts on mountain snow cover in central Scotland from historical patterns. Arctic Antarctic and Alpine Research 39, 488-499.

closely track the timing of snowmelt. Recent research[32] has highlighted that mountain hare in Scotland do not appear to be responding strongly to this selection pressure, with hares remaining white long after the snow has gone. The authors suggest that the predominance of managed, predator-controlled moorland within much of the hare's native range is increasing the survival of habitat mis-matched hares. In combination with genetic drift (a danger to small populations leading to reduced genetic diversity) this elevated level of incongruous coloration may undermine the hare's potential to respond to further change. Scotland aims to re-instate natural habitats and processes in the coming years. If predator numbers increase and/ or habitats are naturalised, mountain hare may suffer particularly high mortality as they will need to *retrospectively adapt* to the new climate. It is unlikely that the mountain hare is the only species in Perth and Kinross harbouring a '*latent maladaptation*' following historic management, complicating its response to climate change.

Responses of other upland associated communities such as wet heaths or peat forming bogs are dependent on the interaction between precipitation and drying in a warming climate and are likely to vary at a local scale. In some scenarios increases in precipitation counter elevated temperature and prevent drying. In others, bogs stop being active, suffer surface drying and a loss of function.

Woodlands

Perthshire contains remnants of Caledonian forest, both coniferous and broad-leaved native woodland along with extensive tracks of timber forest. An assessment of Priority Habitats response to climate change[33] predicted the complete loss of native pinewood from its case study sites by 2080 indicating that climate pressure on native Caledonian forest sites is likely to be severe. Other than sub-arctic and montane communities susceptible to general warming, it is the pattern of rainfall, extreme events, grazing and the potential spread of pathogens that will determine woodland response to a warming climate.

Summer water stress is likely to increase the incidence of crown die back and make trees more susceptible to grazing pressures. There is likely to be an increase in losses to windthrow and flood damage, and the recent rapid spread of ash die back illustrates the impact of new pathogens. Of particular concern in Scotland are *Phytophthora ramorum,* a fungus-like pathogen that is a particular threat to larch, and *Dothistroma* needle blight (DNB), which poses a particular threat to Scotland's commercial forestry and also to native Caledonian pinewoods. As with many broad habitat types of woodlands are likely to persist, subject to management, but there is likely to be a marked shift in species composition.

Future storms can also have an impact on trees, with changes to the intensity and frequency of storms being a major risk factor. Falling trees can have a wider impact causing blockages or damage to other infrastructure. An increase in summer storms is particularly risky, due to trees being in full leaf and therefore heavy. The removal of vulnerable/unsuitable species like Populus ombardii has a cost impact for those undertaking management.

Lowlands

It is likely that productivity of lowland grasslands and arable fields in the east of Scotland will reduce as elevated temperatures are counteracted by increased water stress[34]. This may have several consequences for habitats, both in respect of management and community composition. A pressure to maintain production could result in a reduction of field margin and hedgerow habitat in favour of cropland; conversely more complex habitats, better able to retain water may be seen as a more viable management alternative.

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[32] Zimova M, Giery ST, Newey S, Nowak JJ, Spencer M, Mills LS. 2020 Lack of phenological shift leads to increased camouflage mismatch in mountain hares. Proc. R. Soc. B 287: 20201786. https://doi.org/10.1098/rspb.2020.1786

[33]Carey, P. et al. (2016) Priority Habitats, Protected Sites and Climate Change: Three investigations to inform policy and management for adaptation and mitigation.

[34] *Impact of Climatge Change in Scotland on Crop pest, Weeds and Disease* (2007). Scottish Agricultural College. Available at: https://www.sruc.ac.uk/media/olpkh5eh/tn605-climate-change-pests.pdf.

Whether areas of unmanaged/ low intensity agriculture increase or decrease across Perth and Kinross, grasslands that remain are likely to see a turnover in species as the climate warms. Soft rush (*Juncus effusus*), Scotland's most common weedy form of rush is anticipated to be replaced by hard rush (*Juncus inflexus)* or jointed rush (*Juncus reticulatus*) as summers become warmer and dryer in the east[34] . Similar replacements will be seen across a number of species as climatic envelopes shift. This shift in climatic envelope is illustrated by the northern progression of bee orchid (*Ophrys apifera*) over the last 20 years recorded in the BSBI Plant Atlas 2020[28] which is attributed in part to climate change. Bee orchid and other southern species are likely to expand their range into lowland areas of Perth and Kinross as the climate continues to warm. The numerous species of invertebrate closely associated to specific plants are likely to suffer a concomitant range shift or loss.

Aquatic habitats

Perth and Kinross has a large network of rivers, streams and freshwater lochs. Under the new climate regime aquatic habitats will warm and in particular, smaller streams in the Cairngorms have been found to be most sensitive to air temperature variation[35].

With more intense rainfall, rivers are likely to become more flashy, more erosive and potentially have lower summer base flow. Intensive rainfall events will also mobilise more sediment, adding nutrients and silt to river systems and increase the incidence of storm overflow discharge. These changes will have negative impacts on most riverine species but those requiring clean, cold water such as salmon (*Salmo salar*) and freshwater pearl mussel (*Margaritifera margaritifera*), notified features of the River Tay SAC are at particular risk. Beaver (*Castor fiber*) may play a role in mitigating some impacts of climate change locally as the leaky dams they build dampen flashy river flows, help to maintain baseflows and create wetland refuges during drought. Beaver wetlands also act as filters, extracting sediments and promoting clean gravel habitats downstream.

The impacts on Aquatic Habitats is discussed more in Section 7.5.

Coasts

There is a risk of coastal erosion and flooding associated with sea level rise and increased storm surges. The internationally noted reedbeds along the River Tay are in danger of loss through coastal squeeze unless managed carefully, as they are at risk of being trapped between a rising sea and valuable farmland.

Mobile species

The impact of climate change on mobile species is highly dependent on habitat connectivity. For many species, if connectivity allows there is likely to be a shift in range or distribution rather than a complete loss. For certain species, for example the Scottish Crossbill (*Loxia scotica)* there is nowhere to go. The Scottish Crossbill is endemic to Scotland and strongly associated with Caledonian pinewood. Modelling indicates that the climate envelope it currently occupies will disappear from Scotland by 2100[36], likely leading to the extinction of this iconic species.

Where species can move, the direction of movement is highly dependent on what combination of habitat and resources are presented under a warmer climate. Wildcat (*Felis silvestris*) reintroductions are programmed in the Cairngorms for the coming years. Heavy snowfall impedes wildcat movement, so a reduction in lying snow may allow a range expansion and support this reintroduction. Conversely an expansion of boggy habitat under wetter conditions will restrict potential wildcat habitat.

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[35] Jackson, F.L., Fryer, R.J., Hannah, D.M., Millar, C.P., Malcolm, I.A. (2018). A Spatio-Temporal Statistical Model of Maximum Daily River Temperatures to Inform the Management of Scotland's Atlantic Salmon Rivers Under Climate Change. Science Total Environment.

[36] Huntley, B. *et al.* (2008) "Potential Impacts of Climatic Change on European Breeding Birds," *PLoS ONE*. Edited by J. Chave, 3(1), p. e1439. doi:10.1371/journal.pone.0001439.

7.3 Risks to soils

Table 19: Identified risks to soils and scoring.

Risk ID	Risk	Risk score	Risk narrative
N4	Risks to soils from changing climatic conditions, including seasonal aridity and wetness.	High Action needed More understanding needed.	This risk is high due to the importance of soils to both biodiversity and agriculture and carbon storage within Perth.

Climate risk to soil will increase in Scotland due to heavier rainfall events, which will likely result in erosion, compaction, and pollution. Increased soil moisture deficits are expected in summer, and this is likely to lead to loss of biodiversity and organic matter. Moreover, soil erosion resulting from poor land management and triggered by intense rainfall may also impact water quality, freshwater biodiversity, and GHG emissions. Drained and cultivated lowland peatlands are identified as notably vulnerable to climate change and might impact soil fertility.

Increased frequency and magnitude of intense rainfall events could indicate a further risk of reactivation and run off from contaminated land, especially for former mining areas of which there are a number in Scotland. There are less than 15 sites within Perth and Kinross, all of which are in a concentrated area to the South of Loch Leven, around the settlements of Blairadam and Ballingry and on the border with Fife[37][38]. These former mining areas are concentrated in the Community Councils of Portmoak and Cleish and Blairadam Moreover, the increased temperatures will decrease the amount of frost, this along with an increase in volume of precipitation (winter) and an increase in precipitation intensity (winter) will result in more run-off and mud. In addition, this will mean that diffuse pollution will have a negative impact on the surrounding environment. Diffuse pollution is already a problem but will increase with climate change.

In the upper regions of Perth and Kinross, albedo and snow melt influence local climatology through energy fluxes. Snow also has an insulating effect and helps dampen variations in soil temperatures, thus decreasing the erosion associated with freeze–thaw cycles and protects vegetation from frost damage.

7.4 Risks and opportunities for natural carbon stores, carbon sequestration and GHG emissions from changing climatic conditions.

Table 20: Risks and opportunities for natural carbon stores, carbon sequestration and GHG emissions from changing climatic conditions scoring.

Risk ID	Risk	Risk score	Risk narrative
N5	Risks and opportunities for natural carbon stores, carbon sequestration and GHG emissions from changing climatic conditions, including temperature change and water scarcity.	High Action needed	This risk was scored high due to its importance to the carbon budget of Scotland and overall carbon sequestration within Perth and Kinross. As well as upland areas being particularly impacted by changed to climate.

Reduction in snow cover poses risks to soils and carbon sorted within peat. An area of concern is that as the climate warms there is the potential for it to have an effect on the soil's ability to store carbon and nutrients because of the weakening in the insulation effect of snow. This may lead to increased losses of dissolved

[37] https://www.nmrs.org.uk/mines-map/coal-mining-in-the-british-isles/collieries-of-the-british-isles/coal-mines-scotland/

[38] https://www.nmrs.org.uk/mines-map/coal-mining-in-the-british-isles/collieries-of-the-british-isles/coal-mines-scotland/

carbon and nutrients due to leaching, which would result in changes in nutrient cycling and ecosystem productivity.

Due to wetland dry out and peat erosion, more carbon will be released. This will result in increased GHG emissions. Moreover, wildfires also pose a significant risk to loss of carbon stores. Opportunities may also arise due to a changing climate. For example, regarding peatlands, locations at which carbon sequestration rates are highest are typically associated with mild and wet bioclimates, allowing high primary productivity. However, higher magnitudes of climate change in future may be less favourable. This is particularly worrying as around a fifth (more than 20%) of Scotland is made up of peatlands, which store around 1600 million tonnes of carbon[39]. In Perth and Kinross there is around 476km^2 of peatland[40]. Figure 34, shows some of the landcover which is sensitive to warming winter temperatures, including peatland. Besides the increase in GHG emissions, destruction, erosion from excessive grazing or development on peatland is also detrimental to the surrounding hydrology, as well as to peatland species. Drainage of bogs has reduced water levels resulting in peat drying out and affecting the ability of sphagnum to regenerate the peat.

[39] Scottish Wildlife Trust: Peatlands and soils. [Available online].

[40] Calculate using data provided by https://soils.environment.gov.scot/maps/thematic-maps/carbon-and-peatland-2016-map/ - selecting land classified as 'Blanket bog/peat. or 'Other peat' and using GIS to calculate its area within a Perth and Kinross Boundary.

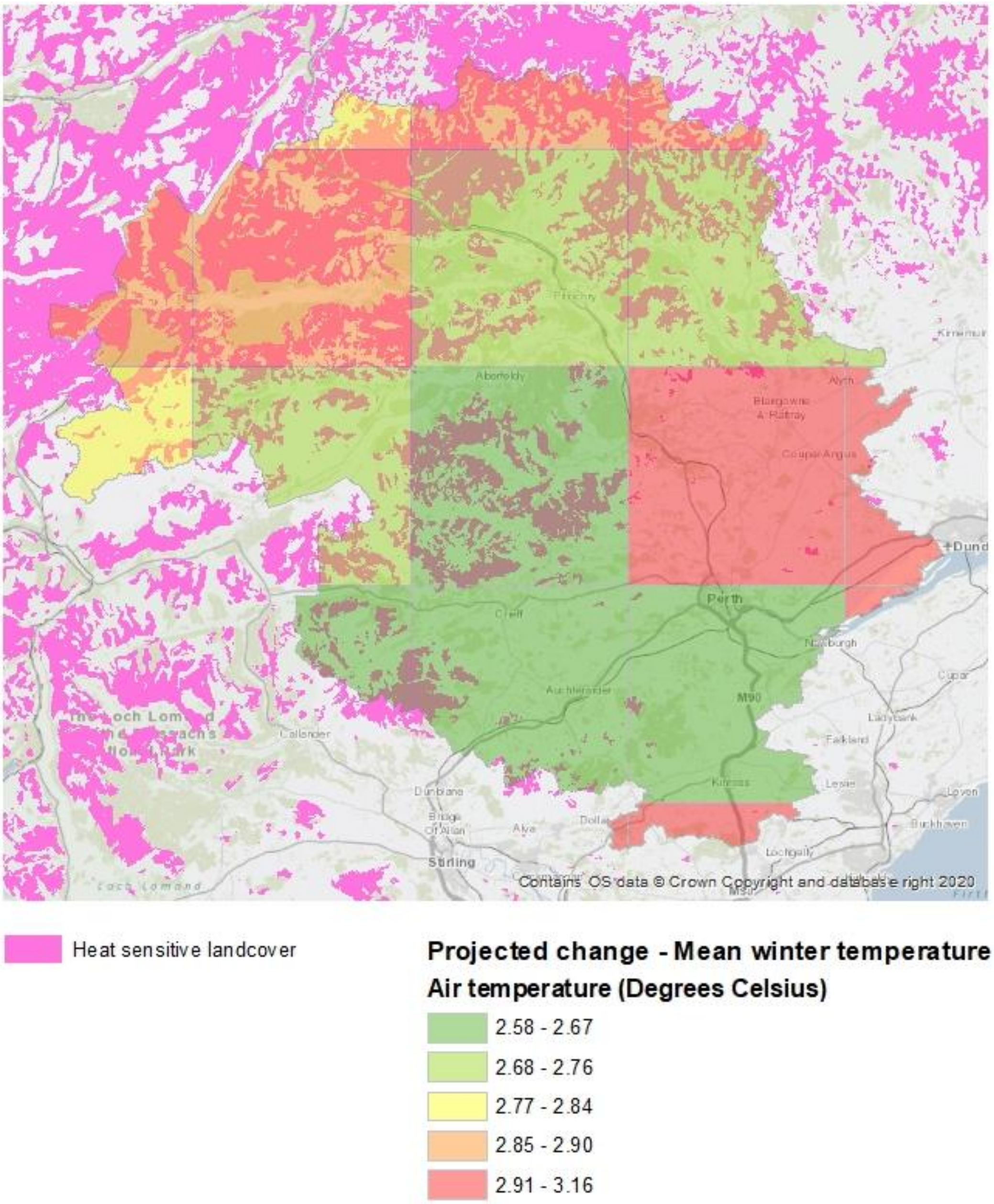

Figure 34 Map showing land cover with is likely to be particularly vulnerable to warming temperatures and compared to projected changed to winter temperature (RCP8.5 for 2080). Landcover types or uses included were: "Blanket bog/peat" "Other peat", "Ski tows", "Snow cover", "heather moor", "Wet heather moor" – data was derivded from Scotland's soils – carbon and Peatland map 2016[41].

[41] https://cagmap.snh.gov.uk/natural-spaces/dataset.jsp?code=PEAT

7.5 Risks and opportunities for freshwater species

Table 21: Climate change risks and opportunities for freshwater species and scoring.

Risk ID	Risk	Risk score	Risk narrative
N6	Risks to freshwater species and habitats from changing climatic conditions and extreme events, including higher water temperatures, flooding and bank erosion, water scarcity and phenological shifts.	High Action needed	The wide-ranging threats from climate change, the importance and extent of Perth and Kinross's freshwater ecosystems means this risk is rated high.
N7	Risks to freshwater species and habitats from pests, pathogens, and non-native species.	High Action needed	The importance and extent of Perth and Kinross's freshwater ecosystems means this risk is rated high. However, given the complexity and variety of factors which lead to an increase in pests etc – the likelihood is difficult to understand and score – unless on a detailed species by species level.

Opportunity ID	Opportunity
NO2	Opportunities to freshwater species and habitats from new species colonisations.

Risks

Climate change and changes to precipitation bring more intense rainfall, meaning rivers are likely to become more flashy, more erosive, and potentially have lower summer base flows. Higher more intense flows can cause increased bank erosion, impacting species living on around the banks of rivers. These changes will have negative impacts on several species, in particular salmon and freshwater pearl mussel. Moreover, more intense rainfall may also mean higher flow though lochs and other freshwater habitats and risks disturbing polluted sediments. Equally, drier summers are projected for Perth and Kinross, and could result in low flow in rivers during the summer months. Low flow can increase water temperatures, reduce habitat quality for freshwater fish and increase the concentration of nutrients and other pollutants.

High temperatures also impact freshwater habitats and the species that occupy them. This can result in loss of sensitive species, as most species have a temperature limit in which they can no longer survive in, and changes in phenology (the study of changes in the timing of seasonal events e.g., flowering) and species composition. Higher temperatures can also directly or indirectly increase the possibility of water quality issues, for example by increasing the rates of biological and chemical processes, especially algal growth rates and nutrients. The changing extent and depth of snow cover can influence hydrology and ecology, with maximum peak flows occurring earlier in the winter season, and potentially higher peak flows and flashier hydrological regimes due to more direct runoff in sensitive catchments, which in turn will negatively impact freshwater species.

Like terrestrial species, pests, pathogens and INNS's also pose risks to freshwater species. The impact of an increase in pests, pathogens and INNS on freshwater ecosystems include competition with native species, predation, introduction of disease, harmless airborne pathogens becoming more infectious, and habitat alteration, which can lead to increased river flooding and economic costs.

Below are some specific examples of how these risks could impact Perth and Kinross. Salmon production and salmon fishing is importance for Perth and Kinross, the River Tay provides salmon spawning grounds and is popular for fishing. A decrease in snow cover changes river temperatures which affects the spawning of important river species like salmon. Moreover, a lack of riparian cover can also affect parr and smolt growth and/or predation. Similarly, wetter winters, heavier rain and higher flows within rivers can impact spawning. Too much rain can also lead to very high flows that scour riverbanks and destroy salmon nests or create silt that suffocates their eggs.

Reduction in snow can cause changes to river flow which impact upon freshwater species. periods of snow in upland catchments, cause very low, groundwater-based, flows in winter, and high flows in spring due to a combination of snowmelt and rainfall. If snow is reduced as the projections suggest this is likely to cause flow patterns to change in these areas if winter precipitation were to fall as rain. This shift would alter the ecohydrological regime and impact species relying on these streams. In addition, snowmelt is necessary to sustain summer flow in these types of catchments.

There is also a risk of coastal erosion and flooding associated with increased sea level rise and storm surges. The internationally noted reedbeds along the Tay are at risk of loss through coastal squeeze unless managed carefully as they are at risk of being trapped between a rising sea and valuable farmland.

Opportunities

Opportunities to freshwater habitats from new species colonisations can include enhanced biodiversity[42], which supports a range of ecosystem services, particularly cultural ones such as recreation (including angling, and enjoyment of wildlife).

Snow cover can exacerbate freshwater pollution by concentrating the deposition of atmospheric pollutants, such as nitrates and sulphates, with a potential impact on aquatic communities Reduction in snow cover could lead to some benefits to water quality.

However, the opportunities from climate change are assessed as low for Scotland and specifically Perth and Kinross, both currently and in the future, as there is low evidence to date, and climate change is likely to a play smaller part in the benefits of colonisation compared to other factors.

7.6 Risks and opportunities from climate change to landscape character

Table 22: Risks and opportunities from climate change to landscape character and scoring.

Risk ID	Risk	Risk score	Risk narrative
N9	Risks from climate change to landscape character.	Medium Monitor risk More understanding needed	This risk is not well understood on a national scale and has both risk and opportunities. However, of Perth and Kinross's current landscape are important to its identify and industries such as tourism and so this risk is ranked medium and needs both monitoring and better understanding.

This risk/opportunity focusses on how future changes to landscape character will occur from a differing natural response to change climate including alterations to biodiversity, soils, geomorphology, hydrological processes, and coastal processes. Landscape character will also be modified by indirect effects of a changing climate, such as through land use change such as new cropping systems. Another indirect effect which could

[42] UK Climate Change Risk Assessment – Scotland's National Summary https://www.ukclimaterisk.org/wp-content/uploads/2021/06/CCRA-Evidence-Report-Scotland-Summary-Final-1.pdf

change the landscape character is an increase in tree cover because of mitigation actions, or alternatively, woodland loss as a result of pests and diseases.

There is little research on this for Scotland and specifically for Perth and Kinross. However, given Perth and Kinross's link to tourism this is likely to be a relevant risk. This has been discussed further in both cultural heritage and risks to tourism, in Chapter 5.

7.7 Conclusions

In terms of risks to nature due to climate change for Perth and Kinross, there are several vulnerabilities and very few opportunities that have been identified.

Climate change, for Perth and Kinross, is expected to cause wetter winters and drier summers. This shift in climate towards more dramatic extremes in weather is expected to pose a risk to terrestrial and freshwater biodiversity, soils and landscape character.

Terrestrial species in the highlands of Perth and Kinross have adapted to the snow cover regime and mild summer temperatures. For example, plant species such as the artic alpine and mountain willow shrubs rely on snow cover and mild wet conditions. These species will suffer as snow cover increases in variability and summer temperatures increase. In addition, drier and warmer summers can potentially promote the survival of new diseases and non-native invasive species which could threaten habitats and species.

The lowlands of Perth and Kinross are characterizable by their generally flat landscape and fertile and nutrient rich soil. With climate change, this area is at increasing risk of pollution and erosion due to increased rainfall and overland runoff. Moreover, there is a risk that as the climate warms the soil, and peatlands, will be unable to store carbon and nutrients as effectively. This could result in an increase in GHG emissions and a negative impact on water quality and freshwater biodiversity.

Less snowmelt in combination with drier summers can impact on freshwater temperature and changes in flow patterns. Freshwater species are at risk due to changes in the hydrological regime and increased pollution from runoff during the winter months due to increased rainfall. Increase in flood-risk also poses a risk to freshwater and terrestrial species. Changes in flow pattern have the potential to alter the surrounding landscape in terms of land-use changes and hydro morphological changes.

8. PKC organisational risks

The previous chapters of this risk assessment have so far provided an overview of the climate risks facing residents, businesses, infrastructure, the natural environment and culture within the Perth and Kinross. This chapter provides an overview of the climate risks facing Perth and Kinross Council, its assets, and associated operations.

8.1 Background

Perth and Kinross Council (PKC) serves an area of 528,600 hectares, and a population of 153,810[43]. PKC currently employs 5,900 people[44]. PKC are responsible for the operation and maintenance of their own offices and many public buildings, including schools and libraries along with its vehicle fleet, waste and water usage, and street lighting. PKC also has a wider influence through directing, supporting, and enabling climate change related action in the wider local authority area; directly through involvement with social housing, transport planning, waste collection and development planning and control; and indirectly through programmes to raise awareness and influence behaviour, and through strategic partnerships in the wider region.

As a 'public body,' PKC have a legal responsibility to consider Adaptation in better understanding the impacts of current and future climate change on their residents and operations[45]. This involves assessing the potential risks of climate change and how they can adapt to such risks.

8.2 Risks to council assets owned by or maintained by PKC.

Table 23: Risks to council owned or maintained assets and scores.

Risk ID	Risk	Risk score	Risk narrative
PKC10	Risks to council-maintained community spaces from higher temperatures.	Low	Heat is not likely to be a priority concern – a change impacting the running of green spaces would be over several years/decades and so would not impact PKC as significantly as other risks. However, in the long term increased growing season and accumulated temperature could cause green space to require more maintenance.
PKC8	Risks to leisure facilities from flooding.	High	Some leisure facilities lie within flood zones – large financial, reputational cost and costs to residents who cannot use these facilities if flooded.

[43] https://www.nrscotland.gov.uk/files/statistics/council-area-data-sheets/perth-and-kinross-council-profile.html#table_pop_est

[44] https://sustainablescotlandnetwork.org/reports/perth-and-kinross-council

[45] Climate Change (Scotland) Act 2009

Risk ID	Risk	Risk score	Risk narrative
PKC7	Risks to council-maintained community spaces from flooding.	High	Some community spaces lie within flood zones – large financial, reputational cost and costs to residents who cannot use these facilities if flooded.
PKC13	Risks to housing and housing provision from high temperatures.	Low	Heat is unlikely to be a large problem – however some housing could be more at risk than others, more research needs to be conducted into housing characteristics and their likelihood to overheat.
PKC5	Risks to Perth and Kinross own estates from flooding.	High	Some of PKC’s estates lie within flood zones – large financial, reputational cost and costs to residents who cannot use these facilities if flooded. Offices or equipment damage could cause problems to normal operating.
PKC6	Risks to housing and housing provision from flooding.	High	There are council houses within flood zones (940 in SEPA projections) – there are high costs associated with providing alternative accommodation and repair, as well as associated costs with disruption to residents.
PKC12	Risks to Perth and Kinross own estates from higher temperatures.	Low	Heat is unlikely to be a large problem – however some buildings could be more at risk than others, more research needs to be conducted into which buildings have characteristics making likelihood to overheat.
PKC14	Risks to road infrastructure from higher temperatures.	Low	Perth and Kinross unlikely to reach temperature that cause large amounts of damage until later in the century and this is uncertain.
PKC4	Risks to road infrastructure from flooding.	High	Some council-maintained roads lie in flood zones, huge costs associated if this risk were to occur.

The following sections provide a more detailed overview of the risks that both heat and flooding are likely to have on PKC’s assets and operations.

8.2.1 Risks to council owned assets and infrastructure from heat.

Increased temperatures and the increased frequency and intensity of heatwave events are likely to impact several of PKC’s owned and operated assets.

Council maintained green spaces

Higher temperatures will pose risks in multiple ways to council-maintained community green spaces. For example, higher temperatures (combined with less summer precipitation) may cause problems for the current vegetation within parks and green spaces. New vegetation species may be needed to replace current ones or more water may be required in greenspace maintenance regimes. More water may also be required for lawns to ensure they do not die off or are scorched/burned due to such higher temperatures. Furthermore, higher temperatures will mean a longer growing season, requiring longer greenspace maintenance regimes and management of flora and lawn areas.

Collectively, this would require more council resources such as additional greenspace staff, who may also need to work longer throughout the year to account for the longer growing season. This would require increased financial resources. Placing more financial pressure on the council to ensure these challenges are addressed. Community spaces and their use may also need to be rethought. For example, more physical or natural shading may be required in parks so people will not overheat and can still enjoy greenspaces when in higher temperatures. This will also have an added benefit in protecting flora and lawn areas from direct sunlight.

Hotter temperatures and drier summers could increase the risk of wildfires in areas of greenspace if not appropriately monitored and maintained, with adequate shading. If this occurs it may impact the safety of the public/residents using greenspaces/community spaces, or impact public transport such using roads or railway lines – having a knock-on financial impact to the Council, public transport providers, businesses, and the wider area. Wildfires can be started in dry hot conditions by BBQs, this may become an increasing threat and need better guidance for the public to reduce this risk.

Council owned and operated estates and housing.

High temperatures and their impact on buildings are discussed in Chapter 4, however, many of these key community buildings and long with some of the social housing stocks are owned and ran by the PKC. High temperatures could increase the likelihood of buildings overheating. If this occurs in buildings within the council remit, this will have multiple negative impacts. Firstly, it can cause users to be uncomfortable and in worst cases result in the building being unusable. This would also have a negative impact on the overall health and wellbeing of users. Furthermore, if this were to occur in schools and health facilities, this would be particularly problematic due to vulnerable users – like the elderly and/or those already suffering from ill health.

If air conditioning were used to reduce this problem, running costs in the summer would increase, with additional knock-on implications for the council's overall ability to reduce its carbon emissions and meet net zero targets. Additional costs may also be incurred through the installation of window blinds or window shading film to protect building users against increasing temperatures by mitigating solar gain in offices. However, if heat pumps have been installed these could be used in reverse to cool building to avoid a separate air conditioning system.

Increasing temperatures and a longer growing season may also impact the fabrics of buildings and rainwater goods through increased biological damage. These same issues will impact residents living in social housing owned and operated by PKC. However, their health and wellbeing are likely to suffer more as a result because they are potentially more vulnerable to increasing temperatures due to their age, health issues and their vulnerability overall. Furthermore, they are likely to be more financially impacted by the cost of air conditioning technologies needed to reduce temperatures in their homes.

Road infrastructure

Increased extreme heating events poses risks to roads that PKC maintains. Asphalt road surfaces begin to melt and suffer from rutting and melting at surface temperatures above 50 °C. However, the relationship between road temperature and air temperature is complex, and depends on incoming radiation, windspeed and surface properties, but it is common for road surface temperatures to exceed 50 °C when air temperature exceeds 25 °C. In summer 2022 there were localised occurrences of this in Bankfoot and elsewhere.

The projected changes to summer temperature mean that within the local authority area, road melt is likely to become a more common recurrence. Impacting the council's maintenance budget and maintenance regime. Increasing temperatures and a longer growing season may also impact road surfaces and verges through increased biological damage.

Higher temperatures are also likely to have an impact on the PKC maintained bridge stocks. Current UK bridge design standards allow for bridge bearing and expansion joints to cater for air shade temperatures of up to 31℃. Consideration will need to be given to assessing and modifying long span bridge expansion joint and bearing arrangements as required. To better understand the assets risk and to mitigate risk of damage to longer span bridges due to higher the pressure on such joints forms higher temperatures. This would have resulted impacts upon PKC's bridge maintenance budget and human resources in that department.

8.2.2 Risks to council owned assets and infrastructure from flooding.

This section provides a detailed overview of risks that flooding is likely to have on PKC assets and operations.

According to SEPA future flooding maps, no council offices sit within future flood zones for either surface, river, or coastal flooding. However, flooding from heavy rain and overrunning sewer systems can occur and has already happened within Perth, with the offices at 2 High St having recently been flooded. The cause of this specific example was blocked roof gullies which resulted in water overflow. The projected increase in rainfall means that maintaining such gullies and ensuring they are not blocked and ready to absorb the required water will become an increased maintenance burden for the council.

Some social housing does sit within future flood zones for surface, river, and coastal flooding, meaning residents (particularly the vulnerable and/or elderly) are likely to be more impacted because of such flood events occurring. Furthermore, several skate parks, play areas and major parks are also located in areas prone to surface and river flooding.

Council maintained community spaces

Increased frequencies and intensities of flooding events will pose risks to council-maintained community green spaces. Areas of greenspace such as planting areas and grassland could be damaged by flooding, either by killing off plant life or from footfall damage on particularly wet and muddy areas of greenspace. This would result in increased costs for the council in repairing and maintaining areas regularly effected by flooding. Flooding can also cause council mainlined paths in community spaces to be eroded. This would increase maintenance costs especially after flood events where paths may need replacing.

These community spaces will be more dangerous for residents and the public (particularly the most vulnerable) due to the ground being muddier, increasing the likelihood of injury to any user of impacted community and/or greenspaces.

Areas of community spaces at higher risk of flooding could also deter the residents and public from using such areas, decreasing the health and wellbeing benefits of all users.

Council owned and operated estates and housing

Increased rainfall and flooding could have a range of negative impacts on council owned and operated estates and housing. Including (but not limited to):

- Increased risk of subsidence to domestic and non-domestic buildings, making it more dangerous to use buildings and increasing maintenance costs.
- Increased risk due to more intense rainfall and flood damage to domestic and non-domestic buildings. Repair and maintenance regimes will increase in cost because of dealing with building fabric issues such as leaking roofs, damper building fabric, and flooding within the building area. This could also include the purchase and installation of upgraded drainage, designed to deal with increased rainfall and flooding events, mitigating the impacts of rain and flood damage on buildings.

- Damper buildings could also impact the respiratory health of employees and residents if issues are not dealt with effectively. Increased flooding and more intense rain events will increase the likelihood of this occurring.
- In extreme circumstances, domestic and non-domestic buildings will become inaccessible if the immediate area is flooded.
    - For residents this may mean displacement and will put additional financial pressure on the council for temporarily rehoming residents using social housing, and in the required repairs as a result of flooding events.
    - For employees, this may mean that they cannot work, meaning council operations being impacted.

Leisure facilities

Leisure facilities (particularly some sports pitches) lie in future flood zones, Perth Leisure centre has already been flooded. The impacts to the council from flooding of such facilities are mainly financial and could be significant, with possible problems associated with insuring infrastructure and assets in areas where flooding is projected to get worse (particularly in floodplains). However, there will also be knock on health impacts to the local population of being unable to use leisure facilities.

Road infrastructure

Increased frequencies and intensities of flood events will have a range of impacts on infrastructure. This includes, but not limited to:

- The closure of major or minor roads, effecting the daily commute of staff and therefore council staff not being able to attend their office or depot, etc.
- The closure of major or minor roads will divert and displace traffic elsewhere, impacting on the roads and air quality of other areas.
- Regular council services (such as road repair/maintenance, bin lorries, etc.) could be delayed.
- Increased damage on road infrastructure means increased repair and maintenance costs.

Bridge scour[46] could be a particular problem for bridge infrastructure across the local authority area. Heavier precipitation increases flow within rivers, causing enhanced erosion activity to bridge arches and foundations. Ultimately this could result in bridge collapse, and or compromise of retaining walls. Many rivers and streams in Perth and Kinross run in steep highland basins, making them flashy in nature. Rurality within the local authority means that if bridges fail or are compromised in anyway communities could be cut off (some bridges provide the only access route to communities). This not only cuts off road access for residents but also emergency services, making cascading impacts likely, especially where vulnerable people reside. More rural bridges may connect key strategic infrastructure with wider Perth and Kinross, such as power stations and wind farms. Additionally, commuting times impacted because of having to use diverted road routes leading to wider economic impact. Long repair times would also lead to reputational damage for PKC. High-level analysis of the potential impact of bridge failure is discussed in Section 7.2.2.

Active travel

Like road infrastructure, active travel networks such as walking and cycling paths may impacted by flooding, particularly in areas where surface, river, or coastal flooding are more likely. This may increase the likelihood of accidents for walkers or cyclists by flooding areas of path network or even because of making ground

[46] The removal of sediment such as sand and gravel from around bridge abutments or piers.

conditions muddier or slippery. Increased flooding, and consequent damage of path networks, will increase costs for PKC relating to the additional repair and maintenance regimes required to be carried out.

8.3 Opportunities for assets

There may be some opportunities of financial savings from reduced repair and maintenance due to warmer winters, meaning potentially less damage resulting from freeze-thawing of building assets and road infrastructure. However, as detailed previously. this will likely be displaced by increased repair, maintenance and retrofit costs of building assets and road infrastructure because of increased flooding. There are no clear opportunities for building assets and infrastructure because of increased temperatures during the summer though there may be a decrease in winter heating burden during the winter, which would result in a reduction in running costs.

8.4 Risks to services and normal operating

This section summarises the high-level risks that climate change will have on PKC's services and normal operating.

Table 24: Risks to services and normal operating and scores.

Risk ID	Risk	Risk score	Risk narrative
PKC1	Risks to council's key supply chains.	High	This risk is very difficult to understand and quantify – due to being reliant on many factors. However, if an important supply chain were to be impacted this could have serious implications of the councils functioning.
PKC15	Risks for Perth and Kinross staff from higher temperatures.	Low	Due to temperature in Perth and Kinross remaining lower than elsewhere and the fact only most vulnerable would be severely impacted by heat this was scored low. However, action may be needed during heatwaves for outdoor workers of those vulnerable

8.4.1 Risks to council supply chains

Climate change is expected to increase the frequency of weather-related disruption to local and global supply chains. This would likely cascade down to have impacts on PKC. Notably, the interruption of supply of goods (such as schools, depots, and offices); increased purchase costs (due to increased scarcity of products and/or services because of increased temperatures and/or flooding); and reduced revenue for the Council[47].

Supply chain risks can also impact supplies needed to reduce the local authorities carbon emissions as planned. This could occur if disruption in other countries or areas of the UK impacts supplies of certain materials, labour or expertise needed to meet carbon reduction targets. Moreover, low carbon procurement and its role in the Councils carbon reduction could be impacted. This could make mitigating carbon emissions from procurement and supply chain challenging because much of the wider emissions associated with this are from the operations, activities, and materials from organisations outside their scope of

[47] https://www.mckinsey.com/business-functions/sustainability/our-insights/could-climate-become-the-weak-link-in-your-supply-chain

influence. Climate change can make attempts to reduce emissions from suppliers, etc., unpredictable, particularly as they adapt their own operations and supply chains, etc. to their own localised climate impacts.

8.4.2 Risks to council employees

Heat poses risks to employees, if buildings in which staff work overheat, staff would become uncomfortable and less productive in offices where there is no air conditioning installed. This would also have a negative impact on the overall health and wellbeing of more vulnerable employees. There will also be higher energy costs during the summer months for PKC if air conditioning was installed.

Extreme heat could also be an issue for those working at home. Employees that work outdoors are at increased risk of heat stroke or other heat related illness during the summer especially during extreme heat events. This might include, people working in waste collection, parks, or other outdoor jobs.

8.5 Opportunities for services and normal operating

There may be opportunities for PKC's services and normal operating as a result of climate change.

The reduction in colder weather in the winter is likely to lead to decreased gritting regimes, resulting in a saving on council resources. Drier summer and warmer winters are likely to make active travel more attractive, such as walking, scooting and cycling alternatives to fossil fuel vehicles. This could potentially improve local air quality because of a potential modal shift from fossil fuel vehicles to active travel alternatives.

8.6 Risks to climate change mitigation plans

This section discusses both risks and opportunities that the impacts of climate change may have on PKC's ability to reduce both their operational and area-wide carbon emissions and ability to achieve net zero. PKC's recently published Climate Change Strategy sets a target to decarbonise their 'operations' in-line with a 1.5°C trajectory and Scottish Government targets, and to support Perth and Kinross Council Area. These include a commitment to achieving a 75% reduction in emissions by 2030 and reaching net zero by no later than 2045.

Whilst climate change impacts Perth and Kinross area-wide emissions and is also the responsibility of individuals and organisations outside of the Council's operational boundary, the Council are still instrumental in identifying and achieving Mitigation, Adaptation and Sustainability targets.

8.6.1 Risks and opportunities to plans to reduce emissions from transport.

A key part of Perth and Kinross's transition to net zero is to reduce emissions from transport.
The key current targets set out by Scottish Government are as follows:

- Net Zero Transport Sector by 2045.
- No new Petrol or Diesel cars by 2030.
- Develop an Electric Vehicle network to support EV uptake by 2030.
- Public sector fleets to be decarbonised, with light fleet by 2020 and heavy fleet by 2030.

Climate change brings some additional challenges to meeting the above goals and reaching the targeted reductions in emissions. Firstly, batteries are a key component of most electric vehicles, materials need to create batteries could be impacted by climate change else were causing supply chain. Climate induced increased in flooding, may interrupt, or delay the roll out of EV infrastructure installation. It may also damage or destroy installed infrastructure.

On the other hand, warmer weather generally and particularly drier summers, may facilitate increased uptake of active travel potentially reducing emissions and air pollution from a modal shift away from fossil fuel vehicles as a result Furthermore, if PKC were to install more Solar PV technologies alongside the installation of EV charge facilities, then there is a potential to reduce the consumption of electricity required to meet the demands of increased EV vehicles across the council area.

8.6.2 Risks and opportunities to plans for reducing emissions from buildings and energy.

A key part of Perth and Kinross's transition to net zero is to reduce emissions from buildings and energy.

The key current targets set out by Scottish Government are as follows:

- Emissions from all buildings in Scotland will need to be near zero by 2045.
- All new buildings consented to use zero emissions heating by 2024.
- All new build social housing to be net zero by 2026.

The key risks to achieving these targets across PKC's domestic and non-domestic buildings are:

- Increasing temperatures with hotter and drier summers.
- Wetter winters and more frequent and intense rainstorm events.

Hotter and drier summers will require the installation of more air conditioning technologies in domestic and non-domestic buildings. The increased need for cooling in the future, accounting for this increased energy consumption in summer months, in addition to existing heating needs in winter (potentially lessened in warmer winters) may hinder efforts to reduce emissions from buildings and energy. This will also mean better monitoring and management of buildings, particularly offices, where ventilation will need to be prioritised to reduce the requirement for air conditioning technologies.

On the other hand, there are potential benefits to reducing emissions from energy use and heating as drier summers means less cloud, and therefore more solar radiation, better supporting a transition to small-scale and large-scale solar PV installations across PKC. However, this may be negated somewhat by wetter, cloudier winters. Additionally, the use of heat pumps may become more efficient as the climate warms. This is due to heat sources being warmer and therefore less energy is needed to extract heat and use it to heat up buildings.

As detailed in previous sections, wetter winters and more frequent and intense rainstorm events can mean increased damage to the fabric of buildings. This will therefore require additional procurement of construction and repair materials (which is further exacerbated by the need to retrofit existing buildings to a net zero standard), making it more challenging to reduce Scope 3 emissions, particularly through the supply chain.

8.6.3 Risks and opportunities to plans for reducing emissions from changes to land-use.

Afforestation efforts to sequester carbon emissions may be impacted by future climate conditions. Whilst this may not necessarily increase carbon emissions (unless such areas of forest are destroyed by wildfires because of hotter, drier summers), this will impact the types of tree species required for sequestering carbon emissions, reducing local temperatures, and improving local air quality. Furthermore, increased temperatures and wetter winters may have a negative impact on endemic tree species and encourage the growth of invasive species, impacting local habitats and biodiversity.

Peatlands are vital carbon sinks. Therefore, climate change is a further justification for action to protect and restore peatlands. Warmer and drier conditions in future are likely to increase the rate of carbon and biodiversity losses from degraded peatlands. Early action to restore these peatlands will at least slow the rate of carbon loss and potentially allow the bogs to adapt to the new conditions and maintain their peat forming function. This will therefore likely increase PKC's overall area wide emissions, but also reduce peatland ability to sequester carbon from the atmosphere, preventing PKC from achieving net zero emissions.

Whilst not directly relating to carbon emissions, PKC's agriculture and local food growing initiatives may be impacted by climate change. A warming climate has the potential to improve growing conditions in Scotland and increase the productivity of our agriculture and forestry. However, climate change will also pose a number of threats, from more variable and extreme weather to the spread of pests and diseases, which may limit this potential. Furthermore, food yields could suffer due to increasingly frequent and severe droughts.

8.7 Conclusions

In conclusion, the negative impacts on council assets and operations (including domestic and non-domestic buildings, road infrastructure, and staff, etc.) outweigh the potential benefits resulting from a warmer localised climate, with warmer and drier summers.

It is evident that the impacts of both increased temperatures and rainfall/flooding impacts will likely have a detrimental impact on council operations, services, and assets if PKC do nothing as a result of this climate risk assessment. Employees and residents (particularly those most vulnerable) are likely to be impacted if council buildings, infrastructure and operations are not proactively adapted to deal with current and future impacts of climate change.

This can be achieved but will be at a financial cost for the council. It must be better integrated into council policies, operations and budget plans going forward – particularly to minimise the damage and wider impacts of extreme weather events such heatwaves and flooding.

9. Conclusion

The CCROA has identified many risks and only a few opportunities for Perth and Kinross associated with climate change. All sectors that were assessed will be impacted these included:

- People, health, communities, and the built environment.
- Natural environment.
- Infrastructure.
- Business and industry.
- Council assets and operations.

Flooding and its impacts are most pressing climate change threat for Perth and Kinross and affects all sectors. Flooding is happening now and will continue to be a threat through the century as rainfall intensity increases.

Heat is likely to cause impacts for Perth and Kinross mid to late century as summer temperatures increase and heatwaves become more regular and extreme. Reduced snowfall is likely to have large impacts on upland wildlife as well as hydrology within Perth and Kinross. Increased temperatures will impact the health of Perth and Kinross.

Many of the risks posed to **nature** are categorised as high impact, given natures importance to both tourism and some of the key industries in Perth and Kinross.

There will be a determinantal impact on the **Council's assets and operations**, including the ability to reduce carbon emissions through the transitional risks. Adopting adaptation measures early on will reduce this impact.

Some opportunities were identified, warmer direr summer and warmer winters, bring some positive impacts. Specifically for energy use, human health and tourism, particularly outdoor activities. However, on balance the risks of climate change far outweigh the opportunities.

The highest scoring risks from the risk assessment confirm that the risk to nature and the risk from flooding must be addressed now to enable Perth and Kinross to adapt to the changing climate. This risk assessment will be revied on an annual basis and over time the risks from rising temperature may become greater. The 10 risks with the highest score (which was a score of 9), are listed in the table below. Refer to the full risk assessment for all high rated risks.

Table 25: All risks with the top score of 9 according to the risk scoring.

Risk Code	Risk	Description	Chapter	Perth and Kinross or PKC
	Risks to terrestrial species from changing climatic conditions and extreme weather events.	This risk includes how changing climatic conditions and extreme weather events, including temperature, water scarcity, wildfire, flooding, wind, and altered hydrology (including water scarcity, flooding and saline intrusion) could impact terrestrial species and habitats.	7	Perth and Kinross
N4	Risks to soils from changing climate.	Risks to soils from changing climatic conditions, including seasonal aridity and wetness - which is likely to degrade soils and have knock on impacts on biodiversity.	7	Perth and Kinross

Risk Code	Risk	Description	Chapter	Perth and Kinross or PKC
N5	Risks and opportunities for natural carbon stores.	Risks and opportunities for natural carbon stores, carbon sequestration and GHG emissions from changing climatic conditions, including temperature change and water scarcity.	7	Perth and Kinross
N6	Risks to freshwater species and habitats from changing climatic conditions.	Risks to freshwater species and habitats from changing climatic conditions and extreme events, including higher water temperatures, flooding, water scarcity and phenological shifts	7	Perth and Kinross
HCB13	Risks to education from flooding.	Flooding has the potential to severely disrupt education in both the short and long term. In the short term, pupils may need to be sent home and schools may be shut. If flooding causes significant damage to facilities, schools may be partially or fully disrupted in the longer term. This may also disproportionately affect those from disadvantaged backgrounds, as studies show that attending school is most important for this group.	4	Perth and Kinross
HCB14	Risks to health and wellbeing from flooding.	Flooding may have severe short-term consequences in the time during and immediately after the flood event; extreme cases would be loss of life if (for example) rivers burst banks. There are also a range of medium to long term consequences such as water contamination or damage to housing. Finally, there are severe mental health impacts such as stress, which could be caused by flooding or ancillary effects such as financial worries.	4	Perth and Kinross
BI2	Risks to business from flooding.	Flooding can severely disrupt businesses in both the short and long term. Flooding may mandate businesses closing for repairs, and may make it difficult for them to get insurance.	6	Perth and Kinross
CH1	Risks to cultural heritage from flooding.	Flooding can damage cultural heritage such as historic buildings. It may also require attractions to be closed to the public if they require repairs.	6	Perth and Kinross
PKC4	Risks to road infrastructure from flooding.	Floods can damage roads and make them impassable, with knock-on effects such as diverting traffic onto other roads. It also affects transport networks such as buses and trains.	5/8	Perth and Kinross/PKC
PKC6	Risks to housing and housing provision from flooding.	Climate change is expected to increase the number of houses affected by flooding as well as influence areas future houses can be built.	8	PKC

10. Next steps

This risk and opportunity assessment is the first step in creating an integrated climate change adaptation plan for Perth and Kinross to build further resilience.

The next step will be to use this risk assessment to create an adaptation action plan for PKC and the citizens of Perth and Kinross to implement, alongside actions that are already underway. Within the PKC "Climate Change Strategy and Action Plan"[48], there are already some adaptation actions such as capital investment in flood protection schemes.

To create a targeted action plan, further work will be required:

- Those risks highlighted as 'need a better understanding', should be a priority for research or evidence gathering over the coming years, these risks should be re-assessed when more evidence becomes available.
- For the highest risks and those categorised as action needed, key stakeholders need to be identified, educated on the risks, and collaboration between different organisations needs to occur to co-develop success full adaptation plans.
- Opportunities have also been identified, however more work is needed to understand how these opportunities can be best optimised.
- A workplan will need to be created and implemented, this will state actions to regularly review this work, to ensure it is up to date and that it considers any new evidence. This specific climate risk workstream will then need to be integrated into existing climate governance structures within PKC.
- Continue to engage with stakeholders and community groups to strengthen their resilience.

By bringing this all together it will help to create a more resilient Perth and Kinross now and in the future.

[48] Perth and Kinross Climate Action (pkclimateaction.co.uk)

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