Vulnerability Analysis

Water quantity in connection with Speyside Malt Whisky production

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Summary

The objective of this research was to assess the **vulnerability** of the upland and hill land use systems that are the **source of water** for **Speyside malt whisky**, to identify the key **factors** that may have **impacts** on the availability of water for distilling in the upcoming 20 years and the ways in which these **impacts can be mitigated**.

The research was conducted as part of MOVING (**MO**untain **V**alorisation through **IN**terconnectedness and **G**reen growth), an EU Horizon 2020 project (2020-2024). The project will build capacities and co-develop policy frameworks across Europe. It will establish new or upscaled value chains to contribute to the resilience and sustainability of mountain areas to climate change.

The research brought together researchers and stakeholders via interviews, pre-workshop questionnaires and in a vulnerability workshop. These stakeholders included environmental and social researchers, Agency and NGO staff, land managers, and whisky industry professionals.

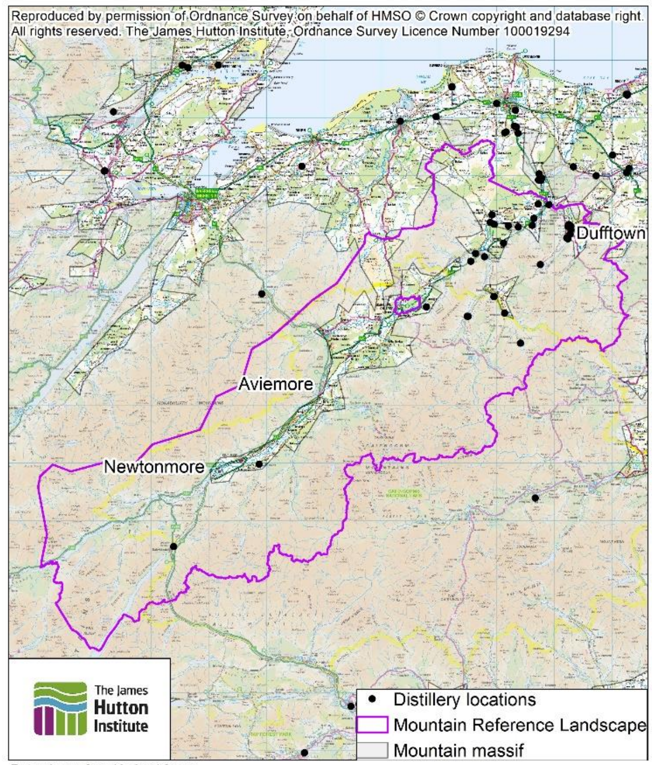
The key conclusions from this Vulnerability Analysis are:

- Water quantity is an important input to the Speyside whisky value chain (particularly for cooling processes) and is considered to be a concern for future production.
- Water quantity is connected to the wider land use system in the mountain reference landscape (the MRL being the Badenoch and Speyside and West Moray local authority units), for example via the ability of peatlands to store water.
- Factors, such as localised overexploitation of water, change in rainfall totals and seasonality, water temperature, and any increase in floods or droughts, are perceived to be important in the MRL.
- The whisky industry is more sensitive to some of these factors than others, reflecting where they can mitigate the effects through onsite distillery operational innovation.
- Land managers and other stakeholders are also undertaking interventions (such as rewetting peatlands, riparian planting or collaborative water management) in the catchment to help manage water resources.

1 Introduction

MOVING (**MO**untain **V**alorisation through **IN**terconnectedness and **G**reen growth) is a Horizon 2020 project (2020-2024). The project will build capacities and co-develop policy frameworks across Europe. It will establish new or upscaled value chains to contribute to the resilience and sustainability of mountain areas to climate change. In Scotland, we are focussing on the **Speyside malt whisky value chain**.

Speyside malt whisky is a global value chain with strong cultural and geographical links to natural resources originating in the **mountains**. Whisky draws attention to water, often an unvalued resource in mountain regions. Land cover, use and management can positively, or negatively, impact on water resources. Climate change may affect both the water quality and quantity, so it was important to engage with all those with a stake in whisky, water or managing upstream land uses about these links.



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ONS Local Administrative Units Level 1 (January 2018) Full Clipped Boundaries in United Kingdom: http://www.nationalarchives.gov.uk/doc/open-government-licence/, Contains National Statistics data © Crown copyright and database right [2017]; Boundaries Scotland 3rd Review Wards - 1999-2007; Ordnance Survey 1:250 000 Scale Colour Raster: © Crown copyright and/or database right 2019 OS; European Environment Agency (EEA) European mountain areas - version 1, Dec. 2008: Copyright holder: European Environment Agency (EEA) (provided by UEvora); Data © OpenStreetMap contributors, ODbL 1.0. Data © OpenStreetMap contributors, ODbL 1.0. https://www.openstreetmap.org/copyright.
Note: in some cases, a single distillery may be represented by more than one point.
Selected locations (within Mountain Reference Landscape, only) are highlighted.

Figure 1 : Location of whisky distilleries and the MRL

The geographical region for this study and is made up of two Local Authority Units (LAU) - Badenoch and Strathspey and West Moray, in Scotland and together these define a **Mountain Reference Landscape (MRL)** for the case study.

Initially, both **water quality** and **quantity** as inputs to the whisky value chain were discussed, via interviews, but it became clear that quantity was of greater concern especially for looking forward so this was chosen as the **reference variable**. A reference variable provides a focus for linking the many and varied factors that may be driving change in a region to their positive or negative outcomes for a specific mountain value chain.

1.1 Objective

The objective of this research was to assess the **vulnerability** of the upland and hill land use systems that are the **source for water** for Speyside malt whisky, to identify the key **factors** that may have **impacts** on the availability of water for distilling in the upcoming 20 years and the ways in which these **impacts can**

be mitigated. The approach notes that a value chain may be exposed to changes in these factors but may not always be sensitive to changes and even where sensitive it may be possible to mitigate impacts through adaptive change e.g., for the whisky industry to infrastructures or production processes.

1.2 Description of the land-use systems in the MRL

The Speyside and West Moray MRL, with an area of just over 3,413 km^2 is an example of upland and mountain land use systems in maritime N.W. Europe. While the maximum elevation is low for a mountain region (1,309 m) the higher elevations within the MRL have sub-alpine vegetation communities and in places skeletal soils and long periods of snow cover. This contrasts over short distances with valley floors (e.g., Aviemore at ~240 m) where it is possible to practice arable agriculture. The MRL is also transitional in terms of climate from very wet western mountains (mean annual rainfall – 2,934mm) to the much drier eastern coastal plains into which the valley opens (731mm). The area has substantial areas of deep peatlands (1,018 km^2 or 30% of the MRL area with >50cm of peat in first 100cm of soil), 73% of which need some degree of hydrological and/or vegetative restoration.

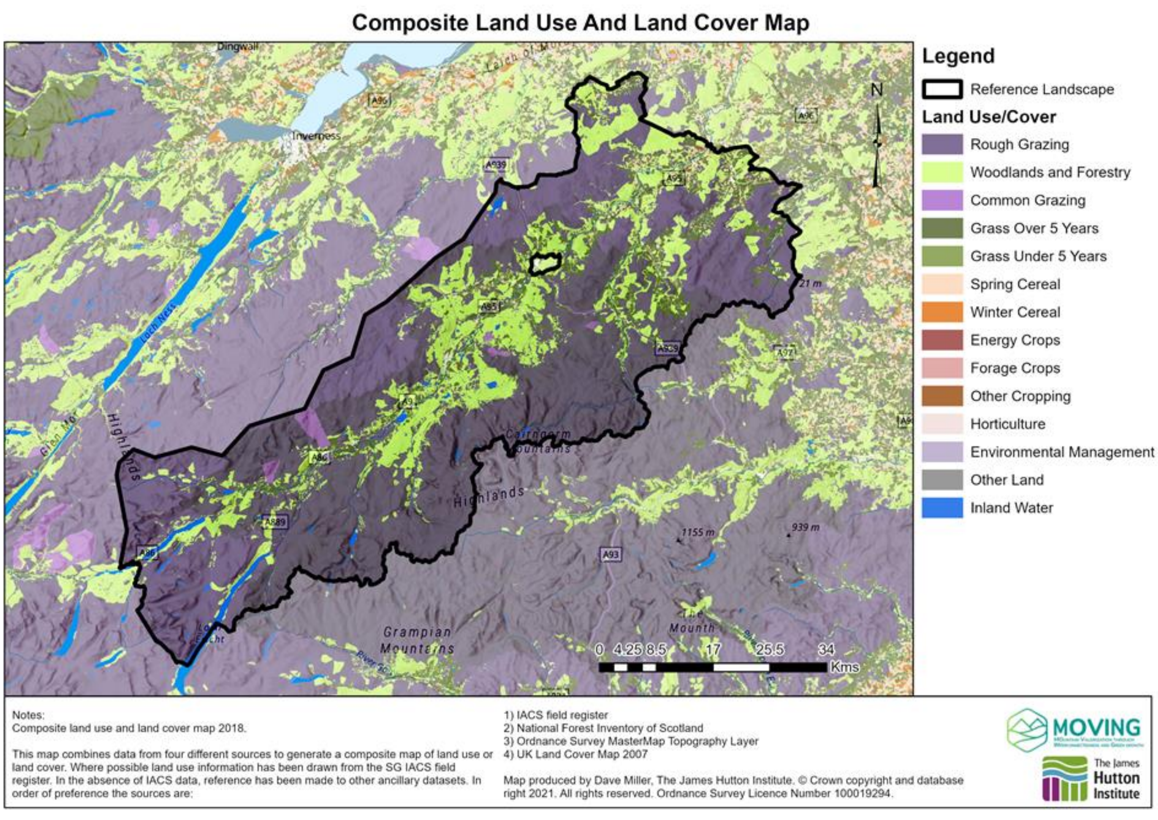


Figure 2: Map of the land cover/use for the MRL

For agricultural capability, the MRL has 12% of the area with very limited agricultural capability (the lowest LCA class, 7), with a further 49% capable only of supporting rough grazing (LCA6.1-6.3). Land capable of supporting improved grassland makes up 24% (LCA classes 5.1-5.3) with a further 13% capable of supporting mixed agriculture (LCA 3.2-4.2).

The higher ground is typically covered with a mix of semi-natural vegetation types - heather (*Calluna vulgaris*), white bent (*Nardus stricta*), flying bent (*Molinia caerulea*) and bog mosses (*Sphagnum spp*), while lower slopes will see more palatable grasses (*Festuca s*pp and *Agrostis spp*). These pastures have some use as pasture (for sheep) but higher elevations are mainly used mainly for hunting (e.g., red grouse – *L. lagopus*, red deer - *Cervus elaphus*, and mountain hares – *Lepus timidus*), the first including the extensive use of fire for vegetation management (there are 8,935 grid cells (200m) with >50% of their area burned or 35,740 ha). The River Spey and its tributaries (1,760 km within the MRL) have world renowned sport fishing for Atlantic salmon (*Salmo salar*). There is also extensive recreational use, skiing, mountaineering, hillwalking, and camping.

Forestry has increased from 14% of the MRL in 1988 to about 20% in 2020 (Scotland has 18%). The woodlands are typically concentrated in the valleys and lower hillsides, but recent plantings have often been specifically riparian. The objectives for woodland creation are both timber production (softwood plantations) and habitat creation (native woodlands), including assisting natural regeneration.

Improved pastures (permanent or temporary grass) make up most the remaining land with 6% and 1% and are used for raising cattle and sheep though with fewer animals taken direct to slaughter with most being sold for finishing in the lowlands.

The MRL has a total population of 37,941 in 2020 with Badenoch and Strathspey having 13,948 and West Moray 23,966. Aviemore is the only settlement large enough to be defined as a remote small town (population 3-10,000, with a 30–60-minute drive to a settlement of >10,000) with 5% of area accessible rural, 36% remote rural and 59% very remote rural (<30, 30-60 or >60-minute drive times to a >10,000 settlement.

2 Research Processes

2.1 Methods and materials outline

The research involved a three-stage process, undertaking expert stakeholder interviews to understand the recent trends in water quality and quantity, followed by short online questionnaire to verify the interview findings and explore the potential future trends, and then by an online workshop to assess how the whisky value chain is affected by these biophysical factors. The workshop was informed by presentations of indicators and maps showing current and future or trend values for a range of factors highlighted a potentially significant in the expert stakeholder interviews – see the Appendix of slides presented at the workshop in Section 5.

This report summarises the findings of each data collection stage as they were deliberated on in the Vulnerability Assessment workshop with stakeholders in December 2021 as well as post-workshop analysis and interpretation by Hutton researchers.

2.2 Methodology and technical insights

The methodology was challenging at times because of both the number of stages and the intensity of each. UCO provided support along the way, but we still found it a struggle at times in terms of the clarity and applicability of the concepts used, the time required from stakeholders over three connected research activities, and the tight timeline in within which to complete the whole task. The methodology was further complicated by the unconventional value chain chosen. Water quantity as the reference variable does connect the land use system to the value chain but is more complex to analyse as it introduces interactions between stakeholder actors and several system components (surface and groundwaters) and has temporal lags and teleconnections via tributaries into the main stem. Furthermore, sometimes it was hard to make clear to stakeholders the differences between the three research stages (interview, questionnaire, and workshop) so it was harder keeping a single cohort of stakeholders engaged through the whole process.

It was, however, possible to learn a lot from participants along the way in terms of the real-life context of the implications of biophysical factors/drivers on water quality and quantity and how they may affect the Speyside whisky value chain. From the interviews and pre-workshop questionnaire, the drivers were recategorized and streamlined, meaning it was possible to focus on discussing in the workshop the factors with greatest relevance. After the three stages, it also became clear that solely water quantity, rather than water quality and quantity, was of most relevance. During the interviews, participants also discussed a wide range of adaptive capacity mechanisms, representing a range of scales and governance levels. These suggestions underpinned fruitful discussions in the workshop, and these mechanisms are highlighted below, with the additional expert evaluation included.

The technical challenges were in collating meaningful maps and metrics for all the drivers and presenting them in a way that provided insights and stimulated systems thinking without being overwhelmingly complex. In most cases, it was possible to generate high-level indicators but with indicators such as rainfall and temperature there are issues of how to step into the most revenant metrics. Previous work guided how this was undertaken but whiskey distilling has very specific direct and/or localised issues but their severity influenced by intervening land management factors which are more diffuse with teleconnections via surface and ground water flows. In some cases, proxies had to be used, e.g., snow cover – i.e., extent, rather than snow melt – i.e., rates. The spatial data integration was completed successfully in most cases – e.g., defining sub catchment associations with distilleries but some data sharing limitations, necessarily imposed by public bodies, made the linkage of water body condition data more challenging.

2.3 Profile and gender of stakeholders

Throughout the analysis we had five female stakeholders, and 11 male stakeholders. We had high participation from stakeholders representing research and extension officers/advisors. More difficult to recruit were land managers – partly we think because our case study is not immediately connected to primary production on land, rather it sought to connect wider land use, indirectly via water flows, to a high value manufacturing and services industry (whisky production). Another reason may have been the substantial time commitment that was potentially required from stakeholders. We did conduct interviews with two estate owners and land manager advisors, however, so still feel able to at least partially account for these stakeholder views in the research.

It is worth noting that the research methodology was robust in the face of using varying cohorts of stakeholders and experts in each of the three stages, but it was crucial that there was a core group with whom it was possible to engage across all stages and who also played a role in helping to explain the key issues in the workshop e.g., within the distilling, land management and water resources NGO's domains. Of the stakeholders who participated in only the vulnerability workshop, all had already been involved in the MOVING project at an early date (i.e., in the MAP/ Stakeholder Advisory Group) so they had an enhanced knowledge of the objectives of the project and how they could contribute.

In addition to the quantitative data from questionnaires and workshop responses the analysis has generated a very rich and nuanced data set from the interviews and workshop recordings. These illustrate the range of sectoral expertise, knowledge of the geography of the MRL and how the factors interact. Whilst the interviews did not reach full data saturation (no new information being added by additional participants) the research team now have a much better grounded and articulated understanding of the key components of the systems and their interactions. All this data will be further exploited in later activities starting in 2022, including potential storymaps and a journal article, and links with other existing Scottish Government funded research.

3 Vulnerability analysis results

This part of the report presents the findings of the Vulnerability Workshop as follows:

1. It first sets out the **factors** that can affect water quantity and thus its potential availability for use in the whisky distilling process – see Section 3.1.
2. The **ranking of factors** is used to confirm and/or prioritise the factors to be discussed in the vulnerability workshop – see Section 3.2.
3. The **susceptibility indicators** quantify the magnitudes and spatial extents of the factors for both the present and future (next 20 years) – Section 3.3.
4. The stakeholders' **perception of past and future trends** was also collected by the pre-workshop questionnaire, see Section 3.4, augmenting the data from the susceptibility indicators.
5. The **sensitivity** of the **water quantity** used by the **whisky value chain** to each of the **factors** was elicited in the vulnerability workshop and is presented in Section 3.5.
6. Three interpretations of **adaptive capacity mechanisms** are presented in Section 3.6. These were identified in the interviews and deliberated on in the vulnerability workshop, but their quantification was undertaken by the research team. The three interpretations are the **viability of the mechanisms** (i.e., potential limitations on their use), **who needs to participate**, and an overall assessment of their **potential to mitigate the impacts** on water quantity caused by the factors.

3.1 Factor descriptions and their components

Derived from interviews with experts and stakeholders the **factors** define a set of phenomena that and affect the water quantity reference variable. Some of these could formally be described as **drivers** – since the way in which they change is determined is beyond the boundaries of the MRL – e.g., change in climate. Others would more formally be **pressures** (e.g., incidence of flooding), **states** (peat soil conditions), **impacts** or **responses** (e.g., land use change) or involve **distributional** issues (e.g., over-exploitation of water resources).

Table 1 : Factor descriptions and their components

Factor	Description and Components
Rainfall	Changes to the overall annual average rainfall. This impacts on the surface and groundwater quantity available for use within the whisky (process water) and a larger volume of water used only for cooling. There is also the need to also consider evapotranspiration loss to the atmosphere for a net input to surface and ground water funds.
Snowmelt	Changes in the snowfall regime, which impacts on the intensity and frequency of snow melt. Snow is a good means of longer-term water storage and slow release which is necessary for year-round abstraction for process and cooling uses. Conversely large amounts of non-melting snow may also reduce water quantity in winter. Rate of melt may also be associated with flooding events (dealt with separately).

Factor	Description and Components
Air Temperature	Average annual air temperature. Water temperature is the direct driver for the reference variable but is infrequently measured, not mapped and there are no future projections, so air temperature is used here as a proxy.
Water Temperature	Average annual surface water temperature. Higher water temperatures in sources used for abstraction for cooling purposes means more volume must be abstracted. Higher water temperature may also influence the fermentation processes.
Extreme Events	Changes in the frequency and/or extent of flooding and drought. Climatic drought influences the availability of surface water (and potentially spring water) necessary for year-round abstraction for process and cooling in whisky distilling. The main current risk is to cooling water volumes but future availability of process water in also a concern. Floods can damage the physical infrastructure of the distilleries; and increase the sediment in the water intake.
Peat Soil Condition	The ability of peat soils to function as water stores, buffering higher inputs and minimising low flows at other times. Changes in the extent of vegetation cover loss that leaves soil vulnerable to erosion, being washed into surface waters during intense rain fall events, and potentially entering the distillery water intake.
Muirburn	Extent and intensity of muirburn influences vegetation cover, water retention and potentially drainage (see the Peat Soil Condition driver). This can lead to more sediment or dissolved organic carbon entering the surface water, and potentially the distillery water intake. This driver was discussed in relation to water quality which by the completion of the analysis was seen as less vulnerable due to the sources used and the degree of control possible in the distilling processes.
Land Use Change	A change in land cover, use or management, in particular the change from rough grazing to forestry. Depending on the location, type and management of the forestry, this can have impacts on the soil-water balance (positive or negative) with implications for surface and ground water flows. This can have impacts on the availability of water for abstraction. Land use/management influences on water quality and quantity can be both diffuse and indirect (e.g., via the mix of land use over the catchment as a whole) or localised and direct (e.g., via riparian woodlands creating microclimates to reduce water temperatures).
Over Exploitation of Water Resources	Extraction of surface water or groundwater beyond the sustainable limit, meaning that the quantity of water available for distilleries (and other users) to abstract is limited to retain environmental flows on which river ecosystems depend.

3.2 Ranking of factors

This step, as part of the stakeholder questionnaire, is intended to ensure that the vulnerability workshop focusses on the key factors. Timing and response rates meant that most of the decision on factors and susceptibility indicators needed to be made before these data were available. The ranking was thus used mainly to confirm decisions and indeed data on rankings was also collected from vulnerability workshop participants who had not previously responded to the stakeholder questionnaire.

The ranking of the factors shown in Table 2 confirms with expectations and factor prioritising from the interviews and reflects discussions in the vulnerability workshop. Overall, the high average values confirm that the factors discussed were relevant. The summary statistics in Table 2 are helpful in showing the degree of concern per factor for the reference variable. The highest ranking comes from the most direct factor (over exploitation), where the impacts of a range of factors are brought together to influence the operation of the distilleries. These factors include both the size of the fund or flow of water but also who else may want/need to use it. The other high ranked factors relate to the biophysical aspects of the size of water flows (rainfall, floods, and droughts) and the key quality (temperature). It is worth noting that for all factors there are fairly widely varying degrees of concern, perhaps reflecting differing stakeholder perspectives or priorities. Lower rankings tend to be associated with either factors that underpin the capability of the land to retain water (snow melt or peat soil condition) or influence its quality (land use change). The lowest ranked factors are either proxies (air temperature) or have effects that can be readily mitigated *within* the industry (muirburn).

Table 2 : Ranking of factors

Factor	Min	Average	Max	Range
Over Exploitation of Water Resources	3	3.6	5	3
Rainfall	2	3.5	5	4
Water Temperature	2	3.5	5	4
Extreme Events	2	3.3	5	4
Snowmelt	1	3.2	4	4
Peat Soil Condition	2	3.2	4	3
Land Use Change	2	3.1	4	3
Air Temperature	2	2.9	5	4
Muirburn	1	2.0	3	3

3.3 Susceptibility Indicators

Susceptibility indicators are the way in which the pressures or other effects of the factors are defined and quantified. This translates the semantic relationships elicited in the interview phase of research into a formal quantified representation of the factors (i.e., as data visualised as charts and map). These then serve to inform the deliberations of the vulnerability workshop.

3.3.1 Rainfall

Indicators selected

1. **Rainfall annual totals and seasonality** for the MRL as a whole – 1961-1990, 2020 and 2050 RCP 4.5 and 8.5 – from summary Evora data – see Figure 9.
2. **Mean annual rainfall map** - 1km grid using downscaled UKCIP18 RCM data – 1961-90 and 2019-50 and difference map – see Figure 10.
3. **Rainfall erosivity change map** – derived from Evora data – see Figure 11.
4. **Evapotranspiration**, annual totals time series (1960-2050) for two example sub-catchments derived from UKCIP18 data and remote sensed solar radiation data – see Figure 12.

Comments

Note the limitations of rainfall alone as an indicator – the phenomena of interest (drought, floods, water availability) are ultimately driven by rainfall but combined with other phenomena to generate complex patterns of change in funds and flows of water and its quality (e.g., temperature).

Gaps

No complete hydrological model that can generate site specific flows (surface and groundwater).

3.3.2 Snowmelt

Indicators selected

1. **Snow cover – observed** - days at a range of elevation for areas within the Cairngorms National Park (a substantial overlap with the MRL). Part of a ClimateXChange report 2019 – see Figure 13.
2. **Snow cover – future** – as above but modelled to 2080 using UKCIP18 RCM data – see Figure 14.

Comments

Availability of snow melt can maintain flow in early summer but there were concerns of very rapid spring snowmelt leading to flooding and snow having the potential to mean low flows in very cold years.

Gaps

Snow days was a proxy for snow volume and had no quantified relation to river flows or flood events.

3.3.3 Air Temperature

Indicators selected

1. **Mean annual** and **seasonal temperatures**;
2. **maximum seasonal temperatures** and
3. **warmest and coldest month** – all for the MRL for 1961-90, 2020 and 2050 RCM 4.5 and 8.5, derived from Evora data – see Figure 15.

Comments

Air temperature is often an indirect cause of impact – e.g., via changing water temperatures so some translation required but it is a relatively simple driver and better modelled than other more direct drivers. Experts were able to translate from air temperatures into other impacts. Direct effects are the potential need for more cooling (draw on water quantity) or increased energy use via refrigeration and some potential for the need to change aspects of the fermentation process (which are being planned for).

Gaps

The main gap is the lack of quantitative modelling directly linking air temperatures with specific impacts. Solar radiation may be a better predictor for some impacts but is typically much less readily available especially as maps and future modelling of localised solar radiation is more uncertain.

3.3.4 Water Temperature

Indicators selected

1. **Mean water temperature** and
2. **maximum water temperatures** for four locations on fishing beats on the Spey river, 1912-2016, see Figure 16, showing the long-term rising trend – see Figure 17 from [Pohle et al 2019](), and further anecdotal evidence of much higher temperatures in headwaters of tributaries.

Comments

Warmer water means the need for larger volumes to achieve the same cooling so a potential impact even of water volumes stay the same or potentially compounding driver.

Gaps

Water temperature is a sparsely monitored variable and not available at all for many of the sub-catchments of importance – there is experimental use of drone-based monitoring to provide spatial data.

3.3.5 Extreme Events

Indicators selected

1. **Flood hazard – current** – map of most extensive area of flooding in the catchment, 1-in-10 year and 1 in 200 year events – source [SEPA]() – see Figure 18
2. **Flood hazard – future** (2080) – map as above but only for 1-in200 events, same source – see Figure 19.
3. **Drought hazard – current** – chart of daily soil water profiles for seven locations within sub-catchments with a range of soil types present – 1990-2000 time series highlighting days at Field/Saturated capacity or below Wilting point, derived from UKCIP18 1km historic data, remote sensed solar radiation data and Hutton soil mapping and databases - Figure 20.
4. **Drought hazard – future** – as above but using the 2040 to 2050 period – see Figure 21.
5. **Threat to private water supplies – future** – estimating of the risk to private water supplies using the levels of rainfall in 2018 as a benchmark (<the 20th percentile of the current rainfall distribution) and calculating the numbers of years in the future in which such levels of rainfall might occur – see the [report online]() and Figure 22.

Comments

There is inevitably some exposure to flooding hazards for distillery infrastructure given they draw water from rivers for cooling. The sites they occupy are though often away from flood plains as their historic use of water flow for motive power precluding them being located on the flood plain.

Gaps

Lack of a long time series of flow data for springs/boreholes or stream/rivers and how this relates to the abstraction needed and the maximum permitted share of flow that can be accessed. Dry years may not immediately (within the year) affect spring/borehole flows and the lags or compensating effects are not quantified.

3.3.6 Peat soil condition

Indicators selected

1. **Peat soil extent and condition** map by Aitkenhead et al – vector map for the MRL, highlighting where land use and drainage may mean peatlands need to be restored - source online report and see Figure 23

Comments

Restoring both the hydrological integrity of peatlands by blocking artificial drains and revegetating areas of bare soils were both seen as ways of storing greater reserves of rainfall to sustain streams and springs during later periods of lower rainfall. A secondary benefit was in reducing particulate matter in water and avoiding issues associated with dissolved organic carbon. The quantity effect was the more significant.

Gaps

The mapping of peat extent and condition needs to be improved (particularly on drainage status) – linking mechanistically (or even statistically) peatland conditions and water flow would be highly desirable.

3.3.7 Muirburn

Indicators selected

1. **Map of presence of muirburn at >50% of area** – 2018 - 200m grid for all rough grazing in holdings within the MRL with grouse butts present (indicating the likely practice of driven grouse shooting). Source – Hutton report (2019) – see Figure 24.
2. **Map of intensity of muirburn** – 2018 – 1km grid for the same coverage as above – an alternative visualisation highlighting the core areas where burning is most intensive – compatible with earlier studies – see Figure 25.
3. **Map of change in intensity of muirburn** – 2018 vs 2005-10 – comparison with an earlier analysis by RSPB – see Figure 26.

Comments

While there was a perception from the stakeholders that wildfires had increased and will increase, the narratives from interviews indicated that the current incidence is so low that it is not affecting nor expected to affect the water system. This is particularly the case since managed burning (muirburn) is practiced extensively.

Muirburn was seen as increasing in intensity but was not seen as a direct risk to water quantity or quality in the MLR. Where muirburn may be significant is if it militates against land users undertaking peatland restoration or makes it less effective – either hydrologically or in vegetation terms. Future heathland vegetation management will be necessary to avoid extensive and/or intensive wildfires and potential soil loss is subsequent periods when the soil is bare. This was not yet seen as a particularly significant risk by the distilling sector.

3.3.8 Land Use Change

Indicators selected

1. **Increase in woodland cover** – across three periods 1988 (baseline), 2010 and 2019, mapped from Land Cover of Scotland 1988, and National Forest Inventory (2010 and 2019) – map (vector) and summary stats – see Figure 27.

Comments

The key land use change identified in interviews was increase in forestry. Riparian forestry was seen as a key element in managing future water temperatures in the headwaters of the catchment. A positive role for trees in mitigating flooding by slowing water flows was also identified. The potential for trees to mean an increase evapotranspiration was noted with the need for the right trees in the right place emphasised.

Gaps

Lack of easily available models to make predictions of evapotranspiration estimates for new woodlands means the need to rely on qualitative judgements.

3.3.9 Over exploitation of water resources

Indicators selected

1. **Extent of production of whisky per distillery** – as a proxy for water demand - source Malt Whisky Yearbook 2021 – see Figure 28.
2. **Waterbodies WFD status for surface flows and levels** - for water bodies in the MRL for 2014, 2021 and estimated for 2027 and future, source SEPA – see Figure 29.
3. **Nature of the current pressures on surface water flows** – from WFD monitoring – source SEPA – see Figure 30.
4. **Water Well Locations** – across the MRL, for 2018, source British Geological Survey.

Comments

The importance of appropriate levels of water exploitation was seen as a key concern for the distilling industry (part of their social license to operate) while noting that this is a growing industry that, in some cases, is seeking to increase production substantially. The concern is mainly with availability of water for cooling processes (more often from rivers) not process water (more often from springs or boreholes). There was recognition of the need to maintain minimum ecological flows and that there were competing pressures in the catchment e.g., from agriculture, hydro-power, tourism and domestic use. The key point here was that process water is a tiny fraction of the total flow and that the cooling water is returned locally albeit potentially with a change in quality (via temperature increase). The dependence of some distilleries on quite localised sources i.e., small sub-catchments could mean that changes that are relatively modest at whole catchment level may have significant local impacts.

Gaps

Lack of long-term localised data and models to link other drivers to water flow were noted.

3.3.10 Other Drivers Considered

Pests, diseases and invasive species

From the interviews, it was determined that this driver was not important to the value chain or reference variable. Stakeholders mentioned some pests, diseases, and invasive species, but none connected to water quality and quantity for Speyside malt whisky. This same finding was verified in the pre-workshop questionnaire, with respondents identifying no connection to the water quality and quantity for Speyside malt whisky production.

Water pollution

It was anticipated that water quality would be a substantial concern for distillers, but most have private water supplies, some are landowners to control management in sub-catchments and the process water (that become part of whisky) is heated to steam as part of distilling. The low intensity and low input farming or sporting systems that dominate MRL also mean that there is a much lower threat from diffuse pollution (chemical or biological). The key risk is contamination of cooling towers by the *legionella* bacterium, but this risk is manageable. The distilling process is thus robust in the face of the levels of pollution present and anticipated so this driver wasn't pursued in the vulnerability workshop.

Demographic change

Numbers of residents and recreational and tourism visitors were noted as being potentially a key driver of demand for water and are thus a concern for distillers and for planners seeking to balance competing water uses – households, agriculture, hydro power, industry and services. The pressures are expected to increase but the impacts specifically relevant to the reference variable (water quantity) are dealt with under the Over exploitation of water resources driver (Section 3.3.9).

3.4 Perception of factor past and future trends

After the completion of the stakeholder interviews, the pre-workshop questionnaire gathered perceptions of past trends and future projections of the effects of the biophysical drivers on water quality and quantity that related to Speyside whisky production. With only five respondents to the questionnaire, any conclusions need to be carefully caveated, but in many cases, there are either research-based studies or expert knowledge that can confirm the trend, provide future projections, and reduce or quantify uncertainty.

Table 3 sorts the drivers by the degree of uncertainty on past trends (the count of respondents who could not or did not provide an answer) and then the degree of uncertainty on future trends (as for past trends).

The summary statistics indicate in most cases moderate (trend average = 0.5 - increased slightly), certain (uncertainty = 1) and continuing (Yes=4) increases for drivers like air temperature and thus also for water temperature and the extreme events of floods and droughts. For some drivers while there is low apparent uncertainty (uncertainty = 1) and a no trend average, this average reflects disagreement on the direction of trends e.g., Peat Soil Conditions and Snowmelt, have minimums of -0.5 (declined slightly), and maximums of 0.5 and 1 (slight or sharp increase). For the over exploitation of water resources (a key driver in the Factor Ranking above), there was also disagreement in direction of trend, and a perception for one of the stakeholders that overexploitation had sharpy increased (max = 1). The views here may need to be further investigated, particularly in the light of the deliberations within the vulnerability workshop. For rainfall there was greater uncertainty (3) as the lived experience within the MRL would, depending on location, give differing perceptions of trend (the SW is increasing and the NE decreasing).

Table 3 : Perception of factor past and future trends

	Trend				Future - trend continues?		
Factor	**Average**	**Min**	**Max**	**Uncertainty**	**Yes**	**No**	**Uncertainty**
Air Temperature	0.5	0.5	0.5	1	4	0	1
Water Temperature	0.5	0.5	0.5	1	4	0	1
Extreme Events	0.6	0.5	1	1	4	0	1
Peat Soil Condition	0.0	-0.5	0.5	1	3	1	1
Snowmelt	0.0	-0.5	1	1	3	0	2
Land Use Change	0.3	0.0	0.5	2	3	0	2
Over Exploitation of Water Resources	0.3	-0.5	1	2	3	0	2
Muirburn	0.5	0.5	0.5	3	1	1	3
Rainfall	-0.3	-0.5	0	3	1	0	4

3.5 Sensitivity of water quantity for distilling to the factors

The sensitivity results conform with the expectations generated by ranking and trend analyses. Again, in Table 4, the drivers are ordered according to uncertainty (low/high and then by average value. The table shows an overall pattern of negative effects (indicated by the positive numbers) – with only two cases in which potentially positive outcomes of the drivers are noted. The stakeholders were most certain of the impacts for over exploitation, extreme events and water temperatures but with some variability in the degree of impact (0.33-0.66). Where there was most uncertainty was in some cases with more complex drivers such as land use change, where the range of options, and their relative magnitudes, made it harder to come to conclusions. For others such as snow melt, there were different emphases on interpreting the driver, generating the widest divergence in anticipated sensitivity. Overall, the greatest sensitivity was assigned to those drivers with the clearest mechanistic links to the refence variable.

Table 4 : Sensitivity of water quantity to factors

Driver	Average	Min	Max	Uncertainty
Over Exploitation of Water Resources	0.53	0.33	0.66	2
Extreme Events	0.46	0.33	0.66	2
Water Temperature	0.39	0.33	0.66	2
Air Temperature	0.46	0.33	0.66	3
Rainfall	0.33	0.00	0.66	3
Peat Soil Condition	0.20	-0.33	0.66	3
Land Use Change	0.33	0.33	0.33	4
Snowmelt	0.20	-0.33	0.66	4
Muirburn	0.17	0.00	0.33	4

3.6 Adaptive capacity mechanisms

3.6.1 Viability of mechanisms

The judgements on viability are presented in Table 5 – ordered by counts of high then medium values. What this reveals, is an overall pattern in which there is a contrast (or even tension) between what is socially acceptable (or desirable) and what is economically viable. The thinking is that the funding of several of the nature-based mitigation mechanisms is limited, either overall or in relation to the challenges faced. There is also limited prospect of these becoming market-based, meaning they will continue to rely on public sector funding in an era where this is becoming increasingly difficult to generate.

Table 5 : Viability of adaptive capacity mechanisms

	VIABILITY			
Adaptive Mechanisms	Economic Viability	Technical Viability	Environmental Benefit	Social Acceptability
Collaborative water management	Low	Medium	High	High
Distillery water management	High	High	Low	Medium
Sustainable land management / Land use change	Low	Low	High	High
Rewetting peatlands	Low	Medium	Medium	High
Peatland habitat restoration	Low	Medium	Medium	High
Instream restoration	Low	Medium	Medium	High
Riparian management	Low	Medium	Medium	High
Managing infrastructure	Medium	Medium	Medium	Medium

An interesting contrast exists between the top two mechanisms where the distillery water management can draw on the resources of a successful industry and has viable engineering options, whereas collaborative water management has the most potential to address the key issue of over-exploitation and is endorsed as desirable by a range of stakeholders but has questions on its economic and technical viability. It is worth noting that the value for environmental benefit of the distillery management is low only in the context of the catchment as whole, since the permanent water uptake by distillers is small and the main issue of concern is the temperature of returned water. Deliberation also highlighted that the rewetting peatlands mechanism should be extended in scope to cover all wetlands (a more extentive land area with the potential to see more impact on water quantity regulation).

3.6.2 Who needs to participate?

The analysis of who needs to participate highlighted several definitional questions for unconventional value chains. In particular, the analysis highlighted that except where the distillery owner is also a land manager (and even then, only in some cases), there is a dependency between independent agents within the MRL with the quantity and quality of water depending at least to some degree on how land use is practiced. Delivery of adaptation therefore depends not on cooperatives in the sense of organisations processing or retailing agricultural products but on cooperation that may be organic and self-organising or facilitated by third parties and reliant on external funding. The nature of the works needed for the mitigations proposed means that there will be the need for specialist contractors or the (re)training of existing workers.

3.6.3 Potential of mitigation of impacts

The analyses of potential for mitigating impacts were informed by the stakeholder interviews, deliberation in the vulnerability workshop and by expert judgements from Hutton staff. Overall, the key take away is that there is rarely a driver for which it is possible to envisage a complete mitigation of impacts with single "silver bullet" measure. 37 of 72 combinations of Adaptive Mechanism and Drivers have slight effects individually – see the cells of Table 6). The cases where complete reduction is possible to envisage (n=4), tend to be where one agent has the decision-making control and the resources available to mitigate and Even in this case mitigation is usually only possible for particular issues, and may still have significant financial implications. The implication of this overall pattern is the need for stakeholders to cooperate to take multiple, layered, small scale actions across the MRL, hypothesising that when considered in aggregate these are more likely to be resilient, reinforcing, and synergistic.

Table 6 summarises the details of the impact reduction by driver and by adaptive mechanism. The table is ordered by counts of complete, moderate, and slight reductions for both adaptive mechanisms and drivers. The most effective measures across the range of drivers are thus in the top left the least bottom right (noting of course that this only their potential to mitigate the negative consequences of driver on water quantity for the distilling industry value chain in the MRL).

Table 6 : Potential of adaptive mechanisms to mitigate impacts

	Adaptive Mechanisms								
Potential	Distillery water management	Collaborative Water Management	Managing Infrastructure	Peatland Habitat Restoration	Riparian Management	Sustainable Land Management / Land Use Change	Rewetting Peatlands	Instream Restoration	**All Mechanisms**
Factors									
Rainfall	Complete reduction	Moderate reduction	Moderate reduction	Slight reduction	Slight reduction	Slight reduction	Slight reduction	Does not affect	
Over Exploitation of Water Resources	Moderate reduction	Complete reduction	Moderate reduction	Slight reduction	Does not affect	Slight reduction	Slight reduction	Slight reduction	
Land Use Change	Complete reduction	Slight reduction	Does not affect	Moderate reduction	Slight reduction	Moderate reduction	Slight reduction	Slight reduction	
Extreme Events	Complete reduction	Moderate reduction	Slight reduction	Slight reduction	Slight reduction	Slight reduction	Slight reduction	Slight reduction	
Snowmelt	Complete reduction	Slight reduction	Slight reduction	Slight reduction	Slight reduction	Does not affect	Slight reduction	Does not affect	
Water Temperature	Slight reduction	Slight reduction	Does not affect	Slight reduction	Moderate reduction	Does not affect	Does not affect	Slight reduction	
Peat Soil Condition	Does not affect	Does not affect	Does not affect	Slight reduction	Slight reduction	Slight reduction	Slight reduction	Does not affect	
Air Temperature	Slight reduction	Slight reduction	Does not affect	Slight reduction	Does not affect	Does not affect	Does not affect	Does not affect	
Muirburn	Does not affect	Does not affect	Does not affect	Does not affect	Does not affect	Slight reduction	Slight reduction	Does not affect	
All Drivers									

The sparkline profiles (miniature charts on the bottom row) highlight the range of drivers to which the mechanism is relevant and the sparklines in the rightmost column summarise the mix of potential for each driver of all the adaptive mechanisms considered. The first summary highlights where an adaptive mechanism may be helpful in mitigating the impacts of several drivers, e.g., distillery water management and collaborative water management arrangements are likely effective across most of the key drivers. The second highlights where there may be synergies between adaptive mechanisms, for example collaborative water management and managing infrastructure (beyond distillery plant) may well synergise with distillery water management in dealing with rainfall and over exploitation. It is also worth noting though, that even when the individual adaption mechanisms potentials are assessed as only slight, then when there are lots of relevant options, as for rainfall, it may be possible that enacting a mix of several of these measures, each individually at smaller scale, may be effective, efficient, feasible and resilient.

4 Next Steps

The outputs within this report have been shared with University of Cordoba researchers leading the task delivering an analysis of the vulnerability and sensitivity of mountain areas across Europe, with results due by August 2022. The Hutton research team will also use the results to in our understanding of the value chain within the MOVING project as well as other connected research projects. There will be a workshop on the current performance of the value chain, incorporating all aspects not just environmental change, in Spring 2022.

5 Appendix – Slides used in the vulnerability workshop

5.1 Introductory slides

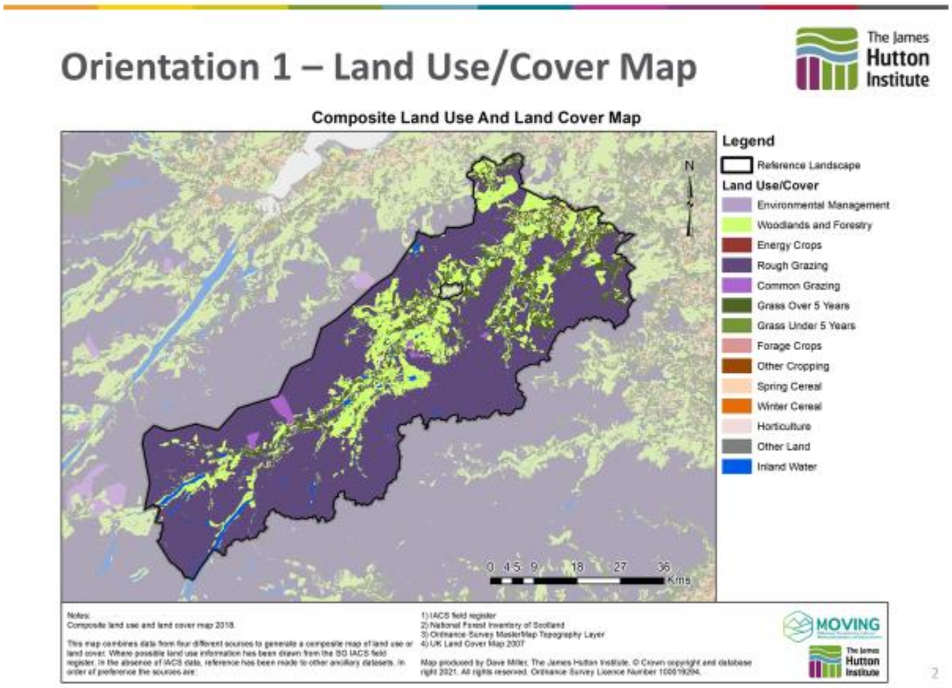


Figure 3 - Land Use/Cover

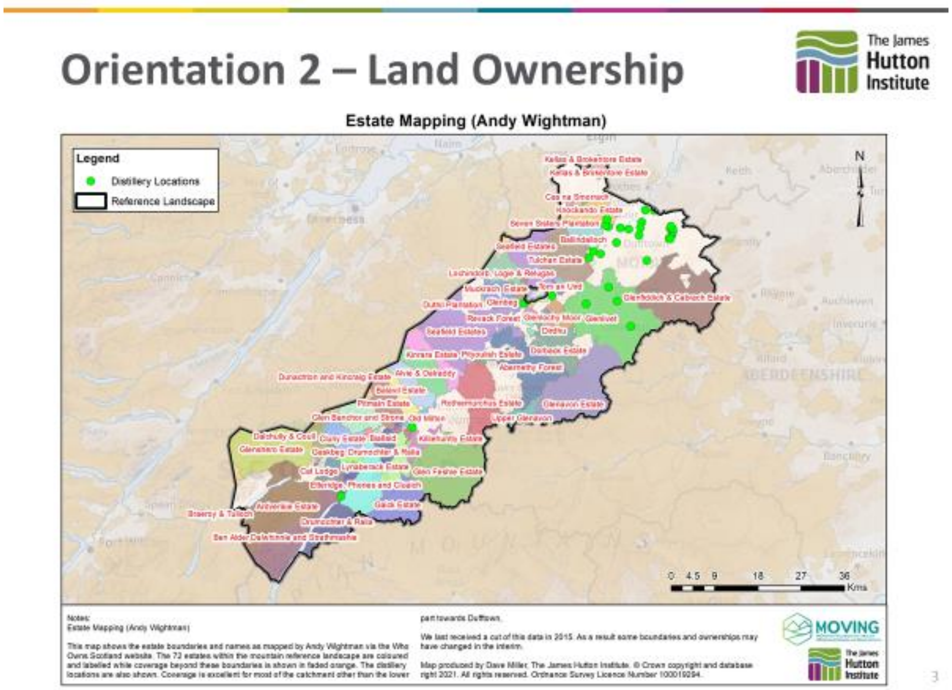


Figure 4 - Land Ownership

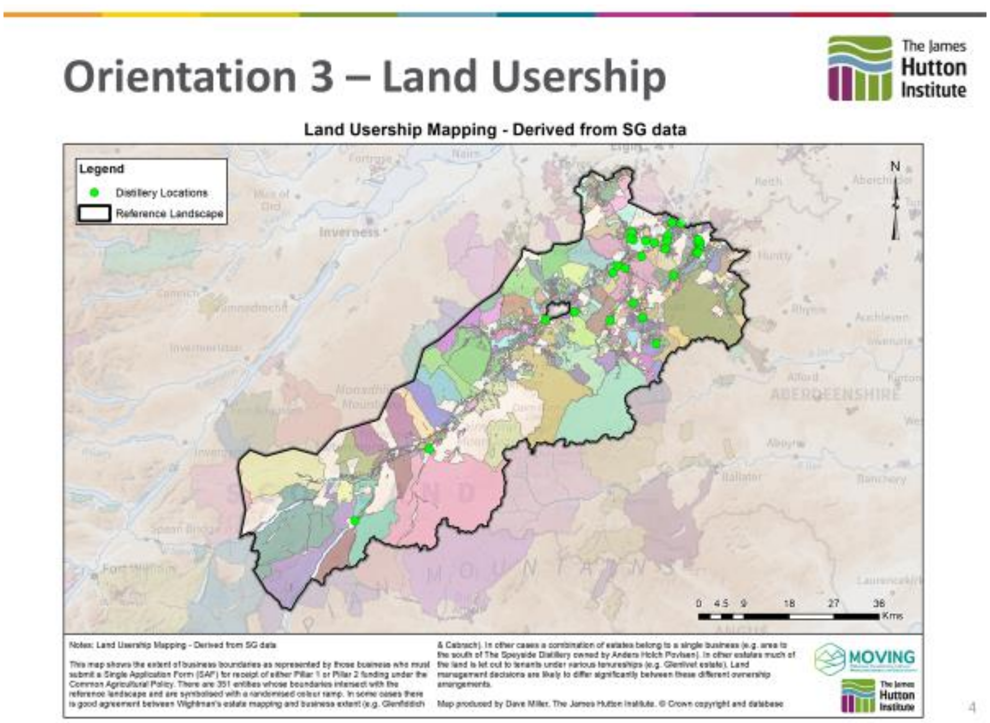


Figure 5 - Land Usership

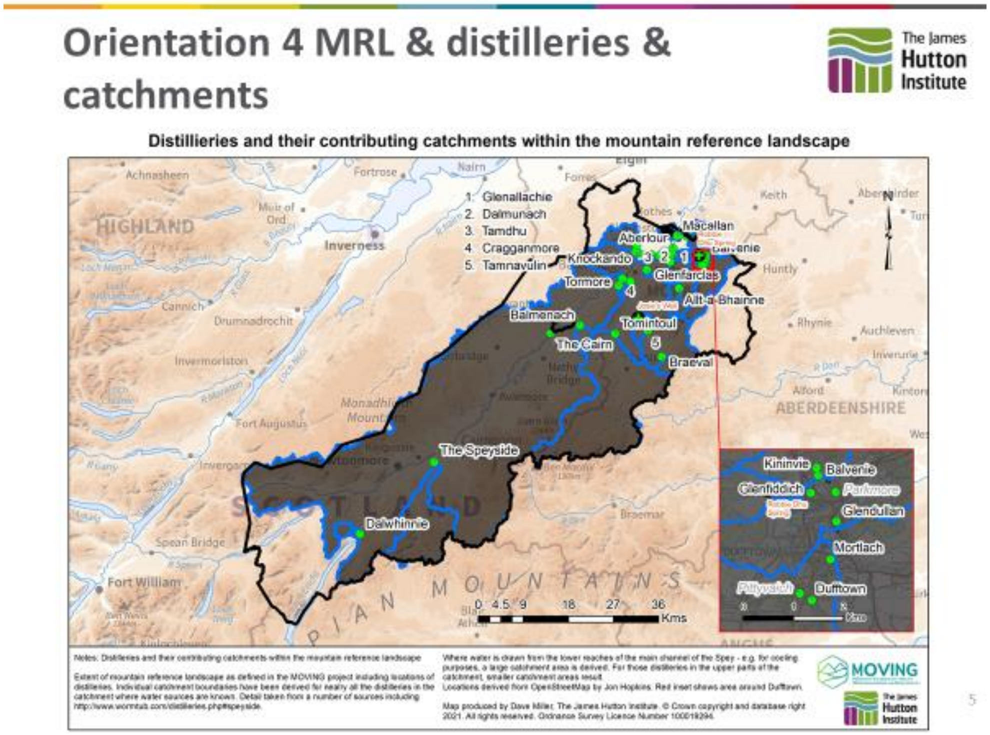


Figure 6 - Distilleries and Catchments

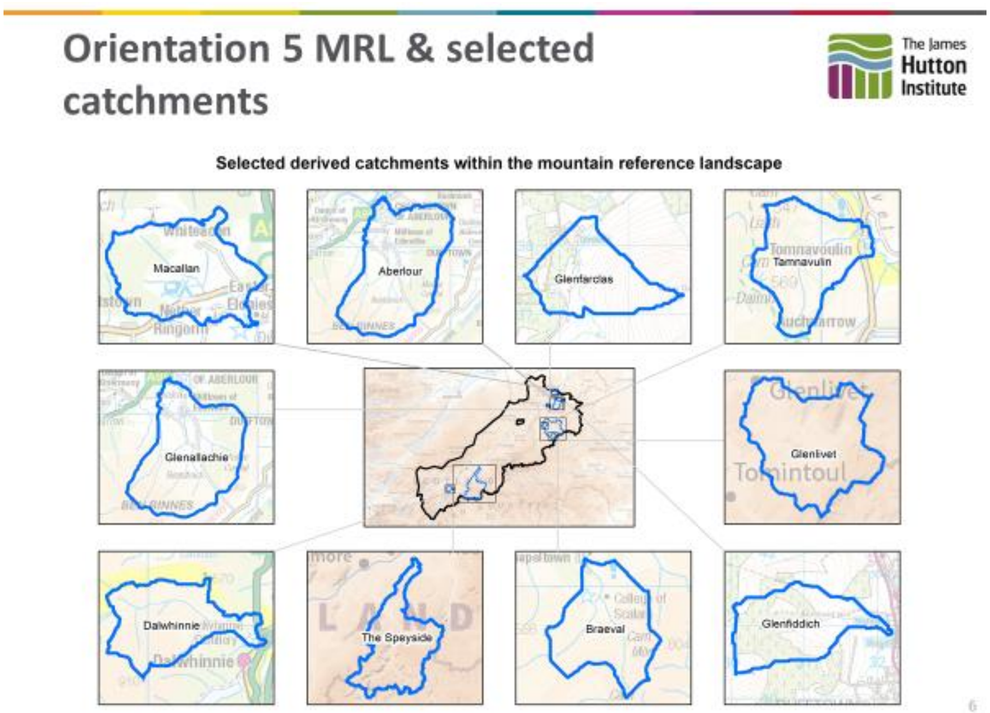


Figure 7 - Catchments for selected distilleries

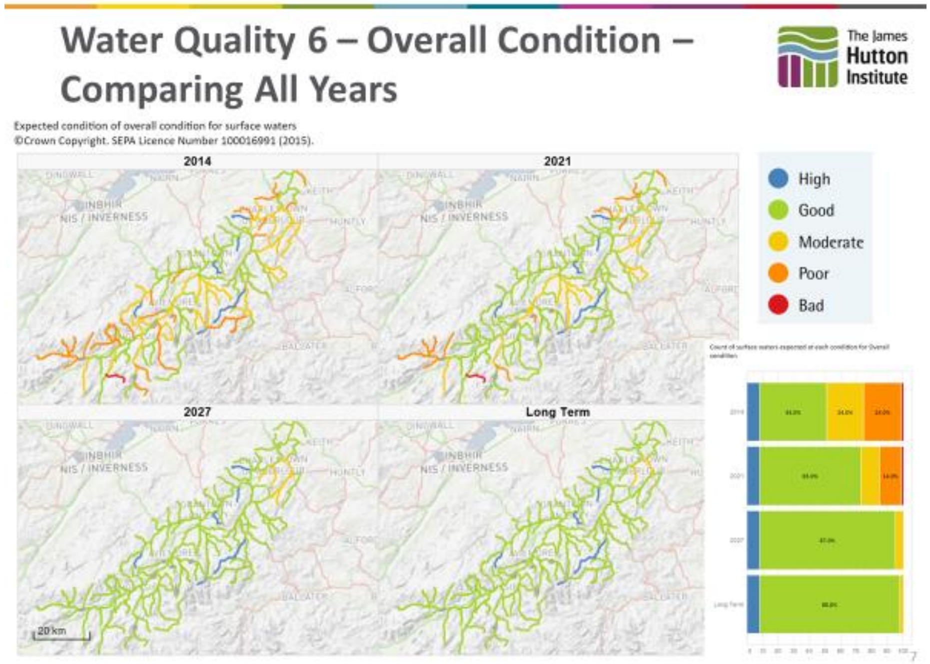


Figure 8 - WFD status for waterbodies in the MRL over time

5.2 Rainfall

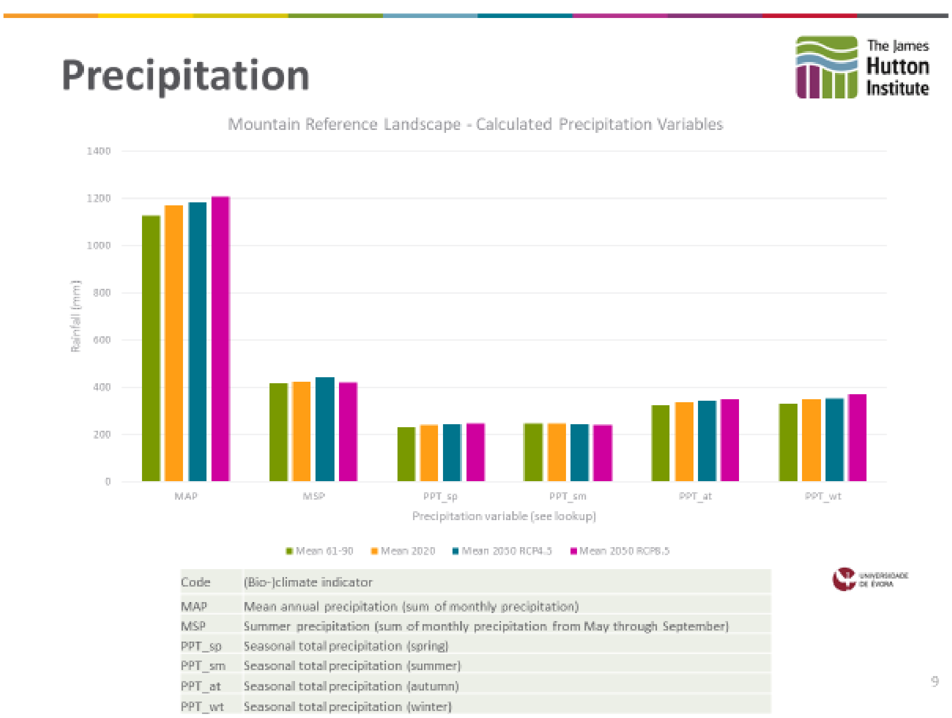


Figure 9 – Precipitation summary for MRL.

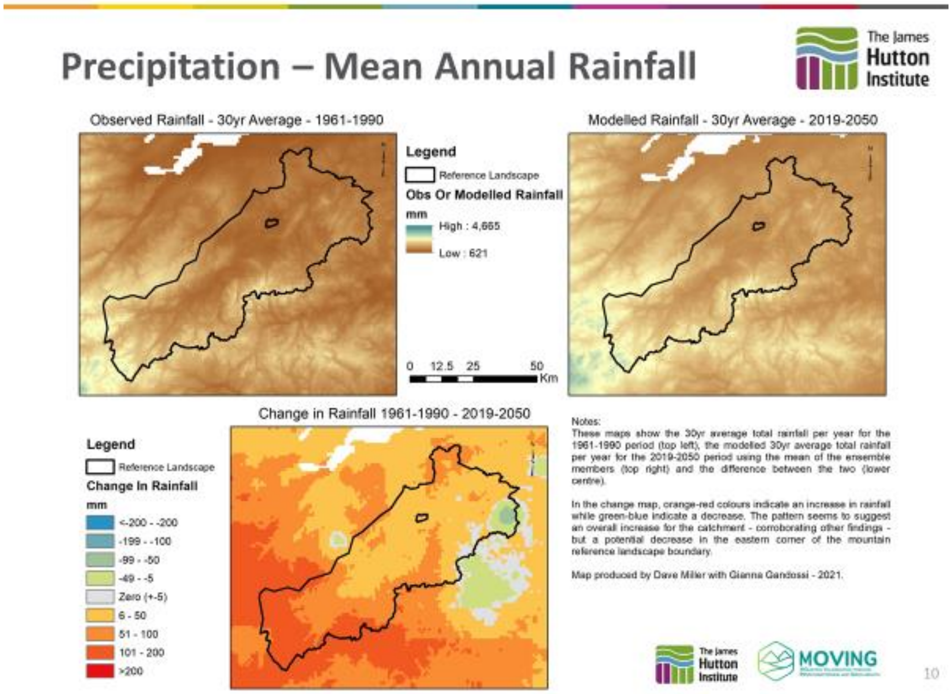


Figure 10 – Precipitation mapping.

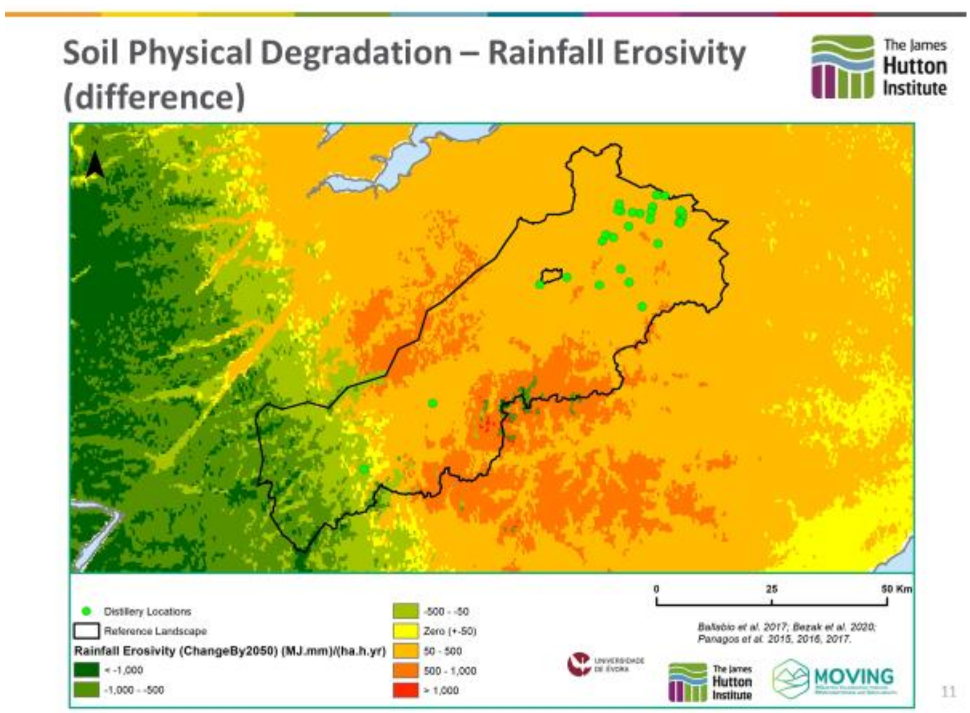


Figure 11 - Rainfall erosivity change

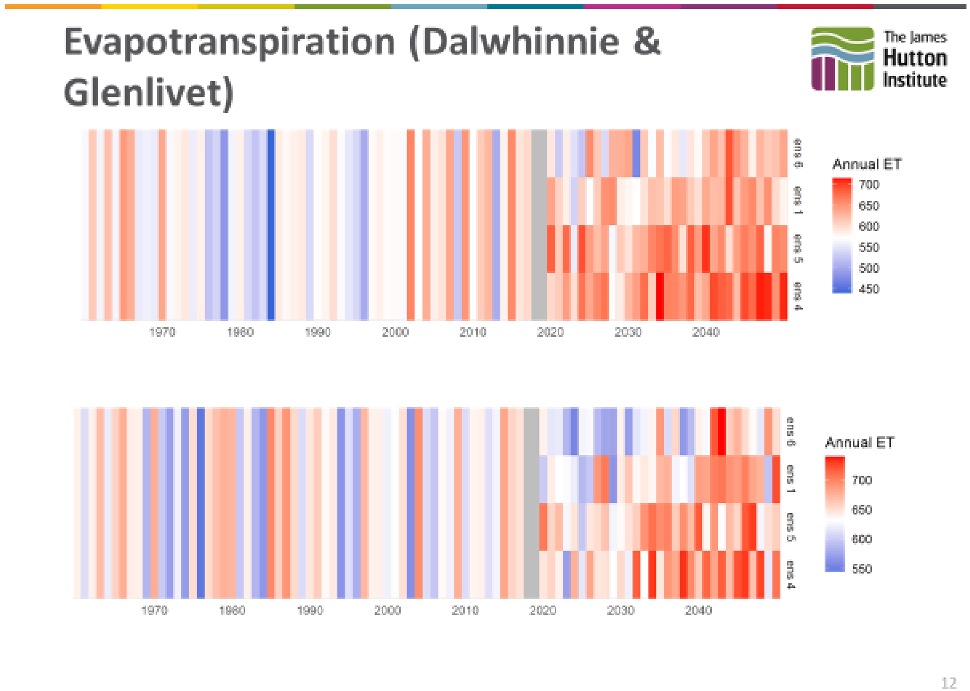


Figure 12 – Evapotranspiration

5.3 Snowmelt

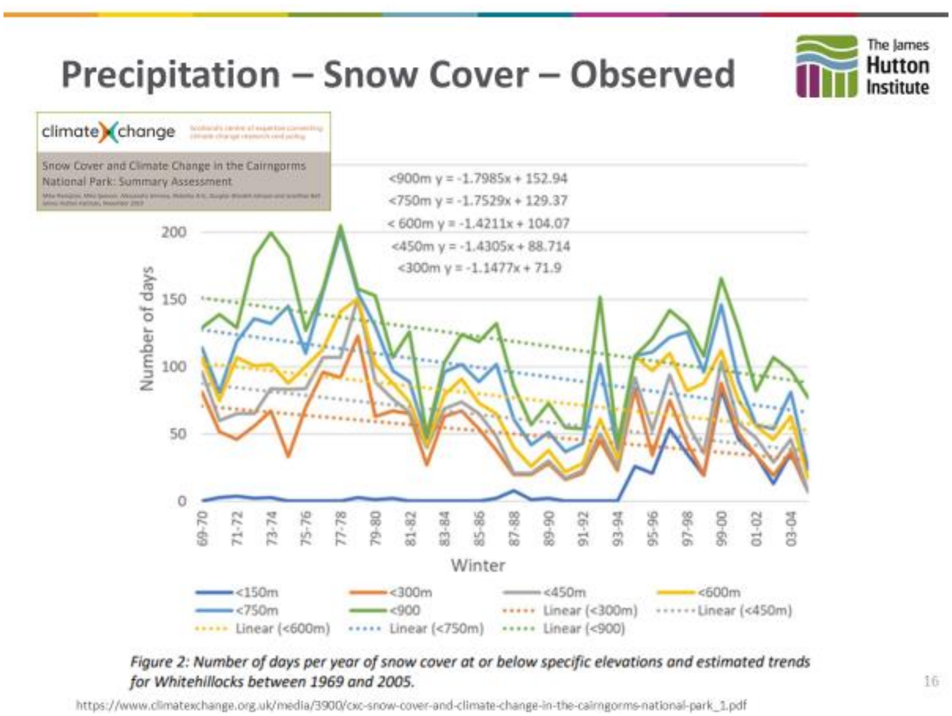


Figure 13 - snow cover – observed

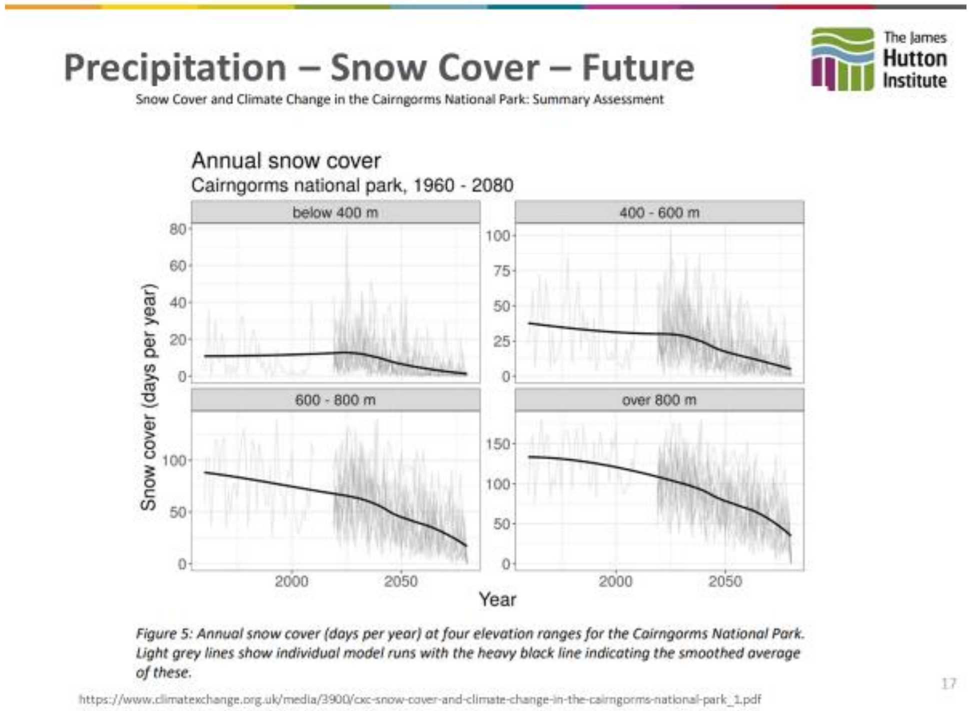


Figure 14 - snow cover – future

5.4 Air Temperature

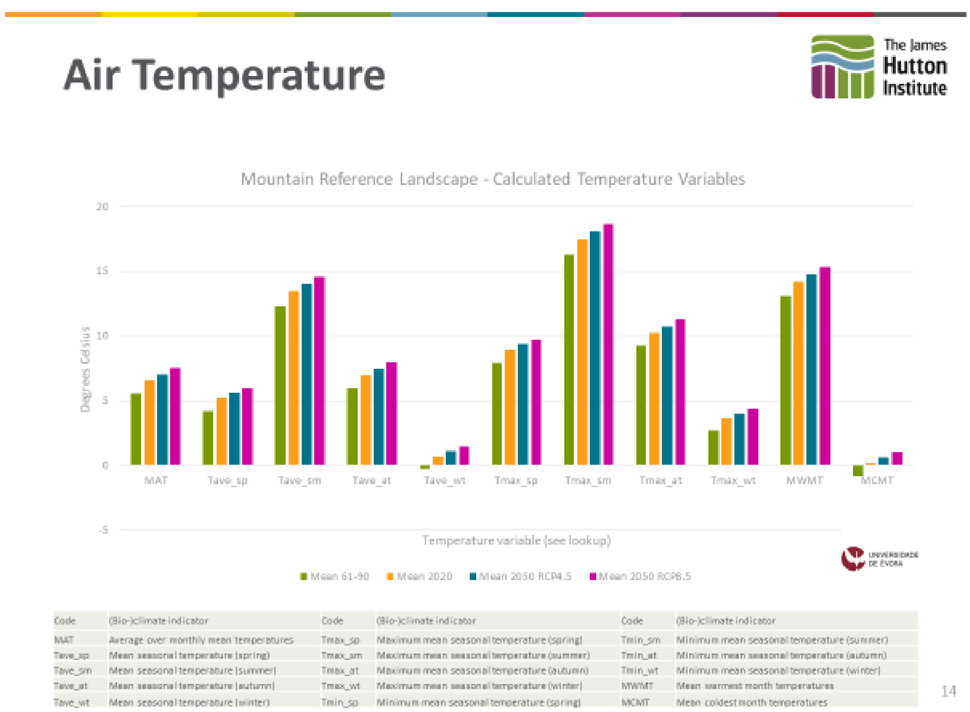


Figure 15 - Air temperature

5.5 Water Temperature

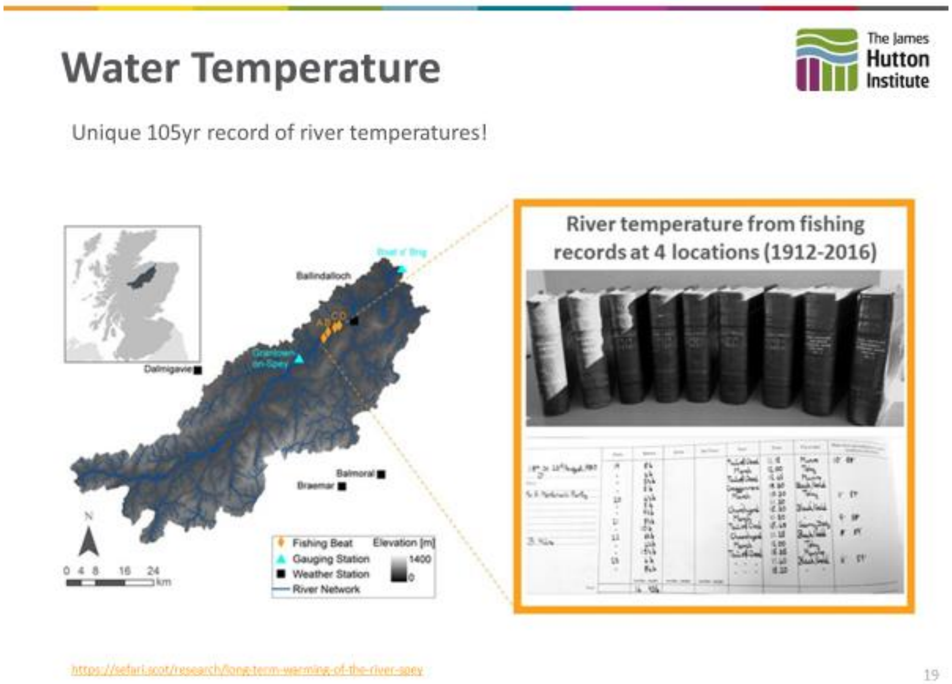


Figure 16: water temperature – sources

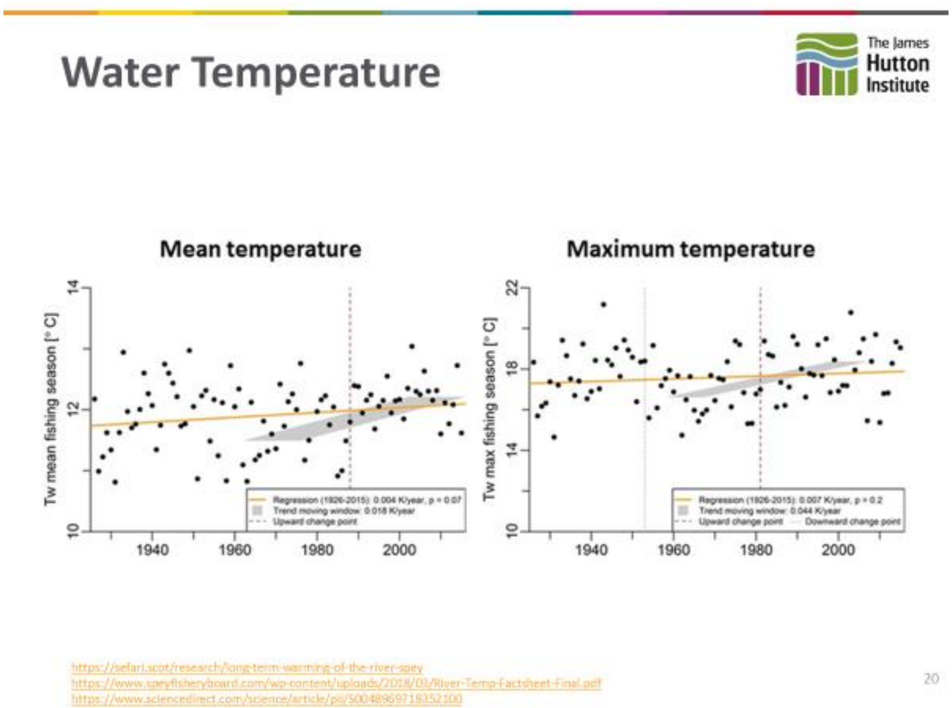


Figure 17: water temperature mean and maximum

5.6 Extreme Events

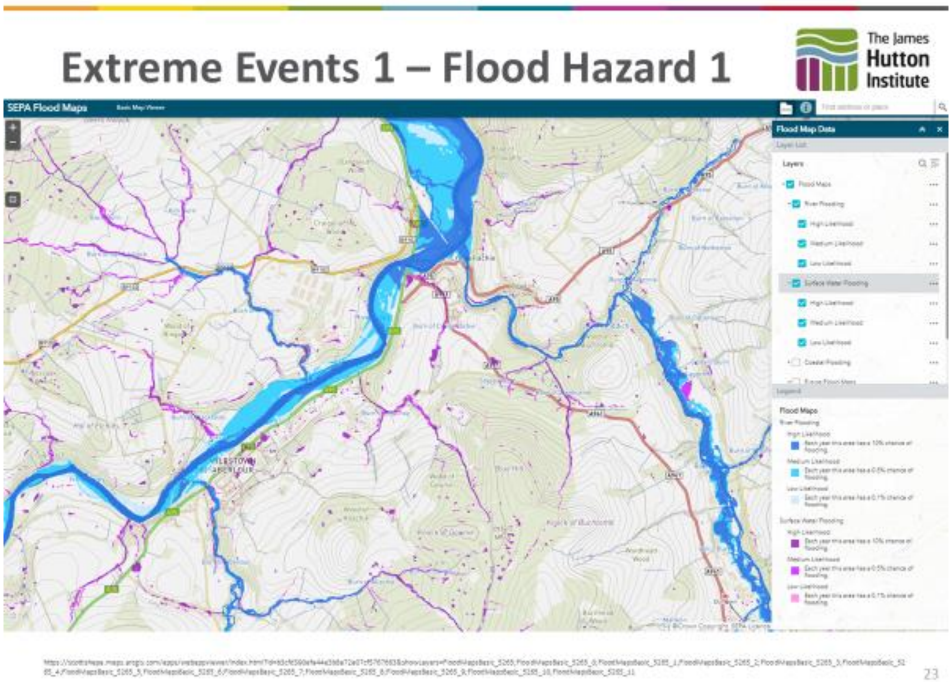


Figure 18: Current flood hazard map

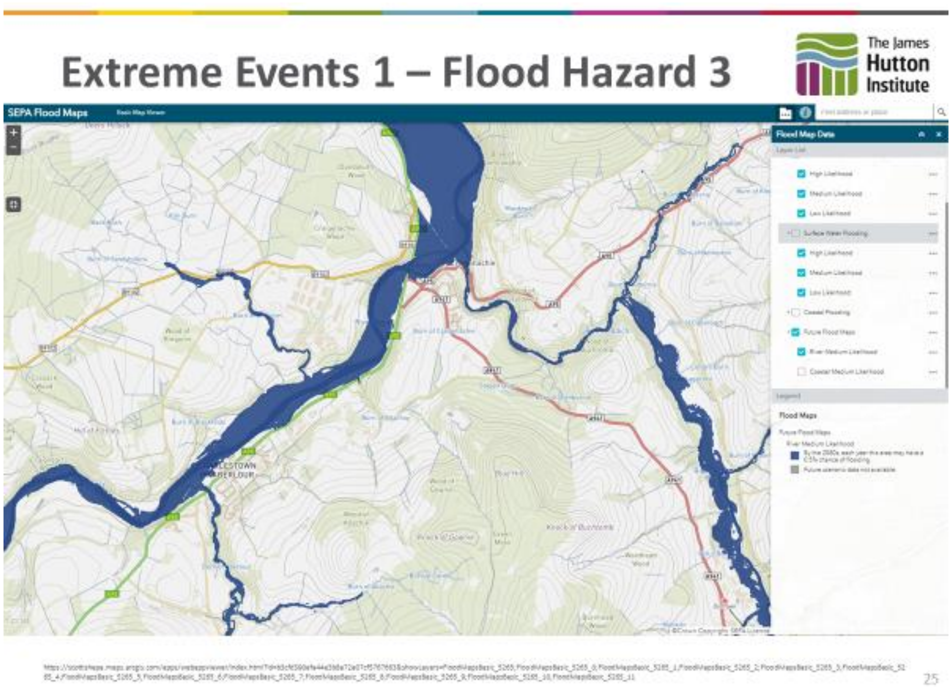


Figure 19 - Future flood hazard map

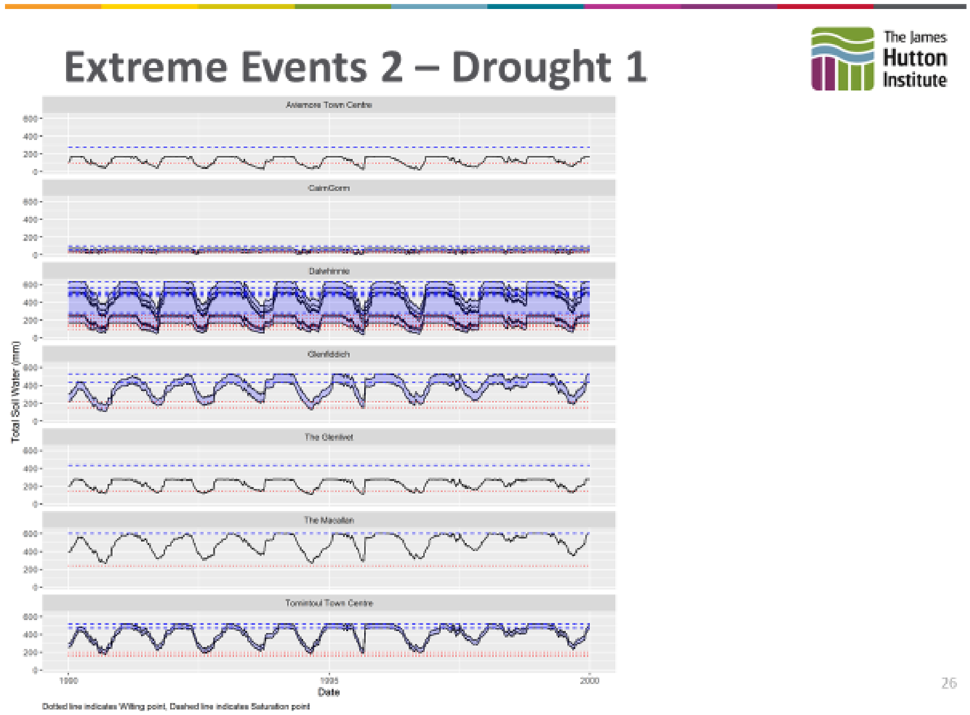


Figure 20 - Soil moisture regimes - 1990-2000

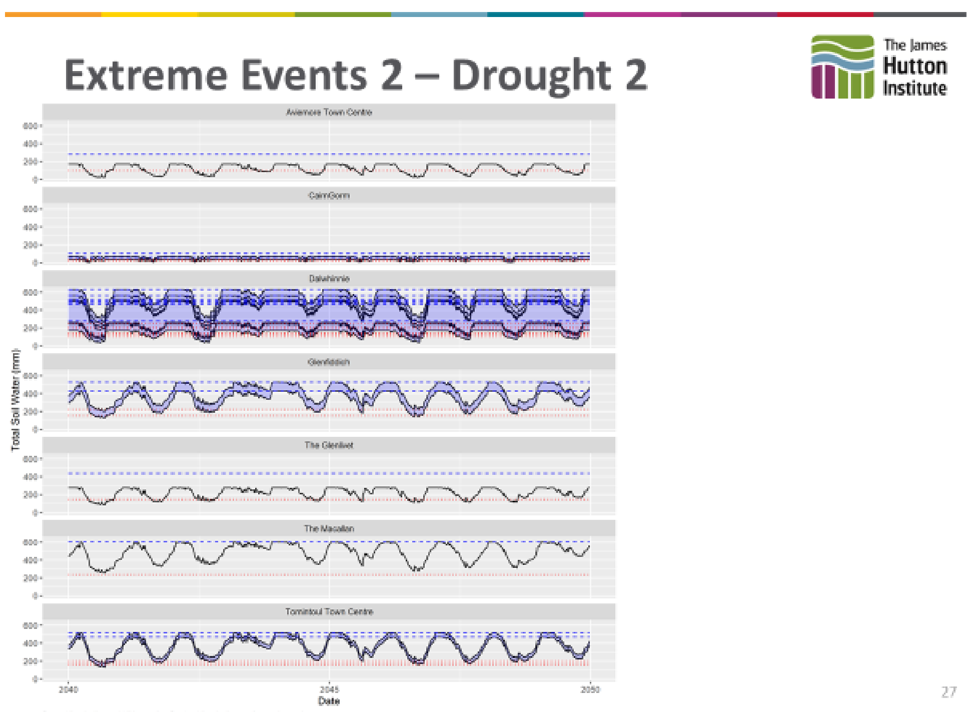


Figure 21 - Soil moisture regime - 2040-2050 scenario using UKCIP18

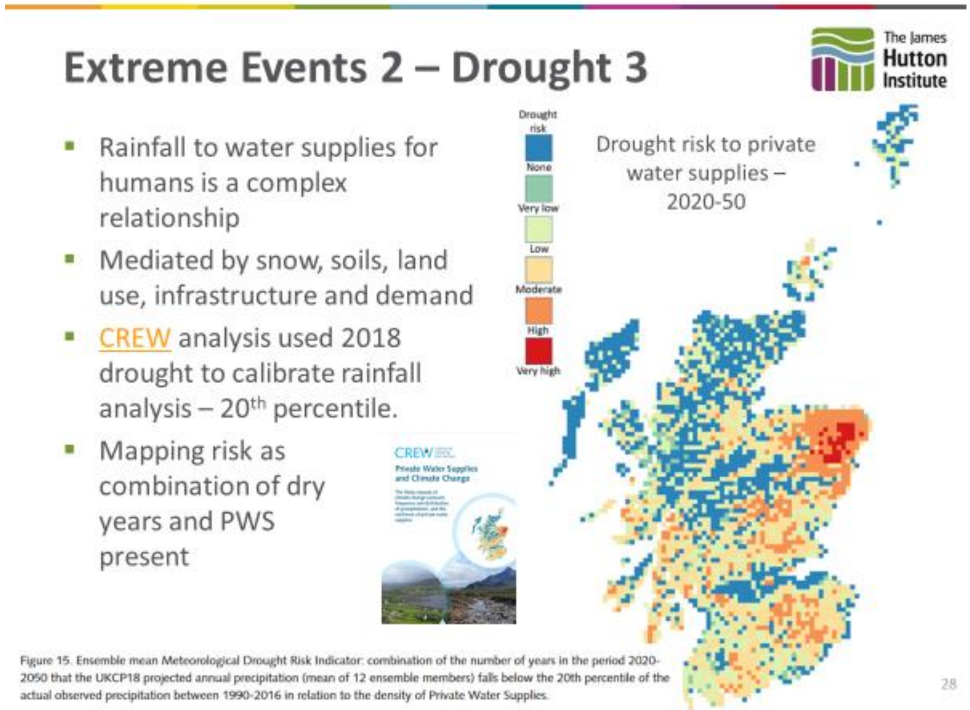


Figure 22: risk to private water supplies

5.7 Peat Soil Conditions

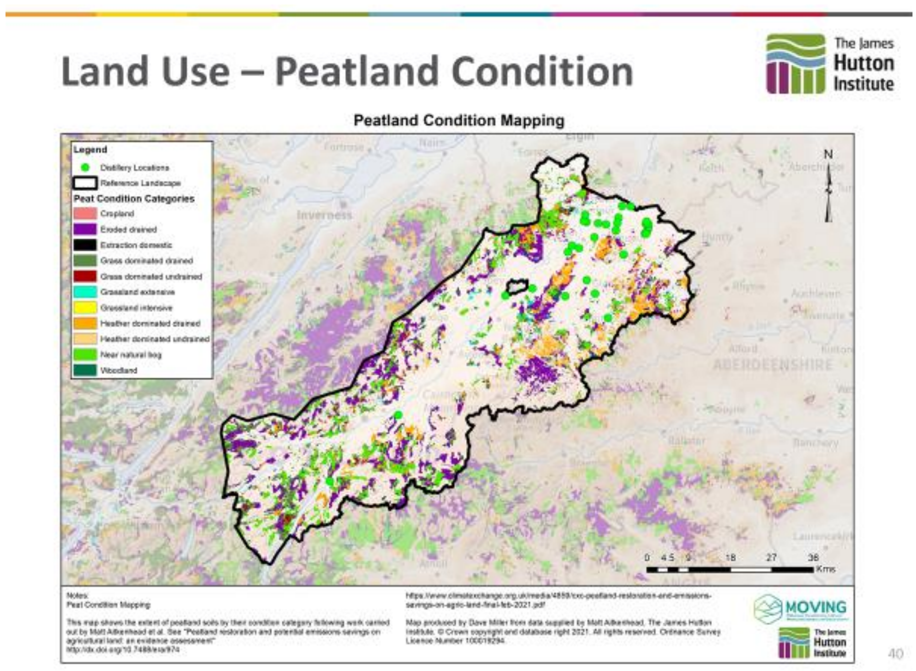


Figure 23: Peat Condition

5.8 Muirburn

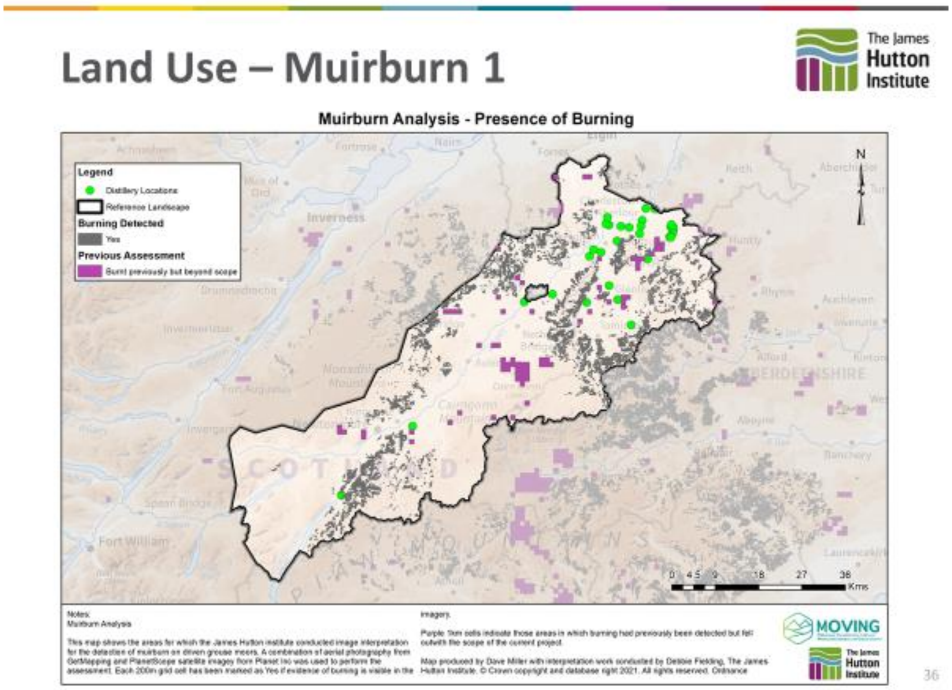


Figure 24 - Muirburn presence

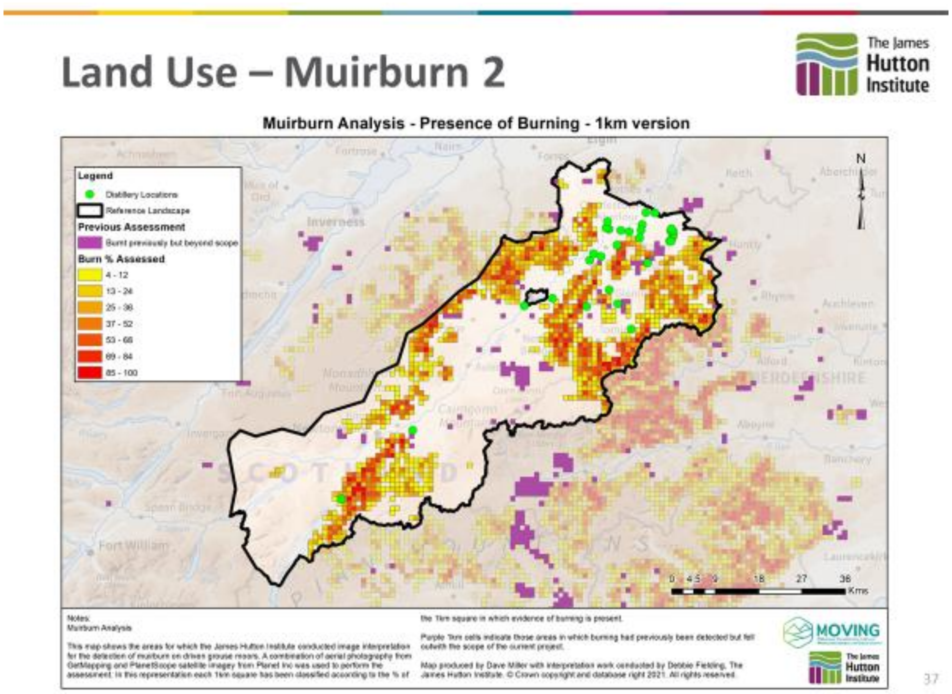


Figure 25 - Muirburn intensity

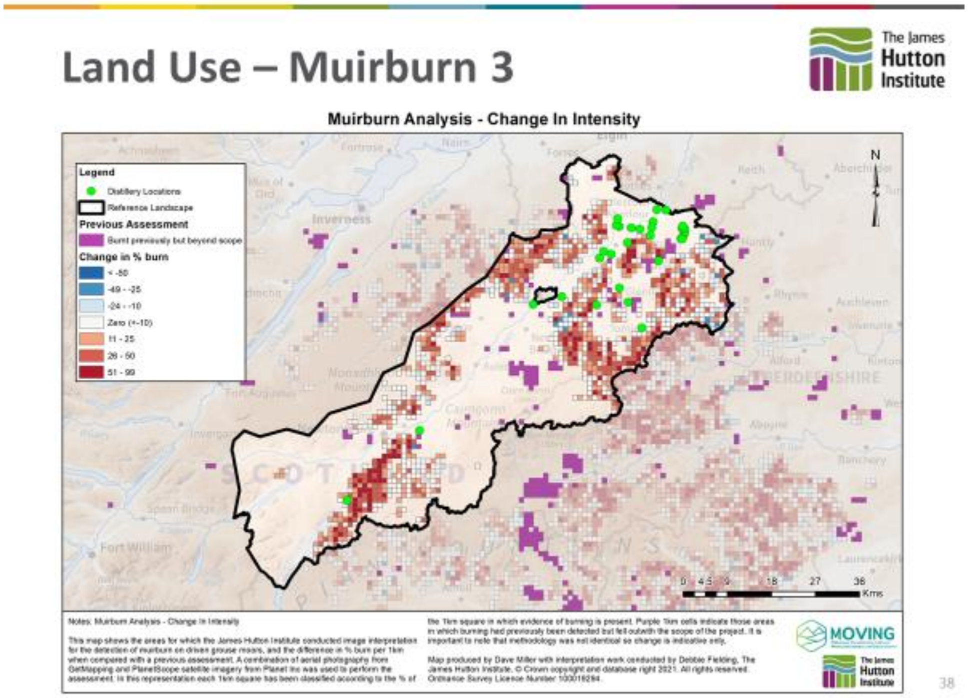
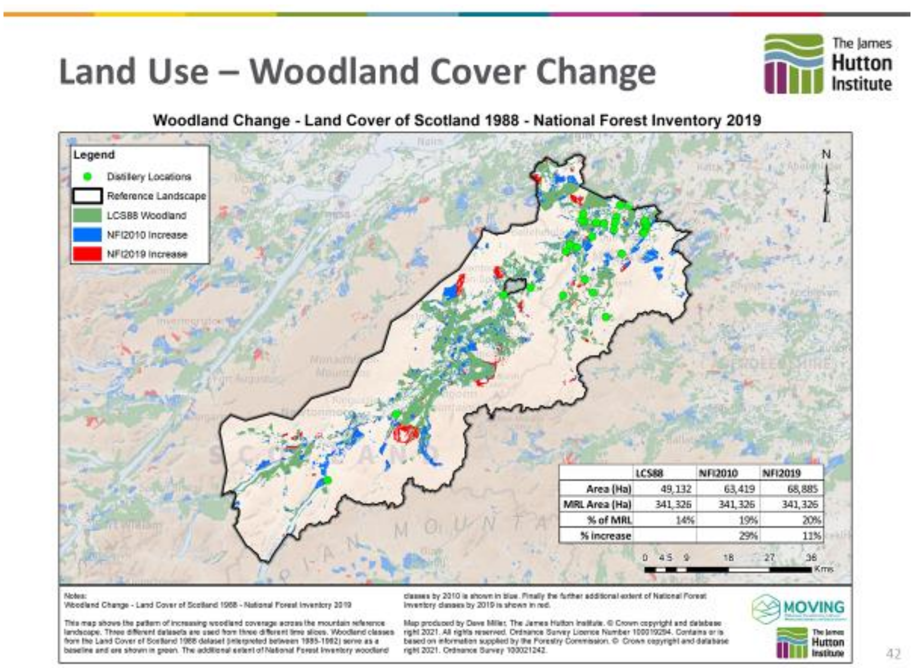


Figure 26 - Muirburn change in intensity

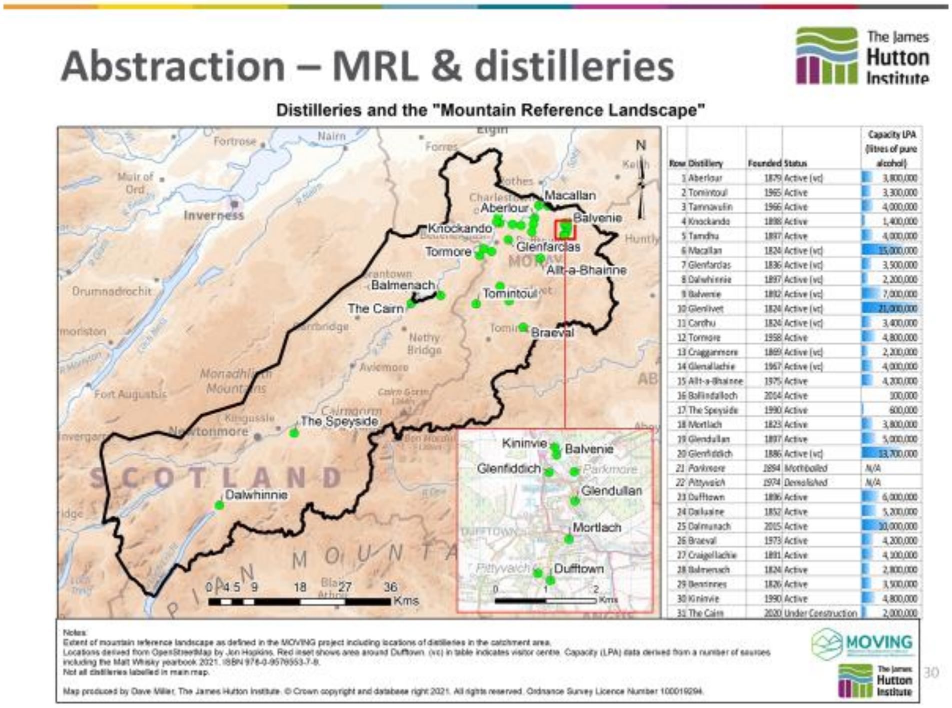
5.9 Land Use Change -Woodlands



	LCS88	NFI2010	NFI2019
Area (Ha)	49,132	63,419	68,885
MRL Area (Ha)	341,326	341,326	341,326
% of MRL	14%	19%	20%
% increase		29%	11%

Figure 27: Woodland Cover Change

5.10 Over Exploitation of Water Resources



Row	Distillery	Founded	Status	Capacity LPA (litres of pure alcohol)
1	Aberlour	1879	Active (vc)	3,800,000
2	Tomintoul	1965	Active	3,300,000
3	Tamnavulin	1966	Active	4,000,000
4	Knockando	1898	Active	1,400,000
5	Tamdhu	1897	Active	4,000,000
6	Macallan	1824	Active (vc)	15,000,000
7	Glenfarclas	1836	Active (vc)	3,500,000
8	Dalwhinnie	1897	Active (vc)	2,200,000
9	Balvenie	1892	Active (vc)	7,000,000
10	Glenlivet	1824	Active (vc)	21,000,000
11	Cardhu	1824	Active (vc)	3,400,000
12	Tormore	1958	Active	4,800,000
13	Cragganmore	1869	Active (vc)	2,200,000
14	Glenallachie	1967	Active (vc)	4,000,000
15	Allt-a-Bhainne	1975	Active	4,200,000
16	Ballindalloch	2014	Active	100,000
17	The Speyside	1990	Active	600,000
18	Mortlach	1823	Active	3,800,000
19	Glendullan	1897	Active	5,000,000
20	Glenfiddich	1886	Active (vc)	13,700,000
21	*Parkmore*	*1894*	*Mothballed*	*N/A*
22	*Pittyvaich*	*1974*	*Demolished*	*N/A*
23	Dufftown	1896	Active	6,000,000
24	Dailuaine	1852	Active	5,200,000
25	Dalmunach	2015	Active	10,000,000
26	Braeval	1973	Active	4,200,000
27	Craigellachie	1891	Active	4,100,000
28	Balmenach	1824	Active	2,800,000
29	Benrinnes	1826	Active	3,500,000
30	Kininvie	1990	Active	4,800,000
31	The Cairn	2020	Under Construction	2,000,000

Figure 28: Distillery locations and production volumes

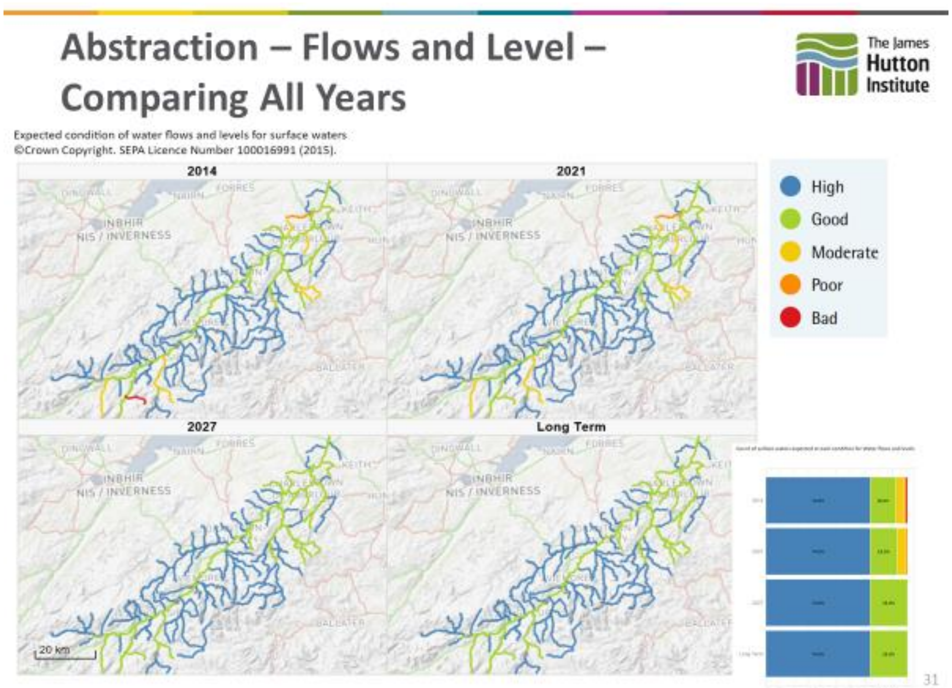
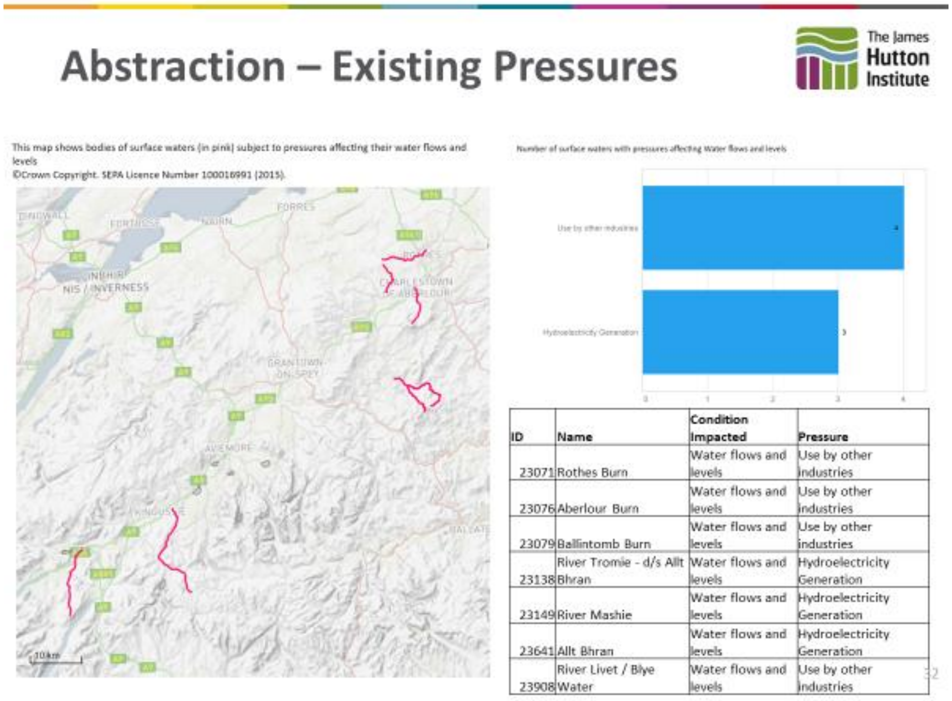


Figure 29 - Water Flow Pressures for 2014, 2021, 2027 and future.



ID	Name	Condition Impacted	Pressure
23071	Rothes Burn	Water flows and levels	Use by other industries
23076	Aberlour Burn	Water flows and levels	Use by other industries
23079	Ballintomb Burn	Water flows and levels	Use by other industries
23138	River Tromie - d/s Allt Bhran	Water flows and levels	Hydroelectricity Generation
23149	River Mashie	Water flows and levels	Hydroelectricity Generation
23641	Allt Bhran	Water flows and levels	Hydroelectricity Generation
23908	River Livet / Blye Water	Water flows and levels	Use by other industries

Figure 30 - Causes of current water flow pressures.

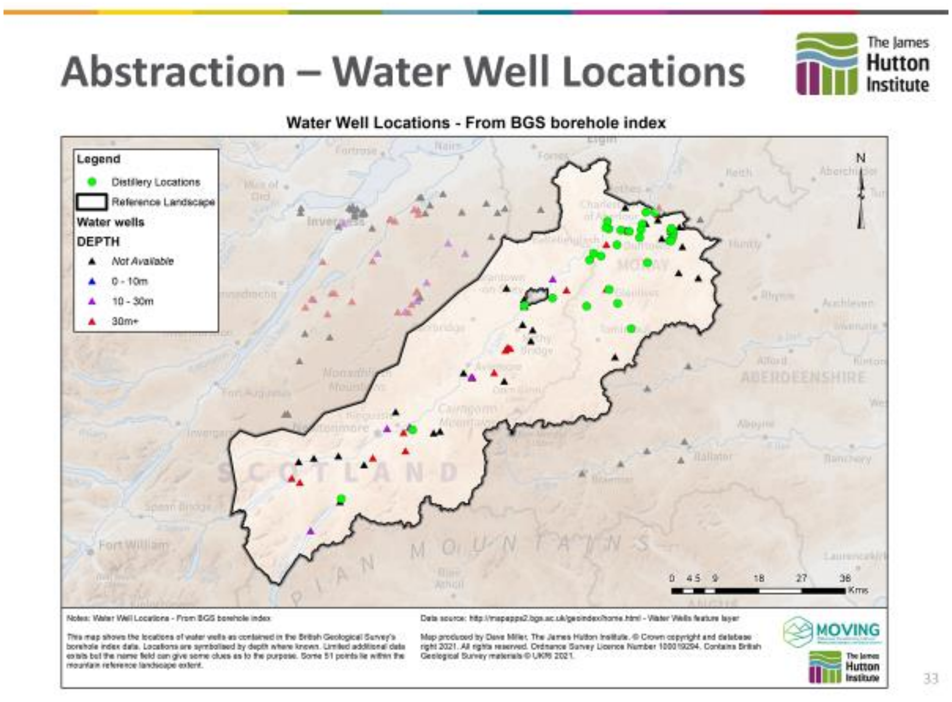


Figure 31: Locations where water wells are recorded.

MOVING

Mountain Valorization through Interconnectedness and Green Growth