Assessment of land manager risk perceptions in relation to natural capital - Deliverable 3.4 KJHI-D5-2 Climate Change Risks to Natural Capital

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Highlights

What were we trying to find out?

We explored land managers' perceptions of the risks posed by climate change, to natural capital in Scotland.

What did we do?

We did so via a survey and semi-structured interviews that concentrated on the risks perceived by land managers, their perceptions about the likelihood and potential impacts of these risks, their attitudes towards responding to these risks, and the information flows that inform their perceptions about climate risk.

What did we learn?

The small sample of respondents showed a high-level of awareness of the risks and potential damage posed by drought, floods, wildfire, as well as temperature extremes (both hot and cold), storms, and a warmer, wetter climate. They suggested specific, and holistic, landscape scale approaches to managing these risks, such as regenerative agriculture, tree planting, improved water management, and diversification, but highlighted a need for coherent policy and support mechanisms to enable them to respond effectively. Learning from experience and learning from peers were important factors in engaging with and acting upon information.

What happens now?

We will use findings and reflections from this study to guide further research over the next 18 months of the project. This may include exploring ways of integrating climate information with land managers' lived experience, linking this research with other SRP projects addressing policy coherence and collaboration, and exploring the perspectives of a larger and wider sample of people.

Executive summary

This report is part of ongoing research in Work Package 3 of the Climate Change Impacts on Natural Capital project, contributing to the Scottish Government's Strategic Research Programme (2022-2027). It describes a study, undertaken in Year 3 of the project (2024-25), in which we explored land managers' perceptions of risk associated with climate change, for natural capital in Scotland. We structured the research around the 'Theory of Planned Behaviour', which asserts that a person's behavioural beliefs in evaluation of a risk, will shape their attitude towards taking action in relation to that risk. We therefore concentrated on the risks perceived by land managers, their perceptions about the likelihood and potential impacts of these risks, their attitudes towards responding to these risks, and the information flows that inform their perceptions about climate risk. We explored these aspects via an online survey and a set of semi-structured interviews.

Despite sharing the survey, via newsletters, with networks totalling around 5,000 land managers, we received a very low response rate (n=22 survey responses; n=7 interviewees). This may indicate a lack of interest or awareness of climate-related risks for natural capital, but could also be related to time constraints, research fatigue, or simply not observing the survey amongst other items in the newsletters.

Within this limited sample, land managers showed a high level of knowledge and awareness about the risks posed to natural capital by climate change. This included awareness of the three risks we focused on (flood, drought and wildfire), as well as more holistic risks associated with a warming and potentially wetter climate. However, the statistical analysis suggested this awareness may not be a strong driver of action to mitigate risk, and some participants expressed uncertainties about whether the risks were truly associated with climate change, or were just part of climate variability.

Land managers thought these risks could result in the loss of productivity in the landscape, generally, as well as specific impacts associated with soil erosion, drought, damage to infrastructure, loss of biodiversity and increased prevalence of pests and diseases. They proposed a range of management options, including those associated with more holistic land management approaches and diversification of land uses, as well as more specific options such as controlled burning (fire risk), shelter belts (flooding, drought and heat).

Generally, land managers saw a need for greater collaboration and coherence in managing the land. They viewed current policies and regulations as hindering action for addressing climate risks, and very often being incoherent. They also stated financial barriers, inertia in land management practices, and a lack of social cohesion as barriers.

The research showed that these land managers wanted to receive information in a coherent, succinct and easily-interpretable manner. Information about long-term climate trends was particularly something they wanted to see. Learning through experience, and through observing peers, were considered important means of gathering information and acting upon it.

The research therefore suggests there is a need for:

- Exploring ways of integrating climate information with individual contexts and the lived experiences of land managers.
- Improving policy coherence and collaboration among actors involved in land management.
- Exploring the perspectives of a larger and wider sample, given the limited engagement of land managers with this research.

Introduction

The RESAS funded project JHI-D5-2 ‘Climate Change Impacts on Natural Capital’ aims to assess risks to, and opportunities for, Scotland’s natural capital assets as a result of climate change. We define natural capital (NC) as the natural resources people depend on for wellbeing and prosperity. As part of this project, we aim to assess stakeholders’ perceptions of climate change risks and the potential impacts of these on NC and the benefits and relationships associated with it. This will help to inform the development and communication of a ‘Risk and Opportunities Assessment Framework’, based on both social perceptions of risk and modelling of biophysical and climatological indicators. In previous phases of this work, we engaged with national level experts, via an online consultation workshop, and then a ‘scenario planning’ process.

The online consultation (Poskitt et al., 2023) revealed experts’ perceptions regarding the types of risks that may be faced by Scotland’s NC, as a result of climate change, whilst the scenario planning process elaborated plausible socio-economic, ecological and climatological future conditions for NC in Scotland and asked stakeholders to assess potential risks and responses therein (Poskitt et al., 2024b). These expert stakeholders identified risks associated with climatic extremes, compounded by degradation of natural capital, which could result in a loss of resilience, and potentially large-scale damage and degradation of NC, with implications for the benefits and relationships people depend on it for. Stakeholders suggested greater diversification (both in terms of genetic diversity in ecosystems, and deployment of diverse management strategies), as well as well-planned integration of different management approaches, knowledge exchange across scales, and coherence of NC governance, as potential responses to these risks. The knowledge and connectedness of rural communities to the landscape were considered important resources for supporting the resilience of natural capital.

In this most recent phase of the project, we conducted a more detailed study into the perceptions of risk that land managers, specifically, hold for NC on the land they manage, the

potential impacts of climate change for the livelihoods that depend on NC, and the potential responses that land managers could take to manage these risks. We also explored the types of information that land managers receive about climate change risk, their information needs, and their preferences for communication about risk. We achieved this via a questionnaire survey of land managers across Scotland, as well as a set of semi-structured interviews with individual land managers. Our questions for both the survey and the interviews were informed by the 'theory of planned behaviour', which asserts that a person's behavioural beliefs in evaluation of a risk, will shape their attitude towards taking action in relation to that risk.

In this report, we describe the theory of planned behaviour and how we applied it to inform this study (Section 2), before explaining our methodology (Section 3). In Section 4, we present the results from both the questionnaire and the interviews, before drawing conclusions and implications from these results and outlining our next steps (Section 5).

1. Using the theory of planned behaviour

In developing the methodology for this study of land managers' risk perceptions, we were guided by the theory of planned behaviour (TPB) (Fishbein and Ajzen, 2011). According to the TPB, an individual's beliefs in evaluation of a risk will shape their attitude towards taking action in relation to that risk, in this case risk associated with climate change (Fishbein and Ajzen, 2011). As illustrated in Figure 1, behavioural beliefs (e.g., a person's evaluation of the potential outcome of a behaviour) determine an individual's attitude towards the intention to mitigate a risk, normative beliefs determine the subjective norms, or social pressure driving mitigation behaviour (McCaffrey et al., 2011), and finally, control beliefs about personal and environmental factors can help or impede attempts to carry out the behaviour (Nox and Myles, 2017). These three predictors, together, lead to the formation of behavioural intention to perform. The stronger the behavioural intention, the more likely the behaviour will be performed. The actual behaviour control can be mediated by skills, abilities and environmental factors too, and may moderate the intention to perform.

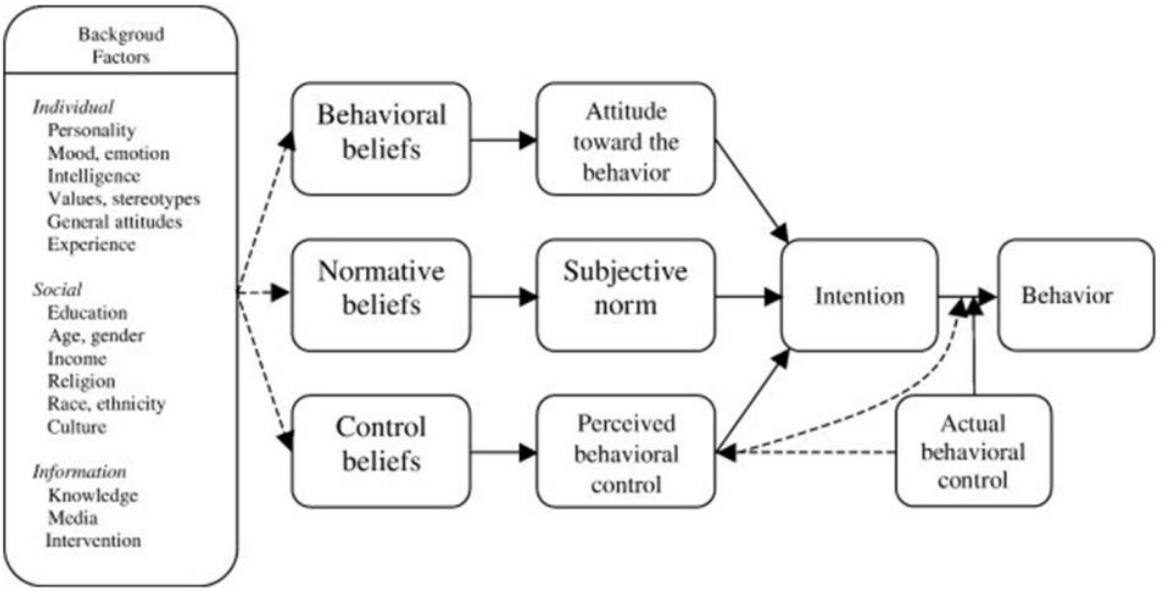

Figure 1: Framework adopted by Nox and Myles (2017) to assess the attitude of reducing the risk of wildfire on residential properties

The TPB has been used widely in studies that assess perceptions of climate-related risks, and we thus considered it to be a useful approach for guiding this study. In practice, we therefore developed and structured questions for the survey and the interviews to assess the factors that the TPB suggests are important in shaping attitudes towards risk.

2. Methodology

3.1 Questionnaire survey

To elicit primary data regarding land managers' perceptions of climate risk, we first used a questionnaire survey (Appendix 1), distributed online, via Qualtrics, in October – November 2024. We distributed the questionnaire survey indirectly to land managers and landowners through contacts held in Scottish Land & Estates and the Soil Association Scotland. In combination, these organizations were able to share the survey with networks of around 5,000 people, via their newsletters.

The survey is structured to address the conceptual model shown in Figure 1, proposing questions related to land managers' attitudes, subjective norms, perceived behavioural control, intention to mitigate and implementation of mitigation strategies, in relation to climate change risks.

The survey was formulated consulting literature on the implementation of the TPB to the mitigation of wildfires (Hall and Slothower, 2009, Martin et al., 2009, McGee et al., 2009, Collins and Bolin, 2009). For more information it is possible to consult a review on social perceptions of wildfire risk and mitigation behaviours (Martino and Rivington, 2022).

The initial section of the questionnaire was designed to depict levels of knowledge about climate change and attitudes towards finding information about it through a range of sources.

After this initial step, respondents were asked to select the type of land owned or managed (choosing between forest, agriculture and peatland), and the main type of impacts experienced or perceived (wildfires, flooding and drought). The following questions led respondents to formulate answers specifically addressing the choices made above. The questionnaire was structured to assess, in the following order:

- the perception of potential damage within the land owned or managed in the coming 5 years;
- the attitude towards mitigation behaviour (by asking respondents to state the importance of taking steps to protect land, and what response options could be adopted to reduce risk);
- the *attitude* to perform certain strategies for contrasting climate change;
- the influence exerted by social pressure, such as influences received from neighbours, people considered important or influential, and pressure from local institutions (*subjective norms*);
- the *capability* to adopt measures against climate change (by asking respondents to provide opinions on the personal, ethical, economic, legal, etc. background contexts that may act as a barrier against risk mitigation);

- the *intention* to implement response measures based on the perceived risk;
- the *implementation* of the mitigation behaviour, where measures have already been undertaken on the land.

The survey concluded with some questions about any existing experiences of impacts from climate change, and a series of queries referring to the socio-economic context of the respondent such as gender, age, level of education and years of experience in land management.

Appendix 1 shows the subset of questions, referring to the closed-ended statements used in the survey instruments. In addition to those queries, the survey included open-ended questions to gather information on climate change risk, the uses of different types of land, the behavioural options that respondents are aware of to mitigate the effect of wildfires, flooding and drought, and any barriers experienced in adopting measures for controlling climate change.

3.2 Semi-structured interviews

We also conducted a set of semi-structured interviews with land managers, in December 2024 – February 2025 to elicit more detail and nuance regarding their perceptions of climate risk for natural capital on the land they manage. We selected a sub-sample of land managers who responded to the survey to take part in the interviews, by asking survey respondents to indicate whether they would be willing to be interviewed, and then following-up with those who indicated that they were willing. In total, we interviewed a sub-sample of 7 land managers. These interviews were similarly structured into themes, guided by the factors that are considered important according to the TPB. However, we used more open-ended questions, and took a less structured approach, compared to the survey, to allow for more free-flowing discussion with participants. The questions started by exploring more about each land manager's own context, in terms of the land and the NC they manage. We then asked land managers about the types of risk they perceived as associated with climate change, as well as the impacts these risks could have for NC. We then asked about their perceived ability to respond to the risks they identified, and the specific response options they considered available to them. Finally, we asked land managers about the types of information they receive about climate-related risk, the types of information they would like to receive to help make decisions in relation to risk, and their preferences for how this information could be communicated. The full list of questions used to stimulate discussion in the interviews is presented in Appendix 3.

3.3. Data analysis

Data from the survey were analysed by measuring the frequencies of the level of agreement of all the closed-ended answers, and complementing this knowledge with a summary of the additional aspects and ideas proposed in the open answers. The questions described in Appendix 1 were used to perform pairwise correlation and logistic regressions to measure what variables significantly drive the intention to mitigate and carry out mitigation behaviour.

Because of the restricted number of data collected (only 22 full questionnaires were received) and the choice of climate change impacts on specific land use, only a few answers

can be used to elaborate information to improve the implementation of the TPB in our case study.

To run the ordered logistic regression, we have worked to avoid specific uses of the three drivers of mitigation and intention to mitigate for each of the three different types of impacts (wildfire, flooding and drought), because of the lack of sufficient data. Therefore, we assume that answers provided for each of these types of impact can be aggregated and interpreted as general impact of climate change. This choice allowed us to use the entire dataset and regress all the 22 observations collected.

In the statistical analysis we have considered the impacts and probability that attitude, social norms and capacity have on the intention to mitigate climate change, and then the impacts that all these variables may have on implementing a mitigation approach (for each of the three climate change impacts). To address the role of some behavioural drivers, we have proposed more than one variable. For instance, social norms are measured considering agreement on different statements that neighbours, trustworthy people and local institutions (civic society) take measures to protect natural capital against climate change. These three variables are assessed independently and not aggregated.

The statistical analysis was performed in three steps: first, a correlation analysis was performed to examine the relationships between the variables, attitude, subjective norms, intention, risk perception and capacity to behave (behavioural control). Then a stepwise regression model was performed to test which variables predict the intention to mitigate, and finally binary logistic regressions were performed to measure the effects on mitigation behaviours on each of the three climate change impacts (wildfire, flooding and drought).

The interview data were recorded and transcribed via Microsoft Teams and checked by the researchers against the interview recordings, since time and resource constraints meant that using a professional transcriber was not possible. We subsequently uploaded the transcripts to the NVivo qualitative analysis software, wherein we conducted a thematic analysis of the qualitative data. This involved reading, carefully, through the transcripts and identifying themes, or ‘codes’ in the responses that the participants gave. In identifying relevant themes, we were guided by the components of the TPB that help to indicate perceptions of risk. Particularly, we looked for the types of risks that participants were aware of, their perceptions of the likelihood and impacts of these risks, as well as their ability to respond to the risks posed to them. In addition, we looked for themes in the types of information that land managers receive about risk, and the types of information they would like to receive to help make decisions about risk, as well as preferences for how such information should be communicated.

3. Results

3.1 Respondent characteristics

Despite being shared with networks of ~5,000 people, only 33 responded to the survey. Of this restricted number, only 22 provided a full set of answers, as illustrated in Appendix 2. The low survey response rate could indicate that climate risks are a low priority among land managers, across Scotland. However, it is not possible to ascertain this, from these results,

as time constraints and research fatigue are also likely to have contributed to this very limited set of responses. Given that the survey was shared as part of newsletters, rather than shared directly with target respondents, it is also possible that recipients simply scanned these newsletters, quickly, and did not notice the survey.

Of those who responded to the survey, more than half of the sample comprises men with more than 20 years of experience in managing land. Two thirds (68%) are 45 years old with a high level of education (50% declared to have a university or post-graduate degree). While some of these socio-economic figures are expected, considering the age of people working in agriculture and forestry, what emerges is that only a few from the vast number of people we contacted replied to the survey. Those who did so may have responded due to a higher sensitivity to climate risk, previous experience, or higher interest and comprehension of a complex phenomenon which requires high levels of competency and knowledge (Appendix 3-Table 1).

The respondents cover all the regions of Scotland (Appendix 3-Table 2) with more cases from Dumfries and Galloway, and Grampian. The most selected type of NC was agricultural land (14), while just a few considered forests (4) and peatlands (4). However, the interviews illustrated that land managers may manage a wide and complex variety of different NC assets and types of land use on their land. In terms of the typology of impacts, half the sample considered flooding as a risk (11) followed by drought (7) and wildfire (3). The main stated use of agricultural land was for livestock grazing or beef production, while multiple uses such as a combination of recreation, tourism, timber, non-timber forest products, agroforestry, were also stated as being carried out on peatlands and forests (Appendix 3-Table 3).

The sub-sample of interviewees, who were selected from the survey respondents, managed land across Highland (n=1), Dumfries and Galloway (n=3), Argyll and Bute (n=1), and Grampian (n=2) regions. Four mentioned that their primary land use was agriculture, whilst two mentioned it was forestry and one considered their land to have multiple land uses, although all seven interviewees acknowledged a range of different land uses on land they manage. All seven interviewees were male. This lack of diversity among the sample is unfortunate, although not for lack of trying, having shared the survey with networks of ~5,000 land managers. Limited time and resources available in the project meant we had limited capacity to seek a more diverse range of respondents within this phase of the project activities.

3.2 Perceptions of risk and risk impacts

In the interviews, land managers spoke about a range of different risks, associated with climate change, that they perceived. In terms of the specific risks we were focusing on, in the study (floods, drought and wildfire), across the board, the interviewees showed strong awareness of these types of risks occurring due to climate change. For example, P7 and P11 commented that they were observing more intense, heavy rainfall events, which could result in flooding: *"we're getting massive amounts of rainfall in very short periods of time,"* (P11); *"You now get minutes of torrential, torrential downpour and the damage by that accelerated rainfall is quite severe,"* (P7). P2, P3, P6, P10 and P11 all spoke about drought as being a

current and future risk. P6 and P11 brought this up, unprompted: *"It's got to the extremes of literally, now we're getting periods in the springtime, in which there's no rain,"* (P11); *"In this area, droughts, we've, we've been getting some dry, quite dry early springs and early summers,"* (P3); *"Now drought is something I'm worried about, even in Dumfries and Galloway,"* (P6). P10, P2, P3, P7, and P9 all indicated concerns about wildfire, although not always without a direct prompt from the researcher: *"Probably the other biggest risk now with us is wildfire,"* (P10).

Land managers also independently brought up a range of other risks that they perceived in relation to climate change. P7, P11, P10 and P9 all mentioned a generally warmer, wetter climate in Scotland, in the future, as a potential risk. *"You know we could just be end up with one very wet warm climate, and not all trees will exist under that, so we have to we have to, we have to manage that accordingly,"* (P11); *"it's certainly going to get hotter," (P7)*. P7 and P11 also mentioned more intense storms as a potential risk: *"Our storms are getting more frequent and more intense,"* (P7). P9 mentioned ocean acidification as a risk, as well as the possibility of permanent snow cover, as a result of the Atlantic Meridional Overturning Circulation (AMOC) collapsing. Although not directly related to climate, P6 also mentioned the breakdown of social and economic systems as a risk.

In terms of the perceived likelihood of these risks, the interviewed land managers all considered the risks they mentioned to be likely, or already being experienced, either on their own land, elsewhere in the country, or internationally. P3 suggested that his land was increasingly facing drought conditions, in recent years: *"In this area, droughts, we've been getting some dry, quite dry early springs and early summers, in more recent years, not the last couple of years, but certainly prior to that would be three out of five years"*. Relatedly, when asked about wildfire, P10, P2, P3, P7 and P9 spoke about increasing conditions that could encourage wildfires: *"I mean clearly that the lack of rainfall and the drought had a bearing on the risk of that fire going. So, there's nothing to put it out,"* (P2). When asked if he thought the risk of floods was increasing, P10 pointed to recent severe floods in Spain: *"**Interviewer:** Do you think that there are likely to be more kind of events that cause the floods to happen in the first place? **P10** Yeah. Yes, certainly we're seeing well, if you look to Spain, they had an intense flood event, and obviously we're looking at elsewhere in Britain that this could happen with us"*.

The survey analysis also reflected that land managers are aware of climate change risks and impacts on NC. More than half (58%) agreed or strongly agreed to the question "*I consider myself to be well-informed about risks associated with climate change for the land I manage*". This answer is supported by the range of choices proposed as sources of information on climate change such as news, scientific and regional reports. However, the first source remains, for most respondents, the direct experience of climate change on their own land (Figure 2), and on that of their neighbours' land, although none stated that they have suffered damage requiring evacuation from fires and flooding.

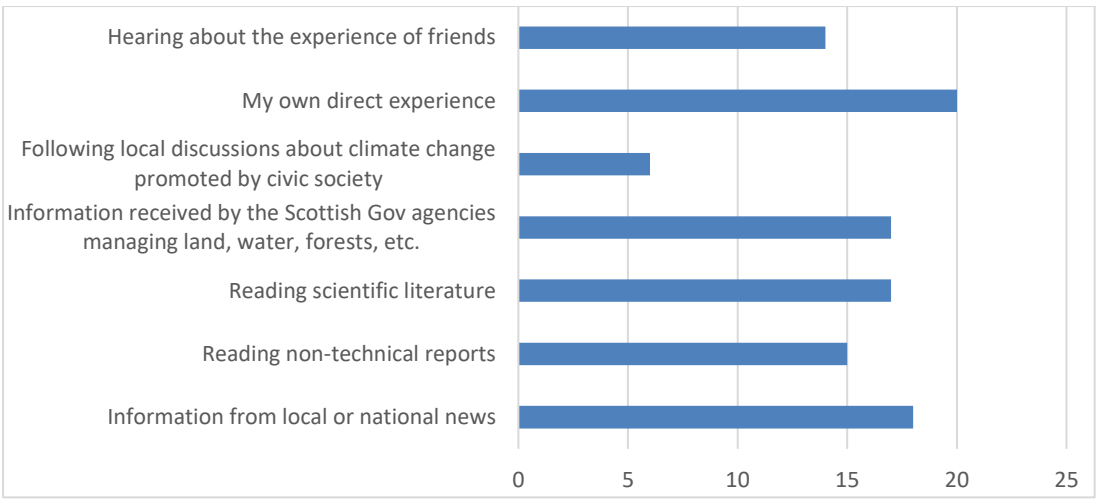

Figure 2: source of information on climate change risks

There is somewhat or strong agreement that land could be damaged by climate change in the next 5 years except for two respondents who are mainly expecting impacts of flooding on agricultural and forest land. This level of disagreement increases when considering the possibility of immediate impacts within a year from now (Appendix 2 – Table 4).

However, several of the interviewees pointed to doubts or uncertainties about whether the risks were increasing, and about the role of climate change within this. P2 indicated that he did not think the likelihood of risk had changed: *"So if you ask me about the risk of each of those hazards, I'd say well, at some point over the next five years, they're definitely going to happen. But you could have asked me that question in 1910 and I'd have given you the same answer"*. P3 was uncertain about whether rainfall was changing or not: *"In 2010, 2011, and 2012, we had a lot of rainfall… We thought, wow, this is climate change, this is not good, because it was really, really wet, but it's now returned more or less back to its normal variation, so we're not quite so worried. And so, was that climate change? Maybe, I don't know"*. In terms of wildfire, P10 and P2 highlighted that land management might have as much influence on wildfire risk as climatological factors: *"we're removing our management of our moorland and vegetation, and every year that builds up, increases the risk of wildfire,"* (P10); *"clearly that the lack of rainfall and the drought had a bearing on the risk of that fire going… But so did changes in management practice, because you know it was able to just keep going, because there was far more for it to burn,"* (P2).

The interviewed land managers described a wide range of impacts that the risks they identified could have for NC. These are summarised in Table 1, below.

Table 1 - Impacts of climate risks, perceived by interviewed land managers

Perceived climate risk	Perceived impacts
Drought	Water shortages (P11, P3, P6, P9)
	Food shortages due to crop failures (P2, P3, P11)
	Soil erosion, due to drying out (P11, P2, P3)
	Reduced output from hydro-energy schemes (P10)
	Reduced productivity from pasture (P3)
	Peat drying out and being lost (P11)

	Trees dying due to insufficient moisture (P11)
Flooding	Loss of grouse and capercaillie chicks due to wet weather (P2)
	Soil erosion due to torrential rain (P7)
	Hindering business development opportunities (P2)
	Drowning farmland (P10)
	Increasing pressure on NC to store water (P11)
Wildfire	Damage to native woodlands and heather (P2, P7)
	Damage to peat (P10)
	Damage to timber forests and resultant loss of income (P3)
Warmer temperatures	Changing characteristics of ecosystems (P2), resulting in reduced fertility from the landscape (P6), prevalence of invasive species (P7), and decline in biodiversity (P9)
	Warmer temperatures favouring increased prevalence of pests and diseases, harming trees (P11, P2, P6) and livestock (P3)
	Heat harmful for livestock (P6, P7)
	Heat harmful to salmon (P2)
	Less winter snow cover, resulting in higher wind damage to peat (P10)
Sea-level rise	More damage from coastal storms (P9)

In addition to identifying discrete risks associated with specific risks, the interviewed land managers were often able to see knock-on effects and holistic impacts across the landscape. For instance, P6 spoke about the potential effects of climate change for biodiversity and the overall fertility of the landscape: *"The fertility of the landscape is dependent upon a diverse and functioning biological scenario. You know the movement of nutrients, the creation of organic matter. All of this is dependent on thriving biological systems. I don't know what effect climate change is going to have. The biological systems will clearly change, whether or not that will result in a decline in the overall productivity of the systems, I suspect it will"*. P7 spoke about the knock-on effects of soil getting washed into rivers and the negative impacts for salmon.

3.3 Responses to risks

In the survey, a few response options were considered to reduce risk. Respondents considered taking steps to protect land against wildfires, flooding and drought to range from important to very important, with just one case reporting the irrelevance of intervening to reduce flooding in forest land. We asked respondents to provide some land use management options to reduce climate change risks (Appendix 2 - Table 5). Preferences were for controlled burning and fire breaks, equipment and training to control fires, and insurance, all applicable to forest land, while rewetting and vegetation management (e.g., cutting and grazing) were mainly considered as good management strategies for peatlands. Flooding was thought to be reducible through better soil management that improves soil permeability, and drought, by building organic matter and reducing land drainage.

A range of options to counteract the effects of climate change were proposed to the respondents and the 5 most appropriate were selected. Figures 3, 4, and 5 summarise the actions considered most effective to limit the consequences of fire, flooding and drought, respectively.

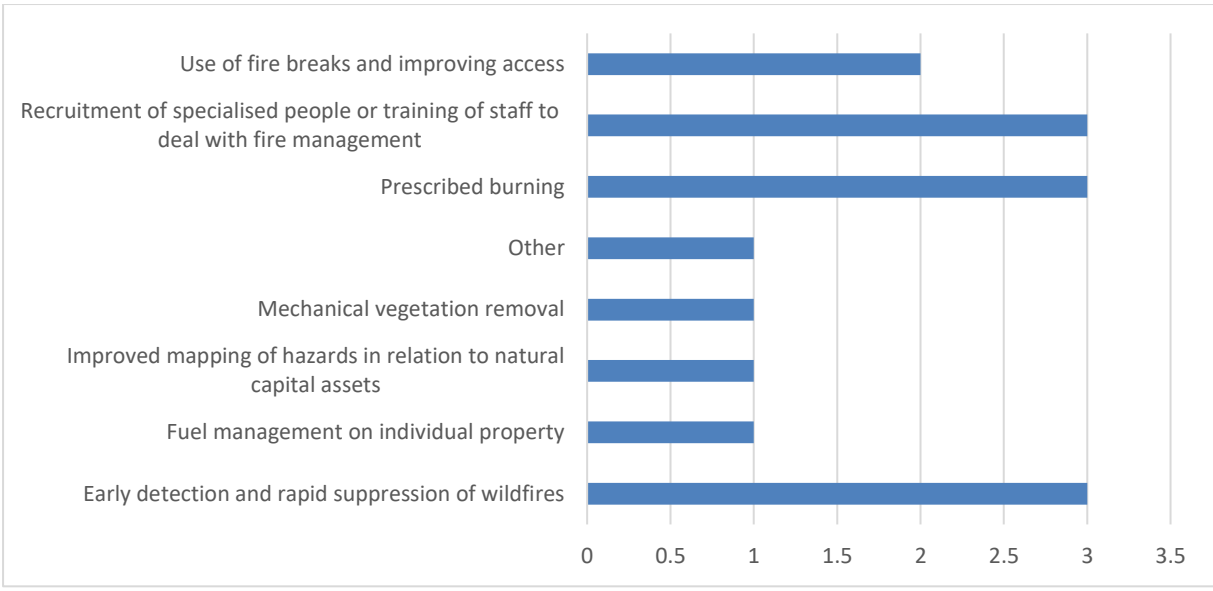

Figure 3: actions selected by respondents to limit the effect of wildfires

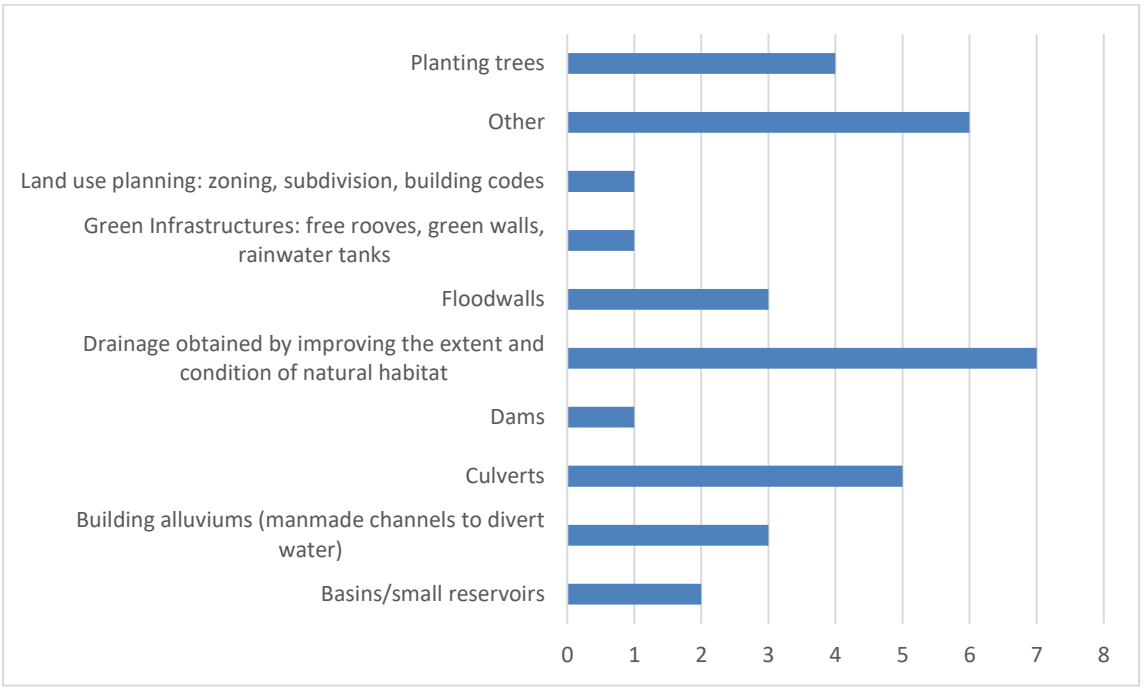

Figure 4: actions selected by respondents to limit the effect of flooding

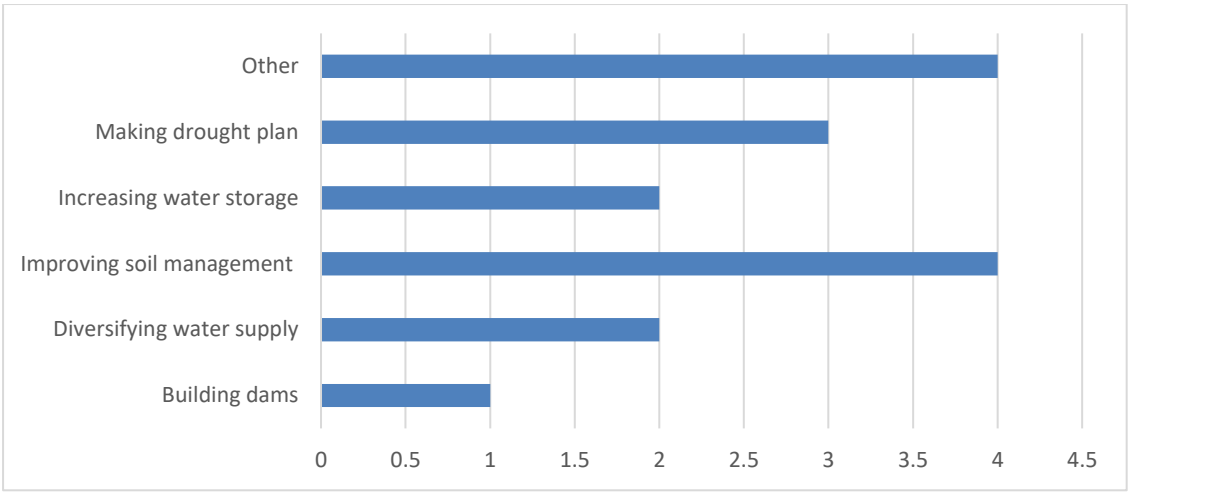

Figure 5: actions selected by respondents to limit the effect of drought

A common result from these answers is the choice of solutions which improve the management of habitats for reducing flooding and drought, while the limitation of wildfires is mainly based on strategies that build on fire suppression rather than fire prevention such as the removal of fuel load. Other answers refer to the need to improve soil structure and improve grassland in the catchment for limiting flooding, while removing drains, planting trees, and using species that require less water can be a solution for limiting the consequences of drought.

In the interviews, a range of potential responses were expressed in relation to drought, wildfire and flooding. Most of the risk responses which emerged indicated that more general responses to climate change risks to NC were considered important.

Drought

Better water flow management was suggested, including re-establishing bogs for water storage, but the most widely suggested response to drought was tree planting to prevent evaporation and erosion and provide shade for plants and livestock. One participant suggested this should consist of diversely planted broadleaf shelter belts. Mud grazing and keeping the animals moving was thought to improve drought resilience although for one participant a better response was selling livestock in times of drought. Self-sufficiency was discussed, since one participant felt a private water supply and self-managing sewage, built resilience to government responses to drought, such as increased taxes and rates.

Flooding

Better floodplain management, such as the prevention of new building development on floodplains, was raised as a response to flood risk, since settlements built originally around estuaries have now grown to largely cover former floodplains and caused these areas to become zones at risk of flooding. Digging large ponds at the tops of tributaries and increasing riparian planting were also mentioned, as was appropriate *"ground preparation"* (P11). The lack of alternative response options that emerged might indicate either a lack of concern for flooding in relation to other risks, or a need for greater information around responses to flood risk, for example, but more research would be needed to confirm the

exact reasons for this.

Wildfire

Fire breaks were described in various form as the main option for responding to the risk of wildfire. Putting herbivores on the land to reduce vegetation was seen as one way of doing this, as was erecting fire break fences and inserting breaks in forested land. Controlled rotational burning was also suggested in relation to moorland heather, using cool burn techniques which remove surface vegetation but avoid burning the peat. This technique was seen as vital for preventing wildfire damage to peat and protecting heather landscapes in the longer term. Additionally, two participants highlighted building resilience for fighting fires as a response. For one this involved seeking grant funding to purchase a fire fogging unit and slurry tankers, while another described previous experiences of fighting wildfires on neighbouring properties, noting the importance of collaborating with neighbours to prevent fire reaching their own land.

General

Whilst responses to the specific risks of drought, flooding and wildfire were discussed, participants seemed particularly focused on the wider impacts of climate change risk to natural capital.

- Holistic Land Management Responses

Managing the landscape as a holistic system was seen by many as an important response to climate change risks to natural capital. This might include maintaining grazing livestock such as sheep for encouraging the growth of heathers and wildflowers, breeding robust, hybrid species of livestock for helping build resilience against *"variations… in their environment and in their diets"* (P3), and riparian planting for increasing shade and improving river habitats for species such as salmon, for example, in times of *"less water, less snow and higher temperatures"* (P2). Another example included optimizing non-productive land by increasing the size and diversity of shelter belts, to create *"natural biodiversity strip[s]"* (P11) to provide *"continuous cover"* (P11), increasing wind protection for crops, sheltering livestock and preserving soils from erosion. Shelter strips could also provide *"a huge vast array of different woods"* (P11), and non-timber forest products. As the climate warms, varieties currently grown in the South could be introduced, and the introduction of wetlands could increase carbon sequestration and provide areas for wetland birds.

One participant discussed the decision not to use chemical fertilizers, pointing instead, towards composting via anaerobic digestion for long-term feeding of the soil, eliminating the need for ploughing and slurry. This reduced toxic leaching into streams and water systems, decontaminated forage, eliminated the need to acidify soil, retained soil oxygenation, and encouraged microbes, insects and worms to condition the soil. Anaerobic digestion produced bacterial proteins for crops and provided methane for heating water. One participant suggested minimising ploughing to prevent carbon leaching, and another found that practicing organic farming without fertilisers, pesticides, ploughing or cultivation over 25 years increased plant biodiversity by 50% long term, soil tests showing good activity and respiration rates, and eliminated the need for supplements for livestock. Another participant

promoted regenerative farming for replacing organic material in the soil, for example mulching using cheap wool that would naturally rot away. This was thought to be particularly relevant since *"we have thousands, millions of sheep all over the place, producing wool that costs the farmer to cut it and get [nothing] back from it"* (P11).

The policy environment would need to enable these changes, one participant, for example, suggesting decision-makers needed to step away from *"silo thinking"* (P11) to ensure policies are connected and progressively designed to support those who want to manage land holistically over the long term and share learning with others, calling for recognition that positive changes take time to come to fruition.

- Diversification

Diversification of swards was suggested for increasing soil carbon, and the replanting of hedgerows for protecting fields and reintroducing biodiversity for protecting against disease. In forestry, diversification countering *"single species plantations"* (P2) was thought to have the capacity to reduce the risk of disease in a warmer, wetter climate and to have a positive impact on carbon sequestration, although a willingness to *"try new things"* was needed to improve the capacity of different tree types to generate good timber (P11). In response to diversification, it was suggested that sawmills, most of which currently *"can't cope with"* (P11) larger logs, should be designed to be able to process a variety of log sizes.

- Carbon Markets

Two participants discussed taking part in carbon markets via carbon credit schemes as a potential response to the wider risks of climate change to natural capital, one considering change of land use from poor quality grazing land to *"high value nature woodland"* (P2) to improve land quality and allow the sale of carbon units. One participant discussed increasing carbon sequestration via tree planting to offset methane emissions from *"belching"* cattle (P7), another considering faster growing trees to be a better option for sequestering carbon.

- Change of Land Use

Alongside various land use changes noted above, change of land use was also an option for one participant who had considered converting land for skiing if colder winters result in increased snowfall, although he noted that this potential climate outcome was just *"speculation"* (P2).

- Building Collaborative Relationships and Personal Responsibility

One participant highlighted the importance of building collaborative relationships between people at the local level: *"the simple truth is that the enormity of what we are dealing with requires teamwork… It will require people to organise together at a local scale to cooperate, communicate and work together… And our society is currently breaking down those processes. As much as it possibly can, as fast as it can"* (P6). At the same time, taking personal responsibility was considered important – whether that be through self-sufficiency in the form of producing woodchips for fuel or producing electricity; as one participant expressed, *"the solution is doing everything we can to repair the natural systems that we've*

damaged… and stop using fossil fuels… I'm busy doing positive things" (P6).

3.4 Barriers and challenges to responding to risks

The survey results conflicted in terms of the influence of peers (neighbours, friends, results conflicted in terms of the influence of peers (neighbours, friends, civil society) on land managers' behaviours in relation to climate risk. When testing the attitude towards 'intention to apply behavioural interventions' in response to risk, the results suggest this is not much affected by the influence of peers, what other people considered important, or specific activities of local institutions. However, the opposite result is found when testing the attitude towards 'implementation of mitigation behaviour' against the same variables (see Table 4 and 6 in section 3.6). This apparent conflict may be a result of the small sample size. We found differences in the level of agreement that neighbours and other people important for the respondent take measures to protect land from wildfires, flooding and drought, while there is a more agreement on the fact the local institutions provide an important role in providing a message to reduce risk from flooding (Appendix 2 - Table 6).

The respondents somewhat agreed or strongly agreed in response to the questions pertaining to capacity to implement some of the mitigation measures proposed above. However, a series of factors may act as barriers against risk mitigation. Responses to wildfires are thought to be limited by excessive regulations and limited financial resources: flooding is impeded by financial barriers, while drought by fiscal disincentives and difficulties in obtaining agreements with estate management. A complete list is proposed in Appendix 2 Table 7.

Notwithstanding these barriers, clear intentions to implement measures to reduce damages caused by wildfire in forest and peatlands are stated, and from flooding in agricultural land. Conversely, not all people who manage forest land agreed that it was necessary to take action to counteract drought in forest. This positive determination to reduce climate risks is supported by past implementation of in-field operations that have focused on prescribed burning and cutting grass to reduce wildfire risk; improved water retention and changed grazing pressure to reduce flooding; planted trees to rebuild soil organic carbon; and regenerative farming practices to reduce the consequences of drought (Appendix 2 – Table 8).

In the interviews, again, participants focused more on the barriers and challenges to the wider risks that climate change poses to NC, rather than restricting their answers to focus only on drought, flooding and wildfire, although some issues related to these were raised.

Drought

In terms of barriers and challenges to responding to the risk of drought, two issues were raised. First, the issue of water abstraction on the River Spey was discussed as a regional barrier to issues of water scarcity. Second, issues with destocking livestock as a response to drought were highlighted, since to restock after the end of a drought, one participant felt that lengthy breeding processes were required to reduce the risk of introducing disease that he felt was attached to buying new stock.

Flooding

In relation to participants' perceived ability to respond to the risk to NC of flooding, one participant noted that policies enacted by SEPA and NatureScot to eradicate the use of flood banks in favour of letting "*it all go wild*" (P10) encroached on capacities to manage flooding. Another participant flagged how draining the lowlands on their own land caused water to swell the river and increase flooding downstream.

Wildfire

For the risk of wildfire, changed land management practices were seen as a barrier to response, because of policy demands for a reduction in cattle and sheep grazing on hillside land, alongside "*huge pressure to reduce the deer numbers, which means that all your fuel loads are building up*" (P10). Several participants were frustrated that while other countries recognised the value of grazing for protecting against wildfires, Scotland seemed to be moving in a different direction. In tandem, land no longer managed for sport but for other uses such as wind farms or sitka plantations was no longer subject to muirburn and carried a build-up of vegetation, one participant worrying that wildfire would *"go through it like a dose of salts"* (P3). A reduction in numbers of gamekeepers with expertise in dealing with wildfires was also felt to be a barrier to responses to wildfire, increasing risks to natural capital, making peatlands particularly vulnerable to burning and to producing excess carbon emissions as a result.

General

- Unhelpful, Disconnected Policies

By far the largest perceived barrier to enacting positive change in respect to climate change risks to NC was the existence of unhelpful, disconnected policies. This played out via multiple layers of bureaucracy enacting conflicting policies related to the UK and Scottish Parliaments, national parks, community councils and sometimes multiple local authorities, leading to confusion and difficulties managing land. At times, participants felt research contradicted these policies, one participant noting that while research called for diversification to only *"65% of any one species"*, the nearby National Park, and Forestry and Land Scotland required *"95% native species. And of course, scotch pine is really about the only commercial conifer that's regarded as native"* (P10). Results pointed to levels of confusion and frustration with policy; as one participant stated *"Somebody needs to get a grip and figure out what is it they're really trying to do, because at the moment it's all over the shop. And that is a major barrier because you just don't know what to do"* (P7).

For some, policies actively prevented them taking the actions they wanted to, or were felt to be actively damaging to land or sustainability goals; for example, policies preventing the use of livestock chemical drenches for parasites without evidence of infection meant prevention was seen as impossible. Policies encouraging the protection of wildflowers and those encouraging the eradication of non-native species were seen as conflicting, while one participant highlighted reductions in funding for fencing which led landowners to protect crops with cheap alternatives, increasing plastic waste, and another highlighted that the incentives system did not encourage re-wilding. Policies designed to set aside land for

recreational uses impacted on opportunities to build resilient food systems through agriculture and the production of non-wood forest products. One participant was frustrated by regulations preventing him from achieving the resilience of self-sufficiency by using nitrogen fertiliser sourced from sewage from his septic tank on his land. Meanwhile, policies encouraging the introduction of beavers into the wild were thought to cause damage to riparian woodlands, impacting abilities to respond to biodiversity loss. Holistic land management was seen as more likely to attract funding, but it was felt that grants which focused on the improvement of only one asset acted to *"silo"* responses (P11). As such it was hard for land managers to manage land holistically in practice. Furthermore, certain policies were seen as a form of greenwashing; Net Zero, for example, was felt by one participant to encourage the importing of timber and other consumer products to be the cause of increasing carbon emissions globally through the relocation of commercial activities to countries without climate regulation.

For some participants, nature friendly policies acted against commercial interests; policies which required large areas of land to be restored in compensation for renewable energy developments were thought to prevent commercial activities like forestry, making energy infrastructure untenable. For one participant, designations preventing renewable energy enterprises within sight of National Parks made re-purposing land for wind farms difficult while another described his frustration that improving peatland near to a potential wind farm site may *"imperil"* (P2) the project.

The power of subsidies to lead decision-making was highlighted by one participant who suggested Scottish policy obliged farmers to adhere to *"creditable welfare standards"* causing them to compete with overseas products not subject to the same standards. One participant felt the existence of subsidies had the potential to prevent action since *"if you know that you will be subsidised to carry out changes to your farming regime at some point, when that regime works out what those subsidies are going to be and how it works, then there's no incentive for you to do that under your own steam upfront"* (P2). Others described how schemes such as the Nature Restoration Fund were *"impenetrable for an individual farmer to get into… unless you speak the language and write all the gibberish… the scheme is designed really for people like the RSPB and others, loads of people, just experts in mapping"* (P7). Others felt conditionality payment requirements produced a *"tremendous bureaucratic load"* (P9).

One participant described how top-down governance, more widely, prevented positive change, calling for education and persuasion for land managers at ground level instead, similar to that provided by local departments of agriculture, suggesting *"I think we should go back to the older way and have the government helping and advising you rather than trying to catch you out all the time"* (P7).

- Lack of Policy Planning

Another element that emerged as a barrier in relation to policy was that of inadequate forward planning, for example in choosing the best species to plant for potential future conditions. One participant pointed to changing policy priorities as a problem, noting that *"we've built up forestry, we've built up food because the government has supported it. The*

government's removing a lot of that support as fast as they can go" (P10), highlighting fears that this would likely impact negatively on the agricultural, food production and timber industries and ultimately for rural economies via job losses. One participant suggested policies focusing on value for money did not take into account the long-term needs of the *"country and planet"* (P11), another felt poor planning had led to the destruction of valuable heather habitats in the pursuit of commercial forestry, while another highlighted how long it would take for measures to increase soil porosity to be effective: *"relying on programmes and other things, I mean… it'll just take forever and never happen"* (P7).

- Carbon Markets

There was a level of scepticism over the use of carbon credits in relation to peatland management. One participant questioned the role of peat in how carbon credits are calculated, stating *"I've since 2015 been searching for the research, of how these carbon credits are calculated, particularly for peatland restoration. And no-one can give me a scientific paper that proves how they've worked out the amount of carbon absorbed or emitted per year by peatland… I'm getting more and more suspicious that the actual research is not there"*. He suspected that peat on his own land, that *"the vast majority will be absorbing carbon, according to the interest of hydrology, up to ¼ of a tonne per hectare per year"* (P10). He suspected mounding peat for tree-planting using mechanised machinery might create more carbon emissions from fuel emissions than it saves, and more damage to peat, pointing out that tree planting takes 50 years to produce net carbon absorption. Another participant suggested competitive criteria for entrance to public sector schemes made it hard to gain access to take part, and highlighted the risk of greenwashing associated with public and private sector carbon credit schemes, which consisted of *"doing something which has to be done anyway, and using it as an excuse to do more harm than the good you've alleviated elsewhere"* (P9).

- Financial Barriers / Cost Effectiveness

Several participants highlighted financial considerations as a barrier to responding to the risks of climate change to natural capital. For example, one participant felt that since it was difficult to quantify risk it was difficult to decide how much money to allocate to response options, leading to compromise or lack of action. Another described the difficulty in persuading other land managers to use wool mulch on their land instead of chemicals: *"and the people… just said no, we're not, we're not willing to pay that amount of money to do it. And you can't argue with that"* (P11), while incentive schemes such as those encouraging carbon offsetting and tree planting led people to take decisions they may not necessarily feel was the best option for responding to climate risk, since *"People will always go where the funding is"* (P11).

Policies driving land managers to increase forest planting were not always successful because they prevented the use of the land for other purposes: *"I don't want to… lose… good farmland because it's so valuable and there's so little of it"* (P10). Others felt commercial decisions sometimes impacted biodiversity, pointing towards the prevalence of sitka spruce plantations which they thought were *"getting leprous and growing everywhere… we're making the same mistakes all over the world"* (P7). Furthermore, low-cost supermarket

pricing was thought to present a significant barrier to managing risks to NC since this risked putting farmers out of business, and as such removing them from the custodianship of the land.

- Inertia in land management practices

Several participants believed inertia played a part in preventing action to mitigate climate change risks to natural capital. For example, one participant discussing the opposition of the sawmill industry to the diversification of tree planting since it would take decades for this new timber to be ready for felling. One participant noted frustration that *"spruce [is] still [the] preferred option for planting commercial forestry"*, destroying traditional heather landscapes: *"it's a disaster"* (P7); *"I suppose government levers take a long, long time to change"* (P7). As another participant put it, *"'t's not just knowing what the policies are but dealing with the lobbying that is supporting those policies"* (P9).

- Lack of Policy Response

Two participants felt so strongly about the negative impact of ineffective policy responses on their own ability to respond that they described protest and even activism activities as a response. One participant, for example, describing how he *"started interacting with the government but found nothing changed, basically… me and my neighbours would interact by responding to planning applications and consultations and so on, um, which used to work, but found each time it did work the rules would be changed, so what we had done wouldn't work the next time"* (P9). This led to engagement in non-violent civil disobedience campaigning around global and local issues. Another suggested *"I think the answer is by persuasion. And responding in the papers to some of these things"* (P10).

- Lack of Social Cohesion / Social Norms

One participant felt lack of social cohesion in society impacts the ability of humans to respond to the challenges of climate change and their impact on natural capital. For him, strong, collaborative relationships were key to *"resolving the challenges that we face"* (P6) and that *"our society is currently breaking down those processes"* (P6) through *"new technologies which… breakdown relationships that exist between people"* (P6), making tasks possible to do in isolation and preventing the building of strong communities and *"localism"* (P6). He felt communities and individuals had been disempowered to take action since they were *"used to receiving from higher authority instructions… what to do and… how to strategize? They leave all of that to somebody else"* (P6). The reluctance amongst land managers to change and the preference to stick to social norms was seen as stemming from *"the necessity of providing for a family"* meaning *"risk becomes very difficult"* (P6). It was therefore important for scientists to take risks and *"put themselves on the line"*(P6) to provide more radical, evidence-based solutions.

3.5 Information flows and decision-making

In the interviews, we also asked land managers about the types of decisions that were affected by the risks and risk impacts they perceived, as well as about the types of information that could help inform these decisions. Of course, intuitively, there are decisions

implicated in the perceived responses, barriers and challenges, outlined above, but when asked, specifically, about decisions influenced by perceived risks, the interviewees also highlighted a range of decision topics. P10, P3, P6, P7 and P9 described decisions related to their management of the landscape as a system, including maintenance of nutrient flows (including carbon), minimising resource use, and dealing with waste products, to ensure the productivity and sustainability of their land. For instance, P7 mentioned reducing ploughing: *"I think trying to stop carbon leaching is a major thing, so hence the plough being thrown away"*. P6 explained that their choice of livestock and grazing patterns were influenced by climate-related risks: *"The choice of cow, a hardy native breed, the Luing, which can stay out all winter and that releases us from all of the costs and the fossil fuel use of bringing animals indoors. The way we manage them, keeping them on the move, making sure that we are benefiting the biology of the soil as much as possible and growing as much grass naturally as possible so that we are sucking up as much carbon".*

P6, P7 and P11 mentioned decisions associated with planting trees, such as the choice of tree, and the timing of planting. *"We're having to seriously look at how we plant trees and when we plant trees, it used to be that you could plant right through from, you know, October all the way through until May time. I now try and have all my planting done by the end of January to give at least a chance that the rooting system gets down a little bit deeper,"* (P11).

P11 and P6 also mentioned water management: *"You just have to expect we're going to get massive amounts of rain in a short space of the time, and we have to make sure that our ground preparation, be it for farming, be it for forest or whatever, has to take that into account,"* (P11).

Turning to the types of information that can help land managers with their decision-making, we asked the interviewees first about the types of information they currently receive, and where they receive it from, in relation to climate risk. P3, P2 and P11 all described gaining information about the landscape, how things respond to different climatic conditions, and what works and what does not, through observation and experience: *"I'm of an age where I have a bit of experience, so I've seen what happens on the farm in certain conditions and I've seen pretty well I think every extreme,"* (P3). *"I think practically looking at things, going out and observing and asking the right question,"* (P11).

A range of sources of information were also mentioned, including technical publications and scientific literature, as well as popular newspapers (P10, P2, P3). *"The forestry industry, the agriculture industry, I mean they both have extensive technical presses that support the people in those industries. Most of the time, they tend to be focused on markets, technical performance, that sort of stuff, but they are also alert to climate risk,"* (P2). *"All these sort of research things, I try to keep up to date with… I'm interested in a lot of the research that goes on,"* (P10). Social media, and specific membership groups were also mentioned as sources of information about climate risk (P2, P3, P6, P7). *"Being a member of Pasture for Life is extremely useful,"* (P6). *"Well, mostly, I don't know what we call them, Facebook, WhatsApp groups. I'm on a climate change one, I'm on a carbon one. I'm on a regeneration one and a Pasture for Life one, and a member of the Soil Association. You get deluge of information,"* (P7).

However, in a similar vein to the concerns about incoherent policy, mentioned above, two of the interviewees were concerned about misinformation, conflicting messages, and sensationalism in information about climate risk. *"I mean, there's a lot of crap, frankly, you know, and the way they write it is just bad because they want people to keep the news coming,"* (P11). *"You know it's all over the shop. It's inconsistent. It's, you know, counterproductive. A lot of the time it contradicts what they've just said the day before,"* (P7).

Turning to the information that land managers said would help inform their decision-making, P2 and P3 stated that they would like to receive more meteorological data that shows patterns in how the climate is changing, as opposed to just short-term variations. P2 stated: *"What we're really interested in is, is there any sort of trend here that that is indicating that we've got a pattern which is definitely going to change, and then we can perhaps start to think about responding to that more positively, rather than thinking well, it's just one of the little bits of ups and downs within weather, which is obviously different to climate"*. P10 and P6 were interested in receiving more information about how to calculate carbon audits on their land: *"I've got to produce a carbon audit for the farm and I just haven't had a chance to get on with it yet, but I know I'm going to sit scratching my head over what to do, so anything that makes that process easier would be very helpful,"* (P6). P3 was particularly interested in information that could help improve the resilience of his pastures to drought: *"If I can get more information about how I can further encourage the resilience of my pastures to drought, the ability of my soils to hold moisture through drought periods to act as a sponge, and to have animals which are resilient."*

P11 and P9 focused more on what they thought needed to be communicated to the public, to encourage action on climate-related risks. P9 thought there needed to be clearer communication of the 'worst case scenario' of not acting: *"Unfortunately the worst-case scenario might be the only scenario, and it's important people know that… [We need to communicate] firstly what are those risks, but secondly what they can do about them, you know, in a way that's palatable to the government and sensitive to people's value systems and will actually achieve doing something about it… A proper understanding of the risks sometimes stops people doing anything at all."*

Here too, there were concerns about the robustness and coherence of information being communicated, particularly from the Scottish Government. P7 was keen to see *"more cohesion",* whilst P9 went as far as suggesting information from the Scottish Government was failing to acknowledge the scale of the problem and the inadequacy of current policies to address it. P6 was keen to avoid information overload and was focused on taking action to redress the challenges associated with climate change.

When asked about how they would like information about risk to be communicated with them, land managers mentioned a range of communication preferences. These are summarised in Table 2, below.

Table 2 - Land managers' communication preferences for information about climate risk to natural capital

Preferred modes of communication for information on climate risk	Interviewees who indicated this preference
Learning from peers	P11, P2, P6, P7

Practical observations and experience	P11, P6, P7
Scientific literature	P2, P9
Emails	P3, P6
Phonecalls	P11, P6
Hard copy	P3
Proactive help and demonstration from experts	P6
Short articles	P11

Learning from peers was a particularly strong preference, with more than half of the interviewees discussing this as a preferred mode of communicating information. For instance, P6 had the following to say: *"They need to see what you're doing, they need to hear what you're doing. They need to see the results, and then they need to be left alone, because as soon as you try and tell people what to do, particularly when there's no example for them to see, people completely switch off. If they can see something or connect with it… that is the way to bring about change"*. Similarly, P7 stated: *"There's nothing better to train farmers than to tell them what their neighbours are doing, or people that they look up to are doing, because then they want to copy it"*.

In addition to specific types of communication, P6, P2, and P11 made general requests for information to be communicated in a succinct way, and interpreted in ways that are usable for land managers. P2 stated: *"The things that really help are data that's collated to be interpretable for our sector"*. Similarly, P11 said: *"The reality is that most land managers don't have a lot of time to read a lot of things… There needs to be, I think, a little bit of thought as to how to get really big messages, succinct into small bite-sized messages"*.

This section has shown the range of climate-related risks that land managers perceive could affect the NC on the land they manage, including drought, flooding and wildfire, as well as other risks. It has also presented land managers' perceived ability to respond to the risks that they face, the decisions that are influenced by climate risks, and the information flows that could help inform these decisions. In the next section, we summarise our findings and their implications, and then outline next steps for this research.

3.6 Statistical analysis of the survey results

Pairwise correlation

Table 3 provides the significant pairwise correlations between TPB variables. Owing to the reduced number of responses provided for wildfire and drought, these correlations capture mainly behavioural aspects relevant to fighting flooding risk. The highest value is reported between capacity for operating and intention to mitigate. Similarly, a strong correlation is found between intention and attitude to mitigate with respect to the impacts caused by flooding. Conversely, subjective norms seem not to have significant effects.

Some of the variables shaping the intention to mitigate present internal links not proposed in the TPB framework. The attitude to reduce risk of flooding is correlated with behavioural control (capacity) and with people close to the respondent (e.g., confidants) that take action to mitigate climate change risk. Having strong relationships with people showing a proactive attitude towards climate risk seems to assert a positive influence on approaches to risk

mitigation. In addition, variables reflecting the actual behavioural control, like experience, are also associated with the perceived behavioural control (capacity) as suggested by the TPB.

Contrarily to the theory, we have not found relationships between mitigation behaviour (implementation) and intention to mitigate. Conversely, this relationship is indirectly mediated by the link with behavioural capacity. External variables such as actual behavioural control may directly relate with mitigation behaviour (implementation) as proposed by the theory. This is what we have observed in the cross correlation between two different climate change impacts where experience of drought is negatively correlated with the implementation of actions for flooding.

These results show that the TPB is only partially verified. The limited number of responses may be the reason for this. In addition, the pairwise correlation does not remove the impact of the confounding variable, limiting the possibility of finding relevant effects on mitigation behaviour. Further analysis addressing these problems is proposed below where logistic regressions are used to identify significant correlations between these variables.

Table 3: significant pairwise correlations between the TPB variables at significant level $p<0.05$.

Variables	**Correlation coefficient**	**p level<0.05**
attitude_flooding and capacity	0.6598	0.00011
attitude_flooding and confidant (social norms)	0.5726	0.00067
Intention and attitude_flooding	0.5322	0.0130
Capacity and intention	0.7122	0.0003
Capacity and experience_flooding	0.5948	0.0045
Capacity and implementation_flooding	0.5948	0.0045
Implementation_drought and experience_flooding	-0.4385	0.0467

Ordered logistic regression

Table 3 reports the findings of an ordered logistic regression on the impacts of the drivers described by the TPB on the intention to mitigate. Owing to the ordered levels of responses provided for the dependent variable intention (ranging from somewhat disagree to strongly agree - strongly disagree was not chosen), the model provides three cut points and the coefficients of the explanatory variables. These cut points are a threshold that defines the boundaries between each level of the ordinal response.

The variables explaining the intention to mitigate are capacity and role of society (social norms) in acting against climate change. The first is positive as expected, while the second is marginally significant but negative. While the coefficient of social norms may seem counterintuitive, this statistical result can be justified if we consider that a clear message from local institutions (civic society, voluntary organisations, etc.) to protect natural capital may not be as strong and powerful as it should be to trigger any intention to change. The pairwise correlation analysis proposed in the previous section has also not proposed any significant

effect for social norms.

Table 4: ordered logistic model to explain the intention to mitigate behaviours. Stepwise regression adding only those variables with p-level <0.10

Dependent variable: Intention	**Coef.**	**Std. err.**	**z**	**P>z**
capacity	3.598	1.1247	3.20	0.001
society (social norm)	-1.113	0.620	-1.79	0.073
/cut1	-1.722	1.087		
/cut2	1.649	0.918		
/cut3	4.644	1.512		
Log likelihood -15.915; N obs=21 ; LR chi2(2)=19.77; Prob>chi2=0.0001' PseudoR2=0.38				

We can use the coefficients proposed at Table 4 to quantify the probability that these variables have on the intention to mitigate as shown at Table 5. Disagreements or limited agreement to the intention to mitigate are not explained, either by capacity or social norms. Only the last category (strong agreement) can be explained. Those who showed to have capacity (positive behavioural control) may influence (with a probability of 42%) the intention to mitigate climate change risk. Conversely, social norms (expressed as role of civic society in climate change mitigation) seem to provide a negative change in the probability to strongly influence (-13%) the intention to mitigate.

Table 5: predicted marginal effect on Intention

Capacity	**Dy/dx**	**Std err**	**z**	**p>z**
Predict Intention (-1)- somewhat disagree	-.142756	.1215062	-1.17	0.240
Predict Intention (0)- neither agree nor disagree	-.1832298	.1281769	-1.43	0.153
Predict intention (1)- somewhat agree	-.0946669	.07885	-1.20	0.230
Predict intention (2)- strongly agree	.4206526	.0588886	7.14	0.000
Society	**Dy/dx**	**Std err**	**z**	**p>z**
Predict Intention (-1)- somewhat disagree	0441776	.0426844	1.03	0.301
Predict Intention (0)- neither agree nor disagree	.0567027	.0516838	1.10	0.273

Predict intention (1)- somewhat agree	.0292958	.0195713	1.50	0.134
Predict intention (2)- strongly agree	-.1301761	.0557785	-2.33	0.020

Binary logistic regression

The consequences of the implementation of mitigation behaviour for flooding risk can be better explored by a binary logistic regression. Table 6, conversely from what is proposed in the pairwise correlation, can explain that intention and social norms (as the role of society in delivering a positive message to reduce climate change risk) have a positive statistical influence on mitigation behaviour. Both have a probability to activate mitigation behaviour of 23% as shown by the analysis of the marginal impacts in Table 7. This result is not surprising and is expected according to the TPB, although it contrasts with the result of the ordered logit model where the effects of agreement on the role of society in reducing climate change was limiting the intention to mitigate.

Because of the limited number of responses, the binary regression analyses has not provided any significant result in explaining the mitigation from the risk of wildfires and drought.

Table 6: binary logistic model explaining the mitigation behaviour for flooding. Stepwise backward regression removing from the full model those variables with p-level >0.10

Implementation (Mitigation behaviour)	**coef**	**Std err**	**z**	**P>z**
society	5.843896	5.399581	1.91	0.056
Intention	5.553746	4.406047	2.16	0.031
cons	.1139928	.114228	-2.17	0.030
Log likelihood -8.933; N obs=21 ; LR chi2(2)=10.04; Prob>chi2=0.0066; PseudoR2=0.36 Variables removed: p = 0.9964 >= 0.1000 removing capacity; p = 0.2240 >= 0.1000 removing confidant p = 0.1978 >= 0.1000 removing neighbours				

Table 7: predicted marginal effect on mitigation behaviour of flooding

	dy/dx	**Std err**	**z**	**P>z**
society	.2374939	.0825367	2.88	0.004
Intention	.2306431	.0560982	4.11	0.000

4. Synthesis, Implications and Next steps

Synthesis of findings

This report presents a research study on Scottish land managers' perceptions of risk, with regards to the effects of climate change on NC. The research involved a survey, distributed via the networks of Scottish Land & Estates and Soil Association Scotland, as well as a set of

semi-structured interviews with land managers. Although the survey was shared with networks totalling around 5,000 land managers, only 22 respondents completed the survey, whilst we were able to interview seven land managers. The small sample size means our findings have limited representativeness. The low uptake may itself indicate that there is limited interest in or understanding of climate risks to natural capital among land managers. However, we cannot claim this with confidence, as other factors such as busyness, lack of time, and research fatigue also likely contributed to low engagement with the research.

Within this small sample of land managers, we were still able to identify some interesting findings. In both the interviews and the survey, participants showed a high level of knowledge and awareness about the risks of climate change for NC. The high level of education possessed by most of the respondents, and shown in the survey, may have contributed to this knowledge and awareness. Land managers perceived all of the risks we targeted in the research (flooding, drought and wildfire) to pose risks to NC on their land, although from the statistical model this variable was not a driver of mitigation behaviour. They also went beyond these specific risks, and demonstrated more holistic concerns about facing warmer, wetter and more variable climatic conditions in the future. However, in the interviews, some land managers raised doubts and uncertainties about the extent to which climate-related risks are really increasing due to climate change, or just a result of latent climate variability and current land use practices.

The land managers in our sample were also able to describe potential impacts of these risks for NC. In terms of drought and flooding, the most prevalent perceived impacts related to loss of productivity in the landscape, as a result of soil erosion and periodic water shortages. Dry spells in Spring were thought to be especially damaging for both agriculture and forestry. More broadly, land managers were concerned about the potential impacts that a warmer, wetter climate could have in terms of changes to biodiversity in the landscape, including the prevalence of new pests and diseases that could cause significant damage, especially to sitka spruce.

In terms of response options, for dealing with risk, much of what land managers suggested involved generally taking a more holistic landscape-scale approach to managing the land, as well as diversifying land use. Specific responses for dealing with wildfire risk included controlled burning and vegetation management, whilst rewetting the landscape and improving management of water flows through a catchment were considered beneficial for all of drought, wildfire, and flood risk. Adding shelter belts of broadleaf trees was considered useful for dealing with heat and slowing down water flows, whilst carbon markets were suggested as a potentially useful approach for helping climate change mitigation. Improving collaboration, in general, and bringing in specialist support for managing wildfires, were considered important.

However, there was a strong sentiment among land managers that current policies and regulations are currently hindering land managers' ability to respond to and mitigate climate change risks. In particular, they felt that current policies are incoherent and sometimes conflicting. Some also felt that policies encouraging them to reduce livestock in the landscape were unhelpful, and that nature-friendly policies went against commercial interests. Financial barriers, a lack of social cohesion, and general inertia in landscape

practices were considered barriers to change. Additionally, the statistical analysis shows no effect of risk perception on the intention and mitigation behaviour, so despite the strong perception of risk and awareness of response options observed, this may not translate into action.

In terms of information that could help land managers in responding to risk, actual and projected long-term trends in climatological conditions were considered useful. In general, the research participants wanted to see coherent messaging, as opposed to seeing different things from different sources. They also wanted to see information communicated in a way that was succinct and easily-interpretable for their own contexts. Learning from experience was a particularly important means of gaining information, and was indeed correlated with behavioural control in the regression analysis. Likewise, the role of social norms showed a positive influence directly on the mitigation behaviour, although the survey results were inconclusive with regards to their role in influencing intention to mitigate. Receiving information via social and professional networks, including associated mailing lists and WhatsApp groups, were also preferred means of receiving information.

Implications and opportunities for further research

Given the importance of learning from experience, and from social networks, it may be useful to explore means of communicating information about climate risk in ways that integrate with land managers' practical experiences and utilise their social networks. Participatory, integrated climate services approaches have been shown to be effective for helping farmers engage with and plan responses to climate-related risks, in international contexts (E.g. PICSA). Further research may usefully draw lessons from such approaches and consider how they may be applied in Scotland.

Land managers clearly considered incoherent and unhelpful policies to be a barrier to responding to climate risks. Increased emphasis on policy coherence would therefore likely help support land managers in responding to risk. Connecting with ongoing research on policy coherence under the 'C3 Land Use Transformations' project may help to identify fruitful future directions for improving coherence. Additionally, the sample's emphasis on holistic, landscape-scale approaches to land management as a response to risk suggests that improving support for landscape-scale collaboration may also help land managers respond to risk. The recent study by Poskitt et al. (2024a) suggests potential avenues for improving support for collaborative landscape management. Further research could therefore also focus on the policy level – investigating how policymakers perceive climate-related risks to natural capital, and how policy may be better enabled to support land managers in responding to such risks.

As noted in the Results, we received a very limited number of responses to the survey, which is a limitation of our research. It is possible that a bigger sample, with representation from more diverse socio-economic groups would have yielded a more balanced set of responses and depicted a more complete picture of land managers' risk perceptions and associated behaviours. Further research could usefully repeat the survey with a wider audience, to explore risk perceptions among a broader range of socio-economic groups.

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RESAS
Rural & Environmental Science and Analytical Services

Scottish Government
Riaghaltas na h-Alba
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Appendix 1- The questionnaire survey. In green the questions used for the regression analysis

Question_Identifier	Question	options
StartDate	Start Date	
EndDate	End Date	
Status	Response Type	
Progress	Progress	
Duration (in seconds)	Duration (in seconds)	
Finished	Finished	
RecordedDate	Recorded Date	
ResponseId	Response ID	
DistributionChannel	Distribution Channel	
UserLanguage	User Language	
Q_RecaptchaScore	Q_RecaptchaScore	
Q1	Consent	consent taking part to the survey
Q2	Consent	consent age >18
Q3_1	We would like to start with a question on your level of knowledge about climate change. To what extent do you agree with the following statement: - I consider myself to be well-informed about risks associated with climate change for the land I manage.	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree

Q4	Which of the following best describes where you gather information about climate change risk? You may select more than one answer, or select 'Other' and type your response. - Selected Choice	I consider myself well informed about climate change by the national or local news; I read non-technical reports containing information about the risks from climate change; I read scientific literature containing information about the risks from climate change I am informed by the national technical agencies of the government which manage forest, water, land etc.; I follow the local discussion on climate change promoted by civic society; I obtain knowledge about climate change from direct experience or from the experiences of my friends, neighbours, family, community members; Other_____
Q4_8_TEXT	Which of the following best describes where you gather information about climate change risk? You may select more than one answer, or select 'Other' and type your response. - Other (please describe) - Text	open question
Q5	The options below suggest a range of natural capital assets. Please choose the option that best describes the most important environmental features on the land you manage:	forests; peatlands; agricultural land
Q6	The options below suggest a range of potential uses for [QID15-ChoiceGroup-SelectedChoices]. Please choose the option that best describes its most important uses on the land you manage. You will then be asked a series of questions about the risks posed by climate change in relation to these assets: - Selected Choice	timber production; carbon sequestration or nature restoration; multiple use (e.g. managed for any combination of recreation, tourism, timber, non-timber forest products, agroforestry, and / or other uses) ; other
Q6_4_TEXT	The options below suggest a range of potential uses for [QID15-ChoiceGroup-SelectedChoices]. Please choose the option that best describes its most important uses on the land you manage. You will then be asked a series of questions about the risks posed by climate change in relation to these assets: - Other (please describe) - Text	open question

Q7	The options below suggest a range of potential uses for [QID15-ChoiceGroup-SelectedChoices]. Please choose the option that best describes its most important uses on the land you manage. You will then be asked a series of questions about the risks posed by climate change in relation to these assets: - Selected Choice	Carbon sequestration and / or nature restoration ; Whiskey production ; Multiple uses (e.g. managed for any combination of whiskey production, carbon sequestration, nature restoration, and / or other uses); Other (please describe)
Q7_4_TEXT	The options below suggest a range of potential uses for [QID15-ChoiceGroup-SelectedChoices]. Please choose the option that best describes its most important uses on the land you manage. You will then be asked a series of questions about the risks posed by climate change in relation to these assets: - Other (please describe) - Text	open question
Q8	The options below suggest a range of potential uses for [QID15-ChoiceGroup-SelectedChoices]. Please choose the option that best describes its most important uses on the land you manage. You will then be asked a series of questions about the risks posed by climate change in relation to these assets: - Selected Choice	Crop production; Livestock grazing or beef production; Other (please describe)
Q8_3_TEXT	The options below suggest a range of potential uses for [QID15-ChoiceGroup-SelectedChoices]. Please choose the option that best describes its most important uses on the land you manage. You will then be asked a series of questions about the risks posed by climate change in relation to these assets: - Other (please describe) - Text	open question
Q9	We would like to explore the impacts of climate change on the land you manage. With reference to the natural capital asset ([QID15-ChoiceGroup-SelectedChoices]) that you selected in Q2, please select the option that best describes the climate change impacts most relevant to the natural assets and their uses on the land you manage (please select one only):	impacts caused by wildfires; impacts caused by flooding; impacts caused by drought

Q10_1	Here are two statements about how you feel about climate change-related risks to the [QID15-ChoiceGroup-SelectedChoices] you own or manage. Please select the option that best describes how much you agree or disagree with each statement: - I believe that the [QID15-ChoiceGroup-SelectedChoices] I manage will be damaged by wildfire within the next five years	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q10_2	Here are two statements about how you feel about climate change-related risks to the [QID15-ChoiceGroup-SelectedChoices] you own or manage. Please select the option that best describes how much you agree or disagree with each statement: - I believe it is unlikely that a wildfire will occur within the next year on nearby land	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q11_1	Here are two statements about how you feel about climate change-related risks to the [QID15-ChoiceGroup-SelectedChoices] you own or manage. Please select the option that best describes how much you agree or disagree with each statement: - I believe that the [QID15-ChoiceGroup-SelectedChoices] I manage will be damaged by flooding within the next five years	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q11_2	Here are two statements about how you feel about climate change-related risks to the [QID15-ChoiceGroup-SelectedChoices] you own or manage. Please select the option that best describes how much you agree or disagree with each statement: - I believe it is unlikely that a flood will occur within the next year on neighbouring land	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q12_1	Here are two statements about how you feel about climate change-related risks to the [QID15-ChoiceGroup-SelectedChoices] you own or manage. Please select the option that best describes how much you agree or disagree with each	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree

	statement: - I believe that the [QID15-ChoiceGroup-SelectedChoices] I manage will be affected by drought within the next five years	
Q12_2	Here are two statements about how you feel about climate change-related risks to the [QID15-ChoiceGroup-SelectedChoices] you own or manage. Please select the option that best describes how much you agree or disagree with each statement: - I believe it is unlikely that a drought will occur within the next year on nearby land	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q13_1	Here is a question that explores how important you feel climate change-related risks to natural capital are on the land you own or manage. Please select the option that best describes your response: - To what extent do you think it is important to take steps to protect the [QID15-ChoiceGroup-SelectedChoices] you manage against fires?	not important at all, slightly important, moderately important, very important, extremely important
Q14	What response options are you aware of that could reduce the risk of [QID15-ChoiceGroup-SelectedChoices] being damaged by fires?	open question
Q15_1	Here is a question that explores how important you feel climate change-related risks to natural capital are on the land you own or manage. Please select the option that best describes your response: - To what extent do you think it is important to take steps to protect the [QID15-ChoiceGroup-SelectedChoices] you manage against flooding?	not important at all, slightly important, moderately important, very important, extremely important
Q16	What response options are you aware of that could reduce the risk of [QID15-ChoiceGroup-SelectedChoices] being damaged by flooding?	open question
Q17_1	Here is a question that explores how important you feel climate change-related risks to natural capital are on the land you own or manage. Please select the option that best describes your response: - To what extent do you think it is important to take steps	not important at all, slightly important, moderately important, very important, extremely important

	to protect the [QID15-ChoiceGroup-SelectedChoices] you manage against drought?	
Q18	What response options are you aware of that could reduce the risk of [QID15-ChoiceGroup-SelectedChoices] being damaged by drought?	open question
Q19_1	Here are three statements about the social context of your attitudes and responses. Please select the option that best describes how much you agree or disagree with each statement: - My neighbours, or land managers I associate with, take measures to protect natural capital on their land from fire	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q19_2	Here are three statements about the social context of your attitudes and responses. Please select the option that best describes how much you agree or disagree with each statement: - People who are important to me take measures to protect natural capital on their land from fire	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q19_3	Here are three statements about the social context of your attitudes and responses. Please select the option that best describes how much you agree or disagree with each statement: - There is a clear message from the local institutions (civic society, voluntary organisations, etc) that represent local communities that it is important to take measures to protect natural capital from fire	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q20_1	Here are three statements about the social context of your attitudes and responses. Please select the option that best describes how much you agree or disagree with each statement: - My neighbours, or land managers I associate with, take measures to protect natural capital on their land from flooding	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q20_2	Here are three statements about the social context of your attitudes and responses. Please select the option that best describes how much you agree or disagree with each statement: - People who are important to me	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree

	take measures to protect natural capital on their land from flooding	
Q20_3	Here are three statements about the social context of your attitudes and responses. Please select the option that best describes how much you agree or disagree with each statement: - There is a clear message from the local institutions (civic society, voluntary organisations etc) that represent local communities that it is important to take measures to protect natural capital from flooding	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q21_1	Here are three statements about the social context of your attitudes and responses. Please select the option that best describes how much you agree or disagree with each statement: - My neighbours, or land managers I associate with, take measures to protect natural capital on their land from drought	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q21_2	Here are three statements about the social context of your attitudes and responses. Please select the option that best describes how much you agree or disagree with each statement: - People who are important to me take measures to protect natural capital on their land from drought	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q21_3	Here are three statements about the social context of your attitudes and responses. Please select the option that best describes how much you agree or disagree with each statement: - There is a clear message from the local institutions (civic society, voluntary organisations etc) that represent local communities that it is important to protect natural capital from drought	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree

Q23	The following is a list of options that could be taken to counteract the effects of fire – Please select the five that you would consider most effective for the [QID15-ChoiceGroup-SelectedChoices] you manage: - Selected Choice	Prescribed burning; Fuel management on individual property; Community disaster preparedness; Use of fire breaks and improving access; Mechanical vegetation removal; Early detection and rapid suppression of wildfires; Improved mapping of hazards in relation to natural capital assets; Recruitment of specialised people or training of staff to deal with fire management ; Others_____
Q23_9_TEXT	The following is a list of options that could be taken to counteract the effects of fire – Please select the five that you would consider most effective for the [QID15-ChoiceGroup-SelectedChoices] you manage: - Other (please describe) - Text	open question
Q24	The following is a list of options that could be taken to counteract the effects of flooding – Please select the five that you would consider most effective for the [QID15-ChoiceGroup-SelectedChoices] you manage: - Selected Choice	Floodwalls; Dams; Culverts; Seawalls; Basins, small reservoirs; Large underground tanks; Green infrastructures: green roofs, green walls, rainwater tanks; Drainage obtained by improving the extent and condition of natural habitat ; Land use planning: zoning, subdivision, building codes; Planting trees; Terrace slopes ; Building alluviums (manmade channel to divert water from flooding); Others _____
Q24_13_TEXT	The following is a list of options that could be taken to counteract the effects of flooding – Please select the five that you would consider most effective for the [QID15-ChoiceGroup-SelectedChoices] you manage: - Other (please describe) - Text	open question
Q25	The following is a list of options that could be taken to counteract the effects of drought – Please select the five that you would consider most effective for the [QID15-ChoiceGroup-SelectedChoices] you manage: - Selected Choice	Making drought plans; Increasing water storage; Building dams; Diversifying water supply; Improving soil management; Recycling water ; Monitoring, metering and forecasting; Adopting or reviewing water tariffs' ;Adjusting legal and institutional frameworks; Using insurance, pricing and economic incentives; Others_____
Q25_11_TEXT	The following is a list of options that could be taken to counteract the effects of drought – Please select the five that you would	open question

	consider most effective for the [QID15-ChoiceGroup-SelectedChoices] you manage: - Other (please describe) - Text	
Q26_1	Here is a statement about how you perceive your ability to adopt measures to take control of climate change related risks. Please select the option that best describes how much you agree or disagree with each statement: - I consider myself able to adopt some / all of the response options listed previously to protect the [QID15-ChoiceGroup-SelectedChoices] I manage from fire	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q27	Please state briefly what barriers (e.g., technical, legal, institutional or economic) you think you may experience in adopting measures for controlling fire on your land:	open question
Q28_1	Here is a statement about how you perceive your ability to adopt measures to take control of climate change related risks. Please select the option that best describes how much you agree or disagree with each statement: - I consider myself able to adopt some / all of the response options listed previously to protect the [QID15-ChoiceGroup-SelectedChoices] I manage from flooding	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q29	Please state briefly what barriers (e.g., technical, legal, institutional or economic) you think you may experience in adopting measures for controlling flooding on your land:	open question
Q30_1	Here is a statement about how you perceive your ability to adopt measures to take control of climate change related risks. Please select the option that best describes how much you agree or disagree with each statement: - I consider myself able to adopt some / all of the response options listed previously to protect the [QID15-ChoiceGroup-SelectedChoices] I manage from drought	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q31	Please state briefly what barriers (e.g., technical, legal, institutional	

	or economic) you think you may experience in adopting measures for controlling drought on your land:	
Q33_1	Here is a statement about your intentions. Please select the option that best describes how much you agree or disagree with the statement: - I intend to implement response options to protect the [QID15-ChoiceGroup-SelectedChoices] I manage from fire over the next five years	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q34_1	Here is a statement about your intentions. Please select the option that best describes how much you agree or disagree with the statement: - I intend to implement response options to protect the [QID15-ChoiceGroup-SelectedChoices] I manage from flooding over the next five years	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q35_1	Here is a statement about your intentions. Please select the option that best describes how much you agree or disagree with the statement: - I intend to implement response options to protect the [QID15-ChoiceGroup-SelectedChoices] I manage from drought over the next five years	strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, strongly agree
Q36	In the past years I have implemented some measures for reducing risk from fire:	yes/no
Q37	What measures have you taken to reduce risk from fire? Please describe:	open question
Q38	In the past years I have implemented some measures for reducing risk from flooding:	yes/no
Q39	What measures have you taken to reduce risk from flooding? Please describe:	open question
Q40	In the past years I have implemented some measures for reducing risk from drought:	yes/no
Q41	What measures have you taken to reduce risk from drought? Please describe:	open question
Q42	I have experienced fire on my land / properties:	yes/no
Q43	I have been evacuated due to fire:	yes/no
Q44	I have seen the consequences of fire on nearby land / properties / wildlands:	yes/no
Q45	I have experienced flooding on my	yes/no

	land / properties:	
Q46	I have been evacuated due to flooding:	yes/no
Q47	I have seen the consequences of flooding on nearby land / properties / wildlands:	yes/no
Q48	I have experienced drought on my land:	yes/no
Q49	I have seen the consequence of drought on nearby land / properties / wildlands:	yes/no
Q50	Which region is the land you manage located in?	Shetland; Orkney; Outer Hebrides; Highland ; Grampian; Tayside; Fife; Lothian; Scottish Borders; East Central; Argyll and Bute; Clyde Valley; Ayrshire; Dumfries and Galloway
Q51	How many years have you been managing the land?	4 or less; From 5 to 9 ; From 10 to 19; More than 20
Q52	Please select your age group in years:	18 to 30; 31 to 45; 45 to 65; Over 65; I do not want to state my age
Q53	Please select your gender:	Male ; Female ; Nonbinary; I do not want to state my gender
Q54	Please select your level of education:	National 5s / GCSEs (or equivalent); Highers / Advanced Highers / A Levels (or equivalent); Further Education / College; University Degree or Postgraduate Degree; None of the above
Q55	Is there a successor in place to look after the land in the future?	yes/no
Q56	Please indicate below if you are happy to be contacted regarding a potential interview at a later date:	open question
Q57	If yes, please tell us your full name:	open question
Q58	Please tell us your email address / full telephone number (whichever is your preferred method of contact):	open question

Appendix 2 - Results of the survey

Appendix 2-Table1: Socio-economic characteristics

years of land management experience	Agricultural Land	Forest	Peatland	**Grand Total**
not stated	1	2	2	**5**
4 or less	1			**1**
From 10 to 19	1		1	**2**
From 5 to 9	2			**2**
More than 20	9	2	1	**12**
Grand Total	**14**	**4**	**4**	**22**
age group of the land manager	Agricultural Land	Forest	Peatland	**Grand Total**
not stated	2	2	2	**6**
30 to 44	1			**1**
45 to 64	6	1	1	**8**
65 or over	5	1	1	**7**
Grand Total	**14**	**4**	**4**	**22**
gender of the land manager	Agricultural Land	Forest	Peatland	Grand Total
not stated	2	2	2	6
Female	2		1	3
Male	9	2	1	12
Non-binary / third gender	1			1
Grand Total	14	4	4	22
level of education of the land manager	Agricultural Land	Forest	Peatland	**Grand Total**
not stated	2	2	2	**6**
Further Education / College	1	1		**2**
Highers / Advanced Highers / A Levels (or equivalent)	1			**1**
National 5s / GCSEs (or equivalent)	1			**1**
University Degree or Postgraduate Degree	9	1	2	**12**
Grand Total	**14**	**4**	**4**	**22**
successor in place	Agricultural	Forest	Peatland	**Grand**

	Land			**Total**
not stated	2	2	2	**6**
No	1			**1**
Yes	11	2	2	**15**
Grand Total	**14**	**4**	**4**	**22**

Appendix 2- Table 2: Climate change risk by region

Region	Agricultural Land	Forest	Peatland	**Grand Total**	
not provided	1	2	2	**5**	
Argyll and Bute	1			**1**	
Clyde Valley			1	**1**	
Dumfries and Galloway	3	1		**4**	
Fife	1			**1**	
Grampian	4		1	**5**	
Highland	1	1		**2**	
Lothian	1			**1**	
Orkney	1			**1**	
Scottish Borders	1			**1**	
Grand Total	**14**	**4**	**4**	**22**	
Regions and impacts of climate change on land	Impacts caused by drought	Impacts caused by flooding	Impacts caused by wildfires	**Grand Total**	
not stated	1	3		**4**	
Argyll and Bute	1			**1**	
Clyde Valley			1	**1**	
Dumfries and Galloway	3	1		**4**	
Fife		1		**1**	
Grampian	1	3	1	**5**	
Highland		1	1	**2**	
Lothian		1		**1**	
Orkney	1			**1**	
Scottish Borders		1		**1**	
Grand Total	**7**	**11**	**3**	**21**	
Agreement on the risk of climate change on natural capital by Region	Neither agree nor disagree	Somewhat agree	Somewhat disagree	Strongly agree	**Grand Total**
not stated		4		3	**7**
Argyll and Bute				1	**1**
Clyde Valley		1			**1**
Dumfries and Galloway		1		3	**4**
Fife				1	**1**
Grampian		1	1	3	**5**
Highland		2			**2**
Lothian				1	**1**

Orkney	1				**1**
Scottish Borders				1	**1**
Grand Total	**1**	**9**	**1**	**13**	**24**
Regions where measures to implement climate change are implemented	Yes	**Grand Total**			
Clyde Valley	1	**1**			
Grampian	1	**1**			
Highland	1	**1**			
Grand Total	**3**	**3**			

Appendix 2- Table 3: Natural capital affected by climate change and main uses of land

Option that best describes the most important environmental features on the land you manage	Count
Agricultural Land	14
Forest	4
Peatland	4
Grand Total	**22**
Main use of land for forest	Count
Multiple uses (e.g. managed for any combination of recreation, tourism, timber, non-timber forest products, agroforestry, and / or other uses)	3
Other (please describe)	1
Grand Total	**4**
Main use of land for peatland	Count
Carbon sequestration and / or nature restoration	1
Multiple uses (e.g. managed for any combination of whiskey production, carbon sequestration, nature restoration, and / or other uses)	2
Grand Total	**3**
Main use of agricultural land	Count
Crop production	3
Livestock grazing or beef production	10
Other (please describe)	1
Grand Total	**14**

Appendix 2 Table 4: Perception of damage in the next five years

Feeling that land will be damaged by wildfire in the next 5 years	Forest	Peatland	**Grand Total**		**Feeling that wildfire will not occur within the next year on nearby land**	Forest	Peatland	**Grand Total**
Somewhat agree	1	1	**2**		Neither agree nor disagree		1	**1**
Strongly agree		1	**1**		Somewhat disagree	1		**1**
Grand Total	**1**	**2**	**3**		Strongly disagree		1	**1**
					Grand Total	**1**	**2**	**3**
Feeling that land will be damaged by flooding in the next 5 years	Agricultural Land	Forest	**Grand Total**		**Feeling that flooding will not occur within the next year on nearby land**	Agricultural Land	Forest	**Grand Total**
Neither agree nor disagree	1		**1**		Neither agree nor disagree	3		**3**
Somewhat agree	4		**4**		Somewhat agree	1		**1**
Strongly agree	3		**3**		Somewhat disagree	1		**1**
Strongly disagree	1	1	**2**		Strongly agree	1	1	**2**
Grand Total	**9**	**1**	**10**		Strongly disagree	3		**3**
					Grand Total	**9**	**1**	**10**
Feeling that land will be damaged by drought in the next 5 years	Agricultural Land	Forest	**Grand Total**		**Feeling that drought will not occur within the next year on nearby land**	**Agricultural Land**	**Forest**	**Grand Total**
Neither agree nor disagree	1		**1**		Neither agree nor disagree	3		**3**
Somewhat agree	2	1	**3**		Somewhat disagree	1	1	**2**
Strongly agree	2	1	**3**		Strongly agree	1		**1**

Grand Total	**5**	**2**	**7**		Strongly disagree		1	**1**
					Grand Total	**5**	**2**	**7**

Appendix 2- Table 5: Proposed strategies to reduce the impact of climate change on natural capital

Response options to reduce risk of being damaged by fire	Forest	Peatland	**Grand Total**
Controlled burning, fire breaks, equipment + training to tackle wildfires, insurance	1		**1**
Rewetting, vegetation management, monitoring, etc		1	**1**
Rotational muirburn, cutting, grazing, re-wetting, removing self-seeded sitka		1	**1**
Grand Total	**1**	**2**	**3**
Response options to reduce risk of being damaged by flooding	Agricultural Land	**Grand Total**	
Avoiding compaction	1	**1**	
Better soil management in the river catchment and reducing pollution from sewage outflows	1	**1**	
Better water retention in soils	1	**1**	
Growing longer grass so that the water cycle can work more efficiently, and more water can infiltrate the soil rather than going straight into water courses is the best, cheapest and most sensible option for protecting any land against flooding.	1	**1**	
Improve permeability of soil, remove stock from vulnerable fields, divert water off the land	1	**1**	
man-made drainage being maintained, natural water courses free from obstructions, health soil to retain water	1	**1**	
none	1	**1**	
Grand Total	**7**	**7**	
Response options to reduce risk of being damaged by drought	Agricultural Land	**Forest**	**Grand Total**
Build soil organic matter. Develop more silvopasture.	1		**1**
Changes to cultivation techniques	1		**1**
Good soil & grassland management. Tree planting. No chemical inputs. Reduce land drainage.	1		**1**
Species choice water management vegetation management		1	**1**
storage of water	1		**1**
Grand Total	**4**	**1**	**5**

Appendix 2 – Table 6: Perception of climate change contrast as influenced by the neighbours, people considered important or influential, and pressure from local institutions

Neighbours, or land managers I associate with, take measures to protect natural capital on their land from fire	Forest	Peatland	**Grand Total**
Somewhat agree		1	**1**
Somewhat disagree	1	1	**2**
Grand Total	**1**	**2**	**3**
People important to me take measures to protect natural capital on their land from fire	Forest	Peatland	**Grand Total**
Neither agree nor disagree		1	**1**
Somewhat agree	1		**1**
Strongly agree		1	**1**
Grand Total	**1**	**2**	**3**
Local institutions provide messages that it is important to take measures to protect natural capital from fire	Forest	Peatland	**Grand Total**
Neither agree nor disagree	1	1	**2**
Somewhat disagree		1	**1**
Grand Total	**1**	**2**	**3**
Neighbours, or land managers I associate with, take measures to protect natural capital on their land from flooding	Agricultural Land	**Grand Total**	
Neither agree nor disagree	3	**3**	
Somewhat agree	2	**2**	
Somewhat disagree	1	**1**	
Strongly agree	1	**1**	
Strongly disagree	1	**1**	
Grand Total	**8**	**8**	
People important to me take measures to protect natural capital on their land from flooding			
Row Labels	Agricultural Land	**Grand Total**	
Neither agree nor disagree	3	**3**	
Somewhat disagree	1	**1**	
Strongly agree	3	**3**	
Strongly disagree	1	**1**	
Grand Total	**8**	**8**	
Local institutions provide messages that it is important to take measures to protect natural capital from flooding	Agricultural Land	**Grand Total**	

Neither agree nor disagree	2	**2**	
Somewhat agree	3	**3**	
Somewhat disagree	2	**2**	
Strongly agree	1	**1**	
Grand Total	**8**	**8**	
Neighbours, or land managers I associate with, take measures to protect natural capital on their land from drought	Agricultural Land	Forest	**Grand Total**
Neither agree nor disagree	1		**1**
Somewhat disagree	1		**1**
Strongly agree		1	**1**
Strongly disagree	2		**2**
Grand Total	**4**	**1**	**5**
People important to me take measures to protect natural capital on their land from drought	Agricultural Land	Forest	**Grand Total**
Neither agree nor disagree	3		**3**
Somewhat agree		1	**1**
Strongly agree	1		**1**
Grand Total	**4**	**1**	**5**
Local institutions provide messages that it is important to take measures to protect natural capital from drought	Agricultural Land	Forest	**Grand Total**
Neither agree nor disagree	1		**1**
Somewhat agree		1	**1**
Somewhat disagree	2		**2**
Strongly disagree	1		**1**
Grand Total	**4**	**1**	**5**

Appendix 2- Table 7: Capability to apply counteracting measures against climate change and barriers

I consider myself able to implement some of the measures for reducing risk from fire as previously listed	Forest	Peatland	**Grand Total**
Somewhat agree	1	1	**2**
Strongly agree		1	**1**
Grand Total	**1**	**2**	**3**
Barriers encountered in adopting measures for controlling fire	Forest	Peatland	**Grand Total**
Finances, time, expertise, equipment, legislation		1	**1**
Unnecessary and overarching regulation		1	**1**
Unnecessary restrictions on controlled burning. Lack of wildfire suppression skills and equipment by staff and SFRSst	1		**1**
Grand Total	**1**	**2**	**3**
I consider myself able to implement some of the measures for reducing risk from flooding as previously listed	Agricultural Land	**Grand Total**	
Somewhat agree	4	**4**	
Strongly agree	4	**4**	
Grand Total	**8**	**8**	
Barriers encountered in adopting measures for controlling flooding	Agricultural Land	**Grand Total**	
Cost v economic return	1	**1**	
Financial	1	**1**	
Financial	1	**1**	
Financial barriers and also time to implement new measures	1	**1**	
It would normally not be cost effective to do any work to alleviate the risks	1	**1**	
Mindset. Not wanting to change grazing practice as it may be different from what was done in the past.	1	**1**	
Planning consent on the physical/structural barriers.	1	**1**	
Planning, finance	1	**1**	
Grand Total	**8**	**8**	
I consider myself able to implement some of the measures for reducing risk from drought as previously listed	Agricultural Land	Forest	**Grand Total**
Neither agree nor disagree	1		**1**
Somewhat agree	3	1	**4**
Grand Total	**4**	**1**	**5**
Barriers encountered in adopting measure for controlling drought	Agricultural Land	Forest	**Grand Total**

Capital and fiscal disincentives	1		**1**
I will have to gain agreement/budget from Estate management.	1		**1**
None	1		**1**
Time and sense of urgency, or lack of it.	1		**1**
Understanding what is required in plans and how they will make a difference on the ground. This is also relevant in relation to the time frames to make the required changes and the time it takes for those changes to take effect. Time is something we don't have!		1	**1**
Grand Total	**4**	**1**	**5**

Appendix 2- Table 8: Implementation of measures to reduce climate change effect

In the past years I have implemented some measures for reducing risks from fire	Forest	Peatland	**Grand Total**
Yes	1	2	**3**
Grand Total	**1**	**2**	**3**
Measures taken to reduce risk from fire	Forest	Peatland	**Grand Total**
Burning, cutting, grazing, re-wetting, removal of self-seeded sitka		1	**1**
Controlled burning, training of staff + purchase of equipment to deal with wildfires, fire breaks, access	1		**1**
rewetting, tree & scrub removal, education		1	**1**
Grand Total	**1**	**2**	**3**
In the past years I have implemented some measures for reducing risks from flooding	Agricultural Land	**Grand Total**	
Yes	8	**8**	
Grand Total	**8**	**8**	
Measures taken to reduce risk from flooding	Agricultural Land	**Grand Total**	
Changed grazing, eliminated fertiliser and stopped topping pasture. In last 5 years, the village has not been flooded having been flooded regularly over previous 30 years.	1	**1**	
Converted arable to grassland	1	**1**	
Digging permanent drainage channels and installing new flood drains	1	**1**	
Improving drainage and clearing ditches	1	**1**	
Reservoir, cleaned ditches, cattle on the hill	1	**1**	
Rewetting peatland, riparian woodland, restoring bogs & ponds, fencing off riparian zones from ruminants	1	**1**	
The land that we manage has been 'drained' for hundreds of years and adapted for agricultural use. Flooding is generally caused by poor soil structure combined with broken drainage systems.	1	**1**	
Grand Total	**7**	**7**	
In the past years I have implemented some measures for reducing risks from drought	Agricultural Land	Forest	**Grand Total**
Yes	4	1	**5**
Grand Total	**4**	**1**	**5**

Measures taken to reduce risk from drought	Agricultural Land	Forest	**Grand Total**
Begun a mob grazing system for improved fertility and soil biology outcomes. We will plant 4000 trees this year.	1		**1**
Built soil organic matter substantially and planted trees. We have a substantial rain and spring-fed reservoir for livestock water.	1		**1**
Changed cultivation techniques	1		**1**
Creating wetland habitats slowing the movement of water and changing species choice.		1	**1**
Water storage	1		**1**
Grand Total	**4**	**1**	**5**

Appendix 3: Interview questions for use in interviews with land managers across rural Scotland. These are inspired by the Theory of Planned Behaviour and experiences exploring perceptions of and responses to risk among farmers in various contexts:

Introductory Interview Prompts: Natural Capital is the Earth's stocks of natural resources (renewable or non-renewable).

Introductory questions

- Thinking about all the land you manage, in which region/council area is this primarily located?
- Thinking about all the land you manage, what are the most important natural capital assets that exist there?

Interview Prompts: Natural Capital might include trees, water, animals living on your land, the land itself, mineral resources etc.

Changes and perceptions of risk

- How likely do you think these natural capital assets are to be affected by: floods, drought, and/or wildfire in the coming 5 years?
- What potential impacts could floods, drought and wildfire have for the natural capital assets on your land?
    - Include consideration of how the impact of one risk could have knock-on effects on others.

Attitudes towards risk and ability to respond

- How do you feel about your ability to respond to these risks?
    - What are the barriers and challenges that affect your ability to respond to these risks?

Information and decision-making

- What land management decisions do these risks influence?
- What information do you currently receive regarding risks posed by climate change to natural capital on your land? From where do you receive this?
- What information do you need to help make decisions regarding the risks posed by climate change to natural capital on your land?
- How would you like this information to be communicated to you?

Other risks or opportunities

- Are there any other risks, besides those of wildfire, flooding and drought, that you think affect natural capital assets on your land? If so, what? How could you respond to them?